ISSN 1946-7664. MCFNS 2019
Vol. 11, Issue 1, pp. 1–256
Mathematical and Computational Forestry & Natural-Resource Sciences

AVAILABLE ONLINE AT HTTP://MCFNS.COM

Submitted: Sep. 1, 2018
Accepted: Mar. 20, 2019
Published: Mar. 30, 2019
Last Correction: Apr. 4, 2019

SPECIAL ISSUE ON SELECTED EXAMPLES OF RECENT TRENDS IN COMPUTING

M. Rajesh* [1], V. Kannan [1], C.J. Cieszewski [2]

[1] *Corresponding Guest Editor; Dept of Computer Science and Engineering, KRS College of Engineering, India*
[2] *Guest Editor, Institute for Artificial Intelligence, University of Georgia, Athens, GA, USA*

Abstract. The presented here a collection of conference papers is a Special Volume on Recent Trends in Computing that was compiled by the editors for the Mathematical and Computational Forestry & Natural-Resource Sciences (MCFNS) journal. The creation of this Special Issue and the Special Section, which contains it, was requested by the organizers of the International Conference on Recent Trends in Computing (ICRTC-2017), held on Dec. 14–15, 2017, at the SRM Institute of Science and Technology (formerly SRM University) on the NCR Campus, Tamil Nadu, India. The purpose of the Special Section hosting this volume is to contain publications originated from this and other similar scientific endeavors involving research on developments of computing technology as relevant to various Computational Sciences associated with natural resources or related to their research and management. In the current issue, dedicated in its entirety to this conference, we present a set of the papers in this category, which includes 29 selected examples of research that have been reviewed externally by the conference organizers.

Keywords: Advanced Computing; Networking; Informatics; Security and Privacy; Trends in Computing;

Part I
Editor's Introduction

1 Conference overview

The scope of the International Conference on Recent Trends in Computing encompasses the fundamental and applied research topics, which deal with various areas of Advance Computing, Networking, Informatics, Security and Privacy, in applications of computing technologies. The conference aims to bring together academic scientists, research scholars, and students, to share and disseminate their research and findings in broadly scoped scientific research topics related to computing, networking, and informatics, and to discuss the practical challenges encountered in the adaptation of the set forth solutions. The conference provides the authors and participants with opportunities for national and international collaboration and networking among universities and institutions from India among other countries, for promoting research and technology development. The conference endeavors to promote the implementation of basic research into applied investigations and to transfer the applied investigation results into practice implementations.

Papers included in this issue stem from the 2017 conference (ICRTC-2017), organized by the Department of Computer Science Engineering, held on Dec. 14–15, 2017, at the SRM Institute of Science and Technology (formerly known as SRM University), NCR Campus, Tamil Nadu, India. Two Guest Editors: M. Rajesh, Dept of Computer Science and Engineering, KRS College of Engineering, India; and V. Kannan, Managing Director, CLDC Research and Development, Coimbatore, Tamilnadu, India, made the selection of the manuscripts for this Special Issue and oversaw the review and copyediting of the selected for publication manuscripts. One editor, C.J. Cieszewski, wrote this introduction and prepared the volume for publication with limited editing of individual manuscript and typesetting of this volume. The topics of consideration for the publication manuscripts related to the conference program are divided into four Tracks covering the areas of "Advanced Computing", "Networking", "Informatics", and "Security and Privacy".

In the area of Advanced Computing, we find topics related to Pattern Recognition, Image Processing and Analysis, Virtual Reality, Document Image Processing, Evolutionary Algorithms, Ubiquitous Computing, Web mining, Perceptual Computing, and other related topics. The area of Networking covers Network Performance Analysis, Fault-Tolerant Systems, Parallel and Distributed Networks, Routing Protocol and Architecture, Network Dependability, Network Optimization, End-to-end resilience, Quality of service, and related topics. The area of Informatics includes Database and Query Processing, Expert Systems, Data Security, Data Privacy Preserving Techniques, Information Retrieval, Knowledge Discovery, Semantic Web, and related topics. Finally, the area of Security and Privacy contains the subareas of Access Control and Authorization, Attacks and Defenses, Anonymity, Security and Privacy for the IoT and 5G, Intrusion Detection and Malware Analysis, Vulnerability Analysis and Assessment, Secure Protocols and Design, Security and Privacy Measures and Policies, Privacy-Preserving Data Publishing & Mining, Wireless Network System and Security, Usable Security and Privacy, Biometric Security Systems, Identity and Trust Management, Critical Infrastructures, Key Management, Fraud Detection, Pervasive Security, Security for Wearable and Haptic Technology, and other related topics.

2 Conference organization

The conference organization was based on several Program functions and Committee activities. The Chief Patron was Dr. T.R. Pachamuthu, Chancellor, SRM University, India. The Convenor was Dr. R.P. Mahapatra, Prof. & HOD SRM University, India. Two conference secretaries were: (a) Rajarajan Muttukrishnan, City University London, UK; and (b) M. Mohan, Assist. Prof., Dept CSE, SRM University, India. The four Program Committee Chairs, Patrons, Coordinators, and Advisory and Technical Committees' members are listed below.

1. **Technical Program Committee Chairs**
   (a) Dr. Hyoung-Nam Kim, Prof., Dept. of Electronics Engineering, Pusan National University (PNU), Korea
   (b) Sanjeevi Kumar Padmanaban, SMIEEE, University of Johannesburg, South Africa
   (c) Dr. Jagadeesh Pasupuleti, Universiti Tenaga Nasional, Malaysia
   (d) Prof. M. Rajesh, Dept of CSE, KRS College of Engineering, India
2. **Patrons**
   (a) Ravi Pachamoothoo, Chairman, SRM Groups, India
   (b) Prof. P. Sathyanarayanan, President, SRM University, India
   (c) Prof. Prabir K Bagchi, Vice Chancellor, SRM University, India
   (d) Dr. Manoj Kumar Pandey, Director, SRM University, NCR Campus, India.
   (e) Dr. S. Viswanathan, Deputy Registrar, SRM Groups, India.
3. **Coordinators**
   (a) Dr. Jitendra Singh, Asso. Prof, Dept CSE, SRM University, India
   (b) P. Velmurugan, Assit. Prof, Dept CSE, SRM University, India
   (c) Mohanraj Ramasamy, Assit. Prof, Dept CSE, SRM University, India
4. **Advisory Committee**
   (a) Audun Josang, Oslo University, Norway
   (b) Greg Gogolin, Ferris State University, USA
   (c) Ljiljana Brankovic, The University of Newcastle, Australia
   (d) Dr. KannanJegathala Krishnan, University of Melbourne, Australia
   (e) Dr. R. Malathi, Annamali Unviresity, India
5. **Technical Committee**
   - Prof. K.T. Arasu, Wright State University Dayton, Ohio, North America
   - Dr. Mohammad Ayoub Khan, Taibah Univeristy, Kindom of Saudi Arabia
   - Dr. Rumyantsev Konstantin, Southern Federal University, Russia
   - Dr. Wen-Juan Hou, National Taiwan Normal University, Taiwan
   - Prof. Syed Akhat Hossain, Daffofil University, Dhaka, Bangladesh
   - Dr. Zoran Bojkovic, University of Belgrade, Serbia
   - Dr. Sophia Rahaman, Manipal University, Dubai
   - Dr. Thippeswamy Mn, University of KwaZulu-Natal, Durban
   - Dr. Lavneet Singh, University of Canberra, Canberra Australia

- A. Nagarajan, JNTU, AP
- Nalla Anandkumar, SETS
- Kuldeep Singh, Scientist-E, (DRDO)
- Prof. J. Amudhavel, CSE (R&D), KL University, A.P
- Dr. K. Thirumalaivasan, ACET, Puducherry
- Dr. K. Ramash Kumar, VIT, A.P.
- Dr. G. Zayaraz, PEC, Pondicherry.
- Dr. N. Alagumurthi, PEC, Puducherry
- Rajesh, KRSC, India
- Sathish Kumar, DRDO
- P. Gurunathan, UAE

3 Organization of the proceedings

These proceedings consist of the introductory Part I, by the editors, and contents Part II, containing selected works presented at the conference by the conference participants. The Table of Contents with Titles and Authors of the included works precedes the individual papers. The submitted manuscripts were reviewed externally by the conference organizers and only moderately edited by the MCFNS editor. Papers with unresolved issues in quality were rejected by the journal editor, while all the other submitted papers have been included in this volume in the form these partial proceedings under one common title.

Part II
Selected conference papers

Contents

A SINGLE STAGE THREE PHASE INVERTER BASED ON CUK CONVERTER FOR PV APPLICATION

P. Sivakumar, M.S. Ramkumar, A. Amudha, K. Balachander, D. Kavitha

Abstract: This project presents a replacement three-phase converter supported the Cuk converter. The principal feature of the planned topology is that the energy storage parts, like inductors and capacitors, is reduced therefore on boost the trustworthiness, and reduce the size and total value. The buck-boost inherent characteristic of the Cuk device, reckoning on the time-varying duty magnitude relation, provides flexibility for stand alone and grid-connected applications once the required output ac voltage is lower or larger than the dc aspect voltage. Average large and little signal models are accustomed to studying the Cuk converter's nonlinear operation. The essential structure, management vogue, and MATLAB/SIMULINK results are given.

Keywords: Buck-boost inverter, Cuk converter, dc–dc converters, proportional integral (PI) control, proportional resonant (PR) control, state space averaging, switched mode power supply (SMPS).

1 Introduction

The Ćuk device can be a form of DC-DC device that has Associate in Nursing output voltage magnitude that's either larger than or however the input voltage magnitude, with Associate in Nursing opposite polarity. It uses a capacitance as its main energy-storage half, in distinction to most different varieties of converters that use Associate in nursing inductance. This paper proposes a spanking new three half converter supported three bifacial 2-switch 2 diode Cuk converters with Associate in Nursing nonobligatory very little dc-link capacitance Associate in Nursing describes an acceptable and wise management structure that may bemused with efficiency in business applications. The planned converter is expedient for the PV applications, where the peaks of the output ac currents unit of measurement required to be flexible over and below the input DC for MPPT operation and for providing simple paralleling at the PCC. A three-phase converter converts a DC input into a three-phase AC output. [1–5]Its three arms unit of measurement unremarkably delayed by Associate in the nursing angle of 120°therefore on generates an AC give. The electrical converter switches each contains magnitude relation of fifty and modification happens once every T/6 of the time T (60°angle interval). The figure below shows a circuit for a three half converter. It's nothing but three single half inverters convey identical DC provides. The pole voltages in A passing three half converter are adequate the pole voltages in single half [*fr1] bridge converter. There is a trend toward normally structured renewable/distributed system ideas thus on crop costs and provide high reliableness. This trend affects dc–ac converter topologies significantly concerning reducing the scale and kind of converter passive components. For dc-to-ac conversion, the quality voltage provides (VSI) is that the foremost typical convertor topology. The voltage provides inverters (VSI) are classified on the premise of their construction and their output voltage and their level of implementation. There are three main varieties of the VSI on the premise of their output voltage as: 1) Single-phase half-bridge converter 2) single-phase full-bridge converter three) 3 half voltage provides converter A. Single half [*fr1] bridge voltage provides the push-pull kind convertor has some disadvantages. It desires the dual power provide for the operation of transistors. Together equipped VSI desires the 2 completely different kinds of transistors, like NPN and PnP, and every the transistors have utterly different switch speed. Owing to these a pair of disadvantages MOSFETs is used within the circuit. The sole half VSI created victimization the MOSFET. The sole half voltage provides converter consists of two MOSFET. The MOSFET square measure works a bit like the switches. In bridge topology, the input DC voltage is symmetrically divided due to identical capacitors connected across the DC provide.

2 Existing System

For dc-to-ac conversion, the normal voltage offer convertor (VSI) is that the most typical device topology. The quick average output voltage of the VSI is typically below the input dc voltage. In general, dc-dc converters, including the Cuk device, unit of measurement time-variant systems. This suggests that the device transfer perform describing the input-output performance depends on the duty relation equally as device parameters this can increase management vogue quality as a result of the device poles and zeros travel through a given physical phenomenon. In addition, the time-varying transfer performs ends up in output voltage and current distortion [6–10].

3 Planned System

In this project, a three-phase dc–ac Cuk converter-based current offer convertor has been planned and assessed. The state house averaging methodology was used to vogue the management structure. An extra management loop reduced distortion with low passive half values. Satisfactory winds up in terms of reduced second-order harmonic components inside the output currents and voltages were obtained. Generally, high-order converters like Cuk converters square measure avoided in convertor applications because of their management quality. The planned single-stage three-phase Cuk-based convertor introduces several deserves once used for PV applications. The planned single-stage three-phase Cuk-based convertor introduces several deserves once used for PV applications. Continuous input current permits direct MPPT techniques and additionally the power of paralleling dc–ac convertors at identical PCC promote the planned device as viable topology for PV applications [11–16].

4 Cuk device

A DC to DC converter takes the voltage from a DC offer and converts the voltage of providing into another DC voltage level. They are the accustomed increase or decrease the voltage level. Typically this can be often commonly used cars, transferable chargers, and transferable videodisc players. Some devices would like an exact amount of voltage to run the device. The associate degree excessive quantity of power can destroy the device, or less power may not be ready to run the device. The converter takes power from the battery and cuts down the voltage level, equally a converter increase the voltage level. As an example, it'd be necessary to step down the power of associate degree outsized battery of 24V to 12V to run a radio. This paper proposes a replacement 3phase convertor supported 3 duplex 2-switch two diode Cuk converters with associate degree optional little dc-link capacitance associate degreed describes an applicable and wise management structure which will be used with efficiency in trade applications. The projected convertor is expedient for the PV applications, where the peaks of the output ac currents are required to be versatile over and below the input DC for MPPT operation and for providing easy paralleling at the PCC. The Cuk converter is used for getting the output voltage with fully completely different polarity. This means that the output voltage magnitude is going to be either larger or smaller than the input, and there is a polarity reversal on the output. The device on the input acts as a filter for the dc provides, to prevent large harmonic current. Not just like the previous converter topologies where energy transfer is expounded to the device. Energy transfer for the Cuk converter depends on the capacitance

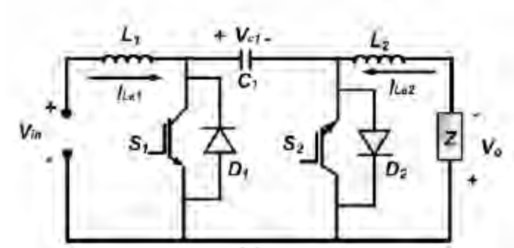


Figure 1: *Cuk converter diagram.*

The operative modes of a Cuk device are shown in Fig. 1. The equipment consists of the associated input voltage provide Vin, a pair of switches S1 and S2, and a pair of parallel diodes D1 and D2. The energy between the voltages provides and conjointly the load is transferred through condenser C1. The energy is holding on instantly in inductors L1 and L2. the basic operation at steady state could also be delineated simply, once S1 is Off, C1 is charged leading IL1 to decrease, whereas L2 is discharged among the load inflicting IL2 to increase. At future switch quantity, once S1 is On, L1 is charged, and IL1 can increase, whereas C1 is discharged inflicting IL2 to increase. It should be deduced that IL1 and IL2 are reticulate via the energy transfer through C1.

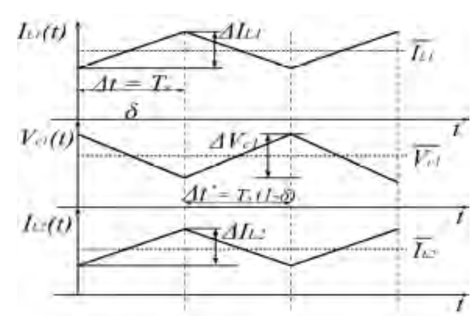


Figure 2: *cuk converter waveform.*

5 Proposed Diagram

The planned three-phase converter supported Cuk converters is shown in Fig. 3. As a current provider, the planned system can be paralleled to any extent any

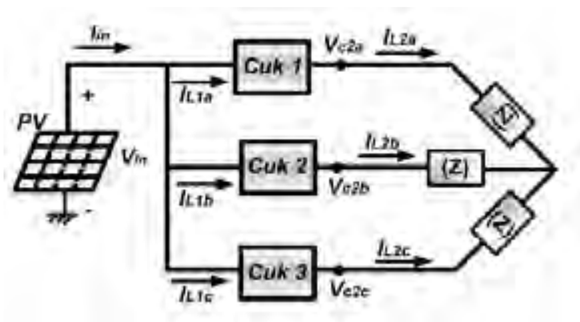


Figure 3: *Cuk based three phase inverter.*

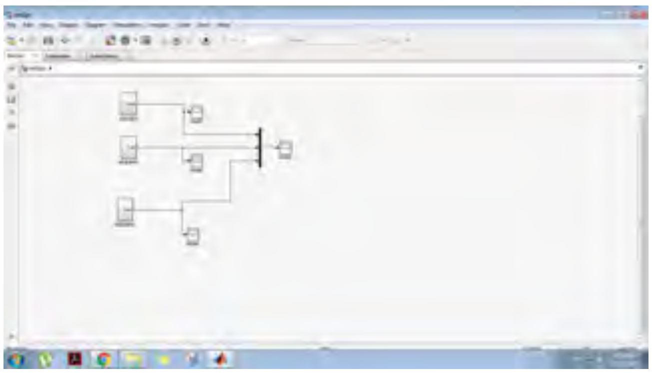


Figure 4: *simulation diagram.*

power extension. Each Cuk device builds a curvilinear output voltage, specifically current, with a dc offset. Assumptive that the dc and ac voltage ratios between output and input unit of measurement Hdc and Hac, severally, following equation explains the relation between the input and output voltage,

Because of the balanced energy operation of the three phases, it's positive that the dc offsets of each half unit of measurement off and conjointly the three-phase load encounters pure curvilinear voltages and currents [21–22].

6 Control Design

The management objective is to trace a predefined actuate output voltage. Vd, Vq, and Vdc unit of measurement the direct, quadrature, and dc offset components of the output voltage at Vc2a, Vc2b, and Vc2c. The subscript [??] refers to a reference worth. Kp and Ki unit of measurement the proportional and integral gains of the proportional integral (PI) controller. The management input is taken into consideration the input voltage Vin. However, normally, the voltage of the PV is constant over a short quantity, relying on the MPPT operation, and thence the management input has to be compelled to be written in terms of the time variable duty relation δ [17–20].

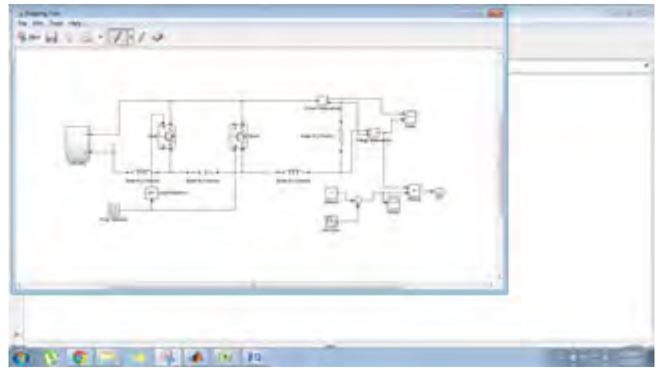


Figure 5: *cuk converter.*

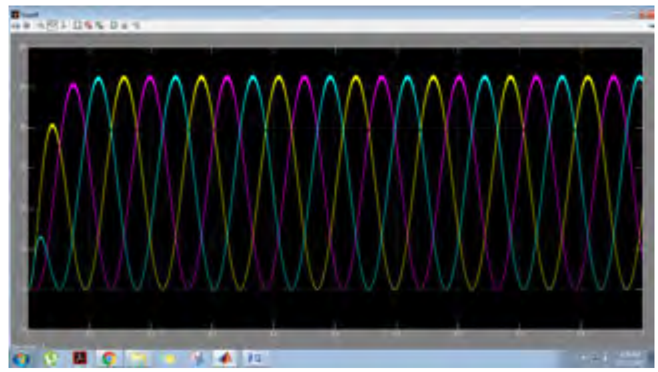


Figure 6: *output waveform.*

7 Conclusion

The projected single-stage three-phase Cuk-based convertor introduces several deserves once used for PV applications. Continuous input current permits direct MPPT techniques and conjointly the power of paralleling dc–ac devices at identical PCC promote the projected device as viable topology for PV applications. Considerably, because of low input current ripple, no capacitance is required across the PV array (and if accustomed bypass high-frequency switch elements, plastic capacitors is employed instead of low responsibility electrolytic types). Generally, high-order converters like Cuk converters are avoided in convertor applications because of their management quality. Moreover, the Cuk converter's inherent nonlinearity might be a reason for output current and voltage distortion. The impact of this nonlinearity is lessened by increasing the Cuk device inductances and capacitance. However, this adversely affects the complete worth, size, and management quality. Throughout this paper, a three-phase dc–ac Cuk converter-based current provide convertor has been projected and assessed. The state house averaging methodology was accustomed vogue the management structure. An additional management loop reduced distortion with

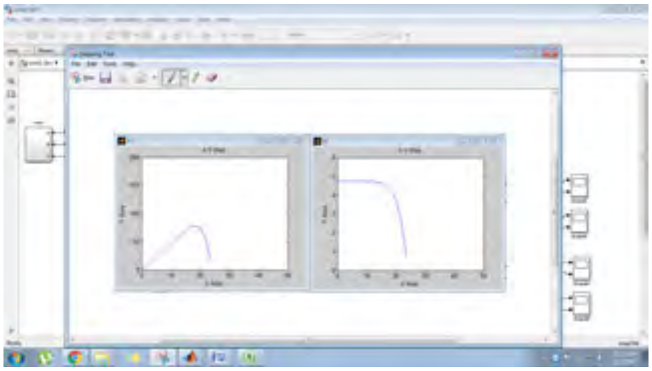


Figure 7: *solar pv,iv graph.*

Table 1: Rated value.

Parameter	Value
V_{in}	50 Vdc
I_{in}	50 A
$V_o(peak)$	50 Vac
$I_{L3}(peak)$	33.33 A
Z	1.5 Ω
δ_{min} and δ_{max}	0 and 0.667
f_s	50 kHz
ΔI_{L1}	0.667 A
ΔI_{L2}	0.667 A
ΔV_{c1}	20 V

$$V_{c2a} = H_a V_{\text{in}}$$
$$H_a = H_{\text{dc}} + H_{\text{ac}} \sin(\omega t + \theta)$$
$$V_{c2b} = H_b V_{\text{in}}$$
$$H_b = H_{\text{dc}} + H_{\text{ac}} \sin\left(\omega t - \frac{2\pi}{3} + \theta\right)$$
$$V_{c2c} = H_c V_{\text{in}}$$
$$H_c = H_{\text{dc}} + H_{\text{ac}} \sin\left(\omega t + \frac{2\pi}{3} + \theta\right)$$

low passive element values. Satisfactory winds up in terms of reduced second-order harmonic parts among the output currents and voltages were obtained and verified by MATLAB/SIMULINK. Associate convertor system was accustomed to manufacturing experimental results that confirmed system performance.

References

[1] X. Hu, C. Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Power Management of a Hybrid Solar- Wind Energy System" International Journal of Engineering Research & Technology vol. 3(2) pp.1988–1992, 2014.

[3] M. Siva Ramkumar, M. Sivaram Krishnan, Dr. A. Amudha "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239–245, 2017.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc " in International Journal of Control Theory and Applications, 10 (2) pp 333–344, 2017.

[5] M Siva RamKumar, Dr. A Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485–6488, 2016.

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763–769,2014.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361–1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2),2014

[9] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1–10, September 2016.

[10] D. Kavitha, Dr. C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973–4562 Vol. 10 No.20 (2015), pg. 17749–17754.

[11] D. Manoharan, Dr. A. Amudha "Condition Monitoring And Life Extension Of EHV Transformer" In-

ternational Journal of Applied Engineering Research, ISSN 0973–4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, Dr. A. Amudha A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973–4562 Volume 10, Number 3 (2015) pp. 6233–6240.

[13] Dr. A. Amudha “Enhancement of Available Transfer Capability using FACTS controller” in International journal of Applied Mechanics and Materials, Vol. 573, pp 340–345

[14] K. Balachander, Dr. P. Vijayakumar, “Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)” International Journal of Applied Environmental Sciences”, Volume - 08, No.16 (2013), pp.2035–2042.

[15] K. Balachander, Dr. P. Vijayakumar, “Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ”, American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, Dr. P. Vijayakumar, “Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India”, Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839–847.

[17] K. Balachander, Dr. P. Vijayakumar, “Renewable Energy System Optimization of Two Different Locations” CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, Dr. Vijayakumar Ponnusamy, ‘Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System’ International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179–186.

[19] K. Balachander, Dr. Vijayakumar Ponnusamy, ‘Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER’ International Journal of Applied Engineering Research’, Volume 7, Number 3 (2012), pp. 247–256.

[20] K. Balachander, S. Kuppusamy, Dr. Vijayakumar Ponnusamy, ‘Modeling and Simulation of VSDFIG and PMSG Wind Turbine System’, International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111–118.

[21] M. Sivaram Krishnan, Dr. A. Amudha, M. Siva Ramkumar, ‘Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms’, International journal of Pure and Applied Mathimatics,118 (11), pp 609–617,2018 DOI:10.12732/ijpam.v118i11.79

[22] S. Motapon, L. Dessaint, K. AI-Haddad, ”A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, ” IEEE Trans. Ind. Electron., vo1.61, no.3, pp.1320,1334, March 2014.

MAXIMUM POWER POINT TRACKING STRATEGY FOR A NEW WIND POWER SYSTEM WITH SUPER CAPACITOR CONNECTED PHOTOVOLTAIC POWER GENERATION SYSTEM AND SUPPORTED TO A DISTRIBUTION POWER GRID

E. Jaiganesh, G. Emayavaramban, A. Amudha, K. Balachander, D. Kavitha

Abstract: Modern hybrid power systems, which combine conventional and renewable power conversion systems, are characterized by extensive system interconnections and increasing dependence on control for optimum utilization of existing resources, especially photovoltaic and wind energy, are the best solution for feeding the mini-grids and isolated loads in remote areas. The supply of reliable and economic electric energy is a major concern of industrial progress and consequent rise in the standard of living. Properly chosen renewable power sources will considerably reduce the need for fossil fuel leading to an increase in the sustainability of the power supply. At the same time, conventional power sources aide the renewable sources in hard environmental conditions, which improve the reliability and stability of the electrical system. The increasing demand for electric power coupled with resources and environmental constraints pose several challenges to system planners. With deregulation of power supply utilities there is a tendency to view the power networks as highways for transmitting electric power from wherever it is available to places where required, depending on the pricing that varies with time of the day. A stand-alone hybrid power system is proposed in this work. The MPPT control of solar Power system (SPS) is achieved by perturbation and observation method and the TSR control method was used for implementing MPPT control of WECS and field oriented mechanism of MSC control system enabling the WECS to extract optimum energy, while the LSC of both the RES's uses synchronous VSI control system. The dynamic performance of a stand-alone wind-solar system with battery storage was analyzed. MATLAB/SIMULINK was used to build the model and simulate the system.

Keywords: Wind Energy Conversion System (WECS), PV system, Maximum Power Point Tracking (MPPT), Supercapacitor.

1 Introduction

The conventional energy generation systems full fill the requirement of the energy demand. To the rigging the current day's energy crisis one renewable method is the method in which power extracts from the incoming son radiation calling Solar Energy, which is globally free for everyone. Solar energy is lavishly available on the earth surface as well as on space so that we can harvest its energy and convert that energy into our suitability form of energy and properly utilize it with efficiently. Power generation from solar energy can be grid connected or it can be an isolated or standalone power generating system that depends on the utility, location of load area, availability of power grid nearby it . Thus where the availability of grids connection is very difficult or costly the solar can be used to supply the power to those areas. The most important two advantages of solar power are that its fuel cost is absolutely zero and solar power generation during its operation does not emit any greenhouse gases. Another advantage of using solar power for small power generation is its portability; we can carry that whenever wherever small power generation is required. The worldwide increasing energy demand Energy saving is one cost effective solution, but does not tackle. Renewable energy is a good option because it gives a clean and green energy, with no CO2 emission. Renewable energy is defined as energy that comes from resources which are naturally refilled on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat. Amongst the renewable source of energy, the photovoltaic power systems are gaining popularity, with heavy demand in energy sector and to reduce environmental pollution around caused due to excess use nonrenewable source of energy. Several system structures are designed for grid connected PV systems. Four different kinds of system configuration are used for grid connected PV power application: the centralized inverter system, the string inverter system, the multi-string inverter system and the module integrated inverter system. How can we increase the amount of photovoltaic (PV) generation? From this viewpoint, we are over viewing electric facilities from power plants to electric appliances in demand sites. PV modules generate DC electric power. The power should be converted to AC that is synchronized with commercial grids to be transmitted and distributed to demand sites. To reduce energy dissipation through the transmission, the power is sent near the demand site after being raised the electric voltage to 66 kV or higher. The power is transformed to 100 V and provided to residential outlets after multi-processed reduction in voltage at substations and pole-mounted transformers. Therefore, we should consider how we can establish efficient transmission and distribution systems for PV generation in addition to cost, efficiency and lifetime for generation facilities, if we utilize the power source as infrastructure. Transmission facilities for PV generation often stay idle as well as generation facilities themselves, because they do not yield electricity during night and poor weather. If contribution from solar power were much smaller than transfer capability, existing facilities could take care of it. To understand this problem easily, we assume a huge PV farm comparable to a nuclear power plant with a giga wattage class output. PV generation, which has poor yield for its footprint, needs vast ground to generate such a big power. Consequently, the generation facilities must be set up in sites far from consuming regions. Transmission facilities must have enough large capacity for maximum current which can be generated under the best weather condition. They do not work during off-generating time such as at night and under poor sunshine. If PV plants supplied constant huge power as dam type hydraulic or nuclear plants, we would make choice of a far-reaching transmission system that connects distant sources and a consuming centre. Electric power storage devices, such as batteries, can absorb fluctuation of PV generation and equalize power transmission. However, this scheme reduces capacity of transmission facilities and requires rather huge additional cost for the huge accumulators. Therefore, until drastically reduced cost is available for storage devices, we cannot adopt this method. Then, put gas turbines together, with which we are able to adjust output power rather rapidly. The combined plant can absorb the fluctuation of PV generation, and consequently, improve the operation ratio for transmissions. However, it requires a parallel established thermal power plant comparable to the PV, which is a roundabout way for our initial goal, the introduction of a large amount of PV. As mentioned above, large scale PV plants in remote sites have a serious problem on economic efficiency. We need a new power system that enables the introduction of a massive amount of distributed PV units in demand sites. This article proposes DC micro grid systems as an option for such a purpose. Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. This wind flow, or motion energy, when "harvested" by modern wind turbines, can be used to generate electricity. The terms "wind energy" or "wind power" describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity to power homes, businesses, schools, and the like. Wind turbines, like aircraft propeller blades, turn in the moving air and power an electric generator that supplies an electric current. Simply stated, a wind turbine is the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. Wind energy is a free, renewable resource, so no matter how much is used today, there will still be the same supply in the future. Wind energy is also a source of clean, non-polluting, electricity. Unlike conventional power plants, wind plants emit no air pollutants or greenhouse gases. Wind costs are much more competitive with other generating technologies because there is no fuel to purchase and minimal operating expenses.[1-5]

2 HYBRID ENERGY SOURCES

2.1 Wind Energy Conversion System

Figure 1 represents the complete wind energy conversion systems (WECS), which converts the energy present in the moving air (wind) to electric energy. The wind passing through the blades of the wind turbine generates a force that turns the turbine shaft. The rotational shaft turns the rotor of an electric generator, which converts mechanical power into electric power. The major components of a typical wind energy conversion system include the wind turbine, generator, interconnection apparatus and control systems. The power developed by the wind turbine mainly depends on the wind speed, swept area of the turbine blade, density of the air, rotational speed of the turbine and the type of connected electric machine.

As shown in figure 1, there are primarily two ways to control the WECS. The first is the Aerodynamic power control at either the Wind Turbine blade or nacelle, and the second is the electric power control at an interconnected apparatus, e.g., the power electronics converters. The flexibility achieved by these two control options facilitates extracting maximum power from the wind during low wind speeds and reducing the mechanical stress on the wind turbine during high wind speeds.[16-20]

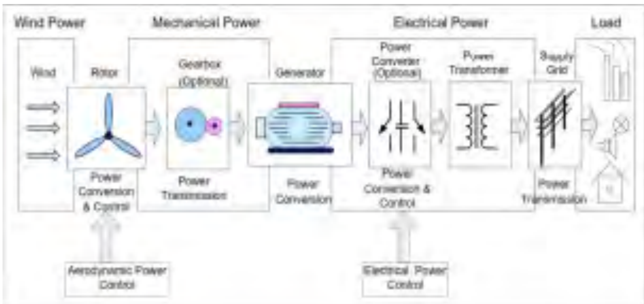


Figure 1: *Wind Energy Conversion System.*

Figure 2: *Photovoltaic cell.*

2.2 PV system

Converting solar energy into electrical energy by PV installations is the most recognized way to use solar energy. Since solar photovoltaic cells are semiconductor devices, they have a lot in common with processing and production techniques of other semiconductor devices such as computers and memory chips. As it is well known, the requirements for purity and quality control of semiconductor devices are quite large. With today's production, which reached a large scale, the whole industry production of solar cells has been developed and, due to low production cost, it is mostly located in the Far East. Photovoltaic cells produced by the majority of today's most large producers are mainly made of crystalline silicon as semiconductor material. Solar photovoltaic modules, which are a result of combination of photovoltaic cells to increase their power, are highly reliable, durable and low noise devices to produce electricity. The fuel for the photovoltaic cell is free. The sun is the only resource that is required for the operation of PV systems, and its energy is almost inexhaustible. A typical photovoltaic cell efficiency is about 15%, which means it can convert 1/6 of solar energy into electricity. Photovoltaic systems produce no noise, there are no moving parts and they do not emit pollutants into the environment. Taking into account the energy consumed in the production of photovoltaic cells, they produce several tens of times less carbon dioxide per unit in relation to the energy produced from fossil fuel technologies. Photovoltaic cell has a lifetime of more than thirty years and is one of the most reliable semiconductor products. Most solar cells are produced from silicon, which is non-toxic and is found in abundance in the earth's crust. Figure 1 shows the photovoltaic cell.

Photovoltaic systems (cell, module, network) require minimal maintenance. At the end of the life cycle, photovoltaic modules can almost be completely recycled. Photovoltaic modules bring electricity to rural areas where there is no electric power grid, and thus increase the life value of these areas. Photovoltaic systems will continue the future development in a direction to become a key factor in the production of electricity for households and buildings in general. The systems are installed on existing roofs and/or are integrated into the facade. These systems contribute to reducing energy consumption in buildings. A series of legislative acts of the European Union in the field of renewable energy and energy efficiency have been developed, particularly promoting photovoltaic technology for achieving the objectives of energy savings and CO2 reduction in public, private and commercial buildings. Also, photovoltaic technology, as a renewable energy source, contributes to power systems through diversification of energy sources and security of electricity supply. By the introduction of incentives for the energy produced by renewable sources in all developed countries, photovoltaic systems have become very affordable, and timely return of investment in photovoltaic systems has become short and constantly decreasing. In recent years, this industry is growing at a rate of 40% per year and the photovoltaic technology creates thousands of jobs at the local level.

2.3 Types of vehicle charging equipment

The word photovoltaic consists of two words: photo, a greek word for light, and voltaic, which defines the measurement value by which the activity of the electric field is expressed, i.e. the difference of potentials. Photovoltaic systems use cells to convert sunlight into electricity. Converting solar energy into electricity in a photovoltaic installation is the most known way of using solar energy. The light has a dual character according to quantum physics. Light is a particle and it is a wave. The particles of light are called photons. Photons are massless particles, moving at light speed. In metals and in the matter generally, electrons can exist as valence or as free. Valence electrons are associated with the atom, while the free electrons can move freely. In order for the valence electron to become free, he must get the energy that is greater than or equal to the energy of binding. Binding energy is the energy by which an electron is bound to an atom in one of the atomic bonds. In the case of photoelectric effect, the electron acquires the required energy by the collision with a photon. Part of the photon energy is consumed for the electron getting free from the influence of the atom which it is attached to, and the remaining energy is converted into kinetic energy of a now free electron. Free electrons obtained by the photoelectric effect are also called photoelectrons. The energy required to release a valence electron from the impact of an atom is called a work out Wi, and it depends on the type of material in which the photoelectric effect has occurred.

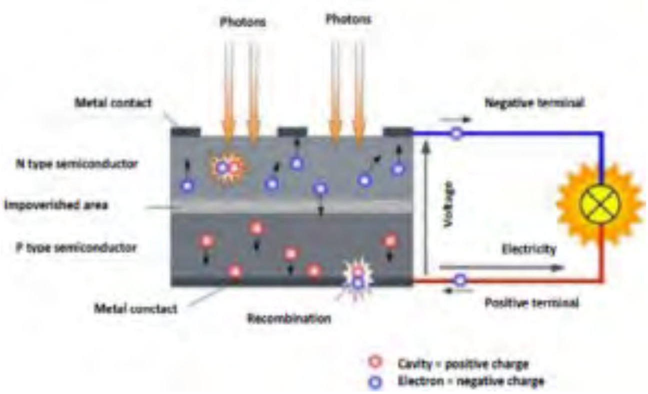


Figure 3: *Functioning of PV cell.*

The previous equation shows that the electron will be released if the photon energy is less than the work output. The photoelectric conversion in the PV junction. PV junction (diode) is a boundary between two differently doped semiconductor layers; one is a P-type layer (excess holes), and the second one is an N-type (excess electrons). At the boundary between the P and the N area, there is a spontaneous electric field, which affects the generated electrons and holes and determines the direction of the current.[12] To obtain the energy by the photoelectric effect, there shall be a directed motion of photoelectrons, i.e. electricity. All charged particles, photoelectrons also, move in a directed motion under the influence of electric field. The electric field in the material itself is located in semiconductors, precisely in the impoverished area of PV junction (diode). It was pointed out for the semiconductors that, along with the free electrons in them, there are cavities as charge carriers, which are a sort of a byproduct in the emergence of free electrons. Cavities occurs whenever the valence electron turns into a free electron, and this process is called the generation, while the reverse process, when the free electron fills the empty spaces - a cavity, is called recombination. If the electron-cavity pairs occur away from the impoverished areas it is possible to recombine before they are separated by the electric field. Photoelectrons and cavities in semiconductors are accumulated at opposite ends, thereby creating an electromotive force. If a consuming device is connected to such a system, the current will flow and we will get electricity. In this way, solar cells produce a voltage around 0,5-0,7 V, with a current density of about several tens of mA/cm2 depending on the solar radiation power as well as on the radiation spectrum. The usefulness of a photovoltaic solar cell is defined as the ratio of electric power provided by the PV solar cells and the solar radiation power. The usefulness of PV solar cells ranges from a few percent to forty percent. The remaining energy that is not converted into electrical energy is mainly converted into heat energy and thus warms the cell. Generally, the increase in solar cell temperature reduces the usefulness of PV cells. Standard calculations for the energy efficiency of solar photovoltaic cells are explained below. Energy conversion efficiency of a solar photovoltaic cell ($\ni$ "ETA") is the percentage of energy from the incident light that actually ends up as electricity. This is calculated at the point of maximum power, Pm, divided by the input light irradiation (E, in W/m2), all under standard test conditions (STC) and the surface of photovoltaic solar cells (AC in m2). STC - standard test conditions, according to which the reference solar radiation is 1.000 W/m2, spectral distribution is 1.5 and cell temperature 250C[11-20]

2.4 Battery

The storage battery or secondary battery is such battery where electrical energy can be stored as chemical energy and this chemical energy is then converted to electrical energy as when required. The conversion of electrical energy into chemical energy by applying external electrical source is known as charging of battery. Whereas conversion of chemical energy into electrical energy for supplying the external load is known as discharging of secondary battery. During charging of battery, current is passed through it which causes some chemical changes inside the battery. This chemical changes absorb energy during their formation. When the battery is connected to the external load, the chemical changes take place in reverse direction, during which the absorbed energy is released as electrical energy and supplied to the load. There are two types of batteries:

1. Primary batteries (disposable batteries): which are designed to be used once and discarded.

2. Secondary batteries (rechargeable batteries): which are designed to be recharged and used multiple times.

Most of the batteries used today with hybrid power system are from the rechargeable type. There are several kinds of rechargeable batteries.

3 MPPT FOR WECS

Wind generation system has been attracting wide attention as a renewable energy source due to depleting fossil fuel reserves and environmental concerns as a direct consequence of using fossil fuel and nuclear energy sources. Wind energy, even though abundant, varies continually as wind speed changes throughout the day. Amount of power output from a WECS depends upon the accuracy with which the peak power points are tracked by the MPPT controller of the WECS control system irrespective of the type of generator used. The maximum power extraction algorithms researched so far can be classified into three main control methods, namely tip speed ratio (TSR) control, power signal feedback (PSF) control and hill-climb search (HCS) control. The TSR control method regulates the rotational speed of the generator in order to maintain the TSR to an optimum value at which power extracted is maximum. This method requires both the wind speed and the turbine speed to be measured or estimated in addition to requiring the knowledge of optimum TSR of the turbine in order for the system to be able extract maximum possible power. Figure 2 shows the block diagram of a WECS with TSR control.

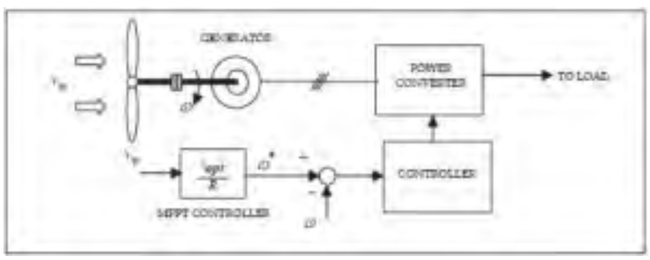


Figure 4: *Tip speed ratio control of WECS.*

In PSF control, it is required to have the knowledge of the wind turbine's maximum power curve, and track this curve through its control mechanisms. The maximum power curves need to be obtained via simulations or off-line experiment on individual wind turbines. In this method, reference power is generated either using a recorded maximum power curve or using the mechanical power equation of the wind turbine where wind speed or the rotor speed is used as the input. Figure 3 shows the block diagram of a WECS with PSF controller for maximum power extraction.[1-3]

The HCS control algorithm continuously searches for the peak power of the wind turbine. It can overcome some of the common problems normally associated with the other two methods. The tracking algorithm, depending upon the location of the operating point and relation between the changes in power and speed, computes the desired optimum signal in order to drive the system to the point of maximum power. Figure 4 shows the principle of HCS control and figure 5 shows a WECS with HCS controller for tracking maximum power points.

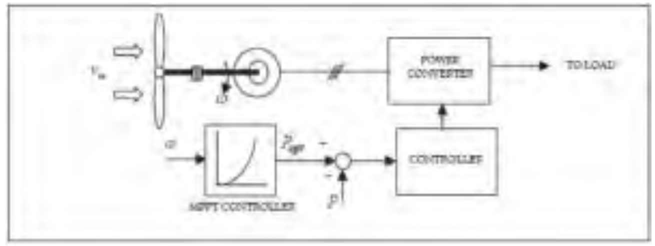


Figure 5: *Power signal feedback control.*

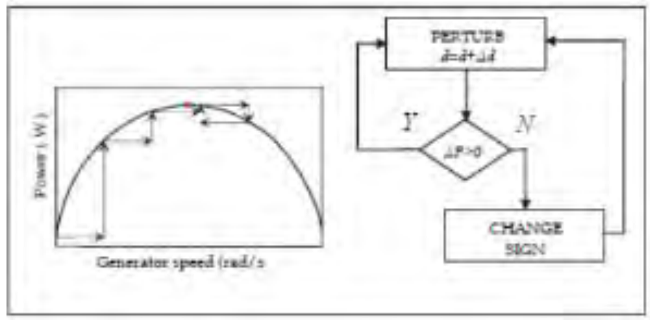


Figure 6: *HSC control principle.*

3.1 MPPT for PMSG based WECS

Permanent Magnet Synchronous Generator is favoured more and more in developing new designs because of higher efficiency, high power density, availability of high-energy permanent magnet material at reasonable price, and possibility of smaller turbine diameter in direct drive applications. Presently, a lot of research efforts are directed towards designing of WECS which is reliable, having low wear and tear, compact, efficient, having low noise and maintenance cost; such a WECS is realisable in the form of a direct drive PMSG wind energy conversion system. [10-16]

There are three commonly used configurations for WECS with these machines for converting variable voltage and variable frequency power to a fixed frequency and fixed voltage power. The power electronics converter configurations most commonly used for PMSG WECS are shown in figure 7. Depending upon the power electronics converter configuration used with a particular PMSG WECS a suitable MPPT controller is developed for its control. All the three methods of MPPT control algorithm are found to be in use for the control of PMSG WECS.

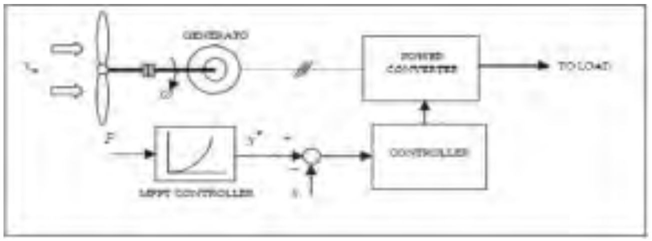


Figure 7: *WECS with hill climb search control.*

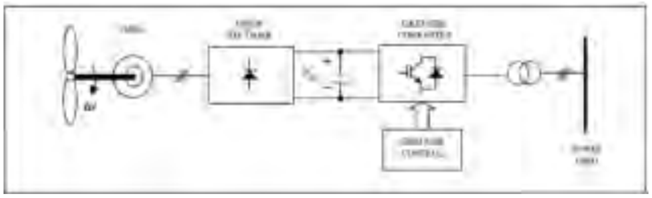


Figure 8: *PMSG WECS.*

3.2 Tip speed control

A wind speed estimation based TSR control is proposed in order to track the peak power points. The wind speed is estimated using neural networks, and further, using the estimated wind speed and knowledge of optimal TSR, the optimal rotor speed command is computed. The generated optimal speed command is applied to the speed control loop of the WECS control system. The PI controller controls the actual rotor speed to the desired value by varying the switching ratio of the PWM inverter. The control target of the inverter is the output power delivered to the load. This WECS uses the power converter configuration shown in figure 6. The block diagram of the ANN-based MPPT controller module is shown in figure 7.

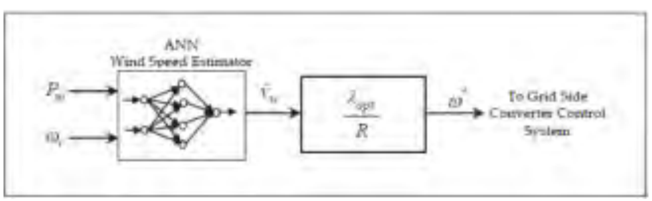


Figure 9: *ANN based MPPT control module.*

3.3 MPPT for PV

MPPT or Maximum Power Point Tracking is algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage). Maximum power varies with solar radiation, ambient temperature and solar cell temperature. A MPPT, or maximum power point tracker is an electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid. To put it simply, they convert a higher voltage DC output from solar panels (and a few wind generators) down to the lower voltage needed to charge batteries. (These are sometimes called "power point trackers" for short - not to be confused with PANEL trackers, which are a solar panel mount that follows, or tracks, the sun). The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient voltage (maximum power point). That is to say: MPPT checks output of PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current into battery. It can also supply power to a DC load, which is connected directly to the battery. MPPT is most effective under these conditions:

1. Cold weather, cloudy or hazy days: Normally, PV module works better at cold temperatures and MPPT is utilized to extract maximum power available from them.

2. When battery is deeply discharged: MPPT can extract more current and charge the battery if the state of charge in the battery is lowers.

Panel tracking is where the panels are on a mount that follows the sun. The most common are the Zomeworks and Wattsun. These optimize output by following the sun across the sky for maximum sunlight. These typically give you about a 15% increase in winter and up to a 35% increase in summer. This is just the opposite of the seasonal variation for MPPT controllers. Since panel temperatures are much lower in winter, they put out more power. And winter is usually when you need the most power from your solar panels due to shorter days. Maximum Power Point Tracking is electronic tracking usually digital. The charge controller looks at the output of the panels, and compares it to the battery voltage. It then figures out what is the best power that the panel can put out to charge the battery. It takes this and converts it to best voltage to get maximum AMPS into the battery. (Remember, it is Amps into the battery that counts). Most modern MPPT's are around 93-97% efficient in the conversion. You typically get a 20 to 45% power gain in winter and 10-15% in summer. Actual gain can vary widely depending weather, temperature, battery state of charge, and other factors. Grid tie systems are becoming more popular as the price of solar drops and electric rates go up. There are several brands of grid-tie only (that is, no battery) inverters available.

All of these have built in MPPT. Efficiency is around 94% to 97% for the MPPT conversion on those. Solar cells are neat things. Unfortunately, they are not very smart. Neither are batteries - in fact batteries are downright stupid. Most PV panels are built to put out a nominal 12 volts. The catch is "nominal". In actual fact, almost all "12 volt" solar panels are designed to put out from 16 to 18 volts. The problem is that a nominal 12 volt battery is pretty close to an actual 12 volts - 10.5 to 12.7 volts, depending on state of charge. Under charge, most batteries want from around 13.2 to 14.4 volts to fully charge quite a bit different than what most panels are designed to put out.[9-14]

4 PROPOSED SYSTEM

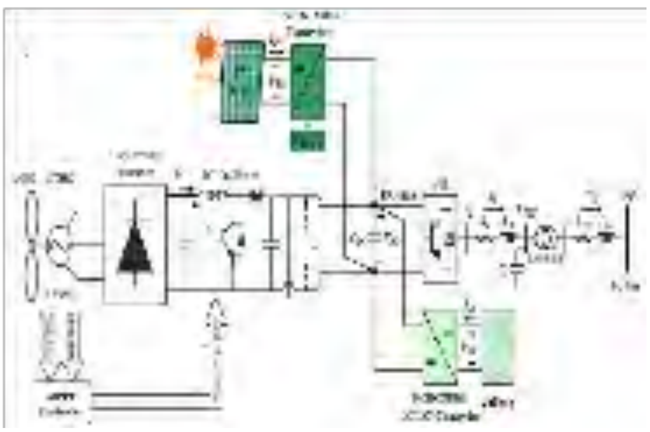


Figure 10: *Block diagram of proposed system.*

Figure 7 shows the block diagram of the proposed Maximum Power Point Tracking (MPPT) system for wind energy conversion system and supercapacitor connected photovoltaic system which is connected with distribution power grid.

4.1 MPPT for WECS and PV to support power grid

MPPT or Maximum Power Point Tracking is calculation that incorporated into charge controllers utilized for removing most extreme accessible power from PV module under specific conditions. The voltage at which PV module can deliver most extreme power is called 'greatest power point' (or pinnacle control voltage). Most extreme power differs with sunlight based radiation, encompassing temperature and sun based cell temperature. A MPPT, or most extreme power point tracker is an electronic DC to DC converter that streamlines the match between the sun powered exhibit (PV boards), and the battery bank or utility framework. Basically, they change over a higher voltage DC yield from sun based boards (and a couple of twist generators) down to the lower voltage expected to charge batteries. (These are some of the time called "control point trackers" for short - not to be mistaken for PANEL trackers, which are a sun powered board mount that takes after, or tracks, the sun). The significant standard of MPPT is to separate the greatest accessible power from PV module by influencing them to work and no more productive voltage (most extreme power point). In other words: MPPT checks yield of PV module, thinks about it to battery voltage at that point fixes what is the best power that PV module can deliver to charge the battery and believers it to the best voltage to get most extreme current into battery. It can likewise supply energy to a DC stack, which is associated specifically to the battery. Wind energy conversion system have been pulling in wide consideration as a sustainable power source because of exhausting petroleum derivative stores and natural worries as an immediate result of utilizing non-renewable energy source and atomic vitality sources. Wind vitality, despite the fact that plentiful, fluctuates persistently as wind speed changes for the duration of the day. The measure of energy yield from a wind energy cpnversion system (WECS) relies on the exactness with which the pinnacle control focuses are followed by the most maximum power point tracking (MPPT) controller of the WECS control framework independent of the kind of generator utilized. This examination gives an audit of over a significant time span MPPT controllers utilized for extricating greatest power from the WECS utilizing lasting magnet synchronous generators (PMSG), squirrel confine enlistment generators (SCIG) and doubly bolstered acceptance generator (DFIG). These controllers can be grouped into three principle control techniques, in particular tip speed ratio (TSR) control, , power signal feedback (PSF) control and hill climb seek (HCS) control. The section begins with a concise foundation of wind vitality transformation frameworks. At that point, principle MPPT control strategies are exhibited, after which, MPPT controllers utilized for separating most extreme conceivable power in WECS are displayed.[7-19]

4.2 PV array

A PV Array consists of a number of individual PV modules or panels that have been wired together in a series and/or parallel to deliver the voltage and amperage a particular system requires. An array can be as small as a single pair of modules, or large enough to cover acres.The performance of PV modules and arrays are generally rated according to their maximum DC power output (watts) under Standard Test Conditions (STC). Standard Test Conditions are defined by a module (cell) operating temperature of 25oC (77 F), and incident solar irradiant level of 1000 W/m2 and under Air Mass 1.5 spectral distribution. Since these conditions are not always typical of how PV modules and arrays operate in the field, actual performance is usually 85 to 90 percent of the STC rating. The simulation of PV system used in proposed work is shown in figure 8.

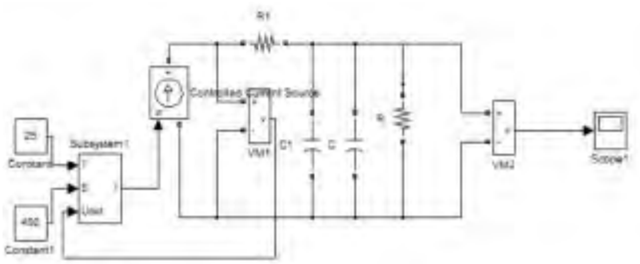


Figure 11: *Simulation diagram of PV system*

4.3 WECS

WECS which converts the energy present in the moving air (wind) to electric energy. The wind passing through the blades of the wind turbine generates a force that turns the turbine shaft. The rotational shaft turns the rotor of an electric generator, which converts mechanical power into electric power. The major components of a typical wind energy conversion system include the wind turbine, generator, interconnection apparatus and control systems. The power developed by the wind turbine mainly depends on the wind speed, swept area of the turbine blade, density of the air, rotational speed of the turbine and the type of connected electric machine. It is shown in figure 9. MPPT for this WECS is shown in figure 10.

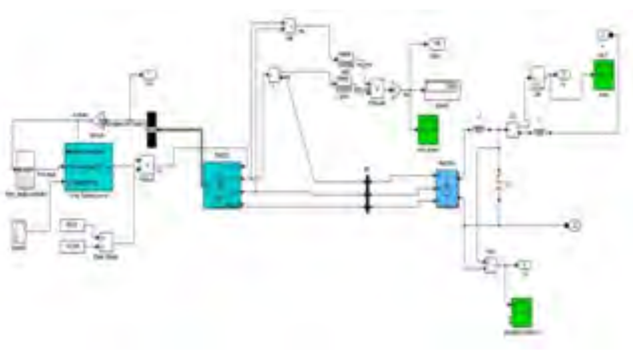


Figure 12: *Wind energy conversion system.*

4.4 Battery

Solar panels cannot produce energy at night or during cloudy periods. But rechargeable batteries can store

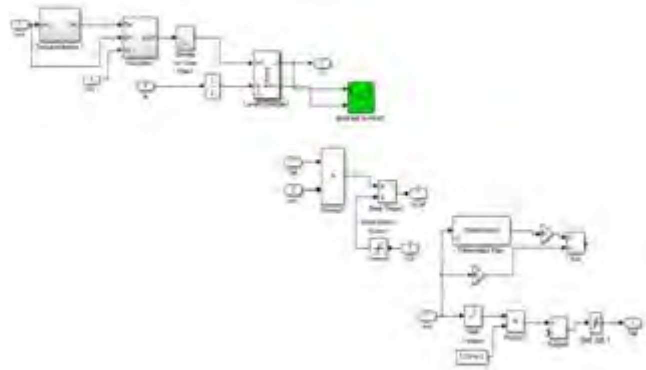


Figure 13: *MPPT for WECS.*

electricity: the photovoltaic panels charge the battery during the day, and this power can be drawn upon in the evening. Residential systems usually use deep-cycle batteries that last for about ten years and can repeatedly charge and discharge about 80 percent of their capacity. While batteries can be expensive, in remote areas it can often be more cost effective to use batteries rather than extending an electricity cable to the grid. But if choosing to go off the grid in this way, the batteries must be sized correctly, with a storage capacity sufficient to meet electricity needs. In most cases, though, purchasing electricity from the grid is cheaper than opting for batteries. The simulation of this battery is shown in figure 11 and the controller that is used to control the battery charging and discharging is called battery manager it is shown in figure 12.

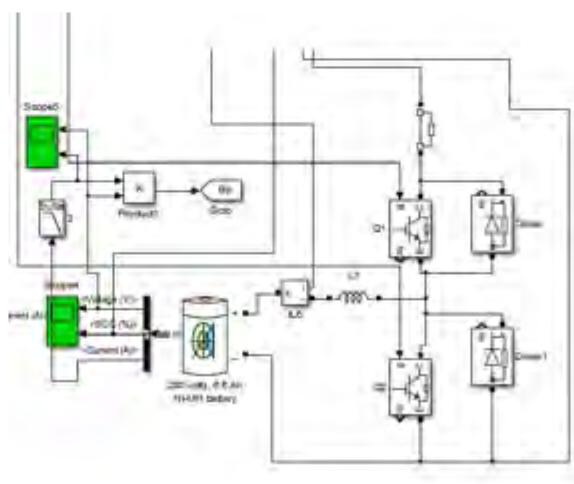


Figure 14: *Battery.*

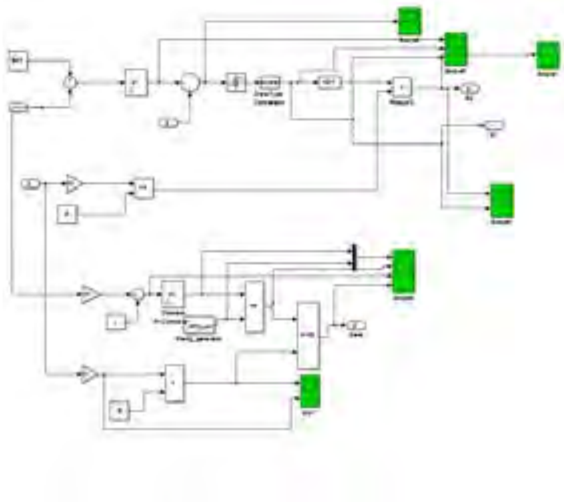


Figure 15: *Battery manager.*

4.5 Boost converter

The boost converter converts an input voltage to a higher output voltage. The boost converter is also called a step-up converter. A boost converter is a DC-to-DC power converter .with an output voltage greater than its input voltage. It is a class of switched mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor and at least one energy storage element, a capacitor C, inductor L or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.[13] Power for the boost converter can come from any suitable DC sources,. A process that changes low DC voltage to a high DC voltage is called DC to DC conversion .It "steps up" the source voltage. Since power must be conserved the output current is lower than the source current. It is used to boost the voltage from the PV, battery and WECS.

4.6 Voltage source inverter (VSI)

An inverter is an electrical device which converts DC voltage, almost always from batteries, into standard household AC voltage so that it is able to be used by common appliances. In short, an inverter converts direct current into alternating current. Direct current is used in many of the small electrical equipment such as solar power systems, since solar cells is only able to produce DC. They are also used in places where a small amount of voltage is to be used or produced such as power batteries which produce only DC. Other than these fuel cells and other power sources also produce DC. The simulation of this voltage source inverter is source is shown in figure 13.

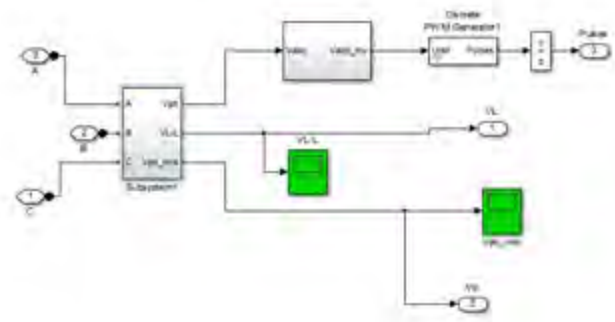


Figure 16: *Voltage source inverter.*

This overall system is connected with the distribution power grid. The simulation layout of this distribution power grid is shown in figure 14.

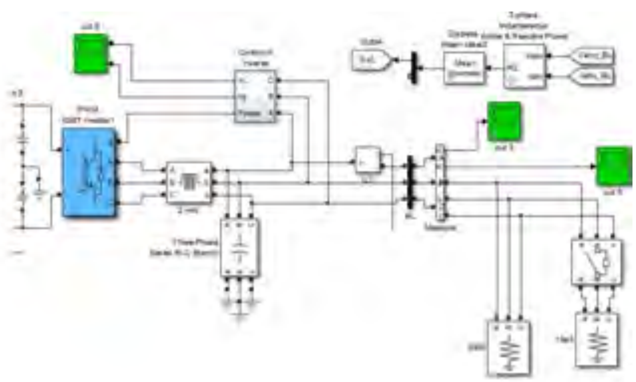


Figure 17: *Distribution power grid.*

In this proposed there are two PV system are connected in parallel to meet the demand, it is shown in figure 15.

The overall proposed system simulation diagram is shown in figure 4.16.

5 RESULTS

The behavior of the complete system of the Maximum Power Point Tracking for a wind energy conversion system with supercapacitor connected photovoltaic system

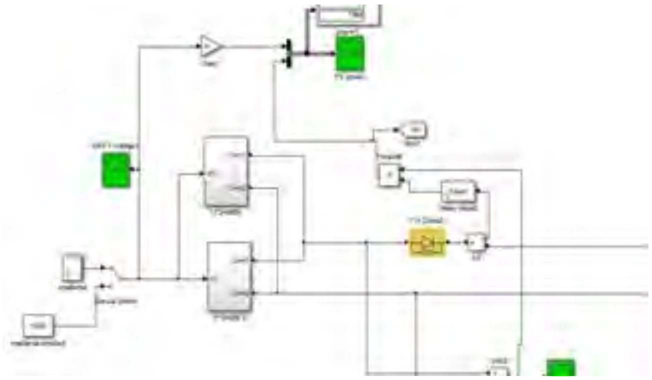


Figure 18: *Parallel PV.*

Figure 19: *Overall simulation of proposed system.*

which supports the distribution power grid is explained by the simulation results. The system comprises two energy sources such as wind energy source and photovoltaic source. The output voltage of the PV system is shown in figure 17

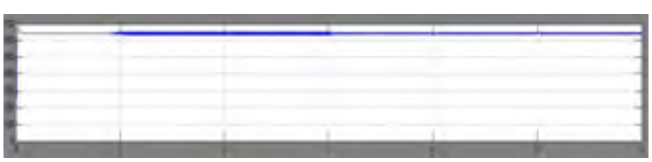


Figure 20: *Output voltage of PV.*

The figure 18 shows the output voltage, current, power of the photovoltaic system and the SOC of the supercapacitor.

The SOC of the battery which indicates the charging and discharging process of battery and the output voltage of the batter after the boost converter is shown in figure 19.

The overall system output voltage and power is shown in figure 20 and the system current is shown in figure 21.

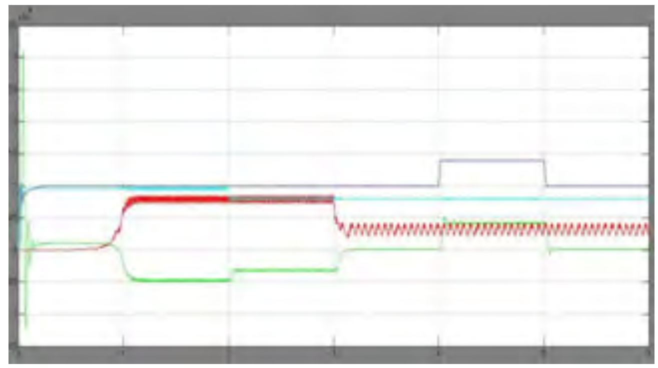


Figure 21: *Output voltage, current, power of PV and SOC of SC.*

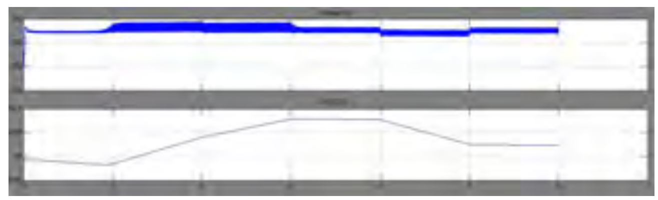


Figure 22: *Output voltage and SOC of battery.*

6 CONCLUSION

Renewable energy sources also called non-conventional type of energy are continuously replenished by natural processes. Hybrid systems are the right solution for a clean energy production. Hybridizing solar and wind power sources provide a realistic form of power generation. This proposed design overcomes the drawbacks of the earlier proposed systems. This system allows the two sources to supply the load separately or simultaneously depending on the availability of the energy sources. MPPT control is done for PV and wind energy so that maximum power is tracked and system work more reliably and efficiently. This system has lower operating cost and finds applications in remote area power generation, constant speed and variable speed energy conversion systems and rural electrification. MATLAB/ SIMULINK software is used to model the PV panel, wind turbine, MPPT controller and proposed hybrid system.

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Power Management of a Hybrid Solar- Wind Energy Sys-

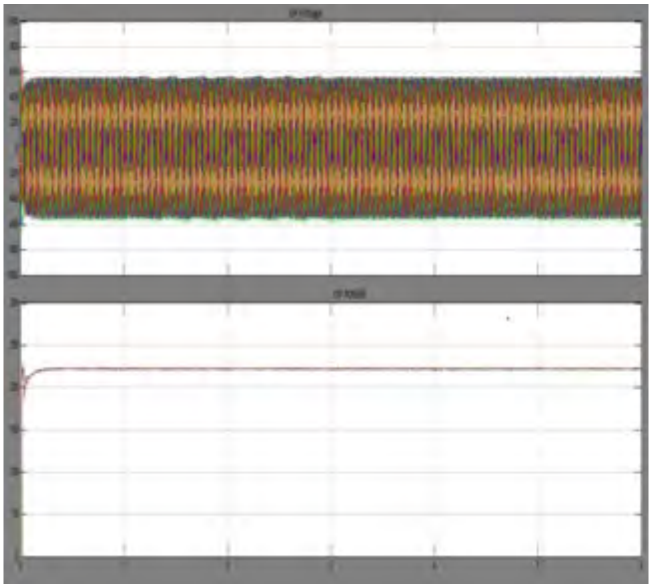


Figure 23: *Overall system voltage and power.*

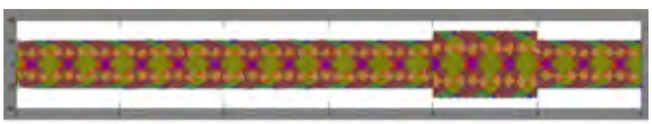


Figure 24: *Proposed system current.*

tem" International Journal of Engineering Research & Technology vol. 3(2) pp.1988-1992, 2014.

[3] M. Siva Ramkumar, M. Sivaram Krishnan, Dr.A.Amudha "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc" in International Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[5] M Siva RamKumar, A. Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016. .

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763-769,2014.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2),2014

[9] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[10] D. Kavitha, C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.20 (2015), pg. 17749-17754.

[11] D. Manoharan, A. Amudha. "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, A. Amudha. A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6233-6240.

[13] A. Amudha. "Enhancement of Available Transfer Capability using FACTS controller" in International journal of Applied Mechanics and Materials, Vol. 573, pp 340-345

[14] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035-2042.

[15] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[17] K. Balachander, P. Vijayakumar, “Renewable Energy System Optimization of Two Different Locations” CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, V. Ponnusamy, ‘Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System’ International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[19] K. Balachander, V. Ponnusamy, ‘Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER’ International Journal of Applied Engineering Research’, Volume 7, Number 3 (2012), pp. 247-256. .

[20] K. Balachander, S. Kuppusamy, V. Ponnusamy, ‘Modeling and Simulation of VSDFIG and PMSG Wind Turbine System’, International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[21] M. Sivaram Krishnan, Dr.A.Amudha, M. Siva Ramkumar, ‘Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms’, International journal of Pure and Applied Mathimatics,118 (11), pp 609-617,2018 DOI:10.12732/ijpam.v118i11.79

[22] S. Motapon, L. Dessaint, K.AI-Haddad, ”A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, ” IEEE Trans. Ind. Electron. , vo1.61, no.3, pp.1320,1334, March 2014.

MODELING, DESIGN AND IMPLEMENTATION OF A POWER CONVERSION SYSTEM FOR WECS BY USING FUZZY BASED MPPT

V. Suresh, G. Emayavaramban, A. Amudha, K. Balachander, D. Kavitha

Abstract: In recent years power generation from renewable energy sources has gained importance in view of supplementing the power obtained from conventional sources. Out of all the renewable energy sources, wind energy conversion system is the greatest contributor to the power generations. During the recent years use of variable speed of the wind turbine is gaining much more importance than the fixed speed wind turbine. Important factors regarding variable speed operation are that it is easy to control and is even more efficient. Therefore, it is important to study the machine modelling of the double fed induction generator (DFIG) for a wind energy conversion system (WECS). One of the major areas in renewable power control includes the grid connected DFIG based WECS. Typically a DFIG based WECS consists of a Wind turbine connected to a DFIG and then the turbine-coupled DFIG is connected to the grid through a power electronic AC-AC converter. In this thesis the Maximum Power Point Tracking technique is implemented to extract the maximum power from the wind energy conversion system. The fuzzy logic controller is designed to control the MPPT. Simulations and analysis are done by the use of MATLAB /SIMULINK software.

Keywords: Wind Energy Conversion System (WECS), Doubly Fed Induction Generator (DFIG) Fuzzy Logic Controller (FLC), Maximum Power Point Tracking (MPPT).

1 Introduction

It is quite accepted that the earth's fossil energy resources are limited, and the cost of global oil, coal and gas production continues to rise beyond their peak. Fossil fuels belong to finite sources and so will be completely exhausted one day or the other. Comparing to the above case renewable energies have been in a great demand due to absence of the emissions of poisonous gases like carbon dioxide and sulphur dioxide. The various types of renewable energy sources contributing to current energy demand consist of water, wind, solar energy and biomass. However the major drawback suffered by hydroelectric power plants is its expensive and costly nature to build and also the plants must operate for a long time to become profitable. The creation of dams may even lead to flooding of lands leading to environmental destruction. Similarly solar energy can only be extracted from solar thermal collectors in the presence of sunlight. Due to this condition solar energy set up becomes impractical in areas where there is little sunlight or heavy rainfall. The reason behind the popularity of wind energy is due to its non-polluting nature, greater efficiency and mainly due to its low operation cost. The increasing development of wind energy has resulted in many new modeling and improved simulation methods. Wind power harnessing procedure has been a task for many years. Since long back wind mills were put into the task of pumping water and grinding grain. Many new technologies such as pitch control and variable speed control methods have been tested and put forward since. Sometimes, wind turbine work in an isolating mode; therefore, there is no grid. Usually there are two, three or even more than three blades on a wind turbine. However according to aerodynamics concept, three blades is the optimum number of blades for a wind turbine. Asynchronous and synchronous ac machines are the main generators that are used in the wind turbines. A wind turbine extracts kinetic energy from the wind and converts this into mechanical energy. Finally, this mechanical energy is converted to electrical energy with the help of a generator. Therefore, the complete system that involves converting the energy of the wind to electricity is called wind energy conversion system. A wind turbine extracts the maximum amount of energy from the wind when operating at an optimal rotor speed, which again depends on speed of wind. The optimal rotor speed varies due to the variable nature of the wind speed.[1-9] Research shows that variable speed operation of the rotor results in a higher energy production compared to a system operating at constant speed. A wind turbine model consists of blades, a generator, a power electronic converter, and power grid. Blades are used to extract power from the wind. By operating the blades at optimal tip speed ratio, maximum amount of energy can be extracted from the variable speed wind turbine. The maximum power point tracking (MPPT) control of variable speed operation is used to achieve high efficiency in wind power systems. The MPPT control is operated using the machine side control system. The function of pitch angle control scheme is to regulate the pitch angle by keeping the output power at rated value even when the wind speed experiences gusts. The double fed induction generator is associated with AC to AC converter, where generator is directly grid connected through the stator windings, keeping into account the grid voltage and frequency fixed. While the rotor windings are fed by rotor side converter at variable frequency through slip rings.[10-20]

2 WIND ENERGY CONVERSION SYSTEM

The emerging awareness for environmental preservation concurrent with the increasingly power demand have become common place to utilities. To satisfy both these conflicting requirements, utilities have focused on the reduction of high polluting sources of energy. The desire to seek alternative renewable energy resources has led to the widespread development of distributed generations (DGs). In many countries, wind electric generators (WEGs) are becoming the main renewable source of electric energy. wind power would be the second largest source of electricity behind hydro and ahead of coal, natural gas and nuclear. An individually installed WEG is commonly referred to as a wind turbine (WT) or simply as a wind generator (WG), and a group of such generators is referred to as a wind power plant (WPP) or wind farm (WF). Wind farms of all sizes are continuously being connected directly to the power grids and they have the potential to replace many of the conventional power plants. This means that wind turbines should possess the general characteristics of conventional power plants such as simplicity of use, long and reliable useful life, low maintenance and low initial cost. Moreover, large wind farms should satisfy very demanding technical requirements such as frequency and voltage control, active and reactive power regulation, and fast response during transient and dynamic situations. WGs can either operate at fixed speed or at variable speed. Due to various reasons such as reduced mechanical stress, flexible active-reactive power controllability, good power quality, low converter rating and low losses, nowadays the most popular topology is the variable speed type Double Fed Induction Generator (DFIG).

2.1 Wind Energy Conversion System

Figure 1 represents the complete wind energy conversion systems (WECS), which converts the energy present in the moving air (wind) to electric energy. The wind passing through the blades of the wind turbine generates a force that turns the turbine shaft. The rotational shaft turns the rotor of an electric generator, which converts mechanical power into electric power. The major components of a typical wind energy conversion system include the wind turbine, generator, interconnection apparatus and control systems. The power developed by the wind turbine mainly depends on the wind speed, swept area of the turbine blade, density of the air, rotational speed of the turbine and the type of connected electric machine.

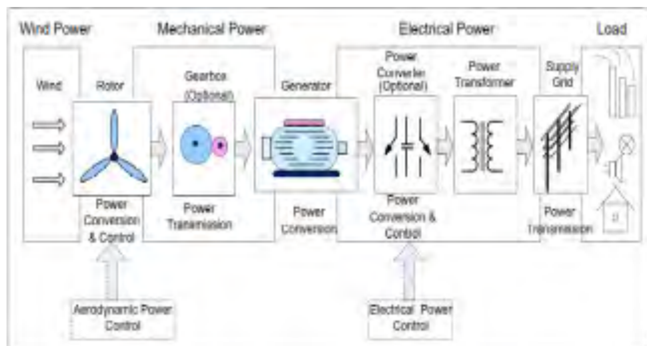


Figure 1: *Wind Energy Conversion System.*

As shown in figure 1, there are primarily two ways to control the WECS. The first is the Aerodynamic power control at either the Wind Turbine blade or nacelle, and the second is the electric power control at an interconnected apparatus, e.g., the power electronics converters. The flexibility achieved by these two control options facilitates extracting maximum power from the wind during low wind speeds and reducing the mechanical stress on the wind turbine during high wind speeds.

3 Doubly Fed Induction Generator

Figure 2 presents the topology of the DFIG, which will be thoroughly analyzed in this section. As shown in figure 2, the DFIG consists of two bi-directional voltage source converters with a back-to-back DC-link, a wound rotor induction machine, and the wind turbine.

3.0.1 Wound Rotor Induction Machine:

The WRIM is a conventional 2-phase wound rotor induction machine. The machine stator winding is directly connected to the grid and the rotor winding is connected to the rotor-side VSC by slip rings and brushes.

3.0.2 Voltage Source Converters:

This type of machine is equipped with two identical VSCs. These converters typically employ IGBTs in their design. The AC excitation is supplied through both the grid-side VSC and the rotor-side VSC. The grid side VSC is connected the ac network. The rotor side converter is connected to the rotor windings. This grid side VSC and the stator are connected to the ac grid via step up transformer to elevate the voltage to the desired grid high voltage level. The VSCs allow a wide range of variable speed operation of the WRIM. If the operational speed range is small, then less power has to be handled by the bidirectional power converter connected to the rotor. If the speed variation is controlled between +/- 20 %, then the converter must have a rating of approximately 20 % of the generator rating. Thus the required converter rating is significantly smaller than the total generator power, but it depends on the selected variable speed range and hence the slip power. Therefore, the size and cost of the power converter increases when the allowable speed range around the synchronous speed increases[11-16].

3.0.3 DC-link with Capacitor:

The capacitor connected to the DC-link acts as a constant, ripple-free DC voltage source, an energy storage device and a source of reactive power. Moreover, the DC-link provides power transmission and stabilization between both unsynchronized AC systems.

3.0.4 Control System:

The control system generates the following commands: the pitch angle command, which is used by the aerodynamic Pitch Control to control the wind power extracted by turbine blades; the voltage command signal Vrc, which is intended to control the rotor side VSC; and the signal Vgc, which is intended to control the grid side VSC (to control the electrical power). In turn, the rotor-side VSC controls the power of the wind turbine, and the grid-side VSC controls the dc-bus voltage and the reactive power at the grid terminals.

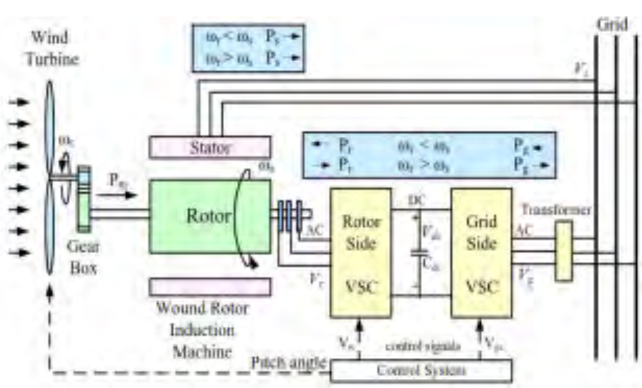


Figure 2: *Doubly Fed Induction Generator type WT.*

By implementing pulse width modulation, it is possible to control the VSCs to generate an output waveform with desired phase angle and voltage magnitude, and at the same time reduce lower order harmonics. [14-23]

3.1 Operating Principle

A wide range of variable speed operating mode can be achieved by applying a controllable voltage across the rotor terminals. This is done through the rotor-side VSC. The applied rotor voltage can be varied in both magnitude and phase by the converter controller, which controls the rotor currents. The rotor side VSC changes the magnitude and angle of the applied voltages and hence decoupled control of real and reactive power can be achieved. The rotor-side VSC controller provides two important functions:

- Variation of generator electromagnetic torque and hence rotor speed.
- Constant stator reactive power output control, stator power factor control or stator terminal voltage control.

The grid-side VSC controller provides:

- Regulation of the voltage of the DC bus capacitor.
- Control of the grid reactive power.

The DFIG exchanges power with the grid when operating in either sub or super synchronous speeds.[15-18]

4 MPPT FOR WECS

Wind generation system has been attracting wide attention as a renewable energy source due to depleting fossil fuel reserves and environmental concerns as a direct consequence of using fossil fuel and nuclear energy sources. Wind energy, even though abundant, varies continually as wind speed changes throughout the day. Amount of power output from a WECS depends upon the accuracy with which the peak power points are tracked by the MPPT controller of the WECS control system irrespective of the type of generator used. The maximum power extraction algorithms researched so far can be classified into three main control methods, namely tip speed ratio (TSR) control, power signal feedback (PSF) control and hill-climb search (HCS) control. The TSR control method regulates the rotational speed of the generator in order to maintain the TSR to an optimum value at which power extracted is maximum. This method requires both the wind speed and the turbine speed to be measured or estimated in addition to requiring the knowledge of optimum TSR of the turbine in order for the system to be able extract maximum possible power. Figure 2 shows the block diagram of a WECS with TSR control.

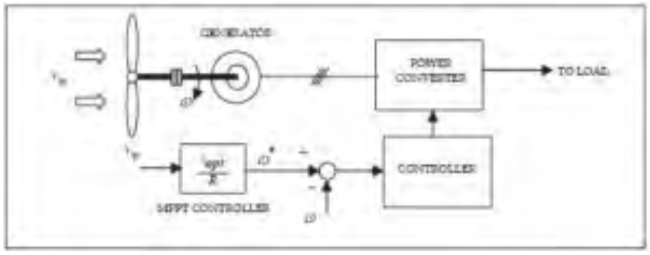


Figure 3: *Tip speed ratio control of WECS.*

In PSF control, it is required to have the knowledge of the wind turbine's maximum power curve, and track this curve through its control mechanisms. The maximum power curves need to be obtained via simulations or off-line experiment on individual wind turbines. In this method, reference power is generated either using a recorded maximum power curve or using the mechanical power equation of the wind turbine where wind speed or the rotor speed is used as the input. Figure 3 shows the block diagram of a WECS with PSF controller for maximum power extraction.

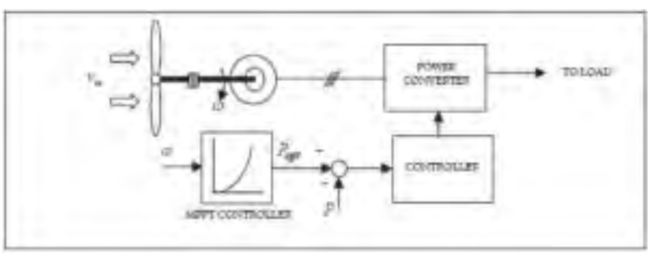


Figure 4: *Power signal feedback control.*

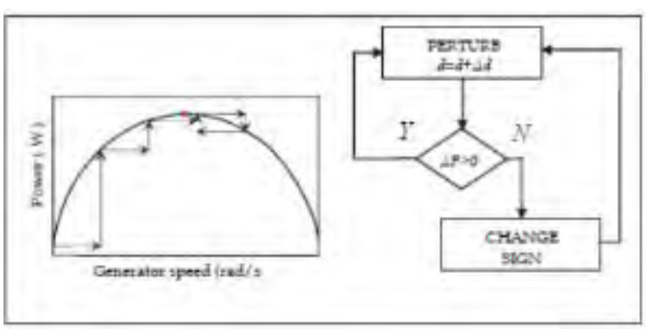


Figure 5: *HSC control principle.*

The HCS control algorithm continuously searches for the peak power of the wind turbine. It can overcome some of the common problems normally associated with

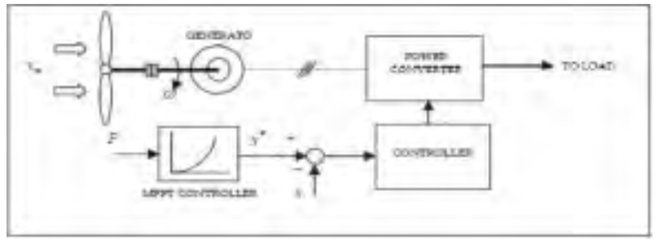


Figure 6: *WECS with hill climb search control.*

the other two methods. The tracking algorithm, depending upon the location of the operating point and relation between the changes in power and speed, computes the desired optimum signal in order to drive the system to the point of maximum power. Figure 4 shows the principle of HCS control and figure 5 shows a WECS with HCS controller for tracking maximum power points.

4.1 MPPT for DFIG based WECS

The PMSG WECS and SCIG WECS have the disadvantages of having power converter rated at 1 p.u. of total system power making them more expensive. Inverter output filters and EMI filters are rated for 1 p.u. output power, making the filter design difficult and costly. Moreover, converter efficiency plays an important role in total system efficiency over the entire operating range. WECS with DFIG uses back to back converter configuration as is shown in figure 3. The power rating of such converter is lower than the machine total rating as the converter does not have to transfer the complete power developed by the DFIG. Such WECS has reduced inverter cost, as the inverter rating is typically 25% of total system power, while the speed range of variable speed WECS is 33% around the synchronous speed. It also has reduced cost of the inverter filters and EMI filters, because filters are rated for 0.25 pu total system power, and inverter harmonics present a smaller fraction of total system harmonics. In this system power factor control can be implemented at lower cost, because the DFIG system basically operates similar to a synchronous generator. The converter has to provide only the excitation energy. The higher cost of the wound rotor induction machine over SCIG is compensated by the reduction in the sizing of the power converters and the increase in energy output. The DFIG is superior to the caged induction machine, due to its ability to produce above rated power. The MPPT control in such system is realized using the machine side control system.[7-13]

4.2 Tip speed ratio control

TSR control is possible with wind speed measurement or estimation. A wind speed estimation based MPPT

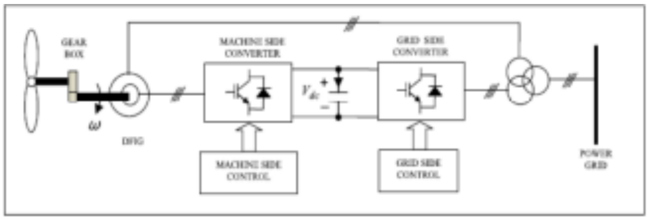


Figure 7: *DFIG WECS.*

controller is proposed for controlling a brushless doubly fed induction generator WECS. The block diagram of the TSR controller is shown in figure 4. The optimum rotor speed, which is the output of the controller, is used as the reference signal for the speed control loop of the machine side converter control system. The method requires the total output power P0 of the WECS and rotor speed as input to the MPPT controller. Using P0 as the input to a look-up table of Ic profile, optimum winding current opt is obtained. The maximum generator efficiency max is estimated at a particular control current optimized operating point using a stored efficiency versus optimum current characteristic of the generator. In the algorithm presented the relations Ic versus PT and Ic versus ∋ were implemented using RBF neural networks. Then, generator input power PT is calculated from the maximum efficiency max and the measured output power P0 .

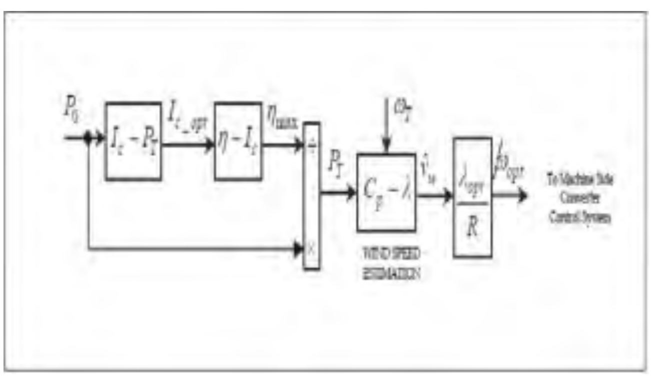


Figure 8: *Generation of optimum speed command.*

The next step involves wind speed estimation which is achieved using Newton-Raphson or bisection method. The estimated wind speed information is used to generate command optimum generator speed for optimum power extraction from WECS. The method is not new; similar work was earlier implemented for controlling a Brushless Doubly Fed Generator. In this method the Brushless Doubly Fed Generator was operated in synchronous mode and input to the controller was only the output power of the WECS.

5 FUZZY LOGIC CONTROLLER

Fuzzy logic is a soft computing tool for embedding structured human knowledge into workable algorithms. The idea of fuzzy logic was introduced by Dr. Lofti Zadeh of UC/Berkley in 1960's as a means of model of uncertainty of natural languages. Fuzzy logic is considered as a logical system that provides a model for human reasoning modes that are approximate rather than exact. The fuzzy logic system can be used to design intelligent systems on the basis of knowledge expressed in human language. There is practically no area of human activity left untouched by intelligent systems as these systems permits the processing of both symbolic and numerical information. The systems designed and developed based on fuzzy logic methods have been proved to be more efficient than those based on conventional approaches. Fuzzy logic has been recently applied in process control, modelling, estimation, identification, stock market prediction, diagnostics, military science, agriculture and so on. One of the pioneering applications of fuzzy logic is in control systems. Fuzzy logic based control is used in various applications. During the past several years, fuzzy logic based control has emerged as one of the most active and fruitful areas for research in the application of fuzzy logic theory, especially in wide range of industrial process which lacks quantitative data regarding the input-output relations. Some important systems for which fuzzy logic based controllers have been extensively used are water quality control system, elevator control system, automatic train operation system, automatic transmission control, nuclear reactor control system, washing machine etc.[11]

5.1 Basics of fuzzy logic theory

Fuzzy logic is another form of artificial intelligence, but its history and applications are more recent than artificial intelligence based expert systems. Fuzzy logic is based on the fact that human thinking does not always follow crispy "YES" – "NO" logic, but it is often vague, uncertain, and indecisive. Fuzzy logic deals with problems that have vagueness, uncertainty, imprecision, approximations or partial truth or qualitative mess. The fuzzy logic is based on fuzzy set theory in which a particular object or variable has a degree of membership in a given set which may be anywhere in the range of 0 to 1. This is different from conventional set theory based on Boolean logic in which a particular object or variable is either a member (logic 1) of a given set or it is not (logic 0). The basic set operations like union (OR), intersection (AND) and complement (NOT) of Boolean logic are also valid for fuzzy logic.

5.2 Basics of Fuzzy Logic Control

Fuzzy logic provides a non-analytic alternative to the classical analytical control theory. Hence, fuzzy logic control is a powerful control tool for systems or processes which are complex and precise mathematical modelling are not possible. Fuzzy logic control is inherently robust and does not require precise, noise free inputs or the measurement or computation of change of parameters. Since the fuzzy logic controller uses defined rules governing the target systems, it can be tuned easily to improve system performance. The fuzzy logic controller is a suitable candidate for the control of multiple input-multiple output systems as it can accept many feedback inputs and generate many control outputs and it needs less storage of data in the form of membership functions and rules than the conventional look up table for non-linear controllers. The block diagram of a closed loop fuzzy logic controller is shown in figure 5. [15-21]

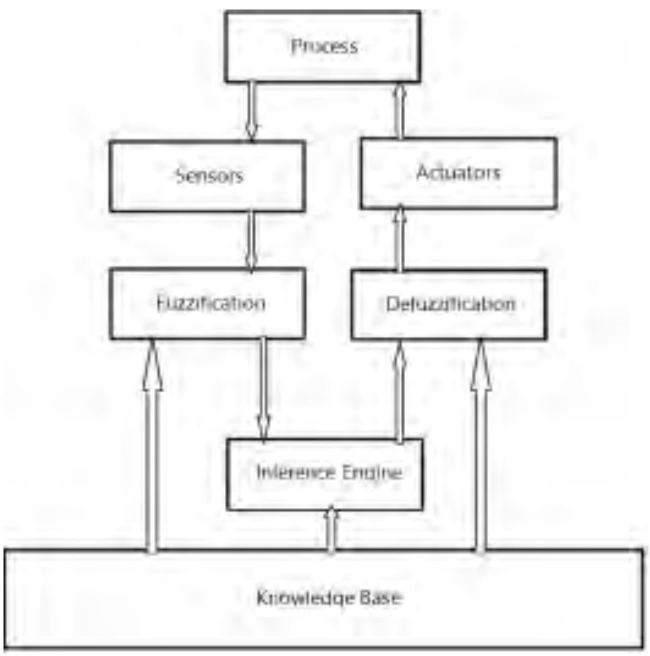


Figure 9: *Fuzzy logic controller.*

In fuzzy logic control of a process or a system, there are two links between the fuzzy logic controller and the process or the system under control, namely the input and output links. The inputs of fuzzy logic controller are linked to the process through sensors and the outputs of the fuzzy logic controller are linked to the process through actuators. The fuzzy logic controller comprises of fuzzification, inference mechanism and de-fuzzification which are executed using information stored in the knowledge.

5.3 Knowledge Base

The knowledge base can be divided into two sub-blocks namely the Data Base and Rule Base. The data base consists of the information required for fuzzifying the crisp input and later defuzzifying the fuzzy outputs to a crisp output. It consists of the membership functions for various fuzzy variables or sets used in the controller design. The rule base consists of a set of rules, which are usually formulated from the expert knowledge of the system. The rules are typically of the form "If. . . . . , then. . . . ." rules. The antecedent part of the rule may be a simple statement or a compound statement using connectives like "and", "or" etc. The consequent part may contain a fuzzy set (Mamdani type and Tsukamoto type) or a linear or a quadratic function of the crisp input variables (Sugeno type). The knowledge base is the heart of fuzzy logic based system it has to be designed with utmost care and requires a lot of expertise in the knowledge of the system into which fuzzy logic controller is being incorporated.

5.4 Fuzzification

As the inputs of fuzzy logic controller are from sensors and the data from sensors are crisp in nature, the fuzzy logic controller cannot use this data directly. Hence, there exists the need for converting this data to the form comprehensible to the fuzzy system. Fuzzification is the process of converting a real scalar crisp value into a fuzzy quantity. This is done by assigning appropriate membership values to each input. The data required to change the crisp value to the fuzzy quantity is stored in the knowledge base in the form of membership functions associated with various linguistic fuzzy variables. A membership function is a function that defines how each point or object in the universe of discourse is assigned a degree of membership or membership value between 0 and 1. The membership function can be an arbitrary curve that is suitable in terms of simplicity, convenience, speed and efficiency. Though a membership function can be an arbitrary curve, there are eleven standard membership functions that are commonly used in engineering applications. These membership functions can be built from several basic functions: piecewise linear functions, sigmoid curve, Gaussian distribution function, and quadratic and cubic polynomial curves. The simplest membership functions can be formed using straight lines. They may be triangular membership function which is a collection of three points forming a triangle or trapezoidal membership function which has a flat top and is just a truncated triangle curve. These membership functions built out of straight lines have the advantage of simplicity. The examples of triangular and trapezoidal membership functions are given in figure 6 and figure 7 respectively. Two types of membership functions can be built using Gaussian distribution curve, a simple Gaussian curve shown in figure 8 and a two sided composite of two different Gaussian curves. The generalized bell membership function is specified by three parameters as shown in 9igure 9.

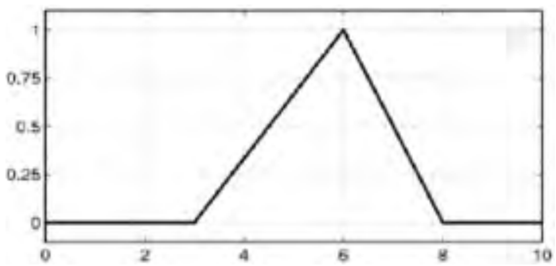


Figure 10: *Triangular membership function .*

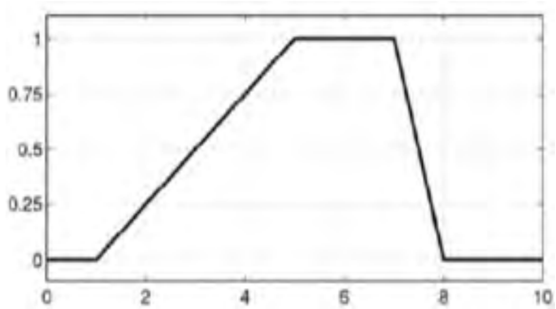


Figure 11: *Trapezoidal membership function.*

Because of their smoothness and nonzero values at all points, Gaussian and bell membership functions are popular membership functions for specifying fuzzy sets. However, they are unable to specify asymmetric membership functions, which are important in many applications. Three types of membership functions are built using sigmoid curves- left open, right open and closed. Two types of closed sigmoid membership functions can be synthesized using two sigmoid functions. They are d-sigmoid membership function using difference between two sigmoid functions, p-sigmoid membership function using the product of two sigmoid functions. The membership functions based on sigmoid curves are asymmetric.

Z-shaped membership functions, S-shaped membership functions and Pi-shaped membership functions are the asymmetrical membership functions which can be built using polynomial based curves. The Z-shaped membership function is the polynomial curve open to the left, S-shaped membership function is the polynomial curve open to the right, and Pishaped membership function has zero on both extremes with a rise in the middle. There is a wide choice of membership function types when a membership function is to be selected. There is no hard and strict rule on the selection of membership functions. The membership functions can be selected to suit the applications in terms of simplicity, convenience, speed and efficiency. The following principles should be adopted for designing membership functions for fuzzy logic controllers. Each membership function overlaps only with the closest neighbouring membership functions. For any input data, the sum of its membership values in all the fuzzy sets (membership functions) should be 1[11-20]

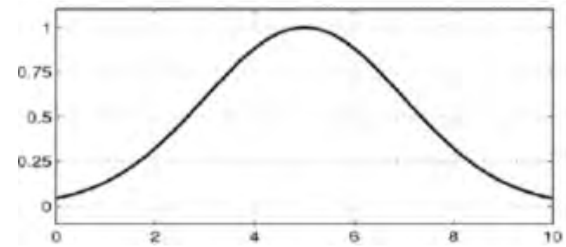


Figure 12: *Gaussian membership function.*

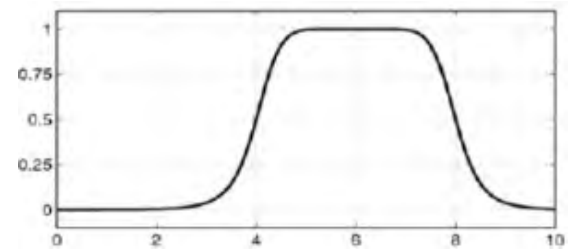


Figure 13: *Generalized bell membership function.*

5.5 Defuzzification

The outputs from the inference engine (Mamdani type) are fuzzy and they need to be converted to crisp outputs before sending them to actuators to control the process. The conversion of a fuzzy quantity to a crisp value is called defuzzification. Some of the commonly used defuzzification methods are discussed here. Centroid method, Center of largest area method, Height method, First of maxima method, Last of maxima method, Mean of maxima method are based on aggregated fuzzy output, ie., all fuzzy outputs corresponding to different rules are aggregated using a union operator (max operator) to an aggregated fuzzy output before defuzzification. The Weighted average method and Center of sums method are based on individual output fuzzy sets. Centroid method or center of gravity method is the most commonly used defuzzification method as this method is very accurate and gives smooth output. In centroid defuzzification method. The center of largest area defuzzification can be used if the aggregate fuzzy set has at-least two convex sub-regions (convex region is the region in which the membership values are strictly monotonically increasing or strictly monotonically decreasing or strictly monotonically increasing and then strictly monotonically decreasing with increasing values of points in the universe). The performance of the defuzzification methods are measured using five criteria. The first one is continuity which means that a small change in the input should not produce a large change in the output. The second criterion is disambiguity which means that the defuzzification method should always result in a unique defuzzified value. The center of largest area method does not satisfy this criterion as there is ambiguity in selecting a defuzzified value when the aggregate membership function has two or more convex subregions with the largest area. The third criterion is plausibiltiy which means that the defuzzified value should lie approximately in the middle of the support region and should have high membership degree. The centroid method does not satisfy this criterion as the defuzzified value determined using centroid method may not have high membership degree in the aggregate membership function though the value lies in the middle of the support region. The fourth one is computational simplicity. The first of maxima method, last of maxima method, mean of maxima method and height method are computationally simpler than centroid method and weighted methods. The fifth criterion is weighting method. The weighted average method is computationally efficient than center of sums method.[14-16]

6 PROPOSED SYSTEM

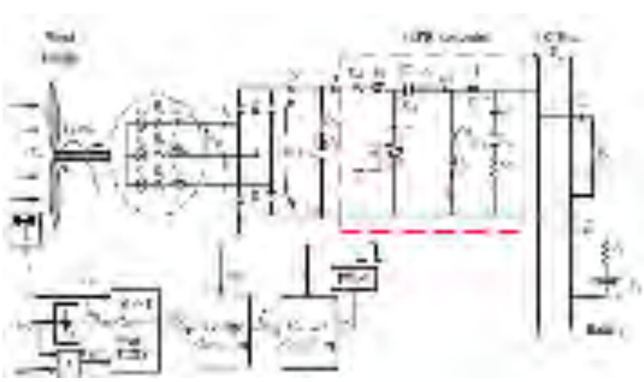


Figure 14: *Block diagram of proposed system.*

Figure 10 shows the block diagram of the proposed MPPT system with fuzzy logic controller

6.1 FLC based MPPT for WECS

Wind electric generators (WEGs) are turning into the primary sustainable wellspring of electric vitality. Wind power would be the second biggest wellspring of power behind hydro and in front of coal, petroleum gas and atomic. A separately introduced WEG is generally alluded to as a breeze turbine (WT) or essentially as a breeze generator (WG), and a gathering of such generators is alluded to as a breeze control plant (WPP) or wind cultivate (WF). Twist ranches of all sizes are consistently being associated straightforwardly to the power frameworks and they can possibly supplant a considerable lot of the regular power plants. This implies wind turbines ought to have the general attributes of ordinary power plants, for example, straightforwardness of utilization, long and solid valuable life, low upkeep and low starting expense.

6.2 Doubly Fed Induction Generator

Among different types of wind turbines, Doubly Fed Induction Generator (DFIG) is used, because it has several advantages over a conventional induction machine in wind power applications. First, as the rotor circuit is controlled by a power electronics converter, the induction generator is able to both import and export reactive power. This has important consequences for power system stability and allows the machine to support the grid during severe voltage disturbance. Second, the control of the rotor voltages and currents enables the induction machine to remain synchronized with the grid while the wind turbine speed varies. A variable speed wind turbine utilizes the available wind resource more efficiently than a fixed speed wind turbine, especially during light wind conditions. Third, the cost of the converter is low when compared with other variable speed solutions because only a fraction of the mechanical power, typically 25-30%, is fed to the grid through the converter, the rest being fed to grid directly from the stator. The efficiency of the DFIG is very good for the same reason. The mathematical model of DFIG used in this proposed system is shown in figure 11. DFIG's wind turbine model is shown figure 12. The controlling sub system DFIG model is shown in figure 13.

6.3 SEPIC converter

The single-ended primary-inductor converter (SEPIC) is a type of DC/DC converter allowing the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input. The output of the SEPIC is controlled by the duty cycle of the control transistor. A SEPIC is essentially a boost converter followed by a buck-boost converter, therefore it is similar to a traditional buck-boost converter, but has advantages of having non-inverted output (the output has the same voltage polarity as the input), using a series capacitor to couple energy from the input to the output (and thus

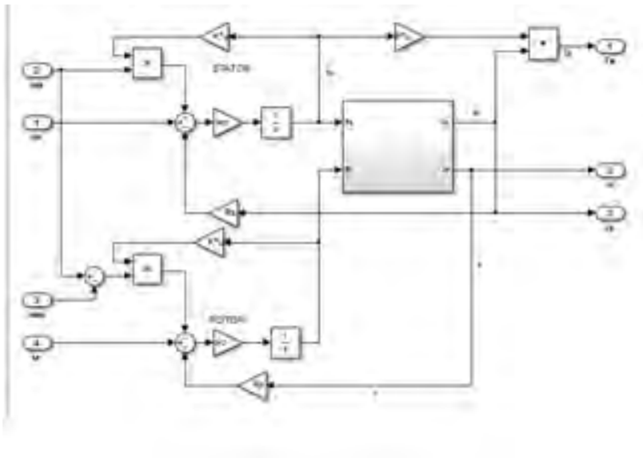


Figure 15: *Mathematical model of DFIG.*

can respond more gracefully to a short-circuit output), and being capable of true shutdown: when the switch is turned off, its output drops to 0 V, following a fairly hefty transient dump of charge. SEPICs are useful in applications in which a battery voltage can be above and below that of the regulator's intended output. For example, a single lithium ion battery typically discharges from 4.2 volts to 3 volts; if other components require 3.3 volts, then the SEPIC would be effective.[13-22]

6.4 Voltage controller

A voltage controller, also called an AC voltage controller or AC regulator is an electronic module based on either thyristors, TRIACs, SCRs or IGBTs, which converts a fixed voltage, fixed frequency alternating current (AC) electrical input supply to obtain variable voltage in output delivered to a resistive load. This varied voltage output is used for dimming street lights, varying heating temperatures in homes or industry, speed control of fans and winding machines and many other applications, in a similar fashion to an autotransformer. Voltage controller modules come under the purview of power electronics. Because they are low-maintenance and very efficient, voltage controllers have largely replaced such modules as magnetic amplifiers and saturable reactors.

6.5 MPPT

Wind generation system has been pulling in wide consideration as a sustainable power source because of draining petroleum derivative stores and ecological worries as an immediate outcome of utilizing non-renewable energy source and atomic vitality sources. Wind vitality, despite the fact that bottomless, differs ceaselessly as wind speed changes for the duration of the day. Measure of power yield from a WECS relies on the exactness with which the maximum power points are followed by the MPPT controller of the WECS control system regardless of the kind of generator utilized. The maximum power extraction calculations researched so far can be grouped into three primary control strategies, to be specific tip speed ratio (TSR) control, power signal feedback (PSF) control and hill-climb search (HCS) control. [43-52]

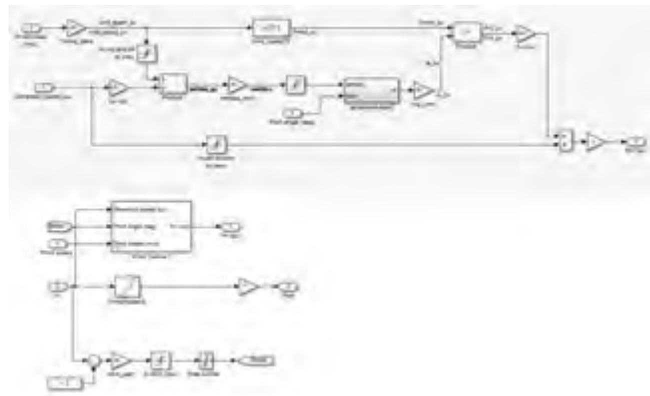


Figure 16: *Wind turbine model.*

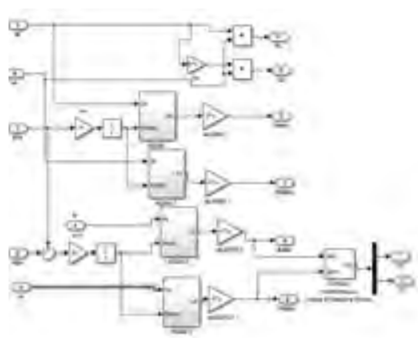


Figure 17: *Wind turbine controller.*

6.6 Fuzzy logic controller

In fuzzy logic, basic control is determined by a set of linguistic rules which are determined by the system. Since numerical variables are converted into linguistic variables, mathematical modelling of the system is not required. The fuzzy logic control is being proposed for controlling the inverter action. The fuzzy logic controller has two real time inputs measured at every sample time, named error and error rate and one output named ac-

Table 1: The FLC rules

E/CE	NB	NS	ZE	PS	PB
NB	NB	NB	NB	NS	ZE
NS	NB	NB	NS	ZE	PS
ZE	NB	NS	ZE	PS	PB
PS	NS	ZE	PB	PB	PB
PB	ZE	PS	PB	PB	PB

tuating signal for each phase. The error input is the difference between the reference voltage (i.e.) 440V and the load voltage (i.e.) affected voltage. The error rate is the rate of this error. Then this input signals are fuzzified and represented in fuzzy set notations as membership functions. The defined 'If ... Then ... ' rules produce output (actuating) signal and these signals are defuzzified to analog control signals for comparing with a carrier signal to control PWM inverter. The rules used in FLC is shown in table 1. There are 25 rules used in this system with the membership functions as

The overall system simulation is shown in figure 14.

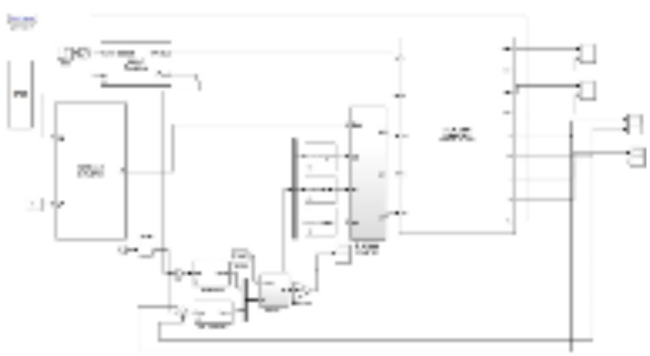


Figure 18: *Overall simulation diagram of proposed system.*

7 RESULTS

The behavior of the fuzzy logic controller based maximum power point tracking system to extract the maximum power from the wind energy conversion system is discussed in this chapter. The voltage of the DFIG wind turbine at stator side with the FLC based MPPT system is shown in figure 15, the current at stator side is shown in figure 16 and the real and reactive power at stator is shown in figure 17.

The voltage of DFIG at rotor side is shown in figure 18, the current at rotor side is shown in figure 19 and the real power at rotor side is shown in figure 20.

Figure 19: *Stator voltage.*

Figure 20: *Stator current.*

8 CONCLUSION

In this paper, a fuzzy logic controller based MPPT control system has been proposed for the fast tracking of MPP under turbulent wind conditions for small-scale WECSs. System behavior with proposed technique under changing wind conditions has been observed and it is evident that the proposed control system can put the system at optimal operating point promptly against random variations in the wind velocity. System performance with proposed experimental results proved that WECS with proposed control system harvests more energy. The proposed MPPT provides the following advantages: 1) improved dynamic response of the system and 2) prerequisite of system's optimal characteristics data is not required. To extract maximum power from the wide range of wind conditions, SEPIC converter is used for the implementation of proposed MPPT system. Since small-scale WECSs are main resources for DERs in grid systems, the proposed system is very much applicable for grid systems.

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

Figure 21: *Stator power.*

Figure 22: *Rotor voltage.*

Figure 23: *Rotor current.*

Figure 24: *Rotor power.*

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Power Management of a Hybrid Solar- Wind Energy System" International Journal of Engineering Research & Technology vol. 3(2) pp.1988-1992, 2014.

[3] M. Siva Ramkumar, M. Sivaram Krishnan, Dr.A.Amudha "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc " in International Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[5] M Siva RamKumar, A. Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016. .

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763-769,2014.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2),2014

[9] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[10] D. Kavitha, C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.20 (2015), pg. 17749-17754.

[11] D. Manoharan, A. Amudha. "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, A. Amudha. A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engi-

neering Research ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6233-6240.

[13] A. Amudha. "Enhancement of Available Transfer Capability using FACTS controller" in International journal of Applied Mechanics and Materials, Vol. 573, pp 340-345

[14] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035-2042.

[15] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[17] K. Balachander, P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, V. Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[19] K. Balachander, V. Ponnusamy, 'Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research', Volume 7, Number 3 (2012), pp. 247-256. .

[20] K. Balachander, S. Kuppusamy, V. Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[21] M. Sivaram Krishnan, Dr.A.Amudha, M. Siva Ramkumar, 'Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms', International journal of Pure and Applied Mathimatics,118 (11), pp 609-617,2018 DOI:10.12732/ijpam.v118i11.79

[22] S. Motapon, L. Dessaint, K.AI-Haddad, "A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, " IEEE Trans. Ind. Electron. , vo1.61, no.3, pp.1320,1334, March 2014.

INTELLIGENT POWER TRACKING ALGORITHM USING ANFIS AND ZETA CONVERTER

S. Nandhini, D. Kavitha, S. Kalaiarasi, A. Amudha, M. Siva Ramkumar

ABSTRACT: Nowadays, environmental problems due to existing power plants seem to acquire more attention around the world, because it increases continuously the earth temperature and warming. Nowadays, renewable energies, especially photovoltaic (PV) energy, considered as palliative energy resource, are growing rapidly and are used in several applications, e.g., battery charging, home energy supply, and pumping systems. However, they suffer from a relatively low conversion efficiency, which makes their optimization necessary. This is done by extracting their maximum power for fluctuating climatic environments. An efficient ANFIS based tracking algorithm is proposed for PV applications under mismatching conditions. PV fed zeta converter is used to step-up the output voltage and track the maximum power efficiently. An ANFIS based MPPT algorithm takes minimum time to find the MPP when subjected to rapid change in irradiance.

Keywords: Adaptive neuro-fuzzy inference system (ANFIS), Incremental conductance algorithm, PV system, ZETA converter

1 INTRODUCTION

Renewable energy flows involve natural phenomena such as sunlight, wind, tides, plant growth, and geothermal heat. Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and bio-fuels and hydrogen derived from renewable resources [1-5].

2 SOLAR PHOTOVOLTAIC (SPV) TECHNOLOGY

Solar Photovoltaic (SPV) technology is one of the most matured renewable energy (RE) technologies and there is an increasing demand of SPV installation both in grid-connected as well as off-grid stand-alone modes. The main drawbacks of solar PV system is its high cost of installation for producing desired power level of electricity which is due to the high manufacturing cost of solar modules compounded with its low conversion efficiency. Most of the times, the power conversion system associated with the solar PV generating unit can cost up to 40% of the total cost.

PV system, in general, is designed to deliver a specific amount of energy as per the requirement of the applications. Therefore, purchase and installation of all PV system will eventually be based on predicted or guaranteed energy production. To make the solar PV system commercially viable, the cost of unit generation of electricity from solar PV system needs to be reduced which, in turn, calls for the development of a low cost, high efficient power conversion systems or schemes for delivering required electrical power. Hence it is always critical to design the most appropriate power converters and to assess their performance to ensure maximum power capture from solar modules along with impeccable power quality, reliability and efficiency. A major challenge that needs to be addressed by the DC-DC converters is to take the non-linear output characteristic of the solar PV sources which varies with solar isolation and temperature and convert it in to appropriate level of voltage [6-10].

The solar array that is developed in the new system is KC200GT and it is simulated employing a model. Here in this model, a PV cell is indicated by a current source that is in parallel with diode and a series resistance as illustrated in Fig 2.1

In this solar array, a precise intention can be represented as

$$I_{sac} = I_{lg} - I_{stc}\left\{ \exp\left[\frac{q_c}{Ak_bT_{em}}\left(V_{sac} + I_{fb}R_s\right)\right] - 1\right\} \tag{1}$$

More generally, the array cell static characteristics, as a function of light intensity and temperature, are given by the above equation. It specifies the nonlinear output characteristics of solar cell. Where solar cell output current I_{sac}), solar cell output voltage (V_{sac}), light generated current I_{lg}), solar cell saturation cur-

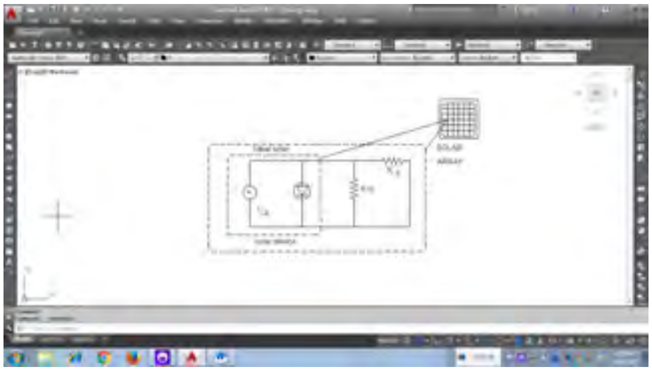


Fig 2.1 Solar cell equivalent circuit.

rent (I_{stc}), electron charge ($1.6021747x10^{-19}C$) (q_c), Ideality factors constant (A) and boltzmann's constant ($1.68x10^{-23}J/K$) (k_b), cell temperature (T_{em}), reference temperature (T_{ref}) feedback array current (I_{fb}), series resistance (R_s) and parallel resistance (R_{pl}), saturation current at reference temperature (I_{sct}) and silicon band gap (Eg0) respectively. Light generated current (I_{lg}) is directly proportionate to the solar irradiation (λ). [11-15]

$$I_{stc} = I_{sct}\left[\frac{T_{em}}{T_{ref}}\right]^3 \exp\left[q_c\frac{Eg0}{I_{fb}k_b}\left\{\frac{1}{T_{ref}} - \frac{1}{T_{em}}\right\}\right] \quad (2)$$

Where Short circuit current (I_{csc}) is linearly dependent on cell temperature and (λ) refers to the standard irradiation (mW/cm2). The light generated current is given by the equation I_{lg}

$$I_{lg} = \left[I_{csc} + k_t\left(T_{std} - 28\right)\right]\frac{\lambda}{100} \quad (3)$$

Where k_t) indicates cell short circuit current at (28^oC) and T_{std}) refers to the standard temperature (298 K). [16-21]

3 NEED FOR MPPT

The cost of the solar energy is still higher than that of energy from fossil fuels, the trend of oil shortage is one factor that increases the cost of fossil fuels and can eventually enable the cost of solar energy to be lower than that of energy from fossil fuels. They have long life, require minimum maintenance, and produce no noise or disturbance. However, they suffer from a relatively low conversion efficiency [10], which makes their optimization necessary. This is done by extracting their maximum power for fluctuating climatic environments [6]. In addition, the advances in the maximum power point tracking (MMPT) algorithm used in solar photo voltaic systems and the resulting efficiency improvement of the inverter enable the cost of solar energy systems to be further reduced. Due to the characteristics of the solar cell, the maximum power of the solar cell cannot be provided without the use of MPPT controller. By using the MPPT converter, the input impedance of the converter can match the output impedance of the solar cell to achieve the maximum power output of the solar cell. Different algorithms have different tracking performances [12-18].

4 INC ALGORITHM

Incremental Conductance (IC) algorithm is considered cheap, and easy to implement for Maximum Power Point Tracking (MPPT). It compares the incremental conductance to the instantaneous conductance in a PV system. Depending on the result, it increases or decreases the voltage until the maximum power point (MPP) is reached.

A PV array under constant irradiance shows a current-voltage characteristic along with a distinct point, known as the maximum power point (MPP), in which the array generates the maximum output power. In Fig 4.1, an instance of 100 Watt PV module characteristics in terms of output power versus voltage (P-V curve) for different irradiance levels are illustrated. The MPP point has also been shown in Fig 4.1.

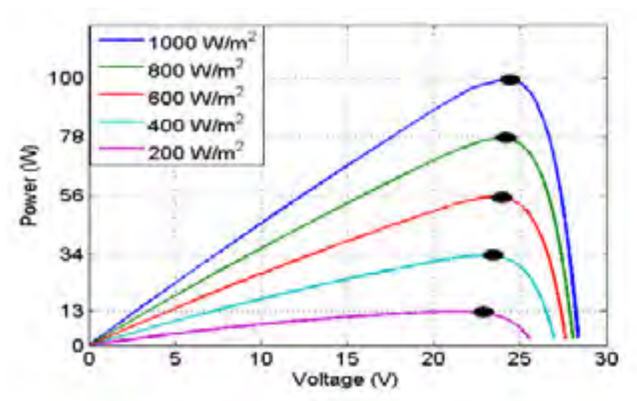


Fig 4.1 PV module characteristics for various irradiation levels: P-V curve.

The problem of maximum power point tracking (MPPT) has been dealt with in various manners earlier: examples of current sweep, fractional technique, linear current control, slide control, fuzzy logic control, neural network etc.,.

The INC algorithm is generally utilized, owing to its convenience in implementation. When the operating voltage of the PV array gets perturbed in a direction given and in case the power obtained from the PV array

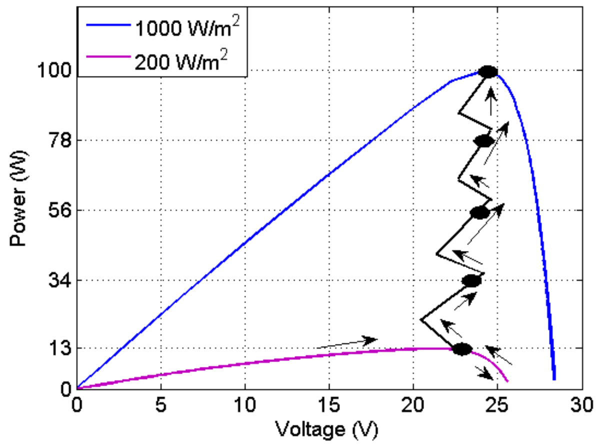


Fig 4.2a INC MPPT operating point path. (a) Slow change in environmental conditions.

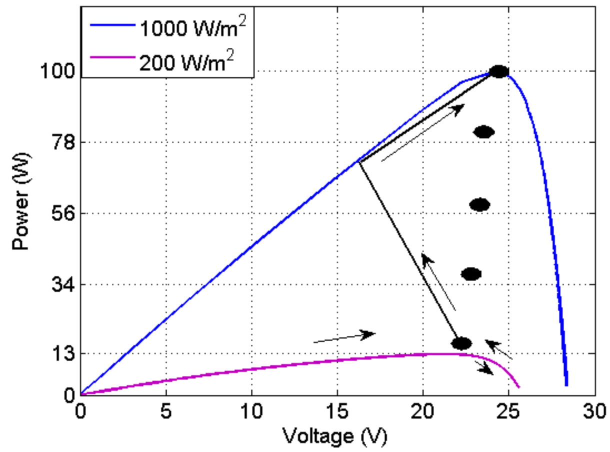


Fig 4.2b INC MPPT operating point path. (b) Rapid change in environmental conditions.

sees an increase, it indicates that the operating point has aligned towards the MPP and, hence, the operating voltage should be perturbed further in the same direction. Else, in case the power obtained from the PV array reduces, the operating point has aligned away from the MPP and, hence, the operating voltage's direction of perturbation should be in opposite direction [1].

A disadvantage of INC MPPT method is that, at steady state condition, the operating point oscillates around the MPP leading to the wastage of some quantity of the energy available. Multiple enhancements of the INC algorithm have been introduced for the purpose of reducing the number of oscillations around the MPP in steady state, though they weaken the rapidity of response of the algorithm to varying atmospheric situations and reduce the efficiency of the algorithm during the times of cloudy days.

The INC algorithm could be confusing during those intervals of time that are characterized by varying atmospheric conditions, as, during such time intervals, the operating point can drift away from the MPP rather of being near to it. This disadvantage is illustrated in Fig 4.2, in which the INC MPPT operating point path for an irradiance variation from ($200W/m^2$) to ($1000W/m^2$) is shown [5-8].

The example shows two diverse behaviours in the plane output power versus voltage (P-V curve). Fig 4.2(a) exhibits the operating point path during slowly varying atmospheric conditions and Fig 4.2(b), rather, the failure of MPPT control in following the MPP while a rapid variation in atmospheric conditions happens is shown. The condition tends to be more complex if the array is submitted to partial shading, i.e., a situation when a portion or the entire module of the PV array obtains irregular irradiation. During partial shading, the P-V curves are characterized by multiple peaks—many local and one global peak (GP) [6]. In case the true GP is not correctly tracked, the INC MPPT algorithm may get stuck at one of the local peak, resulting in considerable power losses. Though P& O algorithm is not capable of dealing with the partial shading situation, they were deficit of the adequate smartness to distinguish between the local and GP. Several efforts have been made to enhance these algorithms in order to address the partial shading. An alternate approach is treating the MPP tracking to be an optimization problem and then using the particle swarm optimization algorithm to look out for the global maxima [17-22].

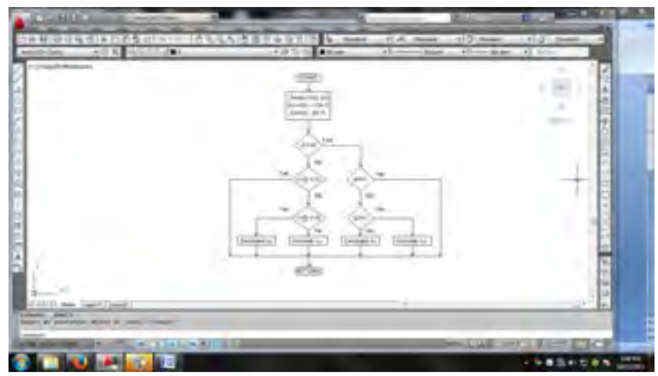


Fig 4.3 Flow chart for INC MPPT.

5 ANFIS LEARNING ALGORITHM

In this section, the hybrid learning algorithm is explained briefly. The ANFIS Learning Algorithm uses a two-pass learning cycle. In the forward pass, S1 is unmodified and S2 is computed using a Least Squared Error (LSE) algorithm (Off-line Learning). In the Backward pass, S2 is unmodified and S1 is computed using a gradient descent algorithm (usually Back Propagation). From the ANFIS structure shown in Fig 5.1, it has been observed that when the values of the premise parameters are fixed, the overall output can be expressed as a linear combination of the consequent parameters.

The hybrid learning algorithm is a combination of both back propagation and the least square algorithms. Each epoch of the hybrid learning algorithm consists of two passes, namely forward pass and backward pass. In the forward pass of the hybrid learning algorithm, functional signals go forward up to layer 4 and the consequent parameters are identified by the least squares estimate. The back propagation is used to identify the nonlinear parameters (premise parameters) and the least square is used for the linear parameters in the consequent parts.

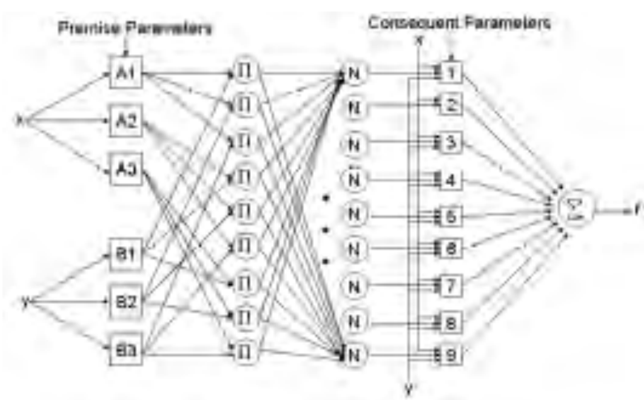


Fig 5.1 Typical ANFIS structure..

The predicated power and calculated powers are compared and the error is given to a proportional integral (PI) controller, to generate operating signals. The operating signal generated by the PI controller is given to the PWM generator. The PWM signal is generated using high frequency of carrier signal as compared to the operating signal. The frequency of carrier signal used is 25 KHz. The generated PWM signals manage the duty cycle of DC–DC converter, in order to adjust the operating point of the PV module. The conventional MPPT control techniques, Perturb and Observe is compared with the advanced ANFIS control technique [4]. Both of them were applied on a chain of energy conversion supplied using a DC/DC Boost converter. It can be realized that MPPT ANFIS controller, which is initially based on the experience of the operator during the training stage, has a very good transient performance. [12-19]

It improves the responses of the photovoltaic system it reduces the time response to the track the maximum power point. This proves the effectiveness of the ANFIS control for photovoltaic systems under varying environmental conditions. Fig 5.3 exhibits the operating point path during slowly varying atmospheric conditions. Sensitivity analysis explores the power delivered from the solar PV system to the continuously varying load demand and the deficient that has to be met from grid. The excess power that can be transferred to the grid which will eliminate the necessity of storage systems such as batteries to store the excess of energy generated. This analysis predicts the power flow all throughout the day and all throughout the year [6-12].

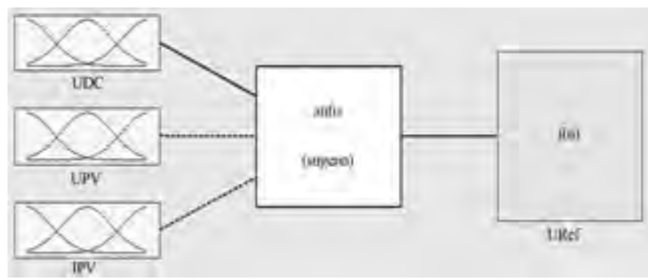


Fig 5.2 ANFIS based MPPT controller.

Fig 5.4 illustrates the whole flow chart of the proposed technique which shows the operation in both the global and local modes.

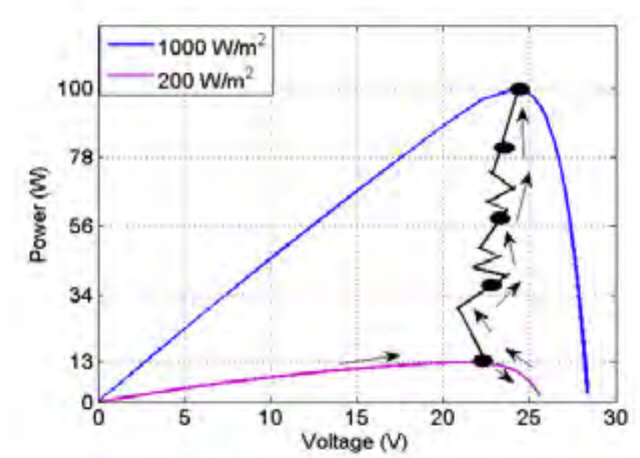


Fig 5.3 ANFIS based MPPT operating point path under rapid change in environmental conditions.

In this flow diagram, in case change in error of power (ΔP) is more than a specific threshold value (P_{thr}), the tracking process begins to look out for the new GP (in the main program). To find (ΔP), the output power of the array, at two different sampling instants, which are 0.05 sec apart, is taken into consideration.

The abrupt variations in insolation are generally smaller in magnitude (smaller than $G = 0.027kW/m^2$) and happens within 1 sec. On the basis of this fact, ($\Delta G < 0.027kW/m^2$), P_{thr} can be fine-tuned in accordance. In addition, the initial duty cycles (three in this case) for the power converter are chosen between (d_{min}) and (d_{max}).

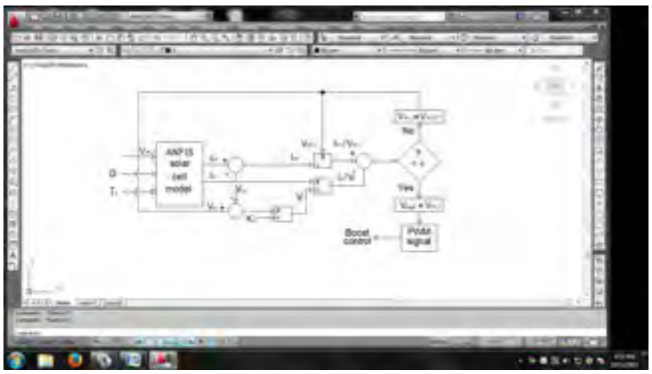


Fig 5.4 ANFIS flowchart.

6 ZETA CONVERTER

The Zeta converter forms the basic block for various converters.

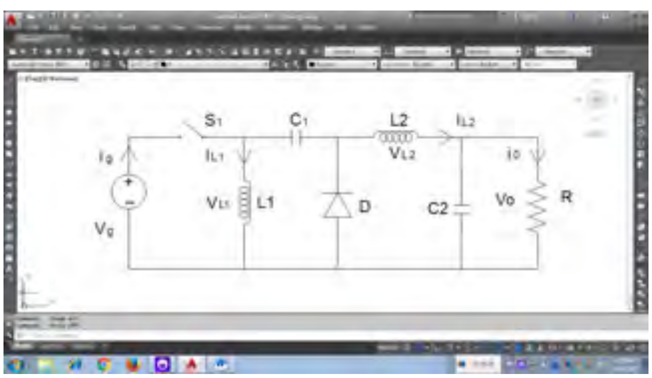


Fig.6.1 Zeta Converter.

The Zeta converter is an inverse SEPIC converter because it can be formed by the interchange of power input ports and power output ports of SEPIC converter [9]. This converter operates by the energy transfer between C1 and L1. It has non inverting buck-boost characteristics. The pulsating input current is the drawback of Zeta converter. This converter provides better input output isolation and have low input ripple and noise.

Belonging to the family of buck-boost converters, the zeta converter can be operated either to increase or to decrease the output voltage. This property offers a boundless region for maximum power point tracking (MPPT) of the SPV array. The MPPT can be performed with simple buck and boost converter if the MPP occurs within the prescribed limits.

Unlike a simple buck-boost converter, the zeta converter has a continuous output current. The output inductor makes the current continuous and ripple free. However, a small ripple filter may be required at the input to smoothen the input current [11-19].

Although consisting of the same number of components as the CUK converter [5], the zeta converter operates as non-inverting buck-boost converter unlike an inverting buck-boost and CUK converter [11]. This property obviates the requirement of associated circuits for negative voltage sensing hence reduces the complexity and probability of slow down the system response.

7 SIMULATION MODEL AND RESULTS

In order to confirm the high performance of the ANFIS based MPPT, experiments were conducted. Fig 7.1 shows the bock diagram of PV with controller. PV model was simulated using both INC technique and ANFIS MPPT controller.

The output duty cycle signal from the controller was given to the ZETA DC-DC converter. PV voltage, current and power at different environment conditions were measured and recorded [13-22].

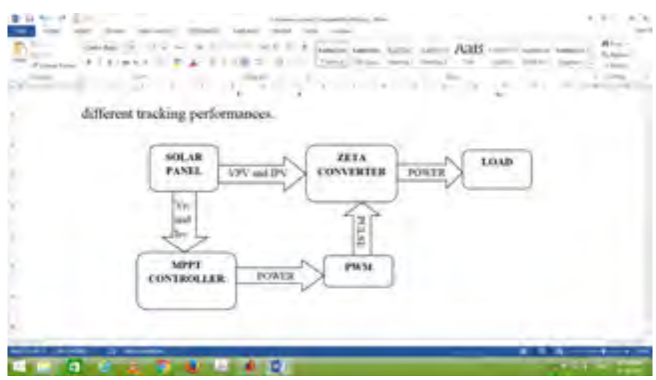


Fig 7.1 Block diagram of PV with controller

The environmental weather conditions used in this experiments were 1000W/m2, 500 W/m2 and 200 W/m2. The simulation is carried out using time (t) =1.5s and a discrete sampled period Ts=1e-006s. Fig 7.2 shows the simulation model for PV using incremental conductance. Fig 7.3 shows the simulation model for MPPT using incremental conductance. Fig 7.6 shows the model for PV using ANFIS controller

7.1 Simulation Models of Incremental conductance

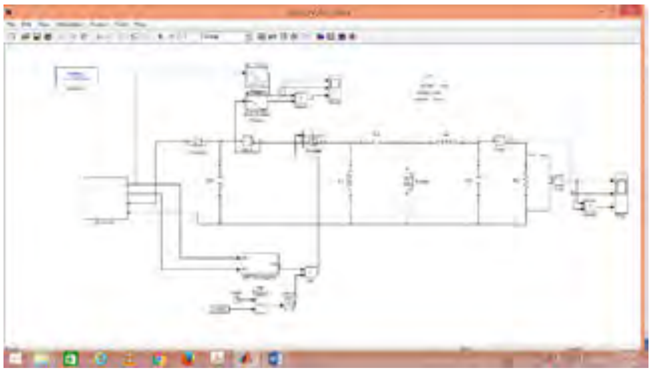


Fig 7.2 Model for PV using INC.

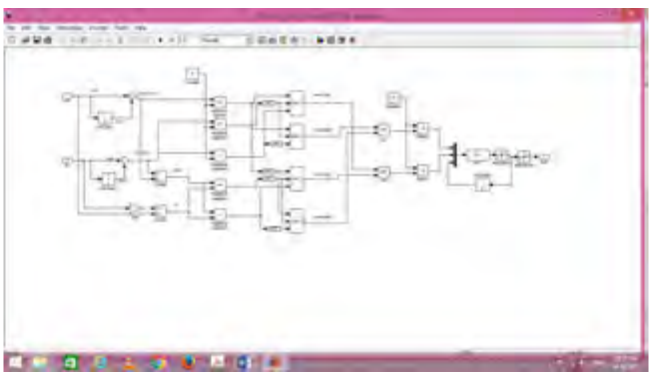


Fig 7.3 Model for MPPT using INC

7.2 Simulation Result of Incremental conductance

7.3 Simulation Model of ANFIS

7.4 Simulation Result of ANFIS

On comparing the results of incremental conductance shown in the Fig 7.4 and the results of ANFIS controller shown in the Fig 7.7 under different environmental condition the efficiency of the PV panel while using ANFIS controller is slightly higher than that of the incremental conductance technique. Also it gives faster and accurate results than incremental conductance. Table 7.1 shows the comparison result of incremental conductance and ANFIS. Incremental conductance is best suited for linear variation of irradiance and it is not suitable for sudden variations as like ANFIS [48-53].

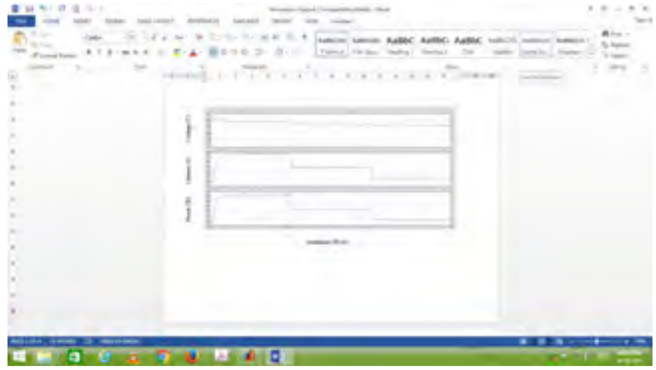


Fig 7.4 Waveform for Irradiation of PV (a) PV Voltage, (b) PV Current, (c) PV Power.

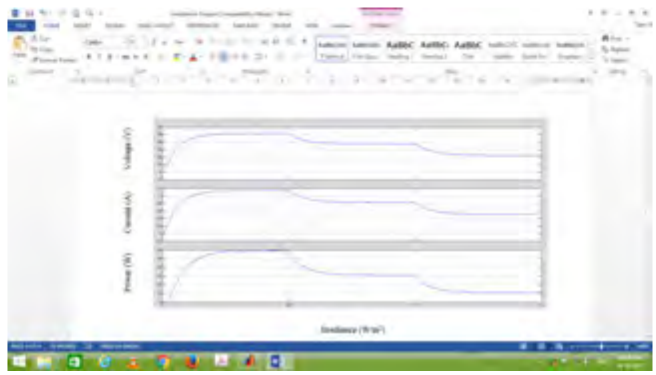


Fig 7.5 Waveform for Converter (a) Voltage, (b) Current, (c) Power using INC MPPT

8 CONCLUSION

From the experimental results, it can be concluded that the ANFIS MPPT algorithm model gives an overall, higher operating power efficiency at the input while the Fuzzy Logic Controller technique has an overall higher power output efficiency using the Zeta converter. With the assist of this technique, the PV module was able to increase the production of the output power at an optimal solution under various circumstances. The ANFIS was implemented to supply the optimal voltage corresponding to the MPP for each environmental circumstance. Then optimized values were used for training the ANFIS. For various conditions the proposed method was verified. Incrementing the number of the training data could be diminished Error of ANFIS.

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

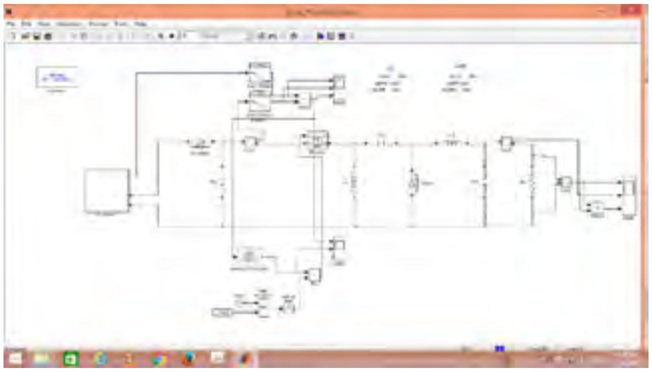


Fig 7.6 Model for PV using ANFIS

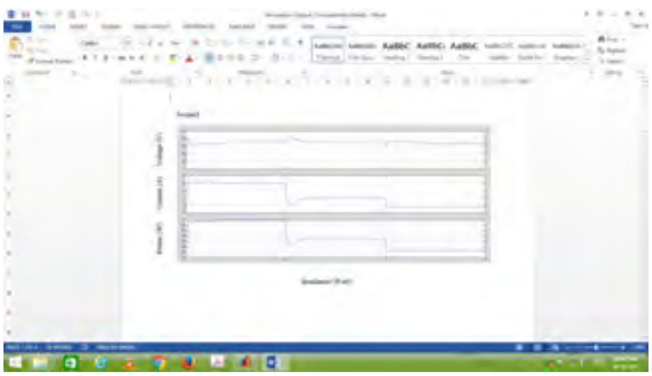


Fig 7.7 Waveform for Irradiation of PV (a) PV Voltage, (b) PV Current, (c) PV Power.

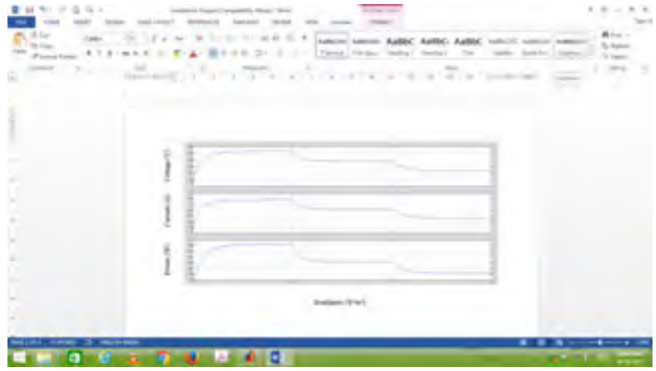
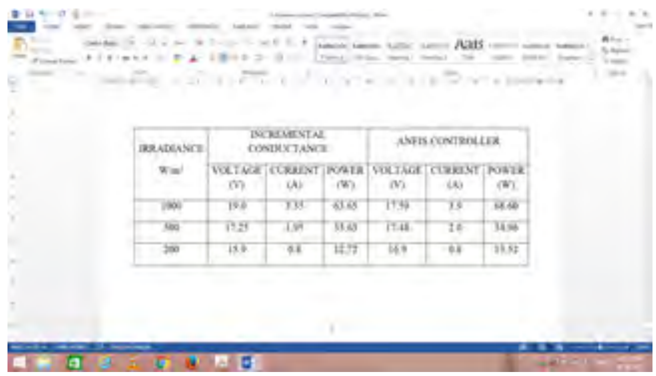


Fig 7.8 Waveform for Converter (a) Voltage, (b) Current, (c) Power using ANFIS



IRRADIANCE	INCREMENTAL CONDUCTANCE			ANFIS CONTROLLER		
W/m²	VOLTAGE (V)	CURRENT (A)	POWER (W)	VOLTAGE (V)	CURRENT (A)	POWER (W)
1000	19.0	3.35	63.65	17.59	3.9	68.60
500	17.25	1.95	33.63	17.48	2.0	34.96
200	15.9	0.8	12.72	16.9	0.8	13.52

Table 7.1 Comparison result of incremental conductance and ANFIS

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Power Management of a Hybrid Solar- Wind Energy System" International Journal of Engineering Research & Technology vol. 3(2) pp.1988-1992, 2014.

[3] M. Siva Ramkumar, M. Sivaram Krishnan, Dr.A.Amudha "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245, 2017.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc " in International Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[5] M Siva RamKumar, A. Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016.

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763-769,2014.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2),2014

[9] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[10] D. Kavitha, C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.20 (2015), pg. 17749-17754.

[11] D. Manoharan, A. Amudha. "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, A. Amudha. A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6233-6240.

[13] A. Amudha. "Enhancement of Available Transfer Capability using FACTS controller" in International journal of Applied Mechanics and Materials, Vol. 573, pp 340-345

[14] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035-2042.

[15] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[17] K. Balachander, P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, V. Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[19] K. Balachander, V. Ponnusamy, 'Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research', Volume 7, Number 3 (2012), pp. 247-256.

[20] K. Balachander, S. Kuppusamy, V. Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[21] M. Sivaram Krishnan, Dr.A.Amudha, M. Siva Ramkumar, 'Execution Examination of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms', International journal of Pure and Applied Mathimatics,118 (11), pp 609-617,2018 DOI:10.12732/ijpam.v118i11.79

[22] S. Motapon, L. Dessaint, K.AI-Haddad, "A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, " IEEE Trans. Ind. Electron., vo1.61, no.3, pp.1320,1334, March 2014.

ANALYSIS OF NEW NOVELTY MULTILEVEL INVERTER CONFIGURATION WITH BOOST CONVERTERS FOR A PHOTOVOLTAIC SYSTEM WITH MPPT

S. Senthil Kumar, D. Kavitha, A. Amudha, G. Emayavaramban, M. Siva Ramkumar

ABSTRACT: This paper proposes a single phase multilevel inverter configuration that conjoins three series connected full bridge inverter and a single half bridge inverter for renewable energy application especially photovoltaic system. This configuration of multilevel inverter reduces the value of total harmonic distortion. The half bridge inverter utilized in the proposed configuration increases the output voltage level to nearly twice the output voltage level of a conventional cascaded H-bridge multilevel inverter. This higher output voltage level is generated with lesser number of power semiconductor switches compared to conventional configuration, thus reducing the total harmonic distortion and switching losses. The effectiveness of the proposed configuration is illustrated by replacing the isolated DC sources in multilevel inverter with individual photovoltaic panels using separate perturb and observer based maximum power point tracking and boost converters. The verification of the proposed system is demonstrated successfully using MATLAB/Simulink based simulation with different irradiation and temperature conditions. Also, the transient operation of the system is verified with results depicted using step change in standard test condition. Selective experimental results are presented to prove the effectiveness of proposed system.

Keywords: Multilevel Inverter (MLI), Harmonic distortion, Switching losses, Photovoltaic system, Perturb & Observer algorithm, MPPT.

1 Introduction

How can we increase the amount of photovoltaic (PV) generation? From this viewpoint, we are over viewing electric facilities from power plants to electric appliances in demand sites. PV modules generate DC electric power. The power should be converted to AC that is synchronized with commercial grids to be transmitted and distributed to demand sites. To reduce energy dissipation through the transmission, the power is sent near the demand site after being raised the electric voltage to 66 kV or higher. The power is transformed to 100 V and provided to residential outlets after multi-processed reduction in voltage at substations and pole-mounted transformers. Therefore, we should consider how we can establish efficient transmission and distribution systems for PV generation in addition to cost, efficiency and lifetime for generation facilities, if we utilize the power source as infrastructure. [1-10] Transmission facilities for PV generation often stay idle as well as generation facilities themselves, because they do not yield electricity during night and poor weather. If contribution from solar power were much smaller than transfer capability, existing facilities could take care of it. To understand this problem easily, we assume a huge PV farm comparable to a nuclear power plant with a giga wattage class output. PV generation, which has poor yield for its footprint, needs vast ground to generate such a big power. Consequently, the generation facilities must be set up in sites far from consuming regions. Transmission facilities must have enough large capacity for maximum current which can be generated under the best weather condition. They do not work during off-generating time such as at night and under poor sunshine. If PV plants supplied constant huge power as dam type hydraulic or nuclear plants, we would make choice of a far-reaching transmission system that connects distant sources and a consuming centre. Electric power storage devices, such as batteries, can absorb fluctuation of PV generation and equalize power transmission. However, this scheme reduces capacity of transmission facilities and requires rather huge additional cost for the huge accumulators. Therefore, until drastically reduced cost is available for storage devices, we cannot adopt this method. Then, put gas turbines together, with which we are able to adjust output power rather rapidly. The combined plant can absorb the fluctuation of PV generation, and consequently, improve the operation ratio for transmissions. However, it requires a parallel established thermal power plant comparable to the PV, which is a roundabout way for our initial goal, the introduction of a large amount of PV. As mentioned above, large scale PV plants in remote sites have a serious problem on economic efficiency. We need a new power system that enables the introduction of a massive amount of distributed PV units in demand sites. This article proposes DC micro grid systems as an option for such a purpose.[11-15] The Photovoltaic (PV) system provides secure, clean and reliable in renewable energy sources with the added advantageous of zero fuel cost, no moving parts, low running cost, minimum maintenance and long-life time. These points of interest make the utilization of PV in many places and also in off-grid installations. Multilevel Inverter (MLI) topologies are proved as substantial global attention by the researchers and front-end industries in various medium and high power applications because of their ability to generate high quality of output waveforms, reducing switching stress across the switches, and reducing switching frequency. In recent years, many topologies have emerged in the field of grid connected MLI in renewable energy application. The basic classification of MLI is Diode-Clamped MLI (DCMLI), Flying Capacitor (FCMLI) and Cascaded H-Bridge MLI (CHBMLI). Although these types of basic MLIs are noticeable in high power applications regardless they have few demerits like components count and voltage balancing problem expect CHBMLI. To overcome this problem, reduced switch MLI topologies are developed in past decades. Many topologies in MLI are ended with DC source, but only a few topologies are integrated with PV applications.[16-21]

2 PV AND MPPT SYSTEM

Converting solar energy into electrical energy by PV installations is the most recognized way to use solar energy. Since solar photovoltaic cells are semiconductor devices, they have a lot in common with processing and production techniques of other semiconductor devices such as computers and memory chips. As it is well known, the requirements for purity and quality control of semiconductor devices are quite large. With today's production, which reached a large scale, the whole industry production of solar cells has been developed and, due to low production cost, it is mostly located in the Far East. Photovoltaic cells produced by the majority of today's most large producers are mainly made of crystalline silicon as semiconductor material. Solar photovoltaic modules, which are a result of combination of photovoltaic cells to increase their power, are highly reliable, durable and low noise devices to produce electricity. The fuel for the photovoltaic cell is free. The sun is the only resource that is required for the operation of PV systems, and its energy is almost inexhaustible. A typical photovoltaic cell efficiency is about 15%, which means it can convert 1/6 of solar energy into electricity. Photovoltaic systems produce no noise, there are no moving parts and they do not emit pollutants into the environment. Taking into account the energy consumed in the production of photovoltaic cells, they produce several tens of times less carbon dioxide per unit in relation to the energy produced from fossil fuel technologies. Photovoltaic cell has a lifetime of more than thirty years and is one of the most reliable semiconductor products. Most solar cells are produced from silicon, which is non-toxic and is found in abundance in the earth's crust. Figure 1 shows the photovoltaic cell.

Figure 1: *Photovoltaic cell.*

Photovoltaic systems (cell, module, network) require minimal maintenance. At the end of the life cycle, photovoltaic modules can almost be completely recycled. Photovoltaic modules bring electricity to rural areas where there is no electric power grid, and thus increase the life value of these areas. Photovoltaic systems will continue the future development in a direction to become a key factor in the production of electricity for households and buildings in general. The systems are installed on existing roofs and/or are integrated into the facade. These systems contribute to reducing energy consumption in buildings. A series of legislative acts of the European Union in the field of renewable energy and energy efficiency have been developed, particularly promoting photovoltaic technology for achieving the objectives of energy savings and CO2 reduction in public, private and commercial buildings. Also, photovoltaic technology, as a renewable energy source, contributes to power systems through diversification of energy sources and security of electricity supply. By the introduction of incentives for the energy produced by renewable sources in all developed countries, photovoltaic systems have become very affordable, and timely return of investment in photovoltaic systems has become short and constantly decreasing. In recent years, this industry is growing at a rate of 40% per year and the photovoltaic technology creates thousands of jobs at the local level.[22]

2.1 Function of the PV cells

The word photovoltaic consists of two words: photo, a greek word for light, and voltaic, which defines the measurement value by which the activity of the electric field is expressed, i.e. the difference of potentials. Photovoltaic systems use cells to convert sunlight into electricity. Converting solar energy into electricity in a photovoltaic installation is the most known way of using solar energy. The light has a dual character according to quantum physics. Light is a particle and it is a wave. The particles of light are called photons. Photons are massless particles, moving at light speed.

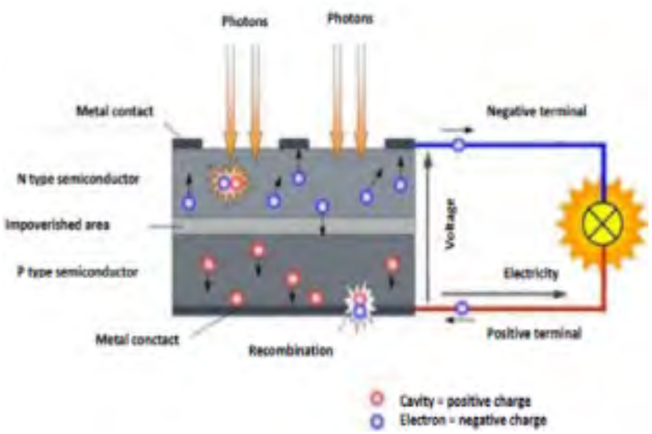


Figure 2: *Functioning of PV cell.*

In metals and in the matter generally, electrons can exist as valence or as free. Valence electrons are associated with the atom, while the free electrons can move freely. In order for the valence electron to become free, he must get the energy that is greater than or equal to the energy of binding. Binding energy is the energy by which an electron is bound to an atom in one of the atomic bonds. In the case of photoelectric effect, the electron acquires the required energy by the collision with a photon. Part of the photon energy is consumed for the electron getting free from the influence of the atom which it is attached to, and the remaining energy is converted into kinetic energy of a now free electron. Free electrons obtained by the photoelectric effect are also called photoelectrons. The energy required to release a valence electron from the impact of an atom is called a work out Wi, and it depends on the type of material in which the photoelectric effect has occurred. The previous equation shows that the electron will be released if the photon energy is less than the work output. The photoelectric conversion in the PV junction. PV junction (diode) is a boundary between two differently doped semiconductor layers; one is a P-type layer (excess holes), and the second one is an N-type (excess electrons). At the boundary between the P and the N area, there is a spontaneous electric field, which affects the generated electrons and holes and determines the direction of the current.[11-14] To obtain the energy by the photoelectric effect, there shall be a directed motion of photoelectrons, i.e. electricity. All charged particles, photoelectrons also, move in a directed motion under the influence of electric field. The electric field in the material itself is located in semiconductors, precisely in the impoverished area of PV junction (diode). It was pointed out for the semiconductors that, along with the free electrons in them, there are cavities as charge carriers, which are a sort of a byproduct in the emergence of free electrons. Cavities occurs whenever the valence electron turns into a free electron, and this process is called the generation, while the reverse process, when the free electron fills the empty spaces - a cavity, is called recombination. If the electron-cavity pairs occur away from the impoverished areas it is possible to recombine before they are separated by the electric field. Photoelectrons and cavities in semiconductors are accumulated at opposite ends, thereby creating an electromotive force. If a consuming device is connected to such a system, the current will flow and we will get electricity. In this way, solar cells produce a voltage around 0,5-0,7 V, with a current density of about several tens of mA/cm2 depending on the solar radiation power as well as on the radiation spectrum. The usefulness of a photovoltaic solar cell is defined as the ratio of electric power provided by the PV solar cells and the solar radiation power. The usefulness of PV solar cells ranges from a few percent to forty percent. The remaining energy that is not converted into electrical energy is mainly converted into heat energy and thus warms the cell. Generally, the increase in solar cell temperature reduces the usefulness of PV cells. Standard calculations for the energy efficiency of solar photovoltaic cells are explained below. Energy conversion efficiency of a solar photovoltaic cell ($\ni$ "ETA") is the percentage of energy from the incident light that actually ends up as electricity. This is calculated at the point of maximum power, Pm, divided by the input light irradiation (E, in W/m2), all under standard test conditions (STC) and the surface of photovoltaic solar cells (AC in m2). STC - standard test conditions, according to which the reference solar radiation is 1.000 W/m2, spectral distribution is 1.5 and cell temperature 250C.

2.2 Solar radiation

The sun is the central star of the solar system in which the Earth is. It has a form of a large glowing ball of gas, the chemical composition of mostly hydrogen and helium, but also other elements that are in it to a lesser extent, like oxygen, carbon, iron, neon, nitrogen, silicon, magnesium and sulfur. Energy from the Sun comes to the Earth in the form of solar radiation. Nuclear reactions take place in the interior of the Sun, during which hydrogen is transformed into helium by a fusion process, accompanied by the release of large amounts of energy, where the temperature reaches 15 million °C. Part of this energy comes to Earth in form of heat and light, and allows all processes, from photosynthesis to the production of electricity in photovoltaic systems. Under optimal conditions, the earth's surface can obtain 1.000 W/m2, while the actual value depends on the location, i.e. latitude, climatological location parameters such as frequency of cloud cover and haze, air pressure, etc. Considering the sunlight and the productivity of photovoltaic systems, it is necessary to understand the following concepts:

- Irradiation, average density of the radiant solar radiation power, which is equal to the ratio of the solar radiation power and surface of the plane perpendicular to the direction of this radiation (W/m2).
- Radiation, which represents the quantity of solar radiation that is radiated on the unit surface at a given time (Wh/m2) or (J/m2). Besides expressing it in hourly values, it is often expressed as daily, monthly or yearly radiation, depending on the time interval.

The solar radiation weakens on its way through the earth's atmosphere due to the interaction with gases and vapors in the atmosphere and arrives at the Earth's surface as direct and diffused. Direct sunlight comes directly from the sun, while scattered or diffused radiation reaches the earth from all directions. Considering direct and diffused radiation on a flat surface, we are talking about the total radiation. In case of an inclined surface, the rejected or reflected radiation has to be added to the direct and diffused radiation. Rejected radiation can be reflected from the ground or water. The largest component of solar radiation is direct, and the maximum radiation should be on a surface perpendicular to the direction of the sun's rays. The greatest radiation at any given moment is only possible if the plane is constantly referred to the movement of the sun in the sky.[15-19] Photovoltaic modules can be mounted in various ways, fixed at a certain angle, or may be moving to better monitor the angle of inclination of the sun during the day for greater energy yield and better results in the production of electricity. Optimal value of the inclination angle of the surface has to be determined for fixed mounted photovoltaic module. The optimum angle of inclined PV module's surfaces is the angle at which it is inclined in relation to a horizontal surface in order to obtain the highest possible annual irradiation. An optimum angle of inclination for a period or certain months in the year can also be calculated. The greatest energy yield of a fixed module system is achieved by placing the modules at the optimal annual angle. As the sunlight radiation is a highly seasonal dependent variable, the average daily radiation values to an inclined surface range from about 1 kWh/m2 in December up to 7 kWh/m2 in June, which means that we obtain a higher energy yield in summer by setting a module at a lower angle, and vice versa. Influence of shading on solar power plant - the maximum electric energy is produced when sunlight directly crosses the PV modules. Shadows created by objects on the roof, wood or other surrounding buildings and skyscrapers substantially affect electricity production. The shade also negatively affects the stability of the system because modules located partially in the shade do not have a linear production of electricity, resulting in voltage changes and inverter disturbances. If only one cell in a module is located in the shade, it can reduce the power of all modules by 75

2.3 MPPT

MPPT or Maximum Power Point Tracking is algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage). Maximum power varies with solar radiation, ambient temperature and solar cell temperature. A MPPT, or maximum power point tracker is an electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid. To put it simply, they convert a higher voltage DC output from solar panels (and a few wind generators) down to the lower voltage needed to charge batteries. (These are sometimes called "power point trackers" for short - not to be confused with PANEL trackers, which are a solar panel mount that follows, or tracks, the sun). The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient voltage (maximum power point). That is to say: MPPT checks output of PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current into battery. It can also supply power to a DC load, which is connected directly to the battery. MPPT is most effective under these conditions:

- Cold weather, cloudy or hazy days: Normally, PV module works better at cold temperatures and MPPT is utilized to extract maximum power available from them.
- When battery is deeply discharged: MPPT can extract more current and charge the battery if the state of charge in the battery is lowers.

Panel tracking is where the panels are on a mount that follows the sun. The most common are the Zomeworks and Wattsun. These optimize output by following the sun across the sky for maximum sunlight. These typically give you about a 15% increase in winter and up to a 35% increase in summer. This is just the opposite of the seasonal variation for MPPT controllers. Since panel temperatures are much lower in winter, they put out more power. And winter is usually when you need the most power from your solar panels due to shorter days. Maximum Power Point Tracking is electronic tracking usually digital. The charge controller looks at the output of the panels, and compares it to the battery voltage. It then figures out what is the best power that the panel can put out to charge the battery. It takes this and converts it to best voltage to get maximum AMPS into the battery. (Remember, it is Amps into the battery that counts). Most modern MPPT's are around 93-97% efficient in the conversion. You typically get a 20 to 45% power gain in winter and 10-15% in summer. Actual gain can vary widely depending weather, temperature, battery state of charge, and other factors. Grid tie systems are becoming more popular as the price of solar drops and electric rates go up. There are several brands of grid-tie only (that is, no battery) inverters available. All of these have built in MPPT. Efficiency is around 94% to 97% for the MPPT conversion on those. Solar cells are neat things. Unfortunately, they are not very smart. Neither are batteries - in fact batteries are downright stupid. Most PV panels are built to put out a nominal 12 volts. The catch is "nominal". In actual fact, almost all "12 volt" solar panels are designed to put out from 16 to 18 volts. The problem is that a nominal 12 volt battery is pretty close to an actual 12 volts - 10.5 to 12.7 volts, depending on state of charge. Under charge, most batteries want from around 13.2 to 14.4 volts to fully charge quite a bit different than what most panels are designed to put out[21-32]

2.4 Woking of MPPT

Here is where the optimization, or maximum power point tracking comes in. Assume battery is low, at 12 volts. A MPPT takes that 17.6 volts at 7.4 amps and converts it down, so that what the battery gets is now 10.8 amps at 12 volts. Now you still have almost 130 watts. Ideally, for 100% power conversion you would get around 11.3 amps at 11.5 volts, but you have to feed the battery a higher voltage to force the amps in. And this is a simplified explanation - in actual fact the output of the MPPT charge controller might vary continually to adjust for getting the maximum amps into the battery. A MPPT tracks the maximum power point, which is going to be different from the STC (Standard Test Conditions) rating under almost all situations. Under very cold conditions a 120 watt panel is actually capable of putting over 130+ watts because the power output goes up as panel temperature goes down - but if you don't have some way of tracking that power point, you are going to lose it. On the other hand under very hot conditions, the power drops - you lose power as the temperature goes up. That is why you get less gain in summer. MPPT's are most effective under these conditions

- Winter, and/or cloudy or hazy days - when the extra power is needed the most.
- Cold weather - solar panels work better at cold temperatures, but without a MPPT you are losing most of that. Cold weather is most likely in winter - the time when sun hours are low and you need the power to recharge batteries the most.
- Low battery charge - the lower the state of charge in your battery, the more current a MPPT puts into them - another time when the extra power is needed the most. You can have both of these conditions at the same time.
- Long wire runs - If you are charging a 12 volt battery, and your panels are 100 feet away, the voltage drop and power loss can be considerable unless you use very large wire. That can be very expensive. But if you have four 12 volt panels wired in series for 48 volts, the power loss is much less, and the controller will convert that high voltage to 12 volts at the battery. That also means that if you have a high voltage panel setup feeding the controller, you can use much smaller wire.[11-19]

The Power point tracker is a high frequency DC to DC converter. They take the DC input from the solar panels, change it to high frequency AC, and convert it back down to a different DC voltage and current to exactly match the panels to the batteries. MPPT's operate at very high audio frequencies, usually in the 20-80 kHz range. The advantage of high frequency circuits is that they can be designed with very high efficiency transformers and small components. The design of high frequency circuits can be very tricky because the problems with portions of the circuit "broadcasting" just like a radio transmitter and causing radio and TV interference. Noise isolation and suppression becomes very important. There are a few non-digital (that is, linear) MPPT's charge controls around. These are much easier and cheaper to build and design than the digital ones. They do improve efficiency somewhat, but overall the efficiency can vary a lot - and we have seen a few lose their n"tracking point" and actually get worse. That can happen occasionally if a cloud passed over the panel - the linear circuit searches for the next best point, but then gets too far out on the deep end to find it again when the sun comes out. Thankfully, not many of these around anymore. The power point tracker (and all DC to DC converters) operates by taking the DC input current, changing it to AC, running through a transformer (usually a toroid, a doughnut looking transformer), and then rectifying it back to DC, followed by the output regulator. In most DC to DC converters, this is strictly an electronic process - no real smarts are involved except for some regulation of the output voltage. Charge controllers for solar panels need a lot more smarts as light and temperature conditions vary continuously all day long, and battery voltage changes.

3 HYBRID MULTILEVEL INVERTER

Many multilevel inverter topologies have been proposed during the last three decades. Modern research has engaged novel inverter topologies and unique modulation schemes. Three different major multilevel inverter structures have been reported in the literature: cascaded H-bridges inverter with separate DC sources, diode clamped (neutral clamped) and flying capacitors (capacitor clamped). The first topology introduced was the series H-bridge design. This was followed by the diode-clamped multilevel inverter which utilizes a bank of series capacitors to split the DC bus voltage. After few years the flying-capacitor (or capacitor clamped) topology was introduced in which instead of series connected capacitors floating capacitors are used to clamp the voltage levels. Another multilevel design, slightly different from the previous ones, involves parallel connection of inverter outputs through inter-phase reactors. In this design the switches must block the entire reverse voltage, but share the load current. Various combinatorial designs have also emerge and been implemented by cascading the fundamental topologies such designs come under hybrid topologies category. These designs can create higher power quality for a given number of semiconductor devices than the fundamental topologies due to a multiplying effect of the number of levels. Moreover, number of modulation techniques and control techniques have been developed for multilevel inverters such as sinusoidal pulse width modulation (SPWM), selective harmonic elimination (SHE-PWM), space vector modulation (SVM), multicarrier modulation and others. In the beginning multilevel inverters were introduced to drive high voltage as in High Voltage Direct Current (HVDC) applications to make the front-end connection between DC and AC lines. In this way the limits on the maximum voltage tolerable by the semiconductor switches were overtaken and the inverters were able to drive directly the line voltage without a transformer. Nowadays it is possible to find multilevel applications even in low voltage field like motor drive because of the high quality of the AC output. In particular back-to-back multilevel systems can drive motors with very good performance concerning the line voltage and current distortions and also reduces the losses. Recent advances in power electronics have made the multilevel concept practical. In fact the concept is so advantageous that several major drive manufacturers have obtained patents on multilevel power inverter and associated switching techniques. In addition, many multilevel inverter applications focus on industrial medium voltage motor drives utility interface for renewable energy systems flexible ac transmission system (FACTS) and traction drive systems.[16]

3.1 Classification of HMLI

Hybrid multilevel inverters are classified on basis of types of power devices used, number of power supplies used, magnitude of the power supplies used and how power devices are connected in circuit. Thus broad classification of hybrid multilevel inverter is as follows:

- Asymmetric Hybrid Multilevel Inverter
- Hybrid Multilevel Inverter Based on Half-Bridge Modules
- New Symmetrical Hybrid Multilevel Inverters
- Hybrid Clamped Five-Level Inverter Topology
- Distinct Series Connected cells Hybrid Multilevel Inverter
- Hybrid Medium-Voltage Inverter based on a NPC Inverter
- New Hybrid Asymmetrical Multilevel H-bridge Inverter
- Hybrid Multilevel Inverter with Single DC Source

3.2 HMLI with single DC source

This inverter includes a standard full bridge 3-leg inverter (one leg for each phase) and an H-bridge in series with each inverter leg as shown in figure 3. It uses only a single DC power source to supply a standard 3-leg inverter along with three full H-bridges supplied by capacitors or batteries. Traditionally, each H-bridge requires a DC power source. The inverter can be used in electric vehicles (EV) / hybrid electric vehicles (HEV) to drive electric motor. And it can be applied for utility interface. As shown in figure 4 the output voltage v1 of single leg (with respect to the ground) is either +Vdc (S5 closed) or - Vdc (S6 closed). This leg is connected in series with a full H-bridge which in turn is supplied by capacitor voltage. If the capacitor is used and kept charged to Vdc, then the output voltage of the H-bridge

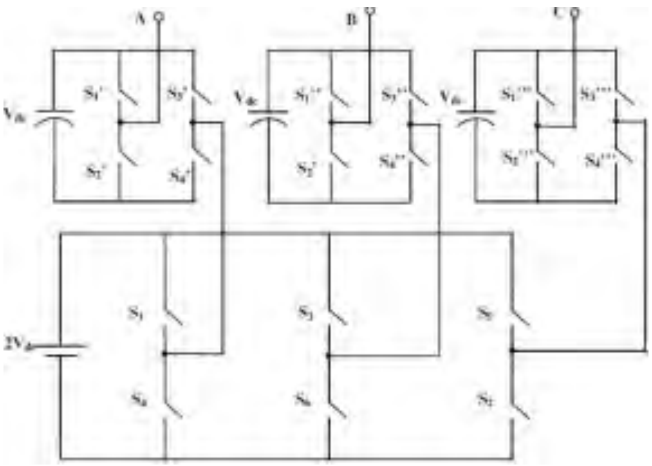


Figure 3: *Three level HMLI with single DC source*

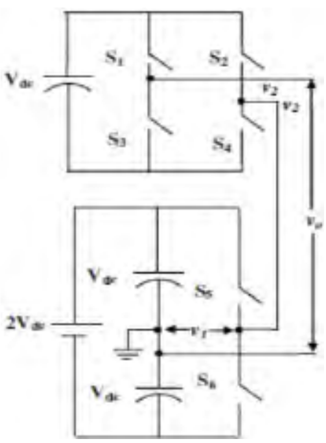


Figure 4: *Single phase HMLI with single DC source.*

can take on the values + Vdc (S1, S4 closed), 0 (S1, S2 closed or S3, S4 closed), or - Vdc (S2, S3 closed).

Figure 5 shows an output voltage example. The capacitor's voltage regulation control method consists of monitoring the output current and the capacitor voltage so that during periods of zero voltage output either the switches S1, S4, and S6 are closed or the switches S2, S3, S5 are closed depending on whether it is necessary to charge or discharge the capacitor. This method depends on the voltage and current not being in phase. That means one needs positive (or negative) current when the voltage is passing through zero in order to charge or discharge the capacitor. Consequently the amount of capacitor voltage the scheme can regulate depends on the phase angle difference of output voltage and current.[12-18]

As figure 6 illustrates, this method of regulating the capacitor voltage depends on the voltage and current not being in phase. That is, one needs positive (or negative) current when the voltage is passing through zero in order

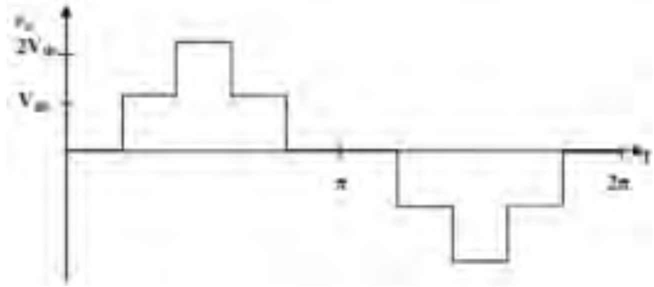


Figure 5: *Output voltage for single phase HMLI with single DC source.*

to charge or discharge the capacitor. Consequently, the amount of capacitor voltage the scheme can regulate depends on the power factor. Thus by maintaining the regulation of the capacitor voltage simultaneously achieves an output voltage waveform which is 25% higher than that obtained using a standard 3-leg inverter by itself.

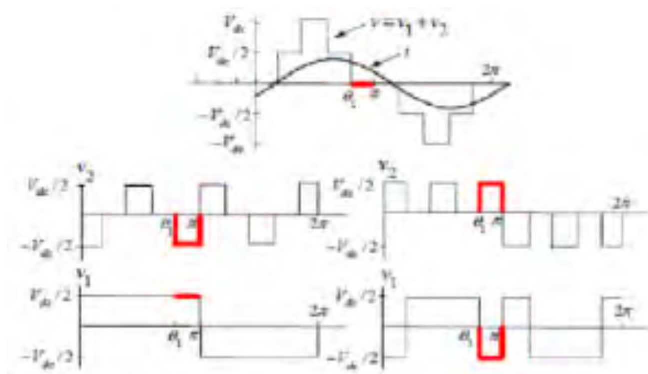


Figure 6: *Capacitor voltage regulation.*

4 PROPOSED SYSTEM

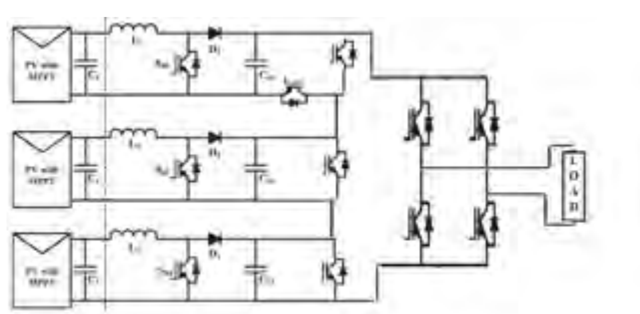


Figure 7: *Proposed multilevel inverter with boost converter.*

Figure 7 shows the proposed MPPT for photovoltaic system with multilevel inverter which is designed with the boost converter to reduce the number of switches in the inverter topology. For this purpose the H-bridge multilevel inverter is used in the proposed design.

4.1 MPPT for PV

MPPT or Maximum Power Point Tracking is calculation that incorporated into charge controllers utilized for removing most extreme accessible power from PV module under specific conditions. The voltage at which PV module can deliver most extreme power is called 'greatest power point' (or pinnacle control voltage). Most extreme power differs with sunlight based radiation, encompassing temperature and sun based cell temperature. A MPPT, or most extreme power point tracker is an electronic DC to DC converter that streamlines the match between the sun powered exhibit (PV boards), and the battery bank or utility framework. Basically, they change over a higher voltage DC yield from sun based boards (and a couple of twist generators) down to the lower voltage expected to charge batteries. (These are some of the time called "control point trackers" for short - not to be mistaken for PANEL trackers, which are a sun powered board mount that takes after, or tracks, the sun).[17] The significant standard of MPPT is to separate the greatest accessible power from PV module by influencing them to work and no more productive voltage (most extreme power point). In other words: MPPT checks yield of PV module, thinks about it to battery voltage at that point fixes what is the best power that PV module can deliver to charge the battery and believers it to the best voltage to get most extreme current into battery. It can likewise supply energy to a DC stack, which is associated specifically to the battery.

4.2 PV array

A PV Array consists of a number of individual PV modules or panels that have been wired together in a series and/or parallel to deliver the voltage and amperage a particular system requires. An array can be as small as a single pair of modules, or large enough to cover acres. The performance of PV modules and arrays are generally rated according to their maximum DC power output (watts) under Standard Test Conditions (STC). Standard Test Conditions are defined by a module (cell) operating temperature of 25oC (77 F), and incident solar irradiant level of 1000 W/m2 and under Air Mass 1.5 spectral distribution. Since these conditions are not always typical of how PV modules and arrays operate in the field, actual performance is usually 85 to 90 percent of the STC rating. The simulation of PV system with MPPT used in proposed work is shown in figure 8.

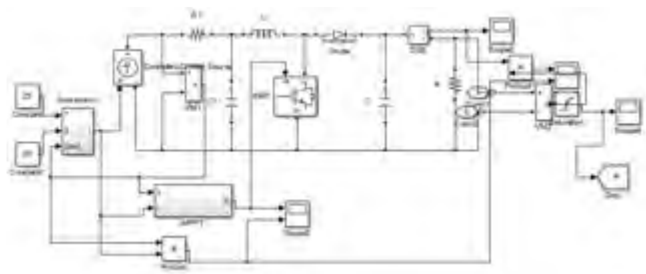


Figure 8: *Simulation diagram of PV system with MPPT.*

4.3 Boost converter

The boost converter converts an input voltage to a higher output voltage. The boost converter is also called a step-up converter. A boost converter is a DC-to-DC power converter .with an output voltage greater than its input voltage. It is a class of switched mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor and at least one energy storage element, a capacitor C, inductor L or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. Power for the boost converter can come from any suitable DC sources,. A process that changes low DC voltage to a high DC voltage is called DC to DC conversion .It "steps up" the source voltage. Since power must be conserved the output current is lower than the source current. It is used to boost the voltage from the PV, battery and WECS.

4.4 H-bridge inverter

An H bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards or backwards. Most DC-to-AC converters (power inverters), most AC/AC converters, the DC-to-DC push–pull converter, most motor controllers, and many other kinds of power electronics use H bridges. In particular, a bipolar stepper motor is almost invariably driven by a motor controller containing two H-bridges. H bridges are available as integrated circuits, or can be built from discrete components. The term H-Bridge is derived from the typical graphical representation of such a circuit. An H bridge is built with four switches (solid-state or mechanical). When the switches S1 and S4 (according to the first figure) are closed (and S2 and S3 are open) a positive voltage will be applied across the motor. By opening S1 and S4 switches and closing S2 and S3 switches, this voltage is reversed, allowing reverse operation of the motor. The simulation diagram of this H-bridge multilevel inverter is shown in figure 9. The modified design of this inverter is shown in figure 10. [18-22]

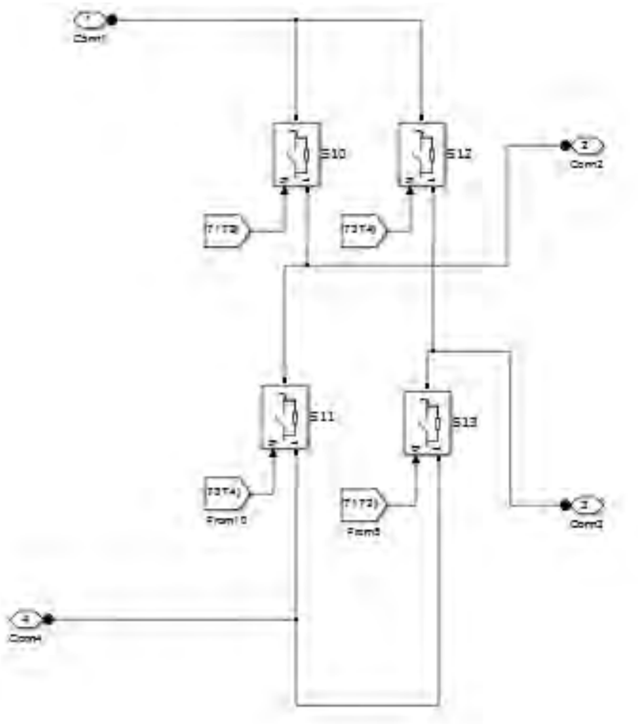


Figure 9: *H-bridge multilevel inverter.*

The pluses are given to the switches in modified H-bridge multilevel inverter to trigger the switches to turn on and to turn off it for particular instants. That pulse circuit to the inverter is shown in figure 11. The overall proposed system that is the MLI configuration with boost converter for PV system with MPPT is shown in figure 12.

5 RESULTS

The behavior of the complete system of the Maximum Power Point Tracking with boost converter for a photovoltaic system which supports the distribution power grid is explained by the simulation results. Consider the proposed PV system consists of three PV arrays which are connected in parallel. These are connected in separate MPPT with boost converter. The output voltage of each PV system is shown in figure 13.

The output of the PV system is DC voltage. It should be converted into AC voltage to utilize by the loads, for the inverter should be used to convert DC to AC. For this purpose the reduced switch modified H-bridge multilevel inverter is used in this proposed system. The pulses to the switches in the modified H-bridge multilevel inverter is shown in figure 14.

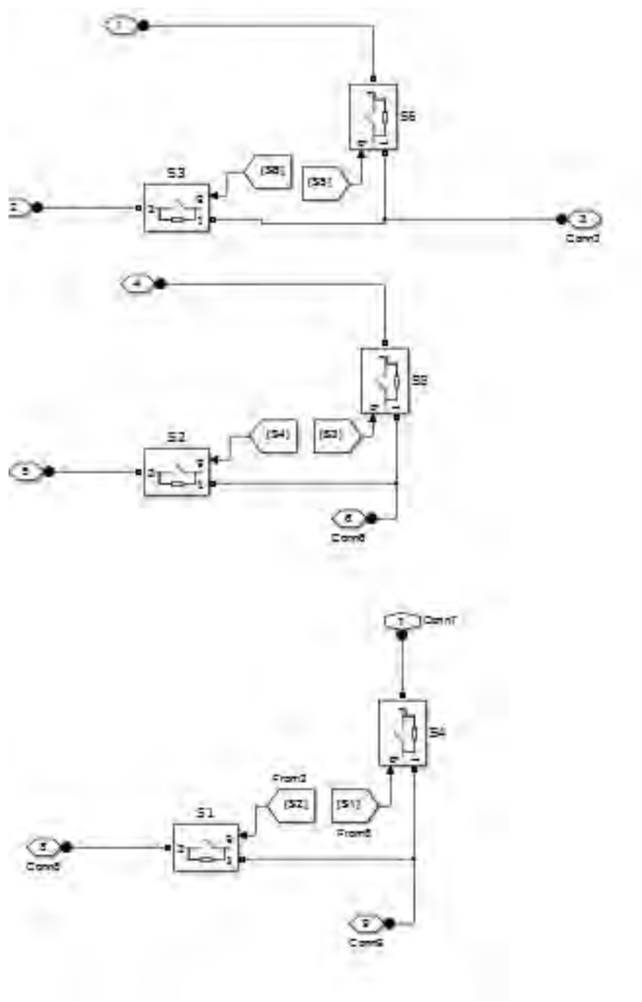


Figure 10: *Modified H-bridge multilevel inverter.*

The inverted voltage which is the overall output DC voltage of PV system inverted by the modified H-bridge multilevel inverter is shown in figure 15.[11-17]

6 CONCLUSION

This paper has discussed about PV based multilevel inverter circuit. Separate solar panels with P& O based MPPT technique is connected in the place of each DC source in the proposed multilevel inverter through boost converters. The complete system is tested and the results are observed for different irradiation condition, different temperature condition and step changes in climate condition (irradiance and temperature) in PV. A main objective of HB circuit based MLI is to increase the output voltage level to nearly twice when compared to conventional MLI. The proposed multilevel inverter has lesser % THD and power losses. Hence the proposed system is found to be well suitable for photovoltaic ap-

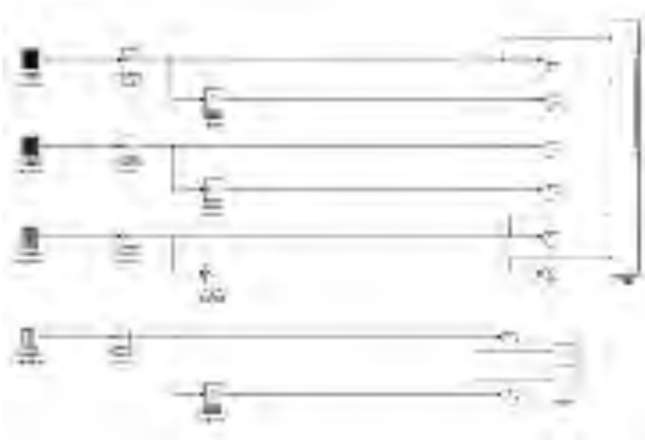


Figure 11: *Pulse circuit for modified H-bridge MLI.*

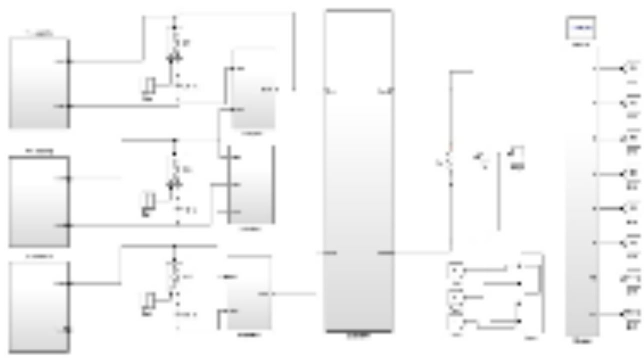


Figure 12: *Overall simulation diagram of proposed system.*

plication. The proposed MLI topology with filters can be connected directly to the utility grid which can operate effectively.

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Power Management of a Hybrid Solar- Wind Energy System" International Journal of Engineering Research & Technology vol. 3(2) pp.1988-1992, 2014.

[3] M. Siva Ramkumar, M. Sivaram Krishnan, Dr.A.Amudha "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

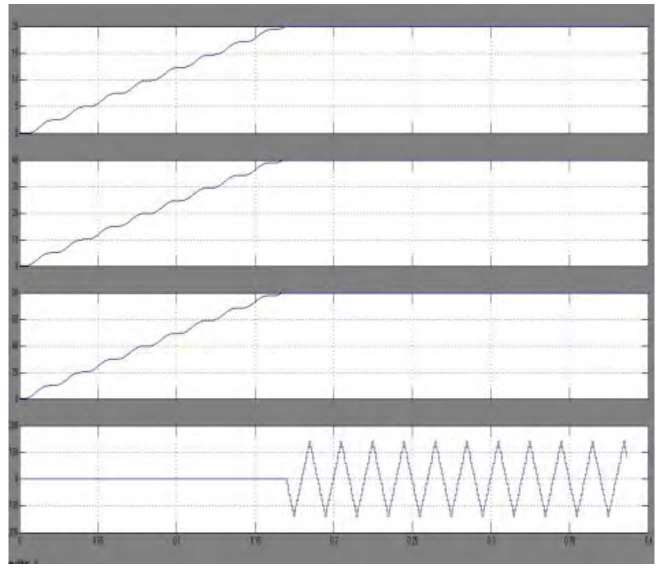


Figure 13: *Output voltage of PV.*

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc " in International Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[5] M Siva RamKumar, A. Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016. .

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763-769,2014.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2),2014

[9] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[10] D. Kavitha, C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless

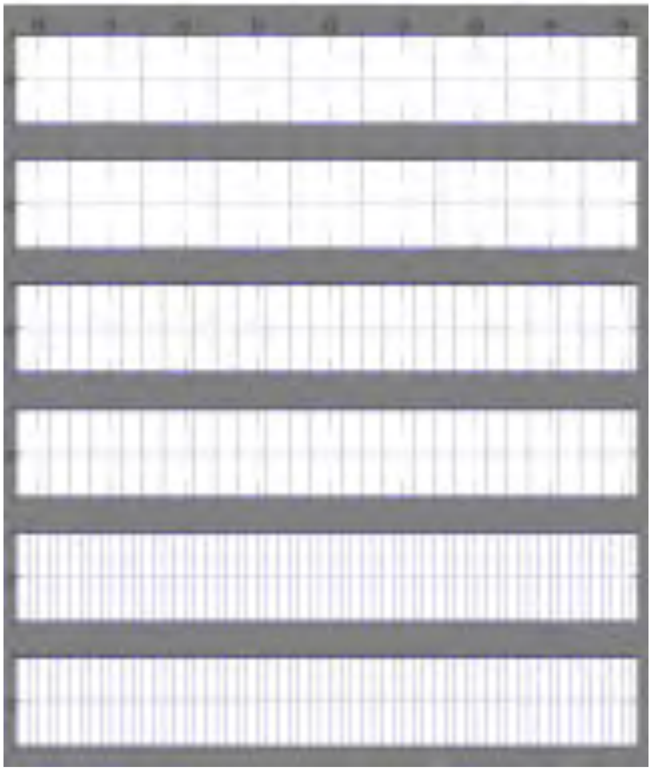


Figure 14: *Pulses to the inverter switches.*

BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.20 (2015), pg. 17749-17754.

[11] D. Manoharan, A. Amudha. "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, A. Amudha. A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6233-6240.

[13] A. Amudha. "Enhancement of Available Transfer Capability using FACTS controller" in International journal of Applied Mechanics and Materials, Vol. 573, pp 340-345

[14] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035-2042.

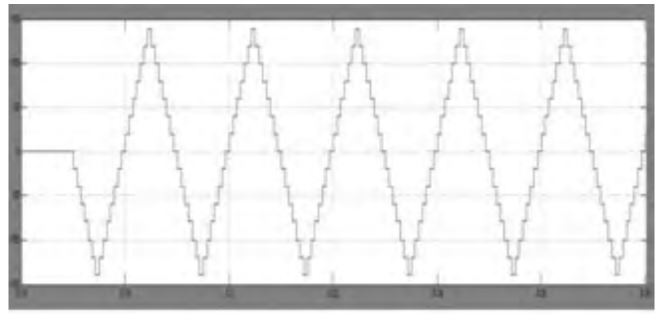


Figure 15: *Overall output of PV system.*

[15] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[17] K. Balachander, P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, V. Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[19] K. Balachander, V. Ponnusamy, 'Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research', Volume 7, Number 3 (2012), pp. 247-256. .

[20] K. Balachander, S. Kuppusamy, V. Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[21] M. Sivaram Krishnan, Dr.A.Amudha, M. Siva Ramkumar, 'Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms', International journal of Pure and Applied Mathimatics,118 (11), pp 609-617,2018 DOI:10.12732/ijpam.v118i11.79

[22] S. Motapon, L. Dessaint, K.AI-Haddad, "A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, " IEEE Trans. Ind. Electron. , vo1.61, no.3, pp.1320,1334, March 2014.

NON ISOLATED INTERLEAVED CUK CONVERTER FOR HIGH VOLTAGE GAIN APPLICATIONS

D. Kavitha, M. Siranjeevi, K. Balachander, M.S. Ramkumar, M.S. Krishnan

Abstract: The paper presents a non-isolated interleaved DC-DC converter with zero voltage switching. In modern power supply applications, the high voltage gain step-up DC-DC converters are widely used. These are fundamental conversion stages in electric vehicle and grid-connected renewables. Due to the low cost and high efficiency, it is not a trivial task. For this reason, the proposed method presented. It designed by a coupled inductor with active clamping to recycle the coupled inductor leakage energy. This model is capable of achieving more voltage gain without the need for extreme modulation signal.

Keywords: Step up, interleaved DC-DC converter, non-isolated, active clamping, zero voltage switching

1 Introduction

Nowadays high voltage step-up gains are mostly used when the power system is energized by low voltage energy sources such as fuel cells, solar arrays, and batteries. The renewable energy applications use high efficiency and step up dc-dc converter for power conversion stages. The examples are grid connected inverter [1–4], electric vehicle trains [5], uninterruptible power supplies system [6] these are operating under extreme duty ratios to achieve maximum voltage gains due to these voltage and current stresses are occurred, and the output diodes often sustain short [7,8]. The cascade boost converter is an attractive solution than single stage boost converter to enlarge the voltage gain without extreme duty ratio operation [9].

The method to enlarge the voltage gain is switched capacitors and switched inductor convertors. It uses the technique of capacitor charge transference, and it is used to reduce the voltage stress on the devices, but this circuit is typically complex. The disadvantage of this method is the device voltage stress is equal to output voltage and significant conduction losses [14, 15].

The push full and full bridge converter achieve high voltage gain by choosing the turns ratio of the high-frequency transformer, but the leakage inductance of a transformer induce voltage stress and increase the switching losses. These types of converters do not offer a feasible solution in green power supply applications [20]. In this paper, non-isolated, ZVS interleaved, high step-up boost converter with the active clamping circuit is proposed. The converter uses two coupled inductors in both flyback and forward mode and a switched capacitor to achieve a high conversion ratio.

Interleaving is followed on the primary side to share input current and cancel the ripple of the coupled inductors and also reduce the switch conduction losses. Importantly, a low turns ratio can be employed to achieve reduced the copper losses and leakage inductance.

The secondary windings of the coupled inductor are connected in series to achieve high voltage at the output and also, the voltage stress of the switches and diodes are reduced. Hence switching losses are further reduced yielding an efficient green power supply solution.

2 Proposed System

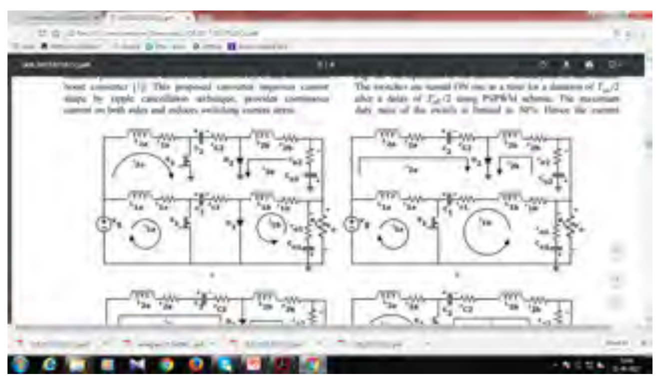


Figure 1: *Interleaved Cuk Converter.*

The interleaved converter is a DC-DC power converter that can produce an output voltage magnitude is either less or greater than the input voltage. It produces the output voltage of opposite polarity with respect to the input voltage because of an inverter converter. In this circuit, the capacitor C2 acts as the primary, and it is used for storing and transferring energy from the input to output. [11–15] The advantage of this the input current and the current feeding the output stage are ripple-free. The dc-dc converter uses the main energy-storage component like a capacitor, but the most types of converters which uses an inductor for the energy-storage component. The Cuk converter gives the advantages of low ripple input and output current over 6 buck-boost converters in terms. The circuit setup is the same as the combination of the buck and boost converters. The buck-boost circuit delivers an inverted output.

All of the output current passes through capacitor C1, and as ripple current. So the capacitor is usually a large electrolytic with a high ripple current rating and low equivalent series resistance, to minimize losses. The major difference between the other converter and the Cuk converter is that uses a capacitor as the energy storing element [7].

3 Operating Principle of cuk Converter

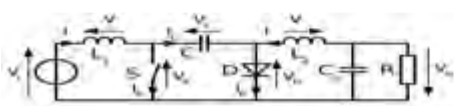


Figure 2: *Non isolated Converter.*

When the switch is turned on, current flows through L1 and S from the input source, storing energy in L1 in the magnetic field. When the switch is turned off, the voltage across inductor L1 reverses to maintain current flow.

In the boost converter current flows through inductor L1 and diode D1 from the input source, charging up the capacitor C1 to a voltage is higher than the input voltage Vin and some of the energy that was stored in L1 transferring to it.

The switch is turned on again, capacitor C1 discharges via inductor L2 into the load, with inductor L2 and C2 acting as a smoothing filter. The energy is being stored again in inductor L1, and it is ready for the next cycle. As with the buck converter, boost converter, buck-boost converter the Cuk converter can operate in two modes continuous and discontinuous current mode. These converters can also operate in discontinuous voltage mode is that the voltage across the capacitor drops to zero during the commutation cycle [8–10].

In the off state condition the Vi is connected in series with capacitor C and inductor L1; therefore, the voltage across the inductor is the difference between the input voltage and the capacitor voltage then the diode gets forward biased. The output capacitor is connected to inductor L2, so the output voltage is directly proportional to the voltage across the inductor 2. The converter is on-state from t=0 to t =DT and is off state from DT to T. The difference between Cuk converter, and buck-

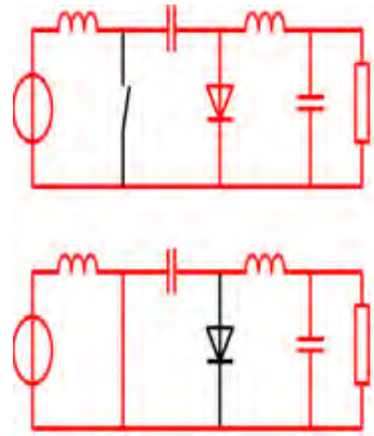


Figure 3: *ON and OFF state of converter.*

boost is that the Cuk converter produces much lower ripple current. By careful adjustment of the inductor values, the ripple in either input or output can be nulled completely. In discontinuous mode the inductor vale is very small or lower than the critical inductance then the current will be a discontinuous mode [15–19].

4 Soft Switching Topologies

The conventional Pulse with modulation converters can operate on hard switching. During the transition period, here the voltage and current pulses move from low to high value or from high to low value. The switching losses occurred were examined by Bodur et al. (2010). These losses arise due to the capacitance of the diode output capacitance of the transistor, and reverse recovery of the diode. It also generates a considerable amount of Electromagnetic interference. It is observed that the switching loss is indirectly proportional to the switching frequency. Therefore the higher switching loss reduces the switching frequency to a minimum value. Types of soft switching techniques are zero voltage switching and zero current switching [10–13].

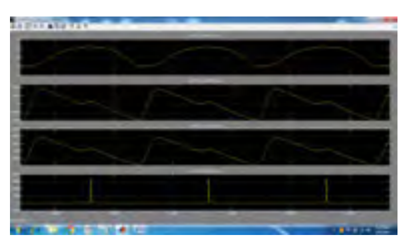


Figure 4: *output voltage, current, switching loss for converter.*

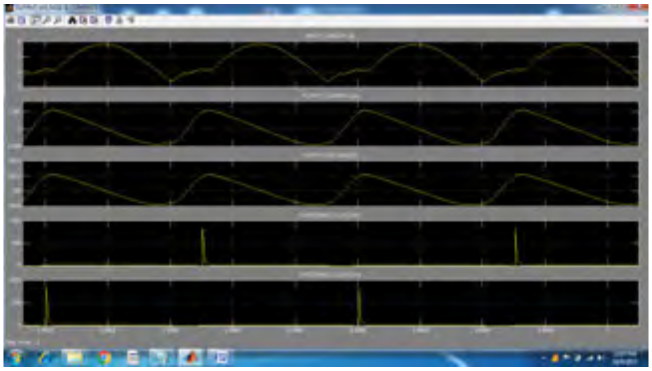


Figure 5: *input current, output current, output voltage interleaved converter.*

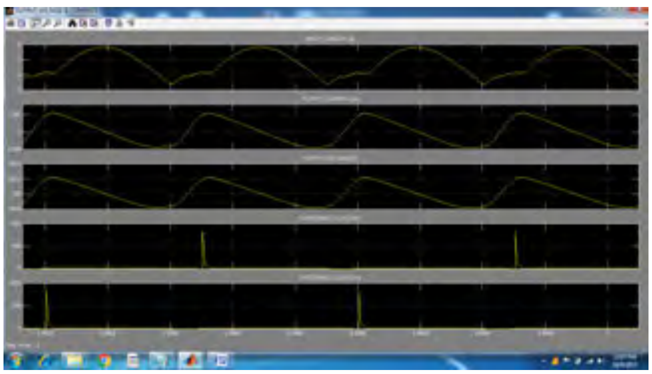


Figure 6: *Switching loss for S1 and S2.*

5 Results and Tables

The analysis of 500W prototype is tested the parameters are input voltage = 12–14V, switching frequency is 50KHz. Clamp capacitors and switched capacitor = 10microfarad, magnetizing inductance is 34.5 microhenry, leakage inductance is 1.6 microhenry [14–18].

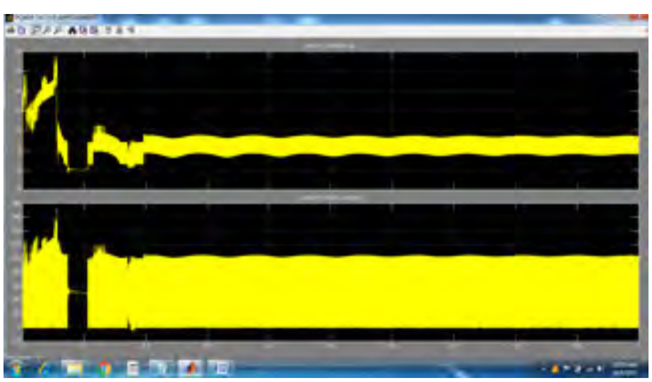


Figure 7: *Capacitor voltage of the converter.*

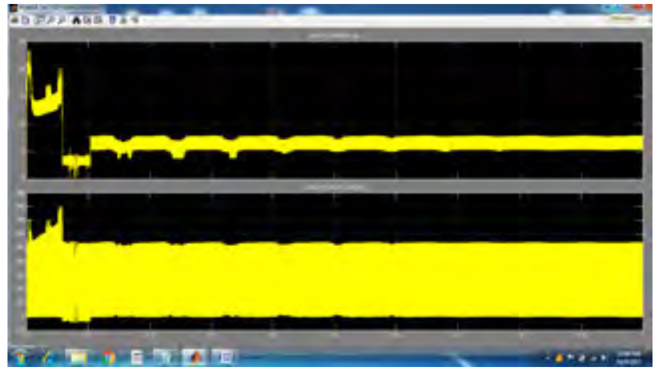


Figure 8: *Capacitor voltage of the interleaved converter.*

6 Conclusion

This paper presents a new interleaved, non-isolated, ZVS converter; based on a winding coupled inductor approach. The circuit is specifically designed for high voltage gain applications. The power converter topology minimizes conduction and switching losses, recycles leakage energy from the coupled inductor, and reduces the voltage stress across semiconductor devices. This paper presents a full analysis of the circuit's principle of operation. Experimental results from a 500 W, 10x voltage gain, prototype dc-dc converter validate the proposed theory. Importantly, the results demonstrate that the circuit is capable of achieving excellent output voltage regulation, a rapid transient response to step load changes, and achieves high-efficiency operation over a wide range of load conditions. Unlike many other solutions, the proposed circuit does not require extreme PWM modulation signals to achieve high boost ratios. Such characteristics make the proposed power converter a strong candidate in many emerging dc-dc power supply applications.

References

[1] X. Hu, C. Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Power Management of a Hybrid Solar- Wind Energy System" International Journal of Engineering Research & Technology vol. 3(2) pp.1988–1992, 2014.

[3] M. Siva Ramkumar, M. Sivaram Krishnan, A. Amudha. "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239–245, 2017.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. “Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc “ in International Journal of Control Theory and Applications, 10 (2) pp 333–344, 2017.

[5] M Siva RamKumar, Dr. A Amudha, R. Rajeev “Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications” in International Journal of Applied Engineering Research, 11(9) pp 6485–6488, 2016.

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara “Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control” in ‘International Journal of Innovative Research in Science, Engineering and Technology’ on 3 (3) pp 763–769,2014.

[7] M. Siva Ramkumar “Unmanned Automated Railway Level Crossing System Using Zigbee” in International Journal of Electronics Engineering Research, 9 (9) pp 1361–1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan “Hybrid Solar-Wind Energy System” in ‘International Journal of Advance Research in Computer Science and Management Studies’ 2(2),2014

[9] Emayavaramban. G, Amudha. A, ‘sEMG Based Classification of Hand Gestures using Artificial Neural Networks’, Indian Journal of Science and Technology, Vol.9 (35), pp. 1–10, September 2016.

[10] D. Kavitha, Dr. C. Vivekanandan, “An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor” in International Journal of Applied Engineering Research, ISSN 0973–4562 Vol. 10 No.20 (2015), pg. 17749–17754.

[11] D. Manoharan, Dr. A. Amudha. “Condition Monitoring And Life Extension Of EHV Transformer” International Journal of Applied Engineering Research, ISSN 0973–4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, Dr. A. Amudha. A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973–4562 Volume 10, Number 3 (2015) pp. 6233–6240.

[13] Dr. A. Amudha. “Enhancement of Available Transfer Capability using FACTS controller” in International journal of Applied Mechanics and Materials, Vol. 573, pp 340–345

[14] K. Balachander, Dr. P. Vijayakumar, “Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)” International Journal of Applied Environmental Sciences”, Volume - 08, No.16 (2013), pp.2035–2042.

[15] K. Balachander, Dr. P. Vijayakumar, “Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ”, American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, Dr. P. Vijayakumar, “Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India”, Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839–847.

[17] K. Balachander, Dr. P. Vijayakumar, “Renewable Energy System Optimization of Two Different Locations” CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, Dr. Vijayakumar Ponnusamy, ‘Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System’ International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179–186.

[19] K. Balachander, Dr. Vijayakumar Ponnusamy, ‘Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER’ International Journal of Applied Engineering Research’, Volume 7, Number 3 (2012), pp. 247–256.

[20] K. Balachander, S. Kuppusamy, Dr. Vijayakumar Ponnusamy, ‘Modeling and Simulation of VSD-FIG and PMSG Wind Turbine System’, International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111–118.

[21] M. Sivaram Krishnan, A. Amudha, M. Siva Ramkumar, ‘Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms’, International journal of Pure and Applied Mathimatics,118 (11), pp 609–617,2018 DOI:10.12732/ijpam.v118i11.79

[22] S. Motapon, L. Dessaint, K. AI-Haddad, "A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, " IEEE Trans. Ind. Electron., vo1.61, no.3, pp.1320,1334, March 2014.

PV AND FUEL CELL BASED DYNAMIC VOLTAGE RESTORER FOR LVRT IMPROVEMENT OF DFIGWTS

R. Shobana, K. Balachander, A. Amudha, G. Emayavaramban, M. Siva Ramkumar

Abstract: The project proposes about the compensating fault ride-through (FRT) of a wind turbine based on doubly-fed induction generator (DFIG), voltage dip by using a PV supported dynamic voltage restorer (DVR). DVR a custom power device is used in series with grid by using coupling transformer. This device is used to protect the critical load in which the fault occurred due to source side disturbance. PV is used as a source to DVR and during fault PV supports DVR to clear the fault. With the proposed control method, the DVR can compensate for the FRT, while the DFIG wind turbine can continue its normal operation as demanded in actual grid codes.

Keywords: Dynamic Voltage Restorer (DVR), Doubly Fed Induction Generator (DFIG), Photovoltaic system (PV), Power Quality (PQ).

1 Introduction

Renewable energy is a good option because it gives a clean and green energy, with no CO2 emission. Renewable energy is defined as energy that comes from resources which are naturally refilled on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat. Amongst the renewable source of energy, the photovoltaic power systems are gaining popularity, with heavy demand in energy sector and to reduce environmental pollution around caused due to excess use nonrenewable source of energy. Several system structures are designed for grid connected PV systems Photovoltaic system, also solar PV power system, or PV system, is a power system designed to supply usable solar power by means of photovoltaic [1-9]. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity, a solar inverter to change the electric current from DC to AC, as well as mounting, cabling and other electrical accessories to set up a working system. It may also use a solar tracking system to improve the system's overall performance and include an integrated battery solution, as prices for storage devices are expected to decline. Strictly speaking, a solar array only encompasses the ensemble of solar panels, the visible part of the PV system, and does not include all the other hardware, often summarized as balance of system (BOS). Moreover, PV systems convert light directly into electricity and shouldn't be confused with other technologies, such as concentrated solar power or solar thermal, used for heating and cooling. . Solar PV system is very reliable and clean source of electricity that can suit a wide range of applications such as residence, industry, agriculture, livestock, etc [10,11]. Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. This wind flow, or motion energy, when "harvested" by modern wind turbines, can be used to generate electricity. The terms "wind energy" or "wind power" describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity to power homes, businesses, schools, and the like. Wind turbines, like aircraft propeller blades, turn in the moving air and power an electric generator that supplies an electric current [12-15]. Simply stated, a wind turbine is the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. Wind energy is a free, renewable resource, so no matter how much is used today, there will still be the same supply in the future. Wind energy is also a source of clean, non-polluting, electricity. Unlike conventional power plants, wind plants emit no air pollutants or greenhouse gases wind costs are much more competitive with other generating technologies because there is no fuel to purchase and minimal operating expenses [16-21]. Dynamic voltage restoration (DVR) is a method and apparatus used to sustain, or restore, an operational electric load during sags, or spikes, in voltage supply. DVR (Dynamic Voltage Restorer) is a static VAR device that has seen applications in a variety of transmission and distribution systems. It is a series compensation device, which protects sensitive electric load from power quality problems such as voltage sags, swells, unbalance and distortion through power electronic controllers that use voltage source converters (VSC). The basic principle of the dynamic voltage restorer is to inject a voltage of required magnitude and frequency, so that it can restore the load side voltage to the desired amplitude and waveform even when the source voltage is unbalanced or distorted. Generally, it employs a gate turn off thyristor (GTO) solid state power electronic switches in a pulse width modulated (PWM) inverter structure [22-23]. The DVR can generate or absorb independently controllable real and reactive power at the load side. In other words, the DVR is made of a solid state DC to AC switching power converter that injects a set of three phase AC output voltages in series and synchronism with the distribution and transmission line voltages. The source of the injected voltage is the commutation process for reactive power demand and an energy source for the real power demand. In normal conditions, the dynamic voltage restorer operates in standby mode. However, during disturbances, nominal system voltage will be compared to the voltage variation. This is to get the differential voltage that should be injected by the DVR in order to maintain supply voltage to the load within limits. Applications the capability of injection voltage by DVR system is 50% of nominal voltage. This allows DVRs to successfully provide protection against sags to 50% for durations of up to 0.1 seconds. Furthermore, most voltage sags rarely reach less than 50%. The dynamic voltage restorer is also used to mitigate the damaging effects of voltage swells, voltage unbalance and other waveform distortions. The project proposes about the renewable system which is supplied to the critical load without disturbing the load parameters. DVR a custom power device which is connected in series with the grid by using coupling transformer. This device is used to protect the critical load in which the fault is occurred due to source side disturbance. DVR uses separate sources that cannot be used for any other purposes. PV is used as a source and during normal operating condition it supports the grid and charges the battery. During fault PV supports DVR to clear the fault. A low voltage right through technique is used that when during grid level voltage decreases due to fault, at that time DFIG tries to go out through the grid. During that condition low voltage right through capability increases and stays within the limit.

2 DYNAMIC VOLTAGE RESTORER

Electrical energy is the simple and well regulated form of energy, can be easily transformed to other forms. Along with its quality and continuity has to maintain for good economy. Power quality has become major concern for today's power industries and consumers. Power quality issues are caused by increasingly demand of electronic equipment and non-linear loads. Many disturbances associated with electrical power are voltage sag, voltage swell, voltage flicker and harmonic contents. This degrades the efficiency and shortens the life time of end user equipment. It also causes data and memory loss of electronic equipment like computer. Due to complexity of power system network voltage sag/swell became the major power quality issue affecting the end consumers and industries. It occurs frequently and results in high losses. Voltage sag is due to sudden disconnection of load, fault in the system and voltage swell is due to single line to ground fault results in voltage rise ofanunfaulted phases. The continuity of power supply can be maintained by clearing the faults at faster rate. Other power quality issues i.e. voltage flickering, harmonics, transients etc. has to be compensated to enhance the power quality. Power electronic devices i.e. Distribution Static Compensator (D-STATCOM) and Dynamic Voltage Restorer (DVR) been recently used for voltage sag/swell compensation. In this project DVR is proposed which can protect the end-consumer load from any unbalance of voltage supply. It is a series compensating device, can maintain the load voltage profile even when the source side voltage is distorted.

2.1 DVR

Now a day's electrical equipment are more sensitive to PQ problems. Voltage sag/swell are one of considerable problem that our power system network is facing today. Without proper mitigation, such problem can cause severe problem and may result in failure of equipment. Modern development in custom devices can solve such problem. DVR is one of the effective solutions for compensation voltage sag/swell. A DVR is a series connected custom device that injects the appropriate/desired voltage to the load bus in order to maintain the voltage profile. However, in standard condition it is in stand-by mode. The compensating voltage is injected by three single phase transformers whose property can be controlled.

2.2 Fuel cell

DVR is series connected compensating devices that restore/maintain the voltage profile at the sensitive loads under voltage unbalance. It is usually connected in the distribution network between Common Point of Coupling (PCC) and load. Figure 1 shows the location of DVR in power system network. The disturbance in the system is detected by control scheme used which gen-

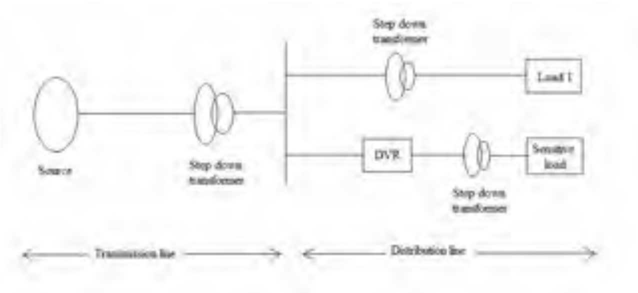


Figure 1: *Location of DVR*

erates the triggering pulses for VSI. Passive filters are used to filter out the harmonic content of injected voltage. DVR injects the filtered output voltage through injection transformer. The basic structure of DVR shown in figure 2 consists of following blocks:

- VSI
- Injection transformer
- Passive filter
- Energy storage unit
- Control circuit
- Location of DVR

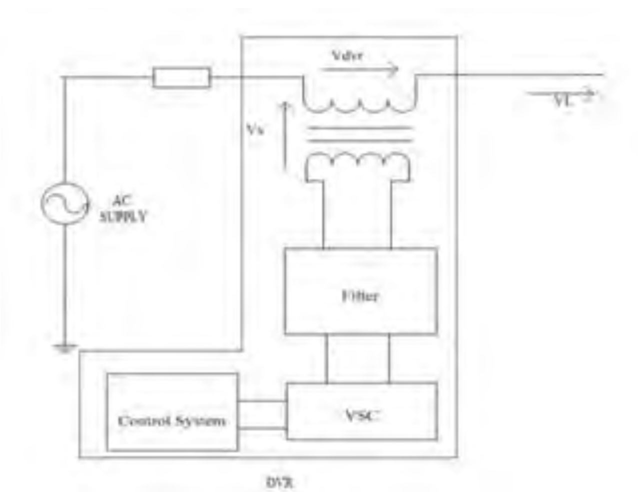


Figure 2: *Basic structure of DVR.*

2.3 Power quality

Power Quality concerns about the utility ability to provide uninterrupted power supply. The quality of electric power is characterized by parameters such as "continuity of supply, voltage magnitude variation, transients and harmonic contents in electrical signals". Synchronization of electrical quantities allows electrical systems to function properly and without failure or malfunction of an electric device. PQ expresses the degree of similarity of practical power supply with ideal power supply.

- If PQ is good then any load connected to the electric network runs efficiently without decreasing its performance.
- If PQ is poor then any load connected to the network leads either to the failure of the equipment or reduction in its lifetime and performance.
- In order to prevent the consequences of poor PQ and to improve the utility performance the electric power are analysed to resolve the PQ issues in order to determine the efficient compensation technique.

3 RENEWABLE ENERGY SOURCE

The emerging awareness for environmental preservation concurrent with the increasingly power demand have become common place to utilities. To satisfy both these conflicting requirements, utilities have focused on the reduction of high polluting sources of energy. The desire to seek alternative renewable energy resources has led to the widespread development of distributed generations (DGs). In many countries, wind electric generators (WEGs) are becoming the main renewable source of electric energy. Wind power would be the second largest source of electricity behind hydro and ahead of coal, natural gas and nuclear. An individually installed WEG is commonly referred to as a wind turbine (WT) or simply as a wind generator (WG), and a group of such generators is referred to as a wind power plant (WPP) or wind farm (WF). Wind farms of all sizes are continuously being connected directly to the power grids and they have the potential to replace many of the conventional power plants. This means that wind turbines should possess the general characteristics of conventional power plants such as simplicity of use, long and reliable useful life, low maintenance and low initial cost. Moreover, large wind farms should satisfy very demanding technical requirements such as frequency and voltage control, active and reactive power regulation, and fast response during transient and dynamic situations. WGs can either operate at fixed speed or at variable speed. Due to various reasons such as reduced mechanical stress, flexible active-reactive power controllability, good power quality, low converter rating and low losses, nowadays the most popular topology is the variable speed type Double Fed Induction Generator (DFIG). Electricity is most needed for our day to day life. There are two ways of electricity generation either by conventionalenergy resources or by non-conventional energy resources.Electrical energy demand increases in word so to fulfil demandwe have to generate electrical energy. Now a day's electricalenergy is generated by the conventional energy resources likecoal, diesel, and nuclear etc. The main drawback of these sourcesis that it produces waste like ash in coal power plant, nuclearwaste in nuclear power plant and taking care of this wastage isvery costly. And it also damages he nature. The nuclear waste isvery harmful to human being also. The conventional energyresources are depleting day by day. Soon it will be completelyvanishes from the earth so we have to find another way to generate electricity. The new source should be reliable, pollutionfree and economical. The non-conventional energy resourcesshould be good alternative energy resources for the conventionalenergy resources. There are many non-conventional energyresources like geothermal, tidal, wind, solar etc. the tidal energyhas drawbacks like it can only implemented on sea shores. Whilegeothermal energy needs very lager step to extract heat fromearth. Solar and wind are easily available in all condition. Thenon-conventional energy resources like solar, wind can be goodalternative source.Solar energy is that energy which is gets by the radiation ofthe sun. Solar energy is present on the earth continuously and inabundant manner. Solar energy is freely available. It doesn'tproduce any gases that mean it is pollution free. It is affordablein cost. It has low maintenance cost. Only problem with solarsystem it cannot produce energy in bad weather condition. But ithas greater efficiency than other energy sources.It only needinitial investment. It has long life span and has lower emission.

3.1 DFIG-Power flow/ operating modes

The DFIG stator is connected to the grid with fixed grid frequency (f) at fixed gridvoltage (V) to generate constant frequency AC Power during all operating conditions and therotor is connected to the frequency converter/VSC having a variable (slip/rotor) frequency (fs=s.fs). At constant frequency fs, the magnetic field produced in the stator rotates at constantangular velocity/speed (ωs=2πfs), which is the synchronous speed of the machine. Thestator rotating magnetic field will induce a voltage between the terminals of the rotor. Thisinduced rotor voltage produces a rotor current (Ir), which in turn produces a rotor magneticfield that rotates at variable angular velocity/speed (ωr=2πf). Usually the stator and rotor have the same number of poles (P) and the convention is that the stator magnetic field rotates clockwise. Therefore, the stator magnetic field rotates clockwise at a fixed constant speed of ωs (rpm)=120fs/P. Since the rotor is connected to the variable frequency VSC, the rotor magnetic field also rotates at a speed of ωr(rpm)=120 fr/ P.

3.2 Principle of PV

The "photovoltaic effect" is the basic physical process through which a solar cell converts sunlight into electricity. In 1839, nineteen year old Edmund Becquerel, a French experimental physicist, discovered the photovoltaic effect while experimenting with an electrolytic cell made up of two metal electrodes. Becquerel found that certain materials would produce small amounts of electric current when exposed to light. Sunlight is composed of photons, or "packets" of energy. These photons contain various amounts of energy corresponding to the different wavelengths of light. When photons strike a solar cell, they may be reflected or absorbed, or they may pass right through. When a photon is absorbed, the energy of the photon is transferred to an electron in an atom of the cell (which is actually a semiconductor). With its newfound energy, the electron is able to escape from its normal position associated with that atom to become part of the current in an electrical circuit. By leaving this position, the electron causes a hole to form. Special electrical properties of the solar cell Ña built-in electric field (thanks to a P-N junction) N provide the voltage needed to drive the current through an external load (such as a light bulb). C. PV Module technology The single junction technology is grouped into two main types; silicon crystalline and thin film technologies. Currently, multi-junction technology is under research and processing, to enhance the PV modules efficiency and to improve the response sensitivity of the sun light spectrum in order to cover the entire incident irradiation wavelength. The main parts of the PV module structure are as follows:

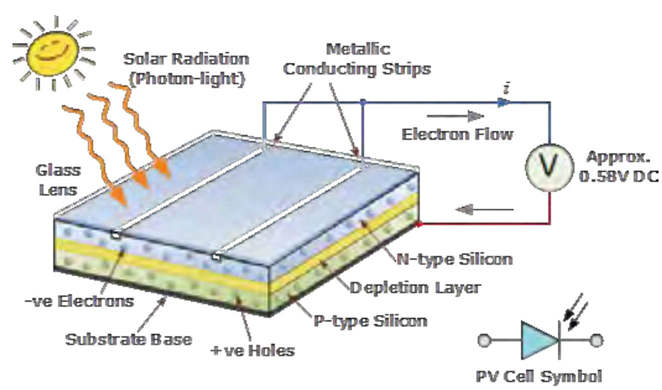


Figure 3: *Structure of PV.*

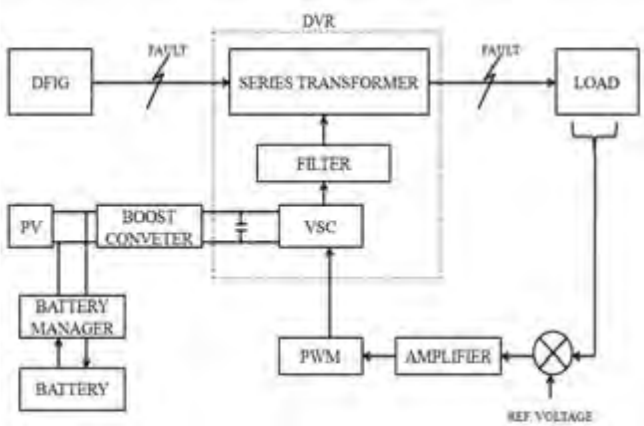


Figure 4: *Block diagram of PV supported DVR*

4 PROPOSED SYSTEM

Figure 4 shows the block diagram of the low voltage right though of wind turbine using DFIG wind turbine and fault mitigation using PV supported DVR. It consists of DVR is a custom power device, DFIG wind turbine, PV module which is fed to the DVR.

4.1 DFIG

Adoubly-fed induction machine is a wound-rotor doubly-fed electric machine and has several advantages over a conventional induction machine in wind power applications. First, as the rotor circuit is controlled by a power electronics converter, the induction generator is able to both import and export reactive power. This has important consequences for power system stability and allows the machine to support the grid during severe voltage disturbances (low voltage ride through, LVRT). Second, the control of the rotor voltages and currents enables the induction machine to remain synchronized with the grid while the wind turbine speed varies. A variable speed wind turbine utilizes the available wind resource more efficiently than a fixed speed wind turbine, especially during light wind conditions. Third, the cost of the converter is low when compared with other variable speed solutions because only a fraction of the mechanical power, typically 25-30%, is fed to the grid through the converter, the rest being fed to grid directly from the stator. The efficiency of the DFIG is very good for the same reason.

4.2 DVR

Dynamic Voltage Restorer is a series connected device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and the critical load feeder. Its primary function is to rapidly boost up the load-side voltage in the event of a disturbance in order to avoid any power disruption to that load there are various circuit topologies and control schemes that can be used to implement a DVR. In addition to its main task which is voltage sags and swells compensation, DVR can also added other features such as: voltage harmonics compensation, voltage transients' Reduction and fault current limitations The general configuration of the DVR consists of a voltage injection transformer, an output filter, an energy storage device, Voltage Source Inverter (VSI), and a Control system.

4.3 PV array

A PV Array consists of a number of individual PV modules or panels that have been wired together in a series and/or parallel to deliver the voltage and amperage a particular system requires. An array can be as small as a single pair of modules, or large enough to cover acres.The performance of PV modules and arrays are generally rated according to their maximum DC power output (watts) under Standard Test Conditions (STC). Standard Test Conditions are defined by a module (cell) operating temperature of 25oC (77 F), and incident solar irradiant level of 1000 W/m2 and under Air Mass 1.5 spectral distribution. Since these conditions are not always typical of how PV modules and arrays operate in the field, actual performance is usually 85 to 90 percent of the STC rating.

4.4 PI Controller

The control system is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The control system of the general configuration typically consists of a voltage correction method which determines the reference voltage that should be injected by DVR and the VSI control which is in this work consists of PWM with PI controller. The controller input is an error signal obtained from the reference voltage and the value of the injected voltage. Such error is processed by a PI controller then the output is provided to the PWM signal generator that controls the DVR inverter to generate the required injected voltage.

4.5 Battery Manager and Battery

A battery management system (BMS) is any electronic system that manages a rechargeable battery (cell or battery pack), such as by protecting the battery from operating outside its safe operating area, monitoring its state, calculating secondary data, reporting that data, controlling its environment, authenticating it and / or balancing it. A battery pack built together with a battery management system with an external communication data bus is a smart battery pack. A smart battery pack must be charged by a smart battery charger.

4.6 Simulation

The simulation diagram of the low voltage right though of wind turbine using DFIG wind turbine and fault mitigation using PV supported DVR which is designed in MATLAB/Simulink consists of the renewable system which is supplied to the critical load without disturbing the load parameters. DVR a custom power device which is connected in series with the grid by using coupling transformer. This device is used to protect the critical load in which the fault is occurred due to source side disturbance. DVR uses separate sources that cannot be used for any other purposes. PV is used as a source and during normal operating condition it supports the grid and charges the battery. During fault PV supports DVR to clear the fault. In normal operating condition it will charge the battery. Grid voltage decreases due to fault, at that time DFIG tries to go out through the grid. During that condition low voltage right through capability increases and stays within the limit. Figure 5 shows the overall simulation diagram of the proposed system.

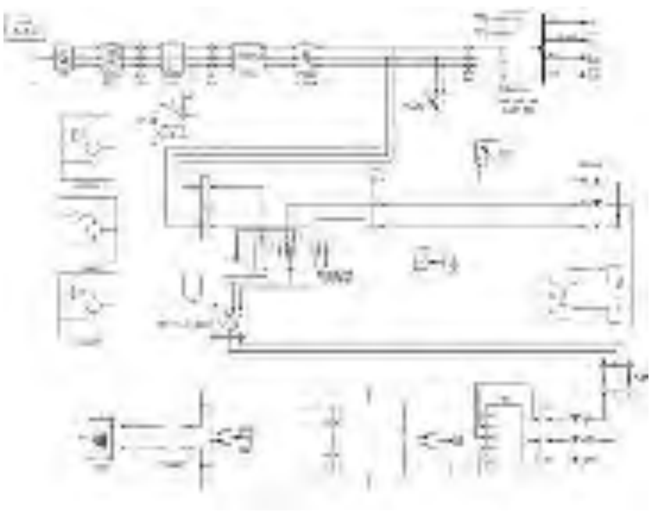


Figure 5: *Overall simulation diagram.*

The system consists of 9MW(6 X 1.5MW) Doubly Fed Induction Generator which produces the voltage of 575V is equal to grid voltage with the frequency of 50Hz. It is one of the renewable energy sources connected with the grid. It is shown in figure 6.

Figure 7 shows the PV system which has the output voltage of 406V. In normal operating condition in charges the battery. When fault occurs it supports the DVR to mitigate the fault. Figure 8 shows the voltage source converter of DVR and its controller. The controller designed to control the DVR is PI controller. The signal from the controller is fed into PWM generator which produces the gate pulses to the voltage source converter.

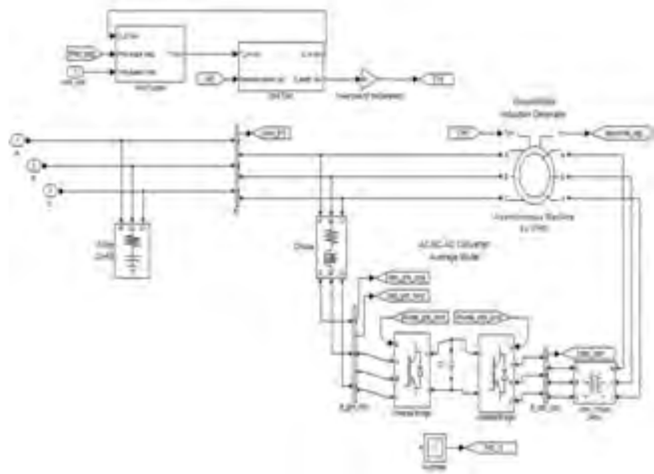


Figure 6: *Simulation of DFIG.*

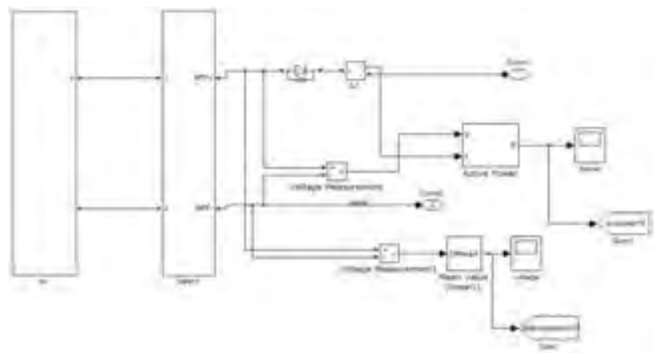


Figure 7: *Simulation of PV.*

In normal operating condition (i.e.) without any fault in line the battery which is connected across the PV will be charged by the PV. It is shown in figure 9.

5 RESULTS

The behavior of the complete system when voltage sag occurs in the line connected to DFIG based wind turbine were explained in the figures. The simulation result of DFIG wind turbine integrated gird voltage is 440V as shown in the figure 10. It is the nominal voltage of the line.

The figure 11 shows the waveform during the fault. Normally the line voltage is 440, when fault is occurred the swell is of 505V during the period of 0.5 to 0.7. The

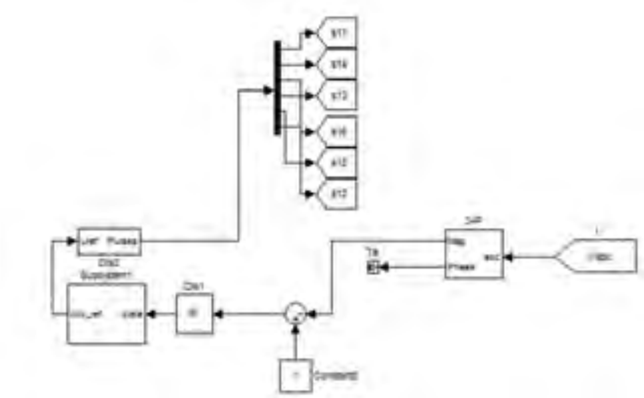


Figure 8: *Simulation of DVR and PI controller.*

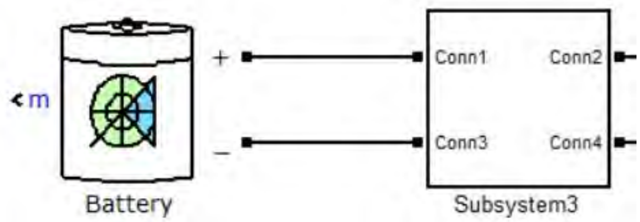


Figure 9: *Simulation of battery.*

sag voltage is 283V for the period of 0.9 to 1.1. During the next instant the swell voltage is 598V that is occurred in the period of 1.3 to 1.5. The range of sag is 345V for the period of 1.7 to 1.9. When there is no any fault in the line the voltage at the load side also equal to the generated voltage. Therefore the voltage at the load side is 440V which supply to the non-linear load that is bridge rectifier.

The fault occurrence in the line also affects the voltage at the load side. It leads to the poor performance of the load. When the voltage sag occurs on line side it will also reflect in load side. Normally the line voltage is 440, when fault is occurred the swell is of 505V during the period of 0.5 to 0.7. The sag voltage is 283V for the period of 0.9 to 1.1. During the next instant the swell voltage is 598V that is occurred in the period of 1.3 to 1.5. The range of sag is 345V for the period of 1.7 to 1.9.

The DVR connected in series with the line compensates the voltage sag and voltage swell in load voltage to protect the loads from the line side disturbances. So the DVR absorbs 65V and 158V to compensate the voltage swell at the incident of 05sec to 0.7sec and 1.3sec to 1.5sec respectively and it injects 65V and 95V to compensate the voltage sag at the incident 0.9sec to 1.1sec and 1.7 sec to 1.9sec respectively as shown in figure 13.

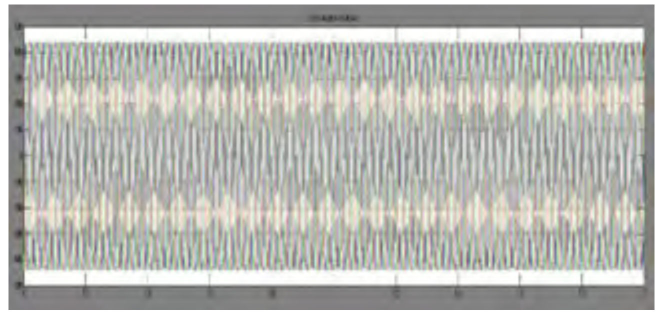


Figure 10: *Nominal line voltage.*

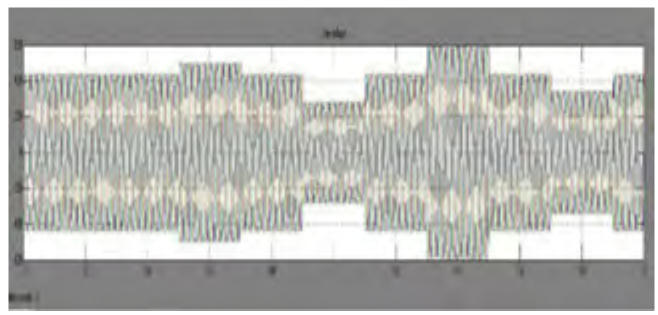


Figure 11: *Voltage sag and swell in line voltage.*

The figure 14 shows load voltage which is compensated using the DVR by injecting and absorbing the voltage according to voltage sag and swell. In the proposed system the PV supports the DVR. The input of the DVR is DC and the supporting device PV to the DVR is DC. The DC link is between the DVR and the PV, the voltage across the DC link is 600V.

6 CONCLUSION

In this proposed work, low voltage right through capability of DFIG wind turbine and fault mitigation using PV supported DVR has been proposed. A detailed power quality mitigation control for the grid was proposed based on DVR a custom power device fed by PV. It allows DVR to utilize active power of PV plant and thus improves the system robustness against sever grid faults. Hence, the power quality issues can be neglected on the load side. Using PI controller, the fault can be detected and mitigated rapidly to obtain the fault right through capability.

References

[1] M. Sownthara, M. Siva Ramkumar, "Wireless Communication Module To Replace Resolver Cable In Welding Robot" in International Journal of Advanced Information Science and Technology on 23(23) pp 230-235,2014.

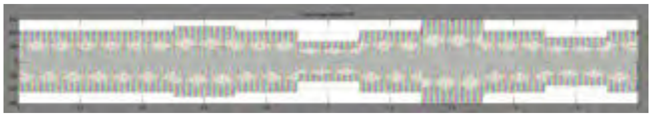


Figure 12: *Load voltage without DVR.*

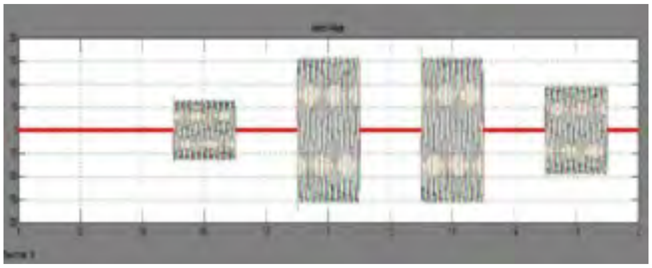


Figure 13: *Injected voltage.*

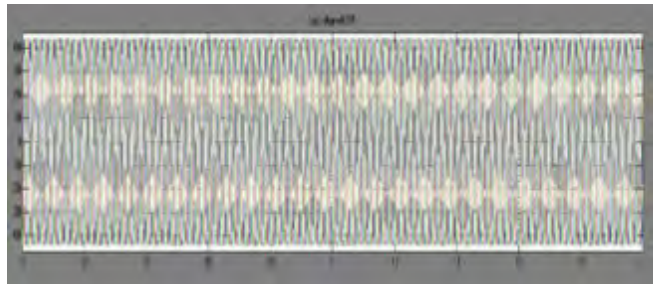


Figure 14: *Load voltage with DVR*

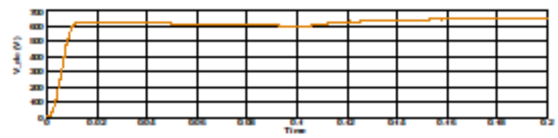


Figure 15: *DC link voltage.*

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2)

[3] M. Sivaram Krishnan, M. Siva Ramkumar, "Power Management of a Hybrid Solar-Wind Energy System, International Journal of Engineering Research & Technology, 2 (1) pp 1988-1992.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, "Power Quality Analysis In Hybrid Energy Generation System" in 'International Journal of Advance Research in Computer Science and Management Studies 2 (1) pp 188-193

[5] S. Sriragavi, M. Sivaram Krishnan, M. Siva Ramkumar "Static Compensator In Power Quality Improvement For Lvts" in International Journal of Scientific Research and Review, 6(11) ,pp 51-60

[6] D. Kavitha, C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.20 (2015), pg. 17749-17754.

[7] A. Amudha. "Enhancement of Available Transfer Capability using FACTS controller" in International journal of Applied Mechanics and Materials, Vol. 573, pp 340-345

[8] A. Amudha. "Optimal placement of Unified Power Flow Controller in the transmission line using SLF algorithm" in International journal of Applied Mechanics and Materials, Vol. 573 (2014) pp 352-355

[9] V .J .Vijayalakshmi, C. S. Ravichandran, A. Amudha. "Predetermination of Higher Order Harmonics by Dual Phase Analysis" in International journal of Applied Mechanics and Materials Vol. 573 (2014) pp 13-18.

[10] Amudha, Christopher Asir Rajan, "Generator scheduling under competitive environment using Memory Management Algorithm" in Alexandria Engineering Journal, Elsevier Volume 52, Issue 3, September 2013, Pages 337–346

[11] K. Balachander, "Design and Hardware Implementation of Speed Control of Induction Motor using Z - Source Inverter", International Journal of Electronics Engineering Research, Vol. 9(6), pp. 931-937.

[12] K. Balachander, A. Amudha," Design and Hardware Implementation of Interleaved Boost Converter Using Sliding Mode Approach", International Journal of Electronics Engineering Research, Volume 9, Number 5 (2017) pp. 745-750

[13] R. Sri Sangeetha, K. Balachander,' Unbalanced and over Current Fault Protection in Low Voltage DC Bus Micro Grid Systems', Middle East Journal of Scientific Research, Volume – 24, No. 2(2016), pp. 465-474.

[14] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035-2042.

[15] K. Balachander, P. Vijayakumar, “Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ”, American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, P. Vijayakumar, “Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India”, Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[17] K. Balachander, P. Vijayakumar, “Renewable Energy System Optimization of Two Different Locations” CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, V. Ponnusamy, ‘Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System’ International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[19] K. Balachander, V. Ponnusamy, ‘Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER’ International Journal of Applied Engineering Research’, Volume 7, Number 3 (2012), pp. 247-256. .

[20] K. Balachander, S. Kuppusamy, V. Ponnusamy, ‘Modeling and Simulation of VSDFIG and PMSG Wind Turbine System’, International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[21] K. Balachander, ‘A Review of Modeling and Simulation of PV Module’, Elixir, Electrical Engineering, 42 (2012) pp. 6798-6802.

[22] S. Kuppusamy, K. Balachander, ‘Embedded based capacitance fuel level sensor’, Elixir, ElectricalEngineering, 43 (2012) pp. 6751-6754

[23] K. Balachander, S. Kuppusamy, V. Ponnusamy, ‘" Comparative Study of Hybrid Photovoltaic-Fuel Cell System / Hybrid Wind-Fuel Cell System for Smart Grid Distributed Generation System” Proceedings of IEEE International Conference on Emerging Trends in Science, Engineering and Technology at JJ College of Engineering, Trichy on 13 th and 14 th December 2012. DOI: 10.1109/ INCOSET. 2012.6513950, pp.462-466

A FUZZY LOGIC APPROACH TO MICROGRID DEMAND RESPONSE IN BOTH OFFLINE AND ONLINE MODE

P. Srinivasan, K. Balachander, A. Amudha, G. Emayavaramban, M. Siva Ramkumar

Abstract: Increasing energy demand is motivating us to search for new way to meet the demand with existing grid system. This can be fulfilled with microgrids. But there is a challenge in controlling point of renewable energy system and energy storage unit in microgrids. That is switching the microgrid according to the demand without disturbing the main grid in both online and offline conditions. This project presents a control method for demand response management to optimize the microgrid composed of PV system, wind turbine, diesel generator and energy storage unit. In order to address the problem, the proposed control technique is fuzzy logic control. This proposed control strategy efficiently manage the response to demand and ensure the independent operation of microgrid with respect to the main grid in both online and offline conditions.

Keywords: Plug-in electric vehicles (PEVs) ,Photovoltaic charging facility (PCF), Distribution network, Taxes CC3200.

1 Introduction

Increase in population drastically increases the demand of electricity by increasing the use of domestic appliances and industrialization. It lead us to find the other sources to fulfil the demand. The renewable energy sources such as Photovoltaic system and wind energy system are the nonconventional energy sources. In photovoltaic system the power extracts from the incoming son radiation calling Solar Energy, which is globally free for everyone. Solar energy is lavishly available on the earth surface as well as on space so that we can harvest its energy and convert that energy into our suitability form of energy and properly utilize it with efficiently. Power generation from solar energy can be grid connected or it can be an isolated or standalone power generating system that depends on the utility, location of load area, availability of power grid nearby it [1-6]. Thus where the availability of grids connection is very difficult or costly the solar can be used to supply the power to those areas. The most important two advantages of solar power are that its fuel cost is absolutely zero and solar power generation during its operation does not emit any greenhouse gases. Another advantage of using solar power for small power generation is its portability; we can carry that whenever wherever small power generation is required. The worldwide increasing energy demand Energy saving is one cost effective solution, but does not tackle. Renewable energy is a good option because it gives a clean and green energy, with no CO2 emission [7-13]. Renewable energy is defined as energy that comes from resources which are naturally refilled on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat. Amongst the renewable source of energy, the photovoltaic power systems are gaining popularity, with heavy demand in energy sector and to reduce environmental pollution around caused due to excess use nonrenewable source of energy. Several system structures are designed for grid connected PV systems. Four different kinds of system configuration are used for grid connected PV power application: the centralized inverter system, the string inverter system, the multi-string inverter system and the module integrated inverter system [14-21]. The main advantages of using a grid connected PV systems are: Effect on the environment is low They can be installed near to the consumer There by transmission lines losses can be saved Cost of maintenance in the generating system can be reduced as there are no moving parts System's modularity will allow the installed capacity to expand and carbon-dioxide Gases are not emitted to the environment. Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. This wind flow, or motion energy, when "harvested" by modern wind turbines, can be used to generate electricity. The terms "wind energy" or "wind power" describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity to power homes, businesses, schools, and the like. Wind turbines, like aircraft propeller blades, turn in the moving air and power an electric generator that supplies an electric current [22-26]. Simply stated, a wind turbine is the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. Wind energy is a free, renewable resource, so no matter how much is used today, there will still be the same supply in the future. Wind energy is also a source of clean, non-polluting, electricity. Unlike conventional power plants, wind plants emit no air pollutants or greenhouse gases. Wind costs are much more competitive with other generating technologies because there is no fuel to purchase and minimal operating expenses [27-31]. These sources are connected with the existing grid system that is main grid system by the technology called microgrid. Microgrid is a localized grouping of electricity sources and loads that normally operates connected to and synchronous with the traditional centralized electrical grid (macrogrid), but can disconnect and function autonomously as physical and/or economic conditions dictate. By this way, it paves a way to effectively integrate various sources of distributed generation (DG), especially Renewable Energy Sources (RES). In proposed system PV system, wind energy system, diesel generator and energy storage system are used in microgrid system. It also provides a good solution for supplying power in case of an emergency by having the ability to change between islanded mode and grid-connected mode. On the other hand, control and protection are big challenges in this type of network configuration. To meet the challenge in the point of control of this system fuzzy logic controller is used in this proposed system. A fuzzy control system is a control system based on fuzzy logic—a mathematical system that analyzesanalog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0 (true or false, respectively). This controlling scheme is used to control the microgrid in both online and offline conditions [32-36].

2 HYBRID POWER SYSTEM

Renewable energy resources are energies generated from natural resources such as wind, sunlight, tide, hydro, biomass, and geothermal which are naturally replenished. Energy crisis, climate changes such as rise of atmosphere temperature due to increase of greenhouse gases emission and the Kyoto Protocol restrictions in generation of these gases, coupled with high oil prices, limitation and depletion of fossil fuels reserves make renewable energies more noticeable. Among the renewable energy resources, wind power has had the world's fastest growing energy source in many developed and developing countries over the last 20 years. Due to efficient and economical utilization of renewable energies, some of renewable energy resources such as wind turbine and solar array are integrated together and produced excess energy is utilized to store in a battery storage. Because of dependency on wind speed and sun irradiance in such a system, its reliability for satisfying the load demands decreases under all conditions. To alleviate these problems, WT and PV sources can be integrated with other alternative systems using hybrid topologies. A hybrid power system consists of a combination of two or more energy sources, converters and/or storage devices [37-41]. Thus, higher efficiency can be obtained by making the best use of their features while overcoming their limitations. Alternate energy conversion systems such as PV panels and wind turbines can be combined with FC power plants to satisfy sustained load demands. An FC power plant uses hydrogen and oxygen to convert chemical energy into electrical energy [42,43].

2.1 Wind energy system

Wind energy is an abundant, renewable, and non-polluting energy resource and its conversion to electricity may reduce dependence on non-renewable energy sources and decrease the air and water pollution that results from the use of conventional energy sources. A wind energy conversion system (WECS), or wind energy harvester is a machine that, powered by the energy of the wind, generates mechanical energy that can be used to directly power machinery or to power an electrical generator for making electricity. The wind energy conversion system (WECS) includes wind turbines, generators, control system, interconnection apparatus as shown in figure 1.

Wind turbines use wind to generate electricity. The kinetic energy in the wind is converted into rotational motion by the rotor, which usually consists of three blades. Then, the shaft is turned by the rotor which transfers the motion into the nacelle. Finally, the output shaft is connected to a generator that converts the rotational movement into electricity [44-49]. The generator uses electromagnetic induction to generate medium voltage electricity, which is equivalent to a few hundred volts. The electricity can then be used immediately or stored for later use. The electricity goes down through heavy electric cables to a transformer. The transformer can increase the voltage to a few thousand volts. The electricity from wind power can be sent to farms, homes, and towns. If the electricity is to be sent to cities and factories, the electricity is sent to a substation where voltage is increased to a few thousand volts. The electricity is then sent through transmission lines [50-53].

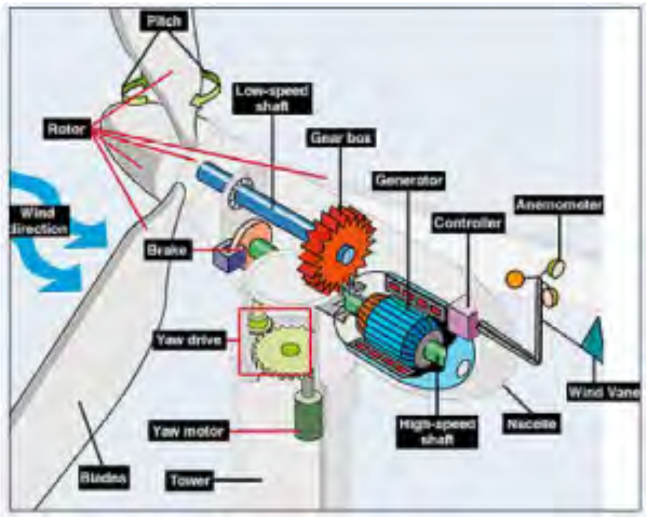


Figure 1 Components of WECS.

2.2 Fuel cell

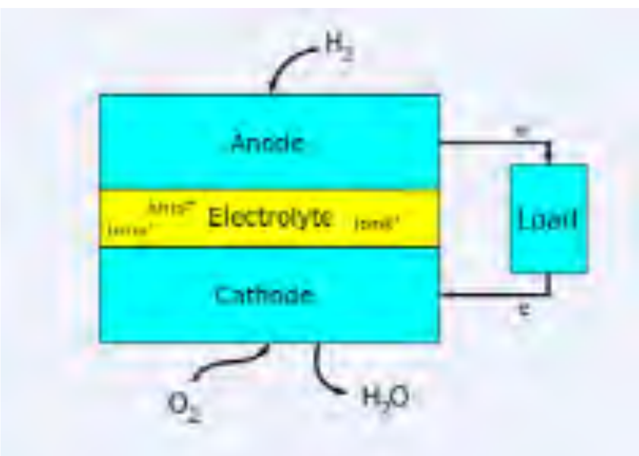


Figure 2 Block Diagram of Fuel Cell.

In a fuel cell system, the chemical energy related to electrochemical reaction of the fuel with oxidant directly change into the water, electricity and heat. Fuels such as H2, methanol, ethanol, and etc have been usually used in fuel cells. The reactions have been done in a fuel cell can be explained in following: Hydrogen in Anode electrode change into a hydrogen ion and electrons is released. These electrons move through external circuit towards the cathode and produce the electrical current as shown in figure 2. Anodic and cathode reactions have been done in the PEM fuel cell with H2 gas in anode in following: The most important part and in the other words the central core of the fuel cell is the Membrane Electrode Assembly (MEA) which is consist of two part namely electro catalyst and membrane. The role of membrane between electrodes is the conduction of produced protons from anode to cathode. The existing ions move towards the cathode through the electrolyte membrane and on that place produce water and heat with free electrons [54-59]. Advantages of fuel cells in comparison with other types of equipment which are producing energy are as follows: higher efficiency, no existence of the mobile parts and as a result lack of sonic pollution, no emissions of environmental polluting gases such as SO2, NO2, CO2, CO, and etc. In contrary of benefits, only disadvantage of fuel cells is their higher cost that this problem will be solved by applying the new technologies and also mass production of these fuel cells [60].

2.3 Electrilyzer

An apparatus in which electrolysis is carried out, consisting of one or many electrolytic cells. An electrolyzer is a vessel filled with an electrolyte, in which electrodes a cathode and anode have been placed; the cathode is connected to the negative pole of the direct-current source and the anode is connected to the positive pole as shown in figure 3.

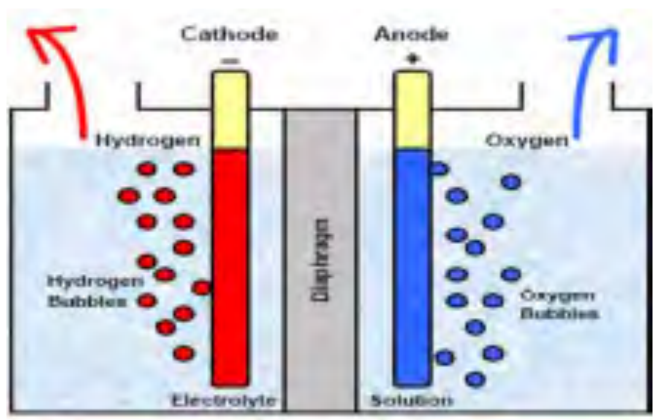


Figure 3 Standard Electrolysis.

2.4 Energy storage device

Energy storage systems are an integral part of a hybrid renewable stand-alone power system, which is critical for ensuring a high level of power quality, reliability and security. Battery Energy Storage System (BESS) are includes batteries, control system and power electronic devices for conversion between alternating and direct current. The batteries convert electrical energy into chemical energy for storage. Batteries are charged and discharged using DC power, regulates the flow of power between batteries and the energy systems is done by a bi-directional power electronic device. Different types of batteries have various advantages and disadvantages in terms of power and energy capabilities, size, weight, and cost. The main types of battery energy storage technologies are: Lead-Acid, Nickel Cadmium, Sodium Sulfur, Nickel Metal Hydride and Lithium-Ion. Lead-Acid batteries, achieve high discharge rates by using deep-cycle batteries. Low energy density, non-environment friendly electrolyte and a relatively limited life-cycle are the limiting factors to its dominant use in urban renewable energy systems. Lead-Acid batteries offer a competitive solution for energy storage applications. Sodium Sulfur batteries have high energy density, high efficiency of charge/discharge and long cycle life. Nickel Cadmium (NiCd) batteries achieve higher energy density, longer cycle life and low maintenance requirements than the Lead-Acid batteries. But, which include the toxic-heaviness of cadmium and higher self-discharge rates than Lead-Acid batteries. Also, NiCd batteries may cost up to ten times more than a Lead-Acid battery making it a very costly alternative. Nickel Metal Hydride (NiMH) is compact batteries and provides lightweight used in hybrid electric vehicles and telecommunication applications [61-64].

2.5 Control structure of hybrid power system

The control structure of such systems can be classified into centralized, distributed, and hybrid control paradigms. In all three cases, each energy source is assumed to have its own controller which can determine optimal operation of the corresponding unit, based on current information. A brief description of each control paradigm is discussed in the following:

1. Centralized control paradigm: In a centralized control paradigm, the measurement signals of all energy units are sent to a centralized controller. This acts as a supervisory controller which makes decisions. The main objective of this is to optimize energy use among the various energy sources of the system. The advantage of this control structure is that the multi-objective energy management system can achieve global optimization based on all available information.

2. Distributed control paradigm: In a fully distributed control paradigm, the measured signals of the energy sources of the hybrid system are sent to their corresponding local controller, as shown in figure 4. The controllers communicate with one another to make decisions to achieve specific goals. An advantage of this scheme is "plug-and-play operation". With this control structure, the computation burden of each controller is greatly reduced, with no single-point failure problems. The main disadvantage is the potential complexity of its communication system. A promising approach for distributed control problems is the Multi-Agent System (MAS), and MAS has been used for power system integration, restoration, reconfiguration and power management of micro-grids.

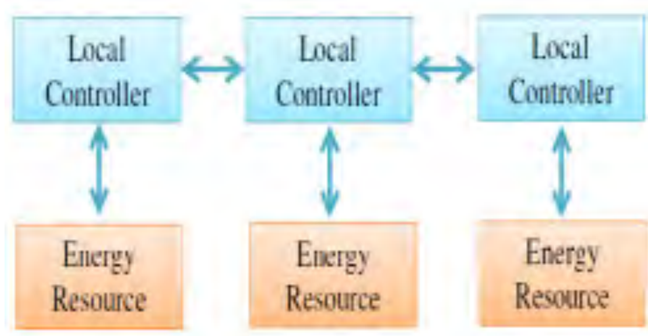


Figure 4 Distributed Control Paradigm..

3. Hybrid centralized and distributed control paradigm: The hybrid control paradigm combines centralized and distributed control schemes, as shown in figure 5. The distributed energy sources are grouped within a sub-system. A centralized control is used within each group, while distributed control is applied to a set of groups. The computational burden of each controller is reduced, and single-point failure problems are mitigated.

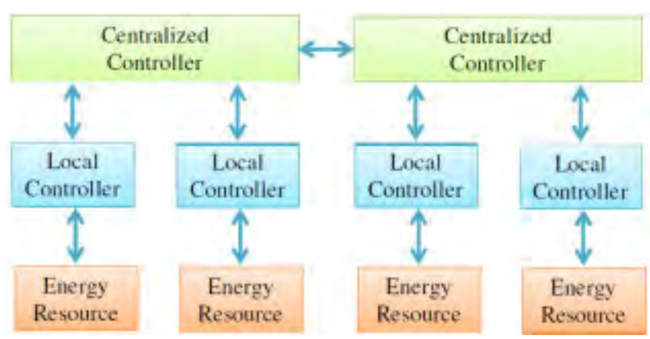


Figure 5 Hybrid Centralized and Distributed Control Paradigm.

A hybrid control scheme, termed multilevel control framework, is shown in figure 6. This is similar to the hybrid control scheme discussed above, with an additional supervisory control level. At the operational level, basic decisions related to real-time operation are made, and actual control of each energy unit is performed very rapidly based on the unit's control objectives, within a millisecond range.

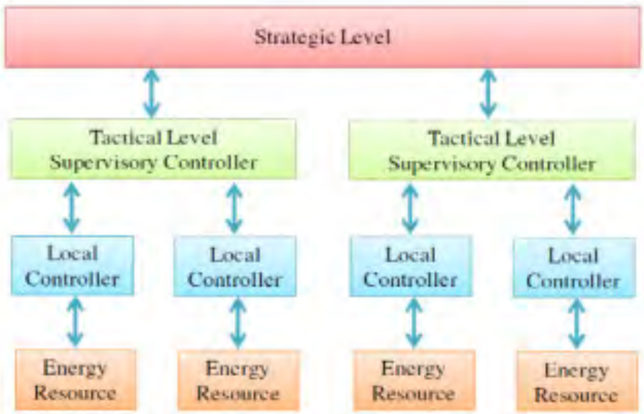


Figure 6 Multi-Level Control Paradigm.

3 FUZZY LOGIC CONTROLLER

FLC is one of the most successful applications of fuzzy set theory, introduced by Zadeh in 1965. Its major features are the use of linguistic variables rather than numerical variables. Linguistic variables, defined as variables whose values are sentences in natural language such as small and large may be represented by fuzzy sets. Over the past few decades, the use of fuzzy set theory, or fuzzy logic, in control systems has gained widespread popularity, especially in Japan. From as early as the mid-1970s. Japanese scientists have been instrumental in transforming the theory of fuzzy logic into a technological realization. Today fuzzy logic-based control systems, or simply fuzzy logic controllers (FLC), can be found in a growing number of products, from washing machines to speedboats, from air condition units to handheld auto focus cameras. Fuzzy controllers have got a lot of advantages compared to the classical controllers such as the simplicity of control, low cost and the possibility to design without knowing the exact mathematical model of the process. Fuzzy logic is one of the successful applications of fuzzy set in which the variables are linguistic rather than the numeric variables. Linguistic variables, defined as variables whose values are sentences in a natural language such as large or small, may be represented by fuzzy sets. Fuzzy set is an extension of a 'crisp' set where an element can only belong to a set full membership or not belong at all no membership. Since power system dynamic characteristics are complex and variable, conventional control methods cannot provide desired results. Intelligent controllers can be replaced with conventional controllers to get fast and good dynamic response in load frequency control problems. If the system robustness and reliability are more important, fuzzy logic controllers can be more useful in solving a wide range of control problems since conventional controllers are slower and also less efficient in nonlinear system applications Fuzzy logic controller is designed to minimize fluctuation on system outputs. There are many studies on power system with fuzzy logic controller. The fuzzy logic inference system as shown in figure 7.

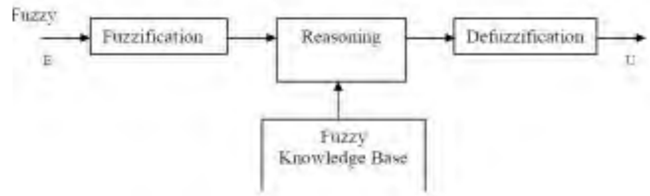


Figure 7 Fuzzy Inference System.

3.1 Fuzzy rule base

The linguistic terms chosen for this controller are three. They are Positive (P), Negative (N)and Zero (Z). After assigning the input, output ranges to define fuzzy sets, mapping each of the possible three input fuzzy values of rotor speed deviation. The rules are framed keeping in mind the nature of the system performance and the common sense. This is prepared by training the controller.

3.2 Membership function

Membership functions and rules are obtained from an understanding of the system behaviour and the applications of the systematic performance and are modified and tuned by the simulation performance. The rule table and the stability of the fine–tuned controller with simulation performance are justified by using the approach evaluated. The rotor speed deviation memberships are divided into 3 triangular fuzzy sets in width, and this allows the operation to change gradually from one state to the next as the membership functions.The membership shapes of I/O fuzzy sets and assignment of the control rules are shown if figure below. Each of the input and output fuzzy variables is assigned three linguistic fuzzy subsets varying from negative (N) to positive (P).

Each subset is associated with a triangular membership function to form a set of seven membership functions for each fuzzy variable. The membership function for each linguistic variable is given in figures 8 and 9. Membership function plots are shown.

Proper values of gains are selected for both the inputs and for the output of FLC. This helps in good performance of the system.

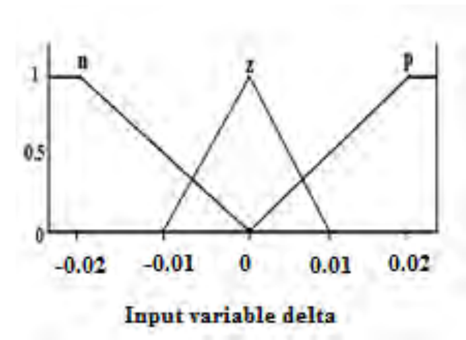


Figure 8 Input variable "rotor speed deviation".

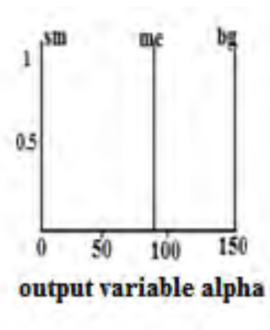
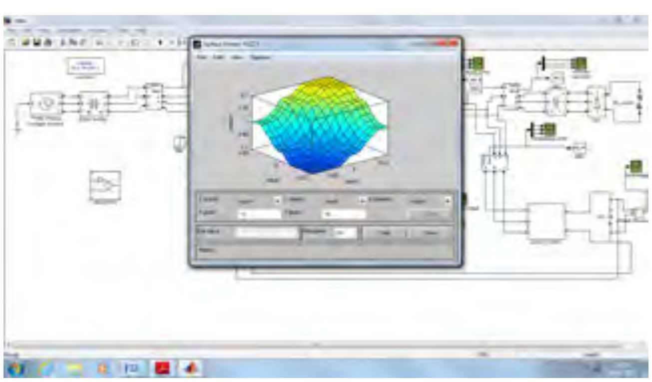


Figure 9 Output variable "alpha".

3.3 Fuzzy inference mechanism

Fuzzy inference is the process which formulates the mapping from a given fuzzy input to a fuzzy output by means of fuzzy logic. The mapping then creates a basis for decision-making. Mamdani-type and Sugenotype are two methods of fuzzy inference system which can be implemented in control field. Here, the Mamdani-type has been used. A set of rules manages the behaviour of the control surface which describes the input and output variables of the system.



10 Surface view of Fuzzy..

Figure Mamdani's fuzzy inference method is the most commonly seen fuzzy methodology. Mamdani method was among the first control systems built using fuzzy set theory. It was proposed by mamdani (1975) as the effort was based on Zadech's (1973) paper on fuzzy algorithms for the complex systems and decision processes. The surface view of fuzzy model as shown in figure 10. Mamdani type inference, as defined it for the Fuzzy Logic Toolbox, expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification. It is possible and in many cases much more efficient, to use a single spike as the output membership functions rather than a distributed fuzzy set. Because, it is a more compact and computationally efficient representation than the other system. The rule viewer depicts the fuzzy inference diagram for a FIS stored in a file. The rule viewer diagram is shown in figure 11. It is used to view the entire implication process from beginning to end. Move around the line indices that correspond to the inputs and then the system readjust and compute the new output.

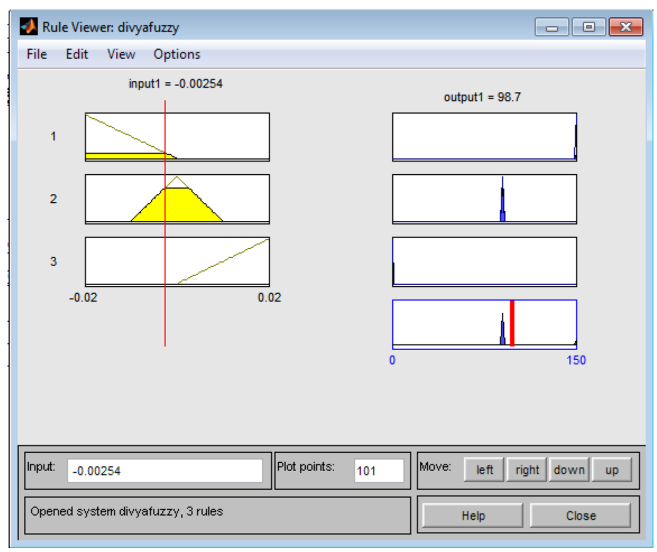


Figure 11 Fuzzy rule viewer.

4 PROPOSED SYSTEM

The proposed hybrid system consists of a wind generator, a fuel cell, an electrolyzer, battery and a grid inverter. The wind generator supplies the load, when the load demand decreases the surplus energy is utilized by the electrolyzer. The electrolysis process is carried out in electrolyzer where the water gets splits into hydrogen and oxygen. The hydrogen is stored in the tank which serves the input to the fuel cell. The battery also utilizes the excess energy. When the demand is greater than wind generation, the deficient power is supplied by the fuel cell utilizing hydrogen from the tank. When the pressure in the tank decreases the fuel cell cannot support the load, then the battery supports the load. The condition when the battery is unable to support the load demand the unit is completely shut down. The performance of the proposed system can be evaluated under varying source and load conditions.

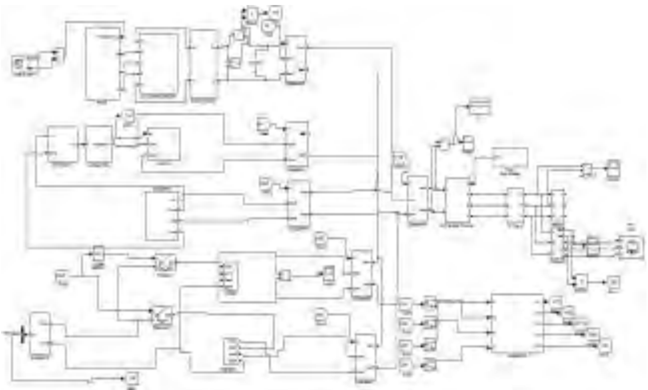


Figure 12 Simulation Model of the Overall System.

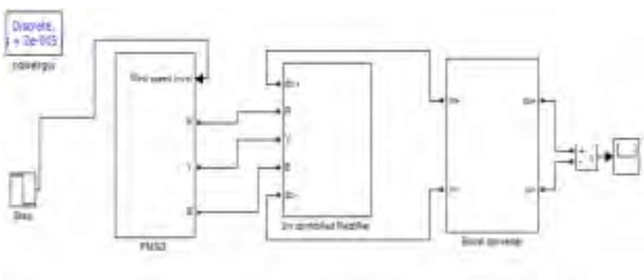


Figure 13 Simulation Model of WECS.

The figure 13 describes wind energy conversion model consisting of PMSG model with uncontrolled rectifier and the boost converter

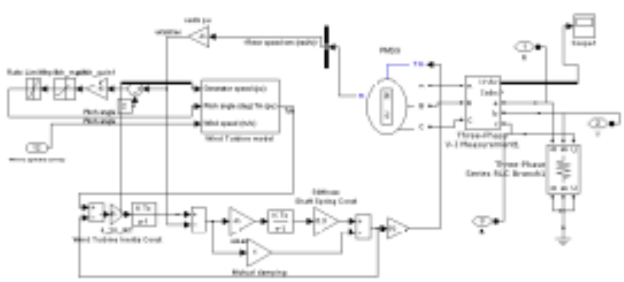


Figure 14 Simulation Model of PMSG.

Due to the unpredictable characteristics of the wind the output voltage from PMSG is variable so uncontrolled rectifier with boost converter is used in order to get constant DC voltage.

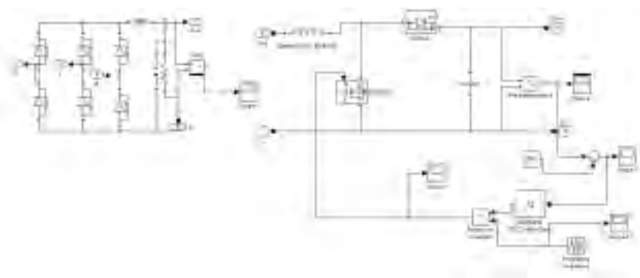


Figure 15 Simulation Model of Uncontrolled Rectifier and Boost Converter.

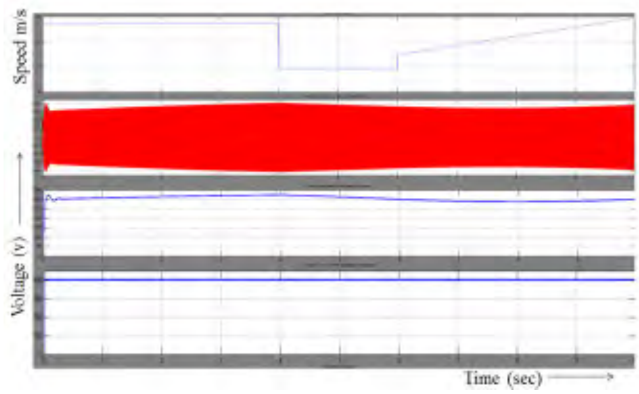


Figure 15 Output Waveform of Wind Energy Conversion Model.

The figure 15 shows varying wind speed and the output voltage from PMSG and uncontrolled rectifier which is 300V and it is boosted to 400V using boost converter. Electrolysis process is carried out in electrolyzer utilizing dc bus voltage and the hydrogen gas is stored in the hydrogen tank which is fed as the input to the fuel cell.

The output waveform shows that 400V of DC bus voltage is bucked to 190 V and fed into the electrolyzer, hydrogen gas is liberated and stored in the storage tank. Detailed descriptions of the individual component models required to simulate a hydrogen PEMFC hybrid system are presented. These models are mainly based on electrical and electrochemical relations.

A 50kW PEM fuel cell is connected to a controller to achieve the suitable operating point. The output of the fuel cell is controlled to 400V so that it can be interfaced with the DC bus.

When the hydrogen flow rate is 65 bar it is fed into the fuel cell, where electrochemical reaction is carried out and the output voltage of fuel cell is 800V dc and again it is bucked to 400V since the DC bus voltage is 400V.

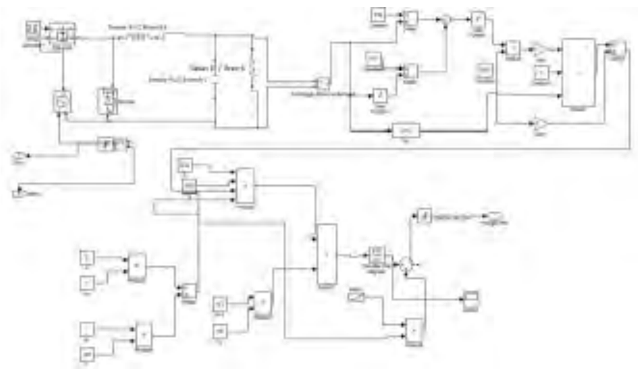


Figure 16 Simulation model of Electroyzer and Hydrogen Storage Tank.

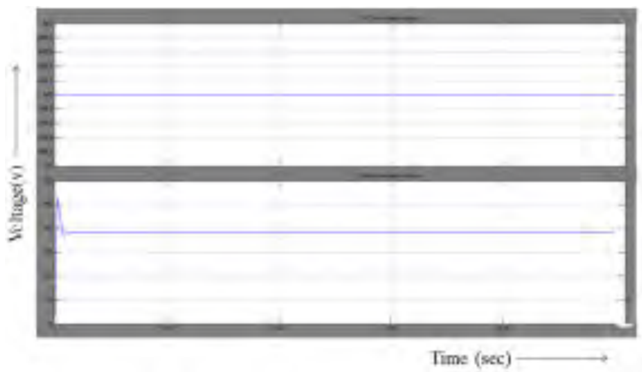


Figure 17 Output Waveform of Buck Converter.

5 PERFORMANCE AND CONTROL STRATEGY

Simulation studies are conducted to evaluate the performance of the proposed system under varying source and load conditions. Case 1: The condition when generation and load is equal. The switching conditions of the hybrid power system is shown in the figure 17.

The waveform describes that only wind generator supplies the load whereas the fuel cell, electrolyzer and battery are at the off condition. The load voltage is shown in the figure 7. Case 2: The condition when generation is greater than the load demand.

The demand is lesser than the generation then the excess energy is utilized by electrolyzer.

The electrolyzer is on and when the hydrogen tank pressure is 65 bar then the battery starts charging. Then the SOC level of the battery is getting increased. Case 3: The condition when the load demand is greater than the generation.

Due to decrease in the generation the deficient power is supplied by the fuel cell when the pressure in the tank is reduced below 65 bar then battery supports the load demand. The switching condition for this case is shown

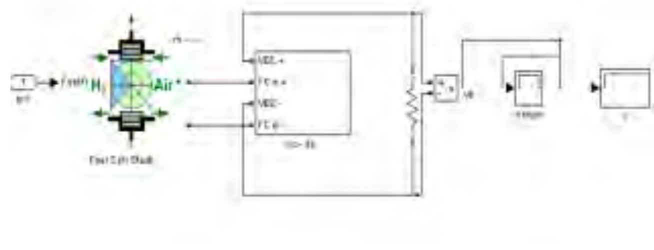


Figure 18 Simulation Model of Fuel Cell.

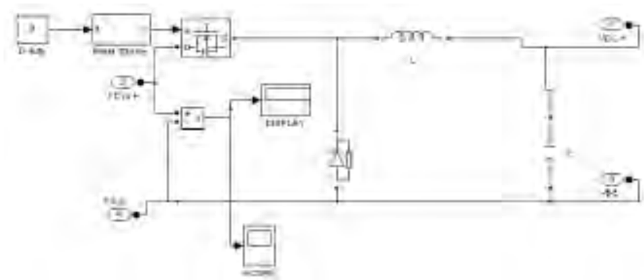


Figure 19 DC-DC Converter.

in the figure 20 the fuel cell is on when the pressure in the tank drops then the discharging signal of the battery is on, electrolyzer, charging circuit of the battery is off. Case 4: The condition when generation decreases further i.e deficient power is not met by any of the sources.

If all sources does not able to supply the demand then the system gets shutdown as shown in figure 21. Thus the aim is to supply the load continuously without interruption considering the above mentioned switching conditions.

6 CONCLUSION

This thesis proposes optimized energy management algorithm for the hybrid power system. The hybrid power system comprises of a wind turbine, a fuel cell, an electrolyzer and battery. The performance of the control strategy is evaluated under different source and load condition. The proposed control system is implemented in the MATLAB/SIMULINK and tested under various source and load condition. Results are presented and discussed. The main aim of the control strategy is to provide permanent supply to the load.

References

[1] K. Govindaraju, V. Bhavithira, D. Kavitha, S. Kuppusamy, and K. Balachander, "Improvement of Voltage Profile and Loss Minimization in IEEE 14 Bus System using FACTS Devices" in International Journal of Control Theory and Applications, ISSN: 0974-

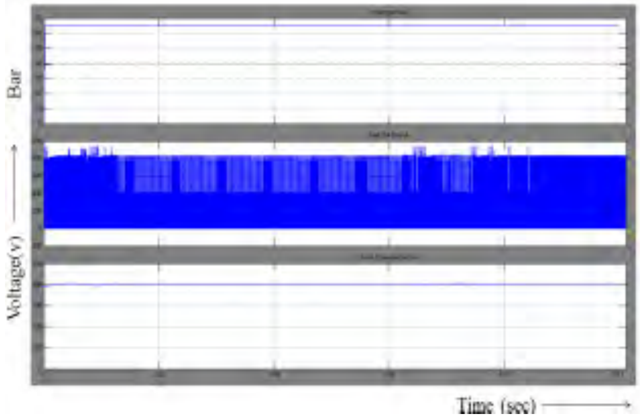


Figure 20 Output Voltage of Fuel Cell with Buck Converter.

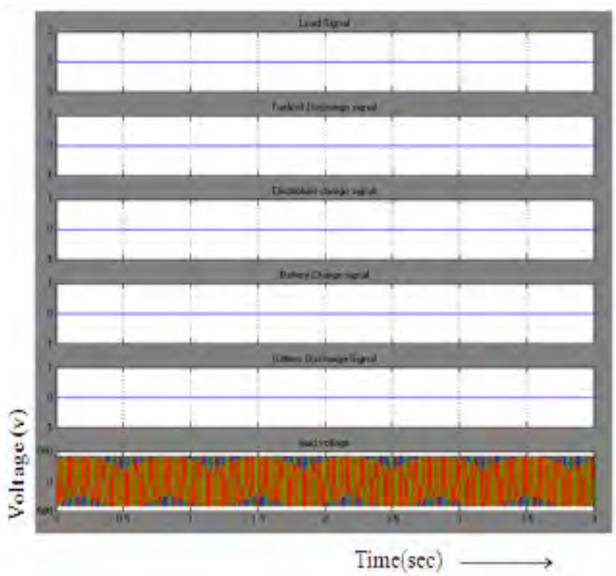


Figure 17 Switching Condition for Case 1.

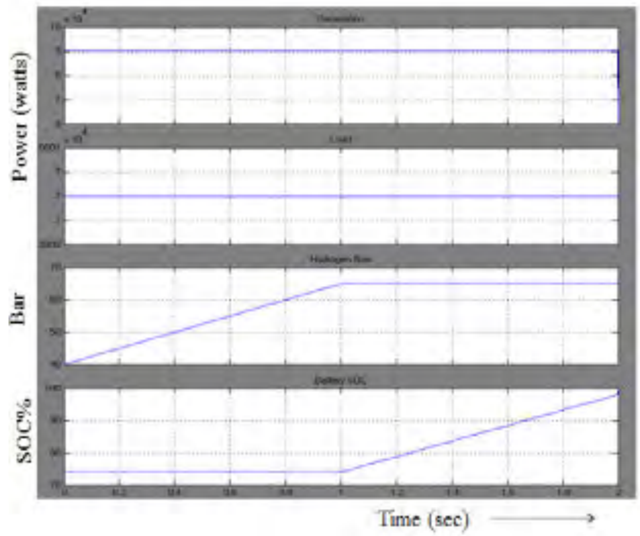


Figure 18 Output Waveform for Case 2.

5572 Vol. 10 No.38 (2017), pg. 213-224.

[2] K. R. Jeyakrishna, A. Amudha. ,K. Balachander, M. SivaRamkumar " Electric Vehicle Battery Charging Station Using Dual Converter Control" in International Journal of Control Theory and Applications, 10 (38) pp 195-203, 2017.

[3] M. R. Latha, S. Kuppusamy, A. Amudha, K. Balachander, M. SivaRamkumar " An Efficient Single Stage Converter Based Pv-Dvr For Improving Voltage Quality" in International Journal of Control Theory and Applications, 10 (38) pp 177-193, 2017.

[4] N. Sivakumar, D. Kavitha, M. Siva Ramkumar, V.Bhavithira, S. Kalaiarasi, "A Single Stage High Gain Converter For Gird Interconnected Renewable Application Using Perturb And Observe" in International Journal of Control Theory and Applications, 10 (38) 161-175, 2017.

[5] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc" in International Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[6] M Siva RamKumar, A. Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016. .

[7] D. Manoharan, A. Amudha. "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)

[8] A. Amudha. "Enhancement of Available Transfer Capability using FACTS controller" in International journal of Applied Mechanics and Materials, Vol. 573, pp 340-345

[9] A. Amudha. "Optimal placement of Unified Power Flow Controller in the transmission line using SLF algorithm" in International journal of Applied Mechanics and Materials, Vol. 573 (2014) pp 352-355

[10] V .J .Vijayalakshmi, C. S. Ravichandran, A. Amudha. "Predetermination of Higher Order Harmonics by Dual Phase Analysis" in International journal of Applied Mechanics and Materials Vol. 573 (2014) pp 13-18.

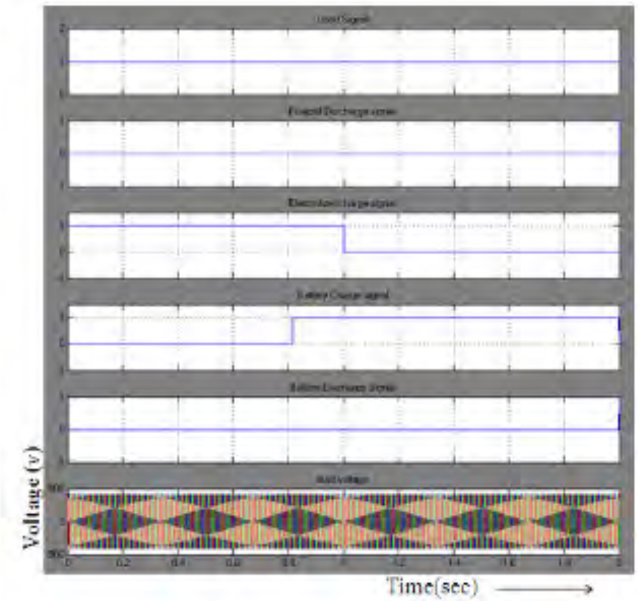


Figure 19 Switching Conditions for Case 2.

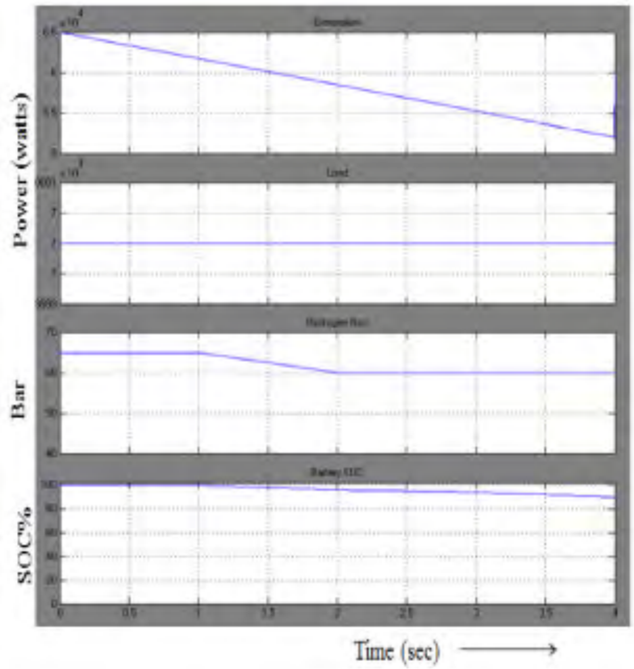


Figure 20 Output Waveform for Case 3.

[11] Amudha, Christopher AsirRajan, "Generator scheduling under competitive environment using Memory Management Algorithm" in Alexandria Engineering Journal, Elsevier Volume 52, Issue 3, September 2013, Pages 337–346

[12] K. Balachander, "Design and Hardware Implementation of Speed Control of Induction Motor using Z - Source Inverter", International Journal of Electronics Engineering Research, Vol. 9(6), pp. 931-937.

[13] K. Balachander, A. Amudha," Design and Hardware Implementation of Interleaved Boost Converter Using Sliding Mode Approach", International Journal of Electronics Engineering Research, Volume 9, Number 5 (2017) pp. 745-750

[14] R. Sri Sangeetha, K. Balachander,' Unbalanced and over Current Fault Protection in Low Voltage DC Bus Micro Grid Systems', Middle East Journal of Scientific Research, Volume – 24, No. 2(2016), pp. 465-474.

[15] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035-2042.

[16] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[17] K. Balachander, P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[18] K. Balachander, P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[19] K. Balachander, V. Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[20] K. Balachander, V. Ponnusamy, 'Optimization, Simulation and Modelingof Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research', Volume 7, Number 3 (2012), pp. 247-256. .

[21] K. Balachander, S. Kuppusamy, V. Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG

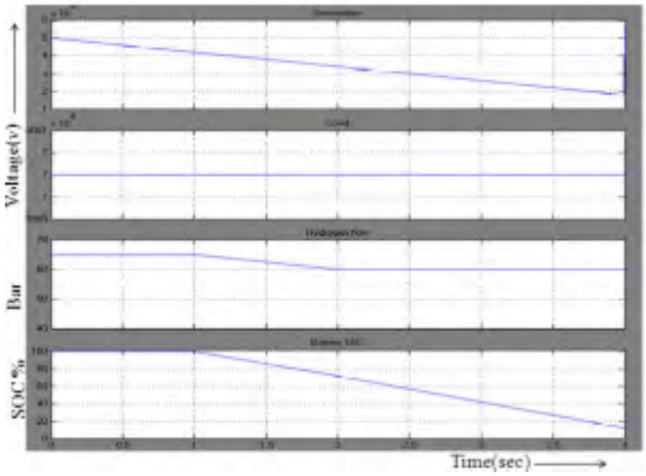


Figure 21 Output Waveform for Case 4.

Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[22] K. Balachander, S. Kuppusamy, V. Ponnusamy, '" Comparative Study of Hybrid Photovoltaic-Fuel Cell System / Hybrid Wind-Fuel Cell System for Smart Grid Distributed Generation System" Proceedings of IEEE International Conference on Emerging Trends in Science, Engineering and Technology at JJ College of Engineering, Trichy on 13 th and 14 th December 2012. DOI: 10.1109/ INCOSET. 2012.6513950, pp.462-466

ANALYSIS AND ENERGY EFFICIENCY OF SMALL-SCALE WIND ENERGY CONVERSION SYSTEM USING ADAPTIVE NETWORK BASED FUZZY INTERFERENCE SYSTEM (ANFIS) OF MAXIMUM POWER POINT TRACKING METHOD

R. Veluchamy, K. Balachander, A.Amudha, M. Siva Ramkumar, G. Emayavaramban

Abstract: The power control of small-scale wind energy conversion system is usually limited by the sluggish mechanical dynamic. Aiming at highlighting this phenomenon, this article introduces a small-scale wind energy conversion system using the permanent magnet synchronous machine as generator to validate different combinations of control strategy resulting from four different maximum power point tracking (MPPT) methods with hysteresis control: one indirect MPPT method based on a look-up table and three direct methods based on perturb and observe relationship. Following two ideal wind speed profiles, a real rapid wind speed profile and using a test bench emulating a small-scale wind turbine, the MPPT methods are compared and analysed based on experimental results. The indirect method operates with the best MPPT performances for all three wind speed profiles while requiring accurate knowledge of the controlled system. The direct methods operate with low MPPT performance under rapid variation of wind speed and the superiority of variable step size is not significant since the dynamic process of the perturbation strongly weakens the effect of MPPT algorithm. In proposed system Adaptive Network-based Fuzzy Interference System is used to control the MPPT.

Keywords: Wind Energy Conversion System, Adaptive Network based Fuzzy Interference System, Maximum Power Point Tracking.

1 Introduction

It is quite accepted that the earth's fossil energy resources are limited, and the cost of global oil, coal and gas production continues to rise beyond their peak. Fossil fuels belong to finite sources and so will be completely exhausted one day or the other. Comparing to the above case renewable energies have been in a great demand due to absence of the emissions of poisonous gases like carbon dioxide and sulphur dioxide. The various types of renewable energy sources contributing to current energy demand consist of water, wind, solar energy and biomass. However the major drawback suffered by hydroelectric power plants is its expensive and costly nature to build and also the plants must operate for a long time to become profitable. The creation of dams may even lead to flooding of lands leading to environmental destruction [1-6]. Similarly solar energy can only be extracted from solar thermal collectors in the presence of sunlight. Due to this condition solar energy set up becomes impractical in areas where there is little sunlight or heavy rainfall. The reason behind the popularity of wind energy is due to its non-polluting nature, greater efficiency and mainly due to its low operation cost [7-9]. The increasing development of wind energy has resulted in many new modeling and improved simulation methods. Wind power harnessing procedure has been a task for many years. Since long back wind mills were put into the task of pumping water and grinding grain. Many new technologies such as pitch control and variable speed control methods have been tested and put forward since. Sometimes, wind turbine work in an isolating mode; therefore, there is no grid. Usually there are two, three or even more than three blades on a wind turbine. However according to aerodynamics concept, three blades is the optimum number of blades for a wind turbine. Asynchronous and synchronous ac machines are the main generators that are used in the wind turbines. A wind turbine extracts kinetic energy from the wind and converts this into mechanical energy. Finally, this mechanical energy is converted to electrical energy with the help of a generator. Therefore, the complete system that involves converting the energy of the wind to electricity is called wind energy conversion system. A wind turbine extracts the maximum amount of energy from the wind when operating at an optimal rotor speed, which again depends on speed of wind. The optimal rotor speed varies due to the variable nature of the wind speed [10-15]. Research shows that variable speed operation of the rotor results in a higher energy production compared to a system operating at constant speed. A wind turbine model consists of blades, a generator, a power electronic converter, and power grid. Blades are used to extract power from the wind. By operating the blades at optimal tip speed ratio, maximum amount of energy can be extracted from the variable speed wind turbine [16-21]. The maximum power point tracking (MPPT) control of variable speed operation is used to achieve high efficiency in wind power systems. The MPPT control is operated using the machine side control system. The function of pitch angle control scheme is to regulate the pitch angle by keeping the output power at rated value even when the wind speed experiences gusts. The double fed induction generator is associated with AC to AC converter, where generator is directly grid connected through the stator windings, keeping into account the grid voltage and frequency fixed. While the rotor windings are fed by rotor side converter at variable frequency through slip rings [22-23].

2 WIND ENERGY CONVERSION SYSTEM

The emerging awareness for environmental preservation concurrent with the increasingly power demand have become common place to utilities. To satisfy both these conflicting requirements, utilities have focused on the reduction of high polluting sources of energy. The desire to seek alternative renewable energy resources has led to the widespread development of distributed generations (DGs). In many countries, wind electric generators (WEGs) are becoming the main renewable source of electric energy. wind power would be the second largest source of electricity behind hydro and ahead of coal, natural gas and nuclear. An individually installed WEG is commonly referred to as a wind turbine (WT) or simply as a wind generator (WG), and a group of such generators is referred to as a wind power plant (WPP) or wind farm (WF). Wind farms of all sizes are continuously being connected directly to the power grids and they have the potential to replace many of the conventional power plants. This means that wind turbines should possess the general characteristics of conventional power plants such as simplicity of use, long and reliable useful life, low maintenance and low initial cost. Moreover, large wind farms should satisfy very demanding technical requirements such as frequency and voltage control, active and reactive power regulation, and fast response during transient and dynamic situations. WGs can either operate at fixed speed or at variable speed. Due to various reasons such as reduced mechanical stress, flexible active-reactive power controllability, good power quality, low converter rating and low losses, nowadays the most popular topology is the variable speed type Double Fed Induction Generator (DFIG).

2.1 Wind Energy Conversion System

Figure 1 represents the complete wind energy conversion systems (WECS), which converts the energy present in the moving air (wind) to electric energy. The wind passing through the blades of the wind turbine generates a force that turns the turbine shaft. The rotational shaft turns the rotor of an electric generator, which converts mechanical power into electric power.

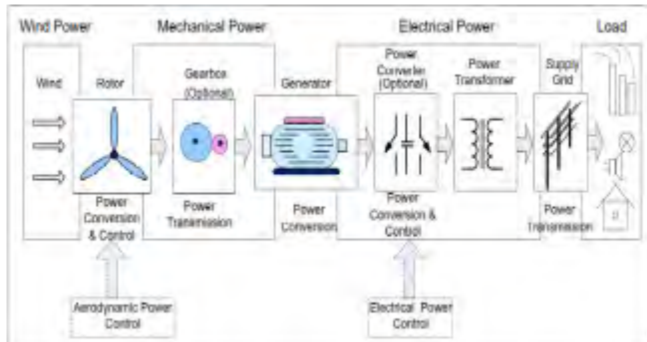


Figure 1 Wind Energy Conversion System.

The major components of a typical wind energy conversion system include the wind turbine, generator, interconnection apparatus and control systems. The power developed by the wind turbine mainly depends on the wind speed, swept area of the turbine blade, density of the air, rotational speed of the turbine and the type of connected electric machine. As shown in figure 1, there are primarily two ways to control the WECS. The first is the Aerodynamic power control at either the Wind Turbine blade or nacelle, and the second is the electric power control at an interconnected apparatus, e.g., the power electronics converters. The flexibility achieved by these two control options facilitates extracting maximum power from the wind during low wind speeds and reducing the mechanical stress on the wind turbine during high wind speeds.

2.2 Doubly Fed Induction Generator

Figure 2 presents the topology of the DFIG, which will be thoroughly analyzed in this section.As shown in figure 2, the DFIG consists of two bi-directional voltage source converters with a back-to-back DC-link, a wound rotor induction machine, and the wind turbine. Wound Rotor Induction Machine:The WRIM is a conventional 2-phase wound rotor induction machine. The machine stator winding is directly connected to the grid and the rotor winding is connected to the rotor-side VSC by slip rings and brushes. Voltage Source Converters:This type of machine is equipped with two identical VSCs. These converters typically employ IGBTs in their design. The AC excitation is supplied through both the grid-side VSC and the rotor-side VSC. The grid side VSC is connected the ac network. The rotor side converter is connected to the rotor windings. This grid side VSC and the stator are connected to the ac grid via step up transformer to elevate the voltage to the desired grid high voltage level. The VSCs allow a wide range of variable speed operation of the WRIM. If the operational speed range is small, then less power has to be handled by the bidirectional power converter connected to the rotor. If the speed variation is controlled between +/- 20 %, then the converter must have a rating of approximately 20 % of the generator rating. Thus the required converter rating is significantly smaller than the total generator power, but it depends on the selected variable speed range and hence the slip power. Therefore, the size and cost of the power converter increases when the allowable speed range around the synchronous speed increases.

2.2.1 DC-link with Capacitor:

The capacitor connected to the DC-link acts as a constant, ripple-free DC voltage source, an energy storage device and a source of reactive power. Moreover, the DC-link provides power transmission and stabilization between both unsynchronized AC systems.

2.2.2 Control System:

The control system generates the following commands: the pitch angle command, which is used by the aerodynamic Pitch Control to control the wind power extracted by turbine blades; the voltage command signal Vrc, which is intended to control the rotor side VSC; and the signal Vgc, which is intended to control the grid side VSC (to control the electrical power).In turn, the rotor-side VSC controls the power of the wind turbine, and the grid-side VSC controls the dc-bus voltage and the reactive power at the grid terminals.

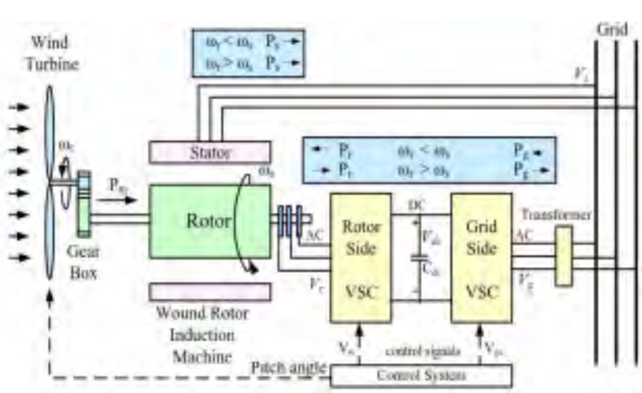


Figure 2Doubly Fed Induction Generator type WT.

By implementing pulse width modulation, it is possible to control the VSCs to generate an output waveform with desired phase angle and voltage magnitude, and at the same time reduce lower order harmonics.

2.3 Operating Principle

A wide range of variable speed operating mode can be achieved by applying a controllable voltage across the rotor terminals. This is done through the rotor-side VSC. The applied rotor voltage can be varied in both magnitude and phase by the converter controller, which controls the rotor currents. The rotor side VSC changes the magnitude and angle of the applied voltages and hence decoupled control of real and reactive power can be achieved. The rotor-side VSC controller provides two important functions:

- Variation of generator electromagnetic torque and hence rotor speed.
- Constant stator reactive power output control, stator power factor control or stator terminal voltage control.

The grid-side VSC controller provides:

- Regulation of the voltage of the DC bus capacitor.
- Control of the grid reactive power.

The DFIG exchanges power with the grid when operating in either sub or super synchronous speeds.

3 MAXIMUM POWER POINT TRACKING

Wind generation system has been attracting wide attention as a renewable energy source due to depleting fossil fuel reserves and environmental concerns as a direct consequence of using fossil fuel and nuclear energy sources. Wind energy, even though abundant, varies continually as wind speed changes throughout the day. Amount of power output from a WECS depends upon the accuracy with which the peak power points are tracked by the MPPT controller of the WECS control system irrespective of the type of generator used. The maximum power extraction algorithms researched so far can be classified into three main control methods, namely tip speed ratio (TSR) control, power signal feedback (PSF) control and hill-climb search (HCS) control. The TSR control method regulates the rotational speed of the generator in order to maintain the TSR to an optimum value at which power extracted is maximum. This method requires both the wind speed and the turbine speed to be measured or estimated in addition to requiring the knowledge of optimum TSR of the turbine in order for the system to be able extract maximum possible power. Figure 3 shows the block diagram of a WECS with TSR control.

Figure 3 Tip speed ratio control of WECS In PSF control, it is required to have the knowledge of the wind turbine's maximum power curve, and track this curve through its control mechanisms. The maximum power curves need to be obtained via simulations or off-line experiment on individual wind turbines. In this method, reference power is generated either using a recorded maximum power curve or using the mechanical power equation of the wind turbine where wind speed or the rotor speed is used as the input. Figure 4 shows the block diagram of a WECS with PSF controller for maximum power extraction.

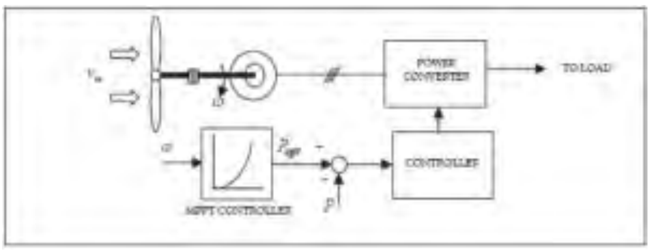


Figure 4 Power signal feedback control

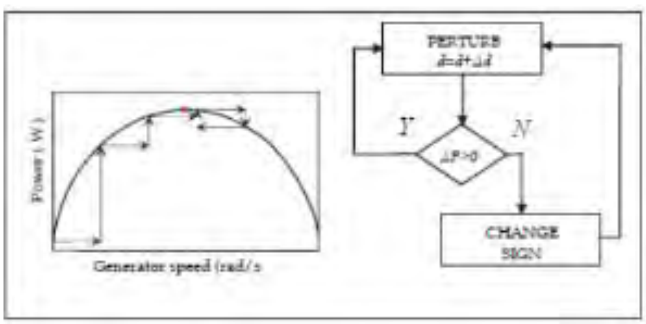


Figure 5 HSC control principle.

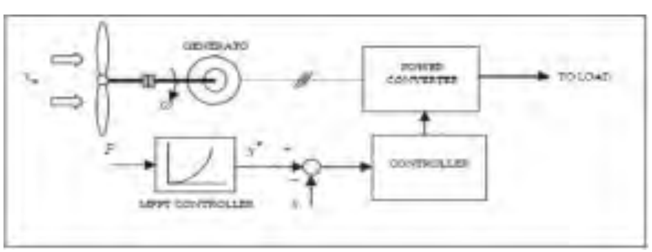


Figure 6 WECS with hill climb search control.

The HCS control algorithm continuously searches for the peak power of the wind turbine. It can overcome some of the common problems normally associated with the other two methods. The tracking algorithm, depending upon the location of the operating point and relation between the changes in power and speed, computes the desired optimum signal in order to drive the system to the point of maximum power. Figure 5 shows the principle of HCS control and figure 6 shows a WECS with HCS controller for tracking maximum power points.

3.1 MPPT for PMSG based WECS

Permanent Magnet Synchronous Generator is favoured more and more in developing new designs because of higher efficiency, high power density, availability of high-energy permanent magnet material at reasonable price, and possibility of smaller turbine diameter in direct drive applications. Presently, a lot of research efforts are directed towards designing of WECS which is reliable, having low wear and tear, compact, efficient, having low noise and maintenance cost; such a WECS is realisable in the form of a direct drive PMSG wind energy conversion system.

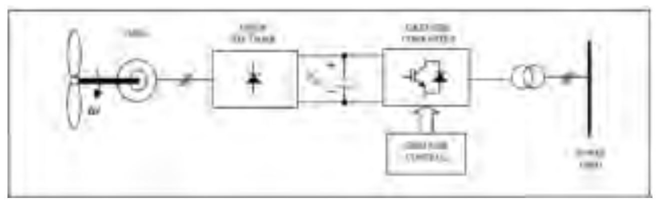


Figure 7 PMSG WECS.

There are three commonly used configurations for WECS with these machines for converting variable voltage and variable frequency power to a fixed frequency and fixed voltage power. The power electronics converter configurations most commonly used for PMSG WECS are shown in figure 7. Depending upon the power electronics converter configuration used with a particular PMSG WECS a suitable MPPT controller is developed for its control. All the three methods of MPPT control algorithm are found to be in use for the control of PMSG WECS.

3.2 Tip speed control

A wind speed estimation based TSR control is proposed in order to track the peak power points. The wind speed is estimated using neural networks, and further, using the estimated wind speed and knowledge of optimal TSR, the optimal rotor speed command is computed. The generated optimal speed command is applied to the speed control loop of the WECS control system. The PI controller controls the actual rotor speed to the desired value by varying the switching ratio of the PWM inverter. The control target of the inverter is the output power delivered to the load. This WECS uses the power converter configuration shown in figure 6. The block diagram of the ANN-based MPPT controller module is shown in figure 8.

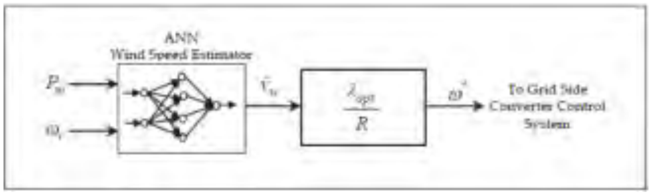


Figure 8 ANN based MPPT control module.

4 ANFIS

A feed-forward neural network could approximate any fuzzy rule based system and any feed-forward neural network may be approximated by a rule based fuzzy inference system. Fusion of Artificial Neural Networks (ANN) and Fuzzy Inference Systems (FIS) have attracted the growing interest of researchers in various scientific and engineering areas due to the growing need of adaptive intelligent systems to solve the real world problems. A neural network learns from scratch by adjusting the interconnections between layers. Fuzzy inference system is a popular computing framework based on the concept of fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning. The advantages of a combination of neural networks and fuzzy inference systems are obvious. An analysis reveals that the drawbacks pertaining to these approaches seem complementary and therefore it is natural to consider building an integrated system combining the concepts. While the learning capability is an advantage from the viewpoint of fuzzy inference system, the automatic formation of linguistic rule base will be advantage from the viewpoint of neural network. There are several works related to the integration of neural networks and fuzzy inference systems.

4.1 Cooperative neuro-fuzzy systems

In the simplest way, a cooperative model can be considered as a pre-processor wherein artificial neural network (ANN) learning mechanism determines the fuzzy inference system (FIS) membership functions or fuzzy rules from the training data. Once the FIS parameters are determined, ANN goes to the background. Fuzzy Associative Memories (FAM), fuzzy rule extraction using self-organizing maps and the systems capable of learning of fuzzy set parameters are some good examples of cooperative neuro-fuzzy systems.

4.2 Fuzzy Associative Memories

Interprets a fuzzy rule as an association between antecedent and consequent parts. If a fuzzy set is seen as a point in the unit hypercube and rules are associations, then it is possible to use neural associative memories to store fuzzy rules. A neural associative memory can be represented by its connection matrix. Associative recall is equivalent to multiplying a key factorwith this matrix. The weights store the correlations between the features of the key k and the information part i. Due to the restricted capacity of associative memories and because of the combination of multiple connection matrices into a single matrix is not recommended due to severe loss of information, it is necessary to store each fuzzy rule in a single FAM. Rules with n conjunctively combined variables in their antecedents can be represented by n FAMs, where each stores a single rule. The FAMs are completed by aggregating all the individual outputs (maximum operator in the case of Mamdani fuzzy system) and a defuzzification component. Learning could be incorporated in FAM, as learning the weights associated with FAMs output or to create FAMs completely by learning. A neural Network-learning algorithm determines the rule weights for the fuzzy rules. Such factors are often interpreted as the influence of a rule and are multiplied with the rule outputs. Rule weights can be replaced equivalently by modifying the membership functions. However, this could result in misinterpretation of fuzzy sets and identical linguistic values might be represented differently in different rules. Kosko suggests a form of adaptive vector quantization technique to learn the FAMs. This approach is termed as differential competitive learning and is very similar to the learning in self-organizing maps. Figure 9 depicts a cooperative neuro-fuzzy model where the neural network learning mechanism is used to determine the fuzzy rules, parameters of fuzzy sets, rule weights etc. Kosko's adaptive FAM is a cooperative neuro fuzzy model because it uses a learning technique to determine the rules and its weights. The main disadvantage of FAM is the weighting of rules. Just because certain rules, does not have much influence does not mean that they are very unimportant. Hence, the reliability of FAMs for certain applications is questionable. Due to implementation simplicity, FAMs are used in many applications.

4.3 Concurrent neuro-fuzzy system

In a concurrent model, neural network assists the fuzzy system continuously (or vice versa) to determine the required parameters especially if the input variables of the controller cannot be measured directly. Such combinations do overall system. Learning takes place only in the neural network and the fuzzy system remains un-

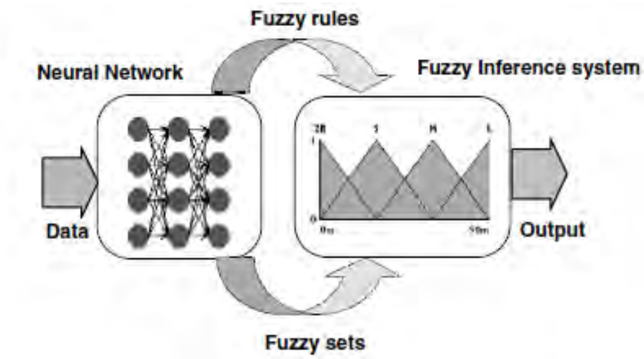


Figure 9 Cooperative neuro-fuzzy model.

changed during this phase. In some cases the fuzzy outputs might not be directly applicable to the process. In that case neural network can act as a postprocessor of fuzzy outputs. Figure 4.2 depicts a concurrent neuro-fuzzy model where in the input data is fed to a neural network and the output of the neural network is further processed by the fuzzy system.

4.4 Integrated neuro-fuzzy systems

In an integrated model, neural network learning algorithms are used to determine the parameters of fuzzy inference systems. Integrated neuro-fuzzy systems share data structures and knowledge representations. A fuzzy inference system can utilize human expertise by storing its essential components in rule base and database, and perform fuzzy reasoning to infer the overall output value. The derivation of if-then rules and corresponding membership functions depends heavily on the a priori knowledge about the system under consideration. However there is no systematic way to transform experiences of knowledge of human experts to the knowledge base of a fuzzy inference system. There is also a need for adaptability or some learning algorithms to produce outputs within the required error rate. On the other hand, neural network learning mechanism does not rely on human expertise. Due to the homogenous structure of neural network, it is hard to extract structured knowledge from either the weights or the configuration of the network. The weights of the neural network represent the coefficients of the hyper-plane that partition the input space into two regions with different output values. If we can visualize this hyper-plane structure from the training data then the subsequent learning procedures in a neural network can be reduced. However, in reality, the a priori knowledge is usually obtained from human experts, it is most appropriate to express the knowledge as a set of fuzzy if-then rules, and it is very difficult to encode into a neural network.

Table 1: Comparison between neural network and fuzzy interference system

Artificial Neural Network	Fuzzy Inference System
Difficult to use prior rule knowledge Learning from scratch Black box Complicated learning algorithms Difficult to extract knowledge	Prior rule-base can be incorporated Cannot learn (linguistic knowledge) Interpretable (if-then rules) Simple interpretation and implementation Knowledge must be available

Table 1 summarizes the comparison between neural networks and fuzzy inference system. To a large extent, the drawbacks pertaining to these two approaches seem complementary. Therefore, it seems natural to consider building an integrated system combining the concepts of FIS and ANN modeling. A common way to apply a learning algorithm to a fuzzy system is to represent it in a special neural network like architecture. However the conventional neural network learning algorithms (gradient descent) cannot be applied directly to such a system as the functions used in the inference process are usually non differentiable. This problem can be tackled by using differentiable functions in the inference system or by not using the standard neural learning algorithm.

5 PROPOSED SYSTEM

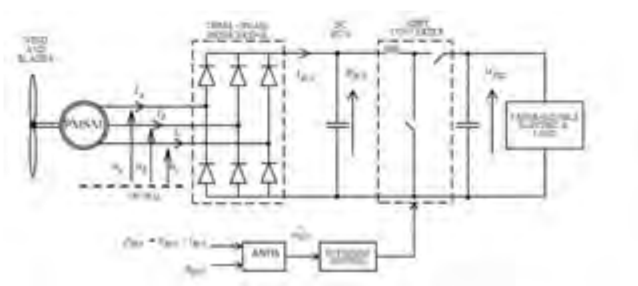


Figure 10 Schematic diagram of the proposed system.

Figure 10 shows the block diagram of the proposed MPPT system with Adaptive Network-based Fuzzy Interference System (ANFIS). Wind electric generators (WEGs) are turning into the primary sustainable wellspring of electric vitality. Wind power would be the second biggest wellspring of power behind hydro and in front of coal, petroleum gas and atomic. A separately introduced WEG is generally alluded to as a breeze turbine (WT) or essentially as a breeze generator (WG), and a gathering of such generators is alluded to as a breeze control plant (WPP) or wind cultivate (WF). The simulation of overall system is shown in figure 11.

Figure 11 Overall simulation diagram of the proposed system.

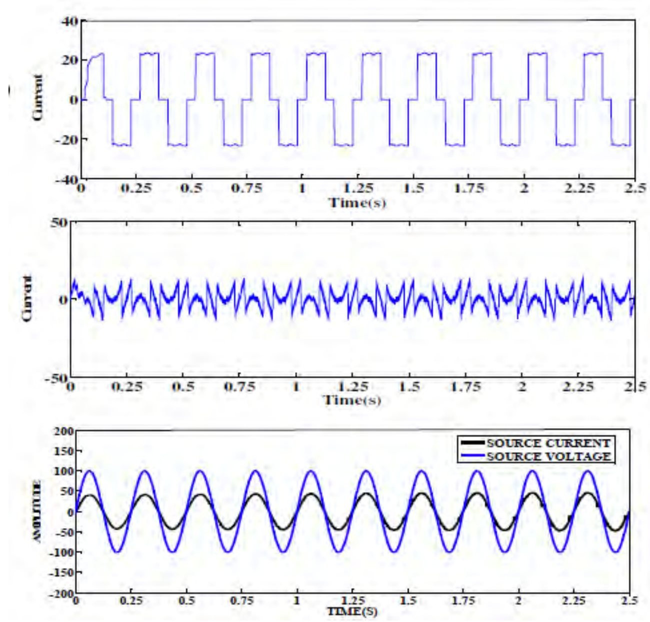


Figure 12 Load current waveform, Compensating current waveform, Source voltage and source current after compensation.

6 RESULT

The power quality improvement capability of the UPQC has been tested using MATLAB. A three phase diode bridge rectifier feeding R , L load is considered as a nonlinear load with total harmonic distortion (THD) of 32% .The series converter is able to compensate up to more than 40% of voltage sag/swell under normal voltage condition. In this simulation study we consider 20% variation of three phase voltage for symmetrical sag/swell and 20% to 30% variation of three phase voltage for asymmetrical sag/swell condition.

Filter with Symmetrical swells condition

7 CONCLUSION

In this paper, a fuzzy logic controller based MPPT control system has been proposed for the fast tracking of MPP under turbulent wind conditions for small-scale WECSs. System behaviour with proposed technique under changing wind conditions has been observed and it is evident that the proposed control system can put the system at optimal operating point promptly against random variations in the wind velocity. System performance with proposed experimental results proved that WECS with proposed control system harvests more energy. The proposed MPPT provides the following advantages: 1) improved dynamic response of the system and 2) prerequisite of system's optimal characteristics data is not required. Since small-scale WECSs are main resources for DERs in grid systems, the proposed system is very much applicable for grid systems.

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] K. Govindaraju, V. Bhavithira, D. Kavitha, S. Kuppusamy, and K. Balachander, "Improvement of Voltage Profile and Loss Minimization in IEEE 14 Bus System using FACTS Devices" in International Journal of Control Theory and Applications, ISSN: 0974-5572 Vol. 10 No.38 (2017), pg. 213-224.

[3] E.Koutroulis, F.Blaabjerg, "Methodology for the optimal design of transformerless grid-connected PV inverters, " Power Electron., lET , vol.5, no. 8, pp.1491,1499, September 2012.

[4] H. Tao, J. L. Duarte, andM. AM. Hendrix, "Line-interactive UPS using a fuel cell as the primary source," IEEE Trans. lnd. Electron., vol. 55, no. 8, pp. 3012-3021, Aug. 2008.

[5] Erickson RW, Maksimovic D. Fundamentals of power electronics. 2nd ed. Norwell, MA: Kluwer; 200 I.

[6] Dr.A.Amudha ,M. SivaRamkumar , M. Sivaram Krishnan "Perturb and Observe Based Photovoltaic Power Generation System For Off-Grid Using Sepic Converter" International Journal of Pure and Applied Mathematics , 114(7), pp. 619-628 , 2017 .

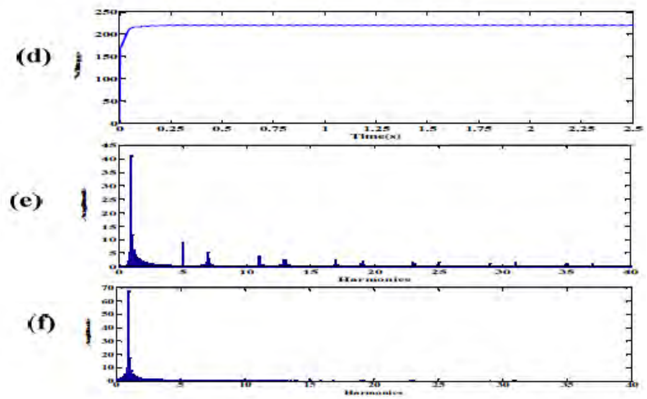


Figure 13 Capacitor voltage waveform, Source current spectrum beforecompensation, Source current.

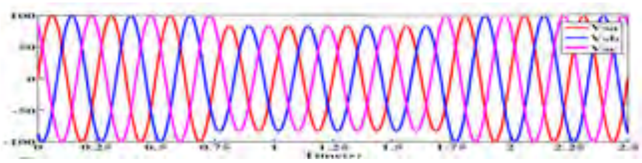


Figure 14 Source voltage with sag.

[7] M. SivaRamkumar, M. Sivaram Krishnan, Dr.A.Amudha "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[8] M. SivaRamkumar, M. Sivaram Krishnan, Dr.A.Amudha "Impedance Source Inverter and Permanent Magnet Synchronous Generator For Variable Speed Wind Turbine " International Journal of Computer & Mathematical Sciences, 6 (9) pp 98-105, 2017.

[9] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017.

[10] M.Subramanian, M. Siva Ramkumar, Dr.A.Amudha, K.Balachander and D.Kavitha"Power Quality Improvement In Low Voltage Transmission

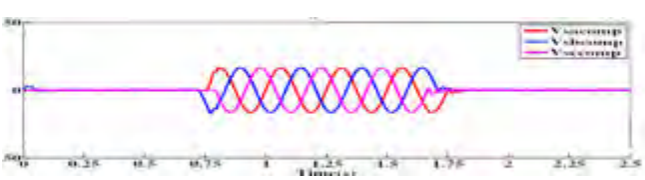


Figure 15 Compensating Voltage.

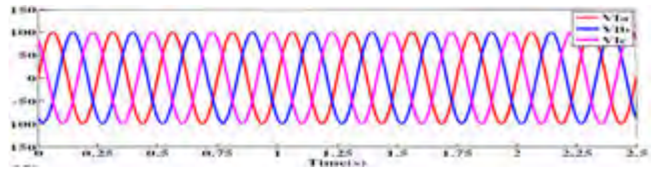


Figure 16 Load voltage after compensation.

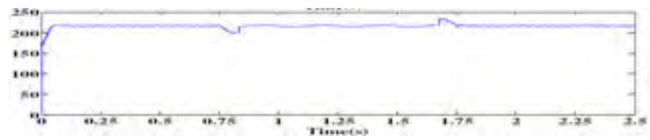


Figure 17 capacitor voltage waveform in Series Active Filter with Symmetrical sag condition.

System Using Static Compensator" in International Journal of Control Theory and Applications (IJCTA) 10 (38) pp 247-261, 2017.

[11] V.Chandra Prabha , Dr.A.Amudha , K.Balachander, M. Siva Ramkumar " MPPTAlgorithm For Grid Integration of Variable Speed Wind Energy Conversion System" in International Journal of Control Theory and Applications, 10 (38) pp 237-246, 2017.

[12] R. Yuvaraj, K. Balachander, A. Amudha, S. Kuppuamy, M. Siva Ramkumar " Modified Interleaved Digital Power Factor Correction Based On The Sliding Mode Approach" in International Journal of Control Theory and Applications, 10 (38) pp 225-235, 2017.

[13] R. Ravichandran, K. Balachander, A. Amudha, M. Siva Ramkumar, S.Kuppusamy" Estimation Of Electrical Parameter Using Fuzzy Logic Controller Based Induction Motor" in International Journal of Control Theory and Applications, 10 (38) pp 205-212 , 2017.

[14] N. Sivakumar, D. Kavitha, M. Siva Ramkumar, V.Bhavithira, S. Kalaiarasi, "A Single Stage High Gain Converter For Gird Interconnected Renewable Application Using Perturb And Observe" in International Journal of Control Theory and Applications, 10 (38) 161-175 , 2017.

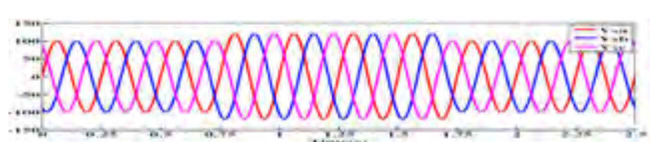


Figure 18 Source voltage with swell.

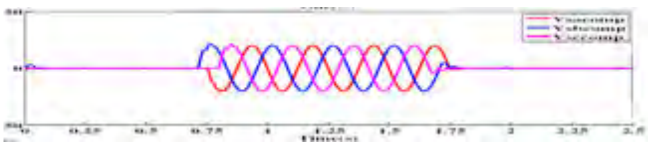


Figure 19 Compensating Voltage.

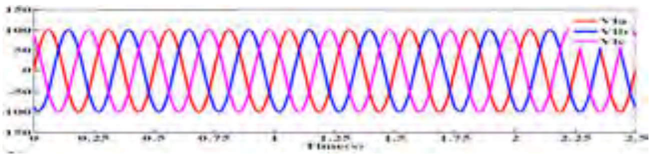


Figure 20 Load voltage after compensation.

[15] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. “Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc“ in International Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[16] M Siva RamKumar, A. Amudha, R. Rajeev “Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications” in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016. .

[17] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara “Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control” in ‘International Journal of Innovative Research in Science, Engineering and Technology’ on 3 (3) pp 763-769,2016.

[18] Emayavaramban. G, Amudha. A, ‘sEMG Based Classification of Hand Gestures using Artificial Neural Networks’, Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[19] Emayavaramban. G, Amudha. A, ‘Recognition of sEMG for Prosthetic Control using Static and Dynamic Neural Networks’, International Journal of Control Theory and Applications,Vol.2 (6), pp.155-165, September 2016.

[20] Emayavaramban. G, Amudha.A, ‘Identifying Hand Gestures using sEMG for Human Machine Interaction’, ARPN Journal of Engineering and Applied Sciences, Vol.11 (21), pp.12777-12785, November 2016.

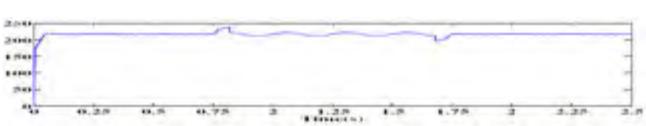


Figure 21 Capacitor voltage waveform in Series Active.

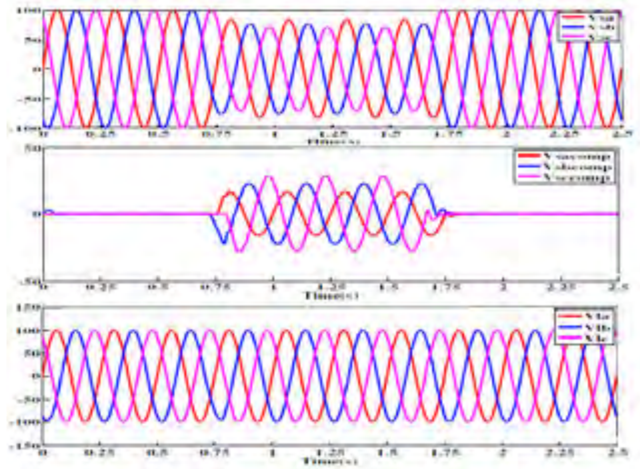


Figure 22 (a) Source voltage with sag, (b) Compensating Voltage, (c) Load voltage after compensation in Series Active Filter with Unsymmetrical sag condition.

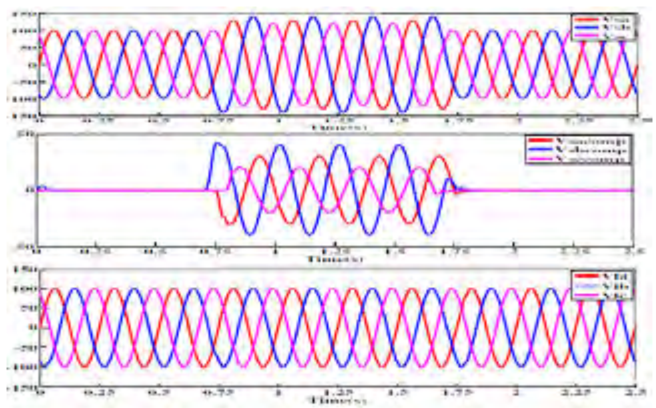


Figure 23 (a) Source voltage with swell, (b) Compensating Voltage, (c) Load voltage after compensation in Series Active Filter with Unsymmetrical swell Condition.

[21] Ramkumar. S, Sathesh Kumar. K, Emayavaramban. G, ‘EOG Signal Classification using Neural Network for Human Computer Interaction’, International Journal of Control Theory and Applications, Vol.2 (6), pp.173-181, September 2016

[22] Ramkumar. S, Emayavaramban. G, Elakkiya. A, ‘A Web Usage Mining Framework for Mining Evolving User Profiles in Dynamic Web Sites’, International Journal of Advanced Research in Computer Science and Software Engineering, Vol.4 (8), pp.889-894, August 2014.

[23] K. Balachander, V. Ponnusamy, ‘Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System’ International Journal

of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

MULTI CONVERTER UNIFIED POWER QUALITY CONDITIONING (MC-UPQC) FOR VARIOUS LOADS WITH ANN APPROACH TO TWO SOURCE CONCEPT

K. Suresh Kumar, K. Balachander, A. Amudha, M. Siva Ramkumar, D. Kavitha

---

Abstract: Maintaining a strategic distance from the PQ aggravation and upgrading the PQ are the troublesome assignments. More power hardware gadgets are utilized to overcome the PQ unsettling influences. Multi converter - Unified power quality conditioner (MC-UPQC) is one of the new power gadgets that are utilized for improving the PQ. The framework can be connected to contiguous feeders to adjust for supply-voltage and load current defects on the principle feeder and full pay of supply voltage blemishes on alternate feeders. In the proposed design, all converters are associated consecutive on the dc side and offer a typical dc-interface capacitor. Offering to one DC connect capacitor. The releasing time of DC connect capacitor is high, thus it is the fundamental issue in MC-UPQC gadget. To wipe out this issue, an upgraded ANN based MC-UPQC is proposed in this work. The transient reaction of the PI dc-connect voltage controller is moderate. In this way, a quick acting dc-connect voltage controller in light of the vitality of a dc-interface capacitor is proposed. The transient reaction of this controller is quick when contrasted with that of the regular dc-connect voltage controller. By utilizing fluffy rationale controller rather than the PI controller the transient reaction is moved forward. The DC capacitor charging yield voltage is expanded and the reaction is quick when contrasted and PI by utilizing the ANN controller and subsequently, the PQ of the framework is improved.

Keywords: Multi converter-Unified Power Quality Conditioner (MC-UPQC), PI controller, Artificial Neural Network (ANN).

---

1 Introduction

The electric industry is poised to make the transformation from a centralized, producer-controlled network to one that is less centralized and more consumer-interactive. The move to a smarter grid promises to change the industry's entire business model and its relationship with all stakeholders, involving and affecting utilities, regulators, energy service providers, technology and automation vendors and all consumers of electric power [1-3]. A smarter grid makes this transformation possible by bringing the philosophies, concepts and technologies that enabled the internet to the utility and the electric grid. More importantly, it enables the industry's best ideas for grid modernization to achieve their full potential [4-7]. In smartgrid systems, the increasing use of nonlinear loads causes power quality problems such as voltage distortions at the Point of Common Coupling (PCC). Unwanted harmonics and voltage sags/swells will cause malfunctioning of devices, overheating of power factor correction capacitors, motors, transformers and cables, and thermal tripping of protective devices installed [8-12]. Therefore, it is necessary to install compensating devices at the PCC to reduce this distortion. The use of unified power quality conditioner (UPQC) is one of the ways to overcome the above power quality problems. The UPQC, an integration of series and shunt active filters, has the capability of compensating for distortions in the supply voltage and unwanted harmonics in the load current simultaneously. Recently, major research works have been carried out on controller designs for UPQCs. However, most of the previous studies did not take the control saturation explicitly into their control design [13-16]. MPC is a control approach involving online optimization, which takes into account the system dynamics, constraints and control objectives. A key motivation of using MPC for UPQC is that MPC is able to handle hard constraints of the process variables explicitly. In UPQC, the manipulated variable is implemented with a Pulse Width Modulation (PWM) technique, which has to be limited to ± 1, so that the active filters will operate in the linear modulation region. Conventional linear controllers usually adopt a conservation design to avoid the violation of such limits, otherwise instability might occur, thus limiting the compensation capability of the UPQC. MPC, on the other hand, can take these input constraints into its online optimization explicitly. The MPC controller and the functional modules of the UPQC are discussed in subsequent sections. Simulation results are reported on a single phase power distribution system. A comparison of performance between the MPC controller and a linear controller called Multi-Variable Regulator (MVR) is carried out [17-21].

2 POWER FLOW CONTROL

Power systems in general are interconnected for economic, security and reliability reasons. Exchange of contracted amounts of real power has been in vogue for a long time for economic and security reasons [22]. To control the power flow on tie lines connecting controls areas, power flow control equipment such as phase shifters are installed. They direct real power between control areas. The interchange of real power is usually done on an hourly basis. On the other hand, reactive power flow control on tie lines is also very important. Reactive power flow control on transmission lines connecting different areas is necessary to regulate remote end voltages. Though local control actions within an area are the most effective during contingencies, occasions may arise when adjacent control areas may be called upon to provide reactive power to avoid low voltages and improve system security [23]. Document B-3 of Northeast Power Coordinating Council (NPCC) on Guidelines for Inter-Area Voltage Control provides the general principles and guidance for effective inter-area voltage control states that "Providing that it is feasible to regulate reactive power flows in its tie lines, each area may establish a mutually agreed upon normal schedule of reactive power flow with adjacent areas and with neighbouring systems in other reliability councils. This schedule should conform to the provisions of the relevant interconnection agreements and may provide for:

- The minimum and maximum voltage at stations at or near terminals of inter area tie lines.
- The receipt of reactive power flow at one tie point in exchange for delivery at another.
- The sharing of reactive requirements of tie lines and series regulating equipment (either equaly or in proportion to line lengths)
- The transfer of reactive power from one area to another"

When an area anticipates or is experiencing an abnormal, but stable, or gradually changing bulk power system voltage condition, it shall implement steps to correct the situation. Recognizing that voltage control problems are most effectively corrected by control actions as close to the source as possible, the area shall use its own resources, but may request assistance from adjacent areas." The above statements clearly calls upon the power flow regulating equipment to not only be able to control red power but also simultaneously control reactive power flow rapidly. Further, the voltage at stations at or near terminals of inter-area tie lines should be controlled within limits. Power flow in a network is not easily controlled because line parameters that determine the flow of power in the system are difficult to control. Fortunately, the ability to control power flow at the transmission level has greatly been influenced by the advances made in the field of high power switching devices. Solid state devices provide transmission utilities the flexibility to control the system power flows. Today, with the availability of high power gate tum-off thyristors (GTO) it has become possible to look beyond the realm of conventional thyrsitors for power flow control. These devices are broadly referred to as Flexible AC Transmission Systems (FACTS). Power flow in a transmission line is a function of the sending (Vs) and receiving (V') end voltages, the phase angle difference (6) between the voltages and the line impedance (X). Control of any of the above parameters cm help to control the power flow and the process is known as compensation. FACTS devices could be placed either in series or in shunt with the transmission line with the intention of controlling the power flow in it. If the transmission line impedance is modified by the addition of FACTS, it termed as series compensation. If the phase angle difference is modified, it is timed as phase angle compensation. Shunt compensation, in which the FACTS device is placed in parallel, is mainly used to improve the system voltage characteristics. Static varcompensator (SVC) belongs to this finally of FACTS devices.

2.1 UPQC concept

The UPQC concept was proposed by Gyugyi. To understand the unified power flow concept, consider a power system with two machines connected by a transmission line of reactance X, (purely inductive) along with two voltage sources V, and V, representing the UPQC as shown in figure 1. The voltage sources denoted by Vs,and V, in the figure 1 are connected in shunt and series respectively at the mid- point of the transmission line. A power system with two machines connected by a transmission line with voltage sources representing the UPQC.

Vsh and Vse representing the UPQC. Voltage source V, is connected to the transmission line through a transformer represented as a reactance X. It is assumed that the voltage sources denoted by V, and V have the capabilities of varying their magnitude and their phase angle. To understand the operation of the source V, the source Vreis disconnected- Reactive power flows from the voltage source V, to bus M if the magnitude of the voltage source V,, is greater than the mid-point voltage V, and

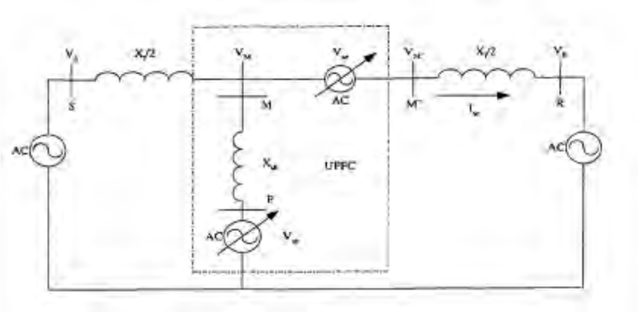


Figure 1: *A power system with two machines connected by a transmission line with voltage sources.*

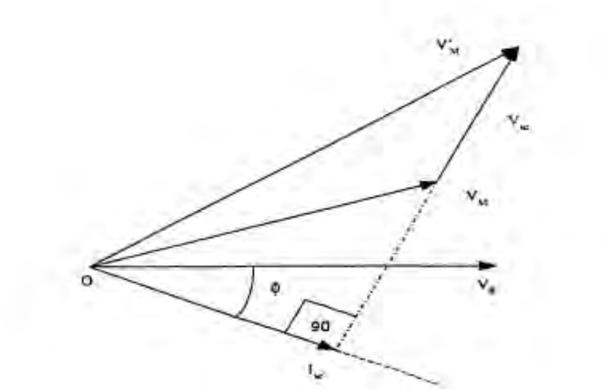


Figure 2: *Phasor relationship between the voltage source and the line current.*

the phase of them are the same. If the phase angle of the voltage source V, leads the phase angle of mid-point voltage Vh, and the magnitude of V, is greater than V, then real and reactive power will flow from the voltage source V,, to the bus M . Conversely, if the magnitude of the shunt voltage V, is less than the midpoint voltage V, but the phase angle difference between them is zero, then only reactive power will flow from the bus M to the bus P. In this process, the voltage source V, is consuming reactive power. If the phase angle of V, leads the phase angle of V,, then both real and reactive power will flow from bus M to bus P and the voltage source is said to be consuming both real and reactive power. By controlling the magnitude and phase angle of the shunt voltage source V,, the direction of real and reactive power flow to the bus M can be controlled. Alliteratively, the voltage source V, can be made to function as a load or as a generator for the power system. In the above operation, if the phase angle difference between the voltage at bus M and that of Vc, is maintained at zero, then by varying the magnitude of V,, reactive power cm either be consumed or generated by V,. This operation cm be compared with that of a thyristor controller reactor with fixed capacitor (shunt compensator) that generates or absorbs reactive power by altering its shunt reactive impedance. It should be noticed that the function of a shunt compensator is being duplicated by the voltage source Vsh.

Now consider only the operation of series voltage source V, in figure 2.1 with the shunt voltage source V, inoperative. It is assumed that the phase angle of the series voltage source V, can be varied. The transmission line current 1, interacts with the sense voltage source Ve causing real and reactive power to be exchanged between the series voltage source and the transmission line. If the voltage source V, and the transmission line current I,, have a phase angle difference of 90 degrees and that the voltage phasor of Vs, leads the line current, the voltage source V, then generates only reactive power. The phasor diagram has been shown in figure 2. Conversely, if the voltage source V, phasor lags the transmission line current I, phasor by 90 degrees, then the voltage source V, will consume reactive power. The above operation should be compared with that of. a series capacitor/series inductor in the transmission line. When capacitors are placed in series with the transmission line. It generates reactive power. The amount of reactive power generated depends on the amount of series compensation and the line current. When inductors are placed in series with the transmission line, it consumes reactive power- In summary, the function of series capacitor could be performed by the series voltage source V, by maintaining its phase to lead the transmission line current Isephasor by 90 degrees. Conversely, the function of a series inductor could be performed by the series voltage source V, by adjusting its phase angle to be lagging the line current 1 phasor by 90 degrees. By properly adjusting the phase angle of the sense voltage source V,, the operation of a phase shifter could be obtained. In the case of a phase shifter, the phase angle of the series voltage source V, leads or lags the voltage of the bus to which it is attached, by 90 degrees. This causes the voltage phasor to shift by an amount depending on the magnitude of the injected voltage. In this case, if the series voltage source V, has a 90 degrees leading or lagging phase relationship with the bus voltage V,, then a phase shift a = tan could be obtained. Figure 3shows the phasor relationship of the series voltage source V, leading the bus voltage V, for phase shifter operation. In summary, by adjusting the phase angle of the series voltage source Vcto be either leading or lagging the bus voltage M by 90 degrees, a phase shifter operation could be obtained. In order to vary the magnitude of phase shift, the magnitude of the sense voltage source V, could be varied. The above illustration has shown al1 the possible functions of shunt compensation, series compensation and phase angle compensation that could be obtained by manipulating the series and the shunt voltage sources magnitude and phase angle of a UPQC.

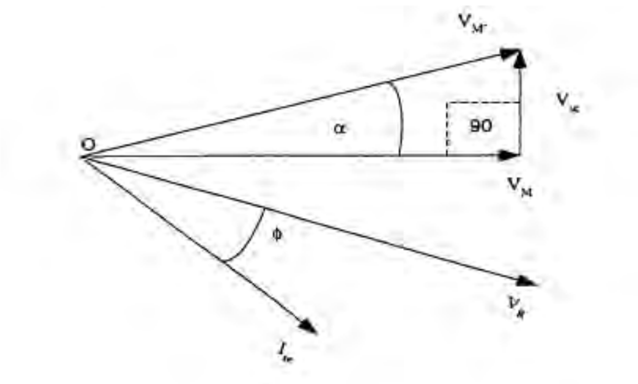


Figure 3: *Phasor relationship between the mid-point voltage and the sense voltage source*

3 ARTIFICIAL NEURAL NETWORK

Artificial neural networks (ANNs) or connectionist systems are computing systems inspired by the biological neural networks that constitute animal brains. Such systems learn (progressively improve performance) to do tasks by considering examples, generally without task-specific programming. For example, in image recognition, they might learn to identify images that contain cats by analyzing example images that have been manually labeled as "cat" or "no cat" and using the analytic results to identify cats in other images. They have found most use in applications difficult to express in a traditional computer algorithm using rule-based programming. An ANN is based on a collection of connected units called artificial neurons, (analogous to axons in a biological brain). Each connection (synapse) between neurons can transmit a signal to another neuron. The receiving (postsynaptic) neuron can process the signal(s) and then signal downstream neurons connected to it. Neurons may have state, generally represented by real numbers, typically between 0 and 1. Neurons and synapses may also have a weight that varies as learning proceeds, which can increase or decrease the strength of the signal that it sends downstream. Further, they may have a threshold such that only if the aggregate signal is below (or above) that level is the downstream signal sent. Typically, neurons are organized in layers. Different layers may perform different kinds of transformations on their inputs. Signals travel from the first (input), to the last (output) layer, possibly after traversing the layers multiple times. The original goal of the neural network approach was to solve problems in the same way that a human brain would. Over time, attention focused on matching specific mental abilities, leading to deviations from biology such as backpropagation, or passing information in the reverse direction and adjusting the network to reflect that information. Neural networks have been used on a variety of tasks, including computer vision, speech recognition, machine translation, social network filtering, playing board and video games, medical diagnosis and in many other domains.

3.1 History

Warren McCulloch and Walter Pitts (1943) created a computational model for neural networks based on mathematics and algorithms called threshold logic. This model paved the way for neural network research to split into two approaches. One approach focused on biological processes in the brain while the other focused on the application of neural networks to artificial intelligence. This work led to work on nerve networks and their link to finite automata.

3.2 Hebbian learning

In the late 1940s, D.O. Hebb created a learning hypothesis based on the mechanism of neural plasticity that is now known as Hebbian learning. Hebbian learning is an unsupervised learning rule. This evolved into models for long term potentiation. Researchers started applying these ideas to computational models in 1948 with Turing's B-type machines. Farley and Clark (1954) first used computational machines, then called "calculators", to simulate a Hebbian network. Other neural network computational machines were created by Rochester, Holland, Habit and DudaRosenblatt (1958) created the perceptron, an algorithm for pattern recognition. With mathematical notation, Rosenblatt described circuitry not in the basic perceptron, such as the exclusive-or circuit that could not be processed by neural networks at the time. In 1959, a biological model proposed by Nobel laureates Hubel and Wiesel was based on their discovery of two types of cells in the primary visual cortex: simple cells and complex cells. The first functional networks with many layers were published by Ivakhnenko and Lapa in 1965, becoming the group method of data handling. Neural network research stagnated after machine learning research by Minsky and Papert (1969), who discovered two key issues with the computational machines that processed neural networks. The first was that basic perceptrons were incapable of processing the exclusive-or circuit. The second was that computers didn't have enough processing power to effectively handle the work required by large neural networks. Neural network research slowed until computers achieved far greater processing power.

3.3 Hardware-based designs

Computational devices were created in CMOS, for both biophysical simulation and neuromorphic computing. Nanodevices for very large scale principal components analyses and convolution may create a new class of neural computing because they are fundamentally analog rather than digital (even though the first implementations may use digital devices.) Ciresan and colleagues (2010) in Schmidhuber's group showed that despite the vanishing gradient problem, GPUs makes backpropagation feasible for many-layered feed forward neural networks. Between 2009 and 2012, recurrent neural networks and deep feedforward neural networks developed in the Schmidhuber's research group, winning eight international competitions in pattern recognition and machine learning. For example, the bi-directional and multi-dimensional long short-term memory (LSTM) of Graves et al. won three competitions in connected handwriting recognition at the 2009 International Conference on Document Analysis and Recognition (ICDAR), without any prior knowledge about the three languages to be learned. Ciresan and colleagues won pattern recognition contests, including the IJCNN 2011 Traffic Sign Recognition Competition, the ISBI 2012 Segmentation of Neuronal Structures in Electron Microscopy Stacks challenge and others. Their neural networks were the first pattern recognizers to achieve human-competitive or even superhuman performance on benchmarks such as traffic sign recognition (IJCNN 2012), or the MNIST handwritten digits problem. Researchers demonstrated (2010) that deep neural networks interfaced with a hidden Markov model with context-dependent states that define the neural network output layer can drastically reduce errors in large-vocabulary speech recognition tasks such as voice search. GPU-based implementations of this approach won many pattern recognition contests, including the IJCNN 2011 Traffic Sign Recognition Competition, the ISBI 2012 Segmentation of neuronal structures in EM stacks challenge, the ImageNet Competition and others. Deep, highly nonlinear neural architectures similar to the neocognitron and the "standard architecture of vision", inspired by simple and complex cells were pretrained by unsupervised methods by Hinton. A team from his lab won a 2012 contest sponsored by Merck to design software to help find molecules that might identify new drugs.

3.4 Convolution networks

As of 2011, the state of the art in deep learning feed forward networks alternated convolution layers and max-pooling layers, topped by several fully or sparsely connected layers followed by a final classification layer. Learning is usually done without unsupervised pretraining. Such supervised deep learning methods were the first artificial pattern recognizers to achieve human-competitive performance on certain tasks.ANNs were able to guarantee shift invariance to deal with small and large natural objects in large cluttered scenes, only when invariance extended beyond shift, to all ANN-learned concepts, such as location, type (object class label), scale, lighting and others. This was realized in Developmental Networks (DNs) whose embodiments are where-What Networks, WWN-1 (2008) through WWN-7 (2013).

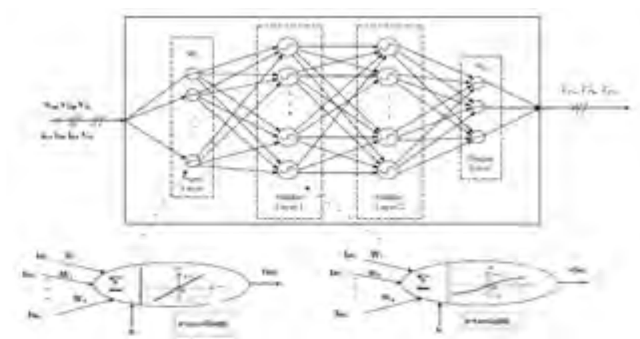


Figure 4: *Neural network for estimation of reference injected current.*

3.5 The structure of ANN

Neural networks are models of biological neural structures. The starting point for most neural networks is a model neuron, as in Figure 5. This neuron consists of multiple inputs and a single output. Each input is modified by a weight, which multiplies with the input value. The neuron will combine these weighted inputs and, with reference to a threshold value and activation function, use these to determine its output. This behaviour follows closely real understanding of how real neurons work.

While there is a fair understanding of how an individual neuron works, there is still a great deal of research and mostly conjecture regarding the way neurons organize themselves and the mechanisms used by arrays of neurons to adapt their behaviour to external stimuli. There are a large number of experimental neural network structures currently in use reflecting this state of continuing research. In our case, we will only describe the structure, mathematics and behaviour of that structure known as the back propagation network. This is the most prevalent and generalized neural network currently in use. To build a back propagation network, proceed in the following fashion. First, take a number of neurons and array them to form a layer. A layer has all its inputs connected to either a preceding layer or the inputs from

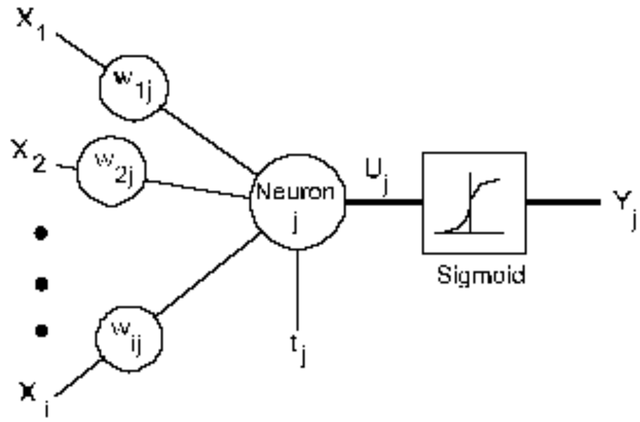


Figure 5: *Model of neural.*

the external world, but not both within the same layer. A layer has all its outputs connected to either a succeeding layer or the outputs to the external world, but not both within the same layer. Next, multiple layers are then array one succeeding the other so that there is an input layer, multiple intermediate layers and finally an output layer, as in figure 6. Intermediate layers, that are those that have no inputs or outputs to the external world, are called hidden layers. Back propagation neural networks are usually fully connected. This means that each neuron is connected to every output from the preceding layer or one input from the external world if the neuron is in the first layer and, correspondingly, each neuron has its output connected to every neuron in the succeeding layer.

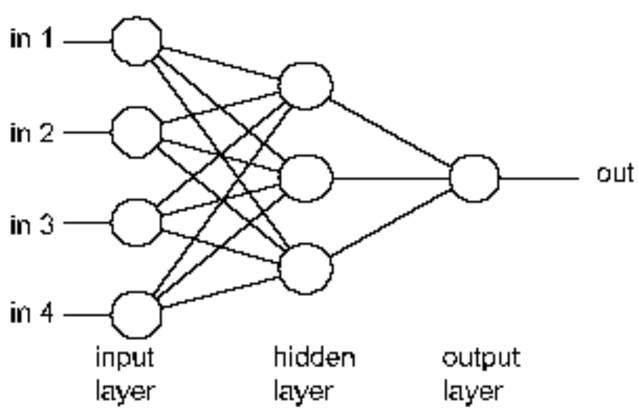


Figure 6: *Backpropagation Network.*

Generally, the input layer is considered a distributor of the signals from the external world. Hidden layers are considered to be categorizers or feature detectors of such signals. The output layer is considered a collector of the features detected and producer of the response. While this view of the neural network may be helpful in conceptualizing the functions of the layers, you should not take this model too literally as the functions described may not be so specific or localized.

4 MODEL FOR LOAD FLOW

Steady state analysis of a power system in the presence of a Unified Power Quality Condition (UPQC) would necessitate a model for the UPQC to be included in load flow studies. It is well known that for solving load flows, real and reactive power at load buses, real power and voltage at generator buses. Voltage and angle at slack bus have to be specified. An appropriate model for UPQC in terms of real and reactive power needs to be developed to incorporate it in to the load flow. This chapter provides the details of the load flow model used for UPQC. A flow chart depicting the procedure for conducting load flow studies with UPQC model has been presented. The results of load flow studies are important as it provides the initial conditions for conducting small-signal and transient stability studies. Further, the design of the fuzzy logic knowledge base for the sense inverter of a UPQC is based on computer simulations which require accurate load flow solutions.

4.1 Mode1 of UPQC

The construction and operation of a unified power controller have been discussed. In a Unified Power Quality Condition consists of two voltage source inverters (VSI) connected back to back with a common DC coupling capacitor as shown in figure 7. Such an arrangement allows for dl the three functions namely series, shunt and phase angle compensation to be unified into one unit. Inverter-1 is connected to the power system through a transformer Ti in shunt and the inverter-2 is connected to the power system through another transformer TT such that the secondary of the transformer T2 is in series with the transmission line. The transformers Ti and T2 would be referred to as shunt and series transformers respectively for the purpose of clarity.

The model given in reference where the shunt inverter and sense inverter of a UPQC are modelled as a voltage source in sense with their transformer reactance is the simplest of al1 the models. The model provides for detailed interaction between the series and the shunt inverter. Figure 8 shows the UPQC model. Xrh and X,, represent the reactance of transformer Ti and T2 respectively. Vshand V, represent the voltage generated by the shunt and the sense inverter respectively. Bus-E and bus-F represent the UPQC bus and the transmission line side bus of UPQC respectively.

For performing load flow studies with UPQC, the series and the shunt inverters are assumed to produce balanced 60 Hz voltages of variable magnitude and phase

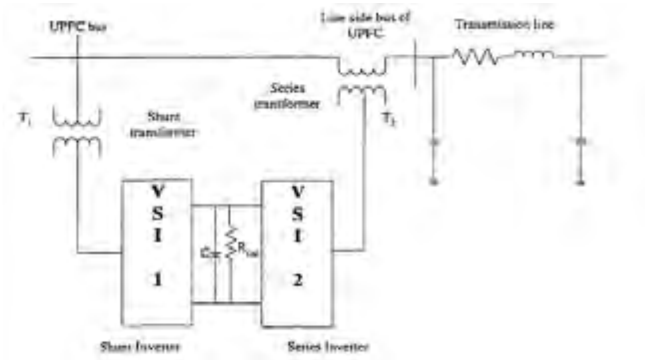


Figure 7: *Unified Power Quality Condition configuration.*

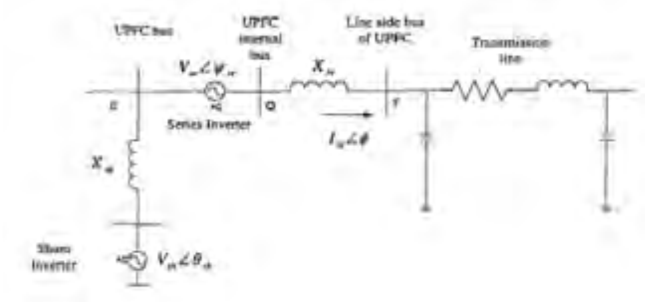


Figure 8: *UPQC model.*

angle. The shunt and the sense voltage sources phasorscan be mathematically represented.

4.2 Load flow procedure

It is well known that load flow analysis is an iterative type of solution. UPQC has the capability of controlling the real power and transmission Line side bus voltage/reactive power flow in a transmission line. Referenceprovides a very simplistic method to solve load flow that is only applicable to small power systems. The method requires information regarding the short circuit impedance at the bus where the UPQC is to be installed. The algorithm provided to perform load flow study is applicable only to assess the impact of UPQC on power systems in a localized way. Niakihasrevised a simpler method of performing load fiowwith UPQC. Here the bus to which the shunt inverter is connected is modelled as a PQ bus and the transmission line side bus is modelled as a PV bus. This method works only when the variables namely, the UPQC bus voltage, real power flow in the transmission line, transmission line side bus voltage are controlled simultaneously. This method will fail if one wishes to control a subset of them. Further, the solution obtained is multi-valued, meaning that one could obtain a load flow solution that could not be feasible or the UPQC parameters could be out of acceptable limits. This requires that the variables be confined within acceptable limits to obtain feasible solutions. To obtain a load flow solution with a specified real power flow in the transmission line and transmission line side voltage with UPQC, the series voltage source Vseis decomposed into two phasors. Figure 9 shows the phasor diagram with the two components of the series voltage source. The UPQC bus voltage phasor is denoted by VE. One phasor denoted by V,, is in quadrature with the UPQC bus voltage phasor(VE) and the other phasor denoted by Vsepi s in-phase with the UPQC bus phasor(VE).T he function of the quadrature component of the sense voltage source V,, is to Vary the phase angle of bus VE to achieve a specified real power flow in the transmission line. The function of the in-phase component of the series voltage source Vseips to achieve a specified transmission line side voltage. The net voltage phasorV, (the phasor sum of VSepan d V') is denoted by phasor AD in Fig.4.4. The D and the Q axes refer to the network ais. Since the series voltage phasorV, is added to the UPQC bus voltage phasorV', the quadrature component of the series voltage that controls the real power has little effect on the reactive power. This is because the quadrature component of the series voltage changes the phase angle with little change in the magnitude of the bus voltage on the transmission line side (Vh,). The in-phase component controls the voltage of the bus on the transmission line side (Vk) has greater effect on the reactive power than on the real power in the transmission line. This is because the in-phase component has little effect on the phase angle. Thus the interaction between the control of real and reactive power flow in a transmission line is to a great extent reduced. This allows the load flow solution process of achieving a specified real power flow in the transmission line and a line side voltage to be separated.

5 MC-UPQC WITH ANN APPROACH

Multi converter -Unified power quality conditioner (MC-UPQC) is one of the new power electronics devices that are used for enhancing the PQ. This work presents a new unified power-quality conditioning system (MC-UPQC), capable of simultaneous compensation for voltage and current in multibus/ multifeeder systems. The discharging time of DC link capacitor is very high, and so it is the main problem in MC- UPQC device. To eliminate this problem, an enhanced ANN based MC-UPQC is proposed in this work. The DC capacitor charging output voltage is increased and the response is fast when compared with PI by using the ANN controller and hence, the PQ of the system is enhanced. The

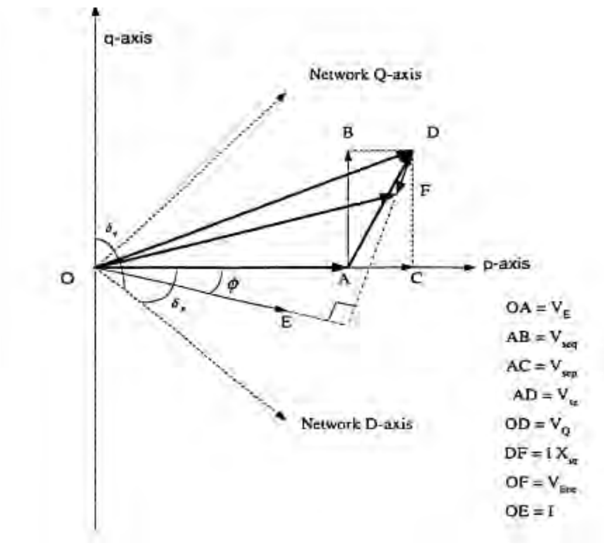


Figure 9: *Phasor diagram showing the two components of the series voltage source*

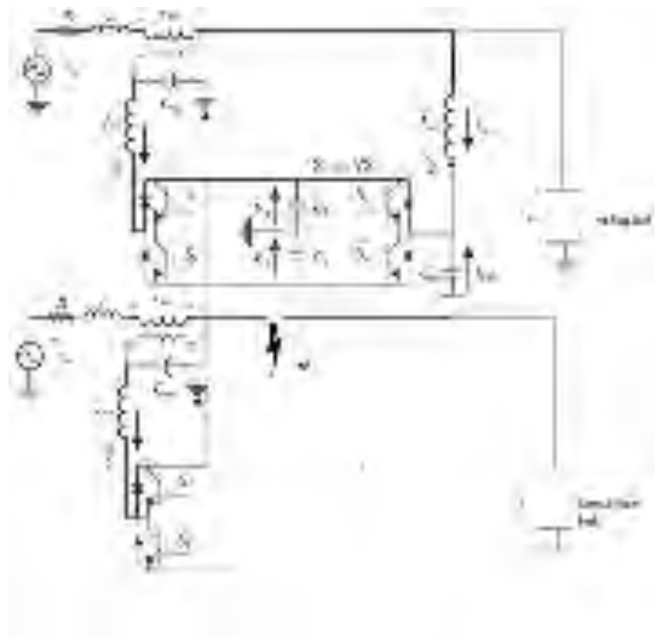


Figure 10: *Schematic diagram of proposed system.*

controllable voltage source used in the proposed system is shown in figure 11.

The proposed system consists of two types of load. They are liner load and non-linear load. The simulation diagram of liner load is shown in figure 12. The simulation diagram of non-liner load is shown in figure 13.

The measurement block in the proposed system simulation is shown in figure 14. The program used in ANN based UPQC is shown in figure 15.

The simulation diagram of the proposed UPQC is shown in figure 16 and the overall system is shown in figure 17.

The behavior of the complete system Multi Converter unified power quality conditioning (MC-UPQC) for various Loads with ANN Approach to Two Source Concept.

MATLAB/Simulink. A three-phase diode rectifier feeding an RL load is considered as nonlinear load. The maximum load power demand is considered as 13 kW + j10 kVAR. The values of source resistance Rs = 0.1 ω and source inductance Ls = 0.1 mH. DC link capacitor value is 2200 μF. To test the operation of UPQC under the voltage sag and swell conditions, 20% sag in line voltage has been created. The UPQC has been simulated using the proposed ANNC. The source current waveform before and after connecting the UPQC is shown in figure 18. It may be noticed that the source current is distorted before connecting the UPQC and it becomes sinusoidal after connecting the UPQC at 0.1s.

The THD of the source current before connecting the UPQC is 24.54%. Harmonic spectrum of the source current after connecting the UPQC is shown in figure 20. The THD of the source current after connecting

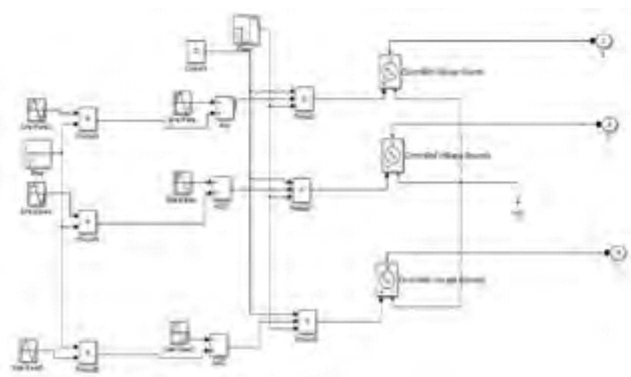


Figure 11: *Controllable voltage source.*

the UPQC is 0.06. The DC link capacitor voltage is held constant at its reference value by the ANNC. To investigate the performance of the proposed UPQC using ANNC, under voltage sag condition, 20% sag has been created in the all the phases of the supply voltage.

6 CONCLUSION

UPQC using ANN has been investigated for compensating reactive power and harmonics. It is clear from the simulation results that the UPQC using ANNC is simple, and is based on sensing the line currents only. The THD of the source current using the proposed ANNC is well below 5%, the harmonic limit imposed by IEEE-519 standard.

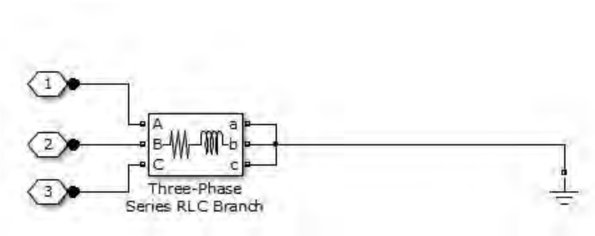


Figure 12: *Linear load.*

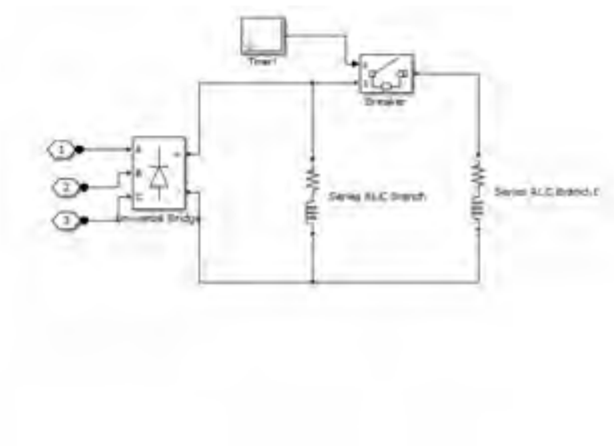


Figure 13: *Non-linear load.*

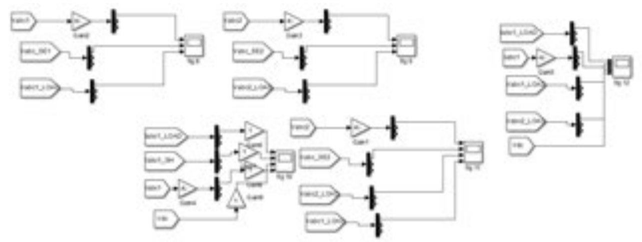


Figure 14: *Measurement blocks.*

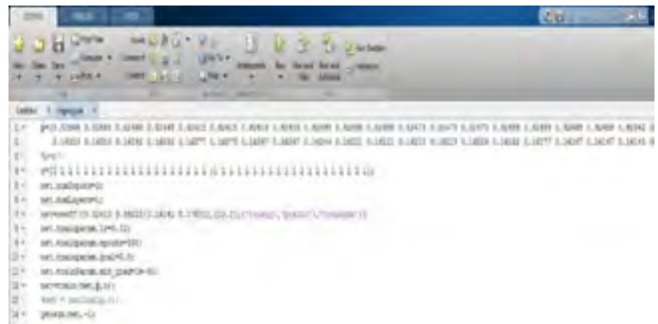


Figure 15: *Program in ANN.*

References

[1] K. Chen, "The impact of energy efficient equipment on system powerquality," in Proc. IEEE Ind. Appl. Conf., 2000, vol. 5, pp. 3240–3247.

[2] Ranade and W. Xu, "An overview of harmonics modeling and simulation,"inTutorial on Harmonics Modeling and Simulation. Piscataway,NJ: IEEE Power Eng. Soc., 1998, pp. 1–5.

[3] A. Thapar, T. K. Saha, and Y. D. Zhao, "Investigation of power quality categorizationand simulating its impact on sensitive electronic equipment,"inProc. IEEE Power Eng. Soc. Gen. Meeting, 2004, vol. 1, pp. 528–533.

[4] J. D. Barros and J. F. Silva, "Multilevel optimal predictive dynamic voltagerestorer," IEEE Trans. Ind. Electron., vol. 57, no. 8, pp. 2747–2760,Aug. 2010.

[5] A. M. Massoud, S. Ahmed, P. N. Enjeti, and B. W. Williams, "Evaluationof a multilevel cascaded-type dynamic voltage restorer employing discontinuousspace vector modulation," IEEE Trans. Ind. Electron., vol. 57, no. 7, pp. 2398–2410, Jul. 2010.

[6] D. E. Kim and D. C. Lee, "Feedback linearization control of three-phaseUPS inverter systems," IEEE Trans. Ind. Electron., vol. 57, no. 3, pp. 963–968, Mar. 2010.

[7] K. Balachander, V. Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology (IJMET), Volume 3, Issue 1, January- April (2012), pp. 179-186.

[8] K. Balachander, Vijayakumar Ponnusamy, 'Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research' (IJAER), Volume 7, Number 3 (2012), pp. 247-256

[9] K. Balachander, S. Kuppusamy, Vijayakumar Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[10] K. Balachander, 'A Review of Modeling and Simulation of PV Module', Elixir, Electrical Engineering, 42 (2012) pp. 6798-6802.

[11] S. Kuppusamy, K. Balachander, 'Embedded based capacitance fuel level sensor', Elixir, Electrical Engineering, 43 (2012) pp. 6751-6754

[12] K. Balachander, S. Kuppusamy, Vijayakumar Ponnusamy, '"Comparative Study of Hybrid

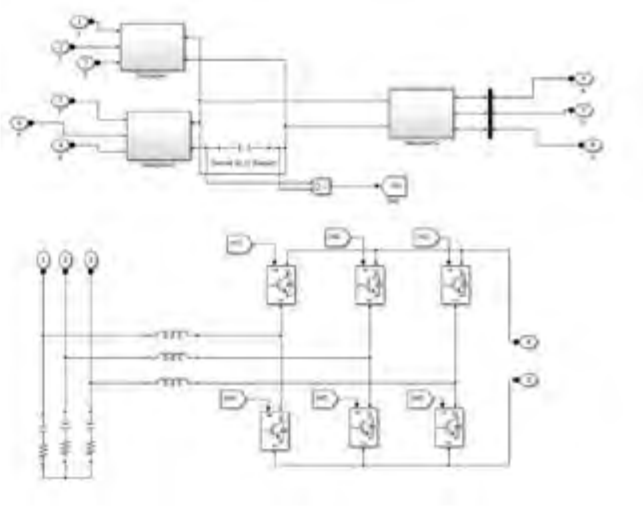


Figure 16: *Proposed UPQC*

Figure 17: *Overall proposed system.*

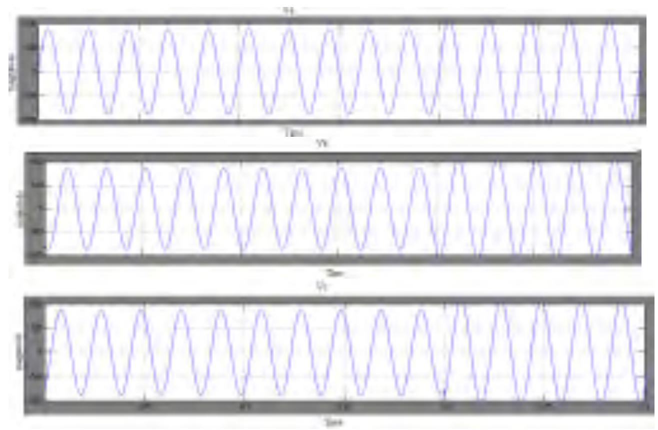


Figure 18: *Voltage waveforms of the system without UPQC.*

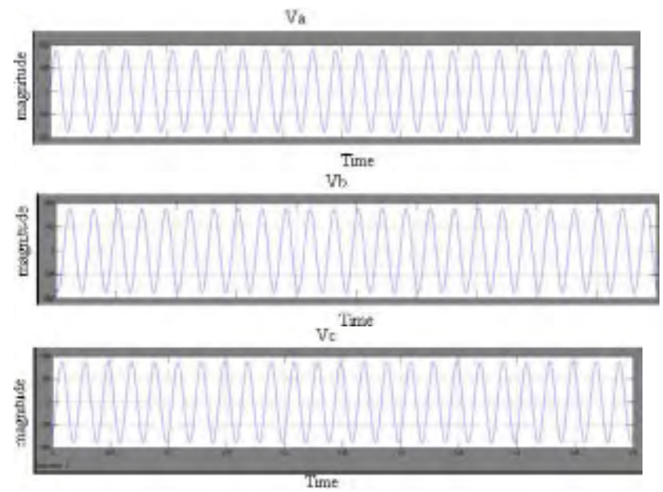


Figure 19: *Voltage waveform with ANNC controlled UPQC.*

Photovoltaic-Fuel Cell System / Hybrid Wind-Fuel Cell System for Smart Grid Distributed Generation System" Proceedings of IEEE International Conference on Emerging Trends in Science, Engineering and Technology at JJ Collage of Engineering, Trichy on 13th and 14th December 2012. DOI: 10.1109/ INCOSET. 2012.6513950, pp.462-466.

[13] ShashidharKasthala,GKDPrasannaVenkatesan,Amudha. A "MIMO PLC Channel Modeling on Indian Residential Networks" International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 14 (2017) pp. 4145-4151.

[14] ShashidharKasthala,GKDPrasannaVenkatesan,Amudha. A "Design and Development of protective coupling interface for characterizing the residential Broadband PLC channel" Journal of Advanced Research in Dynamical and control systems ,1943-023X,Volume 9,SI 2 (2017) pp. 1-15.

[15] Mary p.Varghese ,Amudha. A "A Hybrid Method for solving Unit Commitment Problem with wind power uncertainty" International journal of Control Theory and Applications, Volume 10, (2017) pp. 79-98.

[16] M. Sivaram Krishnan, M. Siva Ramkumar,and A. Amudha, "Frequency Deviation Control in Hybrid Renewable Energy System using FC-UC" International journal of Control Theory and Applications, Volume 10, Number 2 (2017) pp. 333-344.

[17] Amudha. A "Home Automation using IoT" International Journal of Electronics Research,Vol.09 (06),June 2017,pp939-944.

[18] S.Selvaperumal, P.Nedumalpugazhenthi, Amudha. "Aclosed loop performance investigation of various

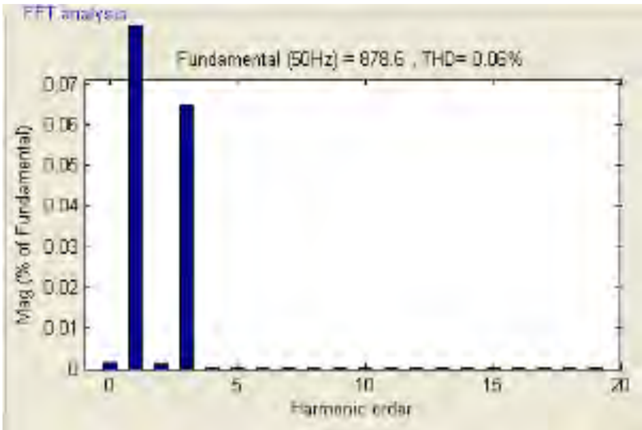


Figure 20: *Total harmonic distortion of system with ANNC.*

controllers based chopper fed drive in marine Applications"Indian Journal of Marine Geo Sciences Vol.46 (05),May 2017,pp1044-1055.

[19] Balachander. K, Amudha. A, "Design and Hardware Implementation of Interleaved

[20] Boost Converter Using Sliding Mode Approach"International Journal of Electronics Engineering Research.Volume 9, Number 5 (2017) pp. 745-750.

[21] R. Gayathri and A. Amudha"Solar Powered Traffic Control System Based on Traffic density with Emergency Vehicle Alert", Middle-East Journal of Scientific Research 24 (2): 234-238, 2016

[22] G. Emayavaramban, A. Amudha, , Identifying Hand Gestures Using SEMG For Human Machine Interaction, ARPN Journal of Engineering and Applied Sciences, VOL. 11, NO. 21,12777-12785, 2016.

[23] G. Emayavaramban, A. Amudha, sEMG based Classification of Hand Gestures using Artificial Neural Network, International Journal of Science and Technology, 9 (35) & 1-10, 2016.

CASCADE COCKCROFT-WALTON VOLTAGE MULTIPLIER APPLIED TO TRANSFORMERLESS HIGH STEP-UP DC-DC CONVERTER

S.S. Kumar, M.S. Ramkumar, A. Amudha, K. Balachander, G. Emayavaramaban

Abstract: This research proposes a change of magnitude dc-dc device supporting the Cockcroft-Walton (CW) voltage number while not a transformer, providing continuous input current, with low ripple, high voltage, quantitative relation and low voltage stress on the switches, diodes, and capacitors. The projected device should be appropriate for applying to low-input-level dc generation systems. In this study, the projected management strategy employs 2 freelance frequencies, one that operates at high frequency to attenuate the scale of the inductance and an opposite one that operates at the comparatively low frequency in keeping with the required output voltage ripple.

Keywords: Cockcroft–Walton (CW) voltage multiplier factor, high voltage quantitative relation, structure electrical converter, increase dc- dc device.

1 Introduction

Cockcroft–Walton (CW) voltage multiplier factor, high voltage quantitative relation, structure electrical converter, increase dc-dc device. The CW could be a voltage multiplier factor that converts AC or pulsing DC electric power from an occasional voltage level to the next DC voltage level. It's created of a voltage multiplier factor ladder network of capacitors and diodes to get high voltages. Unlike transformers, this technique eliminates the need for the serious core and therefore the bulk of insulation/potting needed. [1–5]mistreatment solely capacitors and diodes, these voltage multipliers will maximize comparatively low voltages to extraordinarily high values, whereas at an equivalent nonce way lighter and cheaper than transformers. The most important advantage of such circuits is that the voltage across every stage of the cascade is adequate to solely double the height input voltage in an exceedingly half-wave rectifier. In an exceedingly rectifier, it's thrice the input voltage. It's the advantage of requiring comparatively cheap elements and being simple to insulate. One may faucet the output from any stage, like in an exceedingly multi-tapped electrical device. In observing, the CW incorporates a variety of drawbacks. Because the variety of stages is accumulated, the voltages of the upper stages begin to "sag", primarily as a result of the electrical electric resistance of the capacitors within the lower stages. Also, once supply AN output current, the voltage ripple apace will increase because the variety of stages is accumulated. For these reasons, CW multipliers with a sizable amount of stages are used solely wherever comparatively low output current is needed. These effects will be partly remunerated by increasing the capacitance within the lower stages, by increasing the frequency of the input power and by mistreatment an AC power supply with an sq. or triangular waveform. By driving the CW from a high-frequency supply, like AN electrical converter, or a combination of associate degree electrical converter and HV electrical device, the physical size and weight of the CW power offer may be well reduced. CW multipliers area unit generally wont to develop higher voltages for comparatively low-current applications, like bias voltages starting from tens or many volts to numerous volts for high-energy physics experiments or lightning safety testing. CW multipliers also are found, with a better variety of stages, an optical maser systems, high-voltage power supplies, X-ray systems, LCD backlighting, traveling-wave tube amplifiers, ion pumps, static systems, air ionizers, particle accelerators, copy machines, scientific instrumentation, oscilloscopes television sets and cathode ray tubes, ECT weapons, bug zappers and many other applications that use high-voltage DC. Within the past few decades, the high-voltage dc power provided is widely applied in industries, science, medicine, military, equipment, such as X-ray systems, dirt filtering, insulating check, and static coating [6–9].

2 Existing System

The conventional boost dc-dc device will offer a high voltage gain by victimization a very high duty cycle. However, much, parasitic components related to the electrical device, capacitor, switch, and diode can't be unheeded, and their effects cut back the theoretical voltage gain. Up to now, several changes of magnitude dc-dc converters are to get high voltage ratios while not extraordinarily high duty cycle by victimization isolated transformers or coupled inductors. Among these high change of magnitude dc-dc converters, voltage-fed kind sustains high input current ripple. Thus, providing a low input current ripple and high voltage quantitative relation, current-fed converters square measure usually superior to their counterparts. The standard Cockcroft-Walton (CW) voltage number is extremely in style among high-voltage dc applications. However, the foremost downside is that a high ripple voltage seems at the output once a low-frequency (50or60Hz) utility supply is employed [7–12].

3 Planned system

In this paper, a high change of magnitude device supported the CW voltage number is planned. Replacement of the transformer with the boost-type structure, the planned device provides higher voltage quantitative relation than that of the standard CW voltage number. Thus, the planned device is appropriate for power conversion applications wherever high voltage gains square measure desired. Moreover, the planned device operates in continuous conductivity mode (CCM); therefore the switch stresses, the switch losses, and EMI noise are often reduced similarly [12–18].

4 CW number Techniques

The CW could be a voltage number that converts AC or pulsing DC power from an occasional voltage level to the next DC voltage level. It's created from a voltage number ladder network of capacitors and diodes to come up with high voltages. In contrast to transformers, this methodology eliminates the need for the significant core and also the bulk of insulation/potting needed. Victimization solely capacitors and diodes, these voltage multipliers will boost up comparatively low voltages to extraordinarily high values, whereas at a similar nonce way lighter and cheaper than transformers. The most important advantage of such Circuits is that the voltage across every stage of the cascade is capable solely doubly the height input voltage during a half-wave rectifier. During a rectifier, it's thrice the input voltage. It's the advantage of requiring comparatively affordable elements and being straightforward to insulate. One may faucet the output from any stage, like during a multi-tapped electrical device [11–14].

5 structure electrical converter Techniques

The cascaded H-bride multi-level electrical converter is to use capacitors and switches and needs less variety of elements in every level. This topology consists of a series of power conversion cells and power are often simply scaled. The mix of capacitors and switches combine is named an H-bridge and provides the separate input DC voltage for every H-bridge. It consists of H-bridge cells, and every cell will give the 3 different voltages like zero, positive DC and negative DC voltages. One among the benefits of this kind of multi-level electrical converter is that it desires less variety of elements compared with diode clamped and flying electrical device inverters. The worth and weight of the electrical converter are but those of the 2 inverters. Soft-switching is feasible by the number of the new switch strategies. Construction cascade inverters are accustomed eliminate the large electrical device needed just in case of typical multi-section inverters, clamping diodes needed in case— just in case of diode-clamped inverters and flying electrical devices needed in case of flying capacitor inverters. However, these need a sizable amount of isolated voltages to produce every cell [19].

5.1 Common Mode Voltage:

The construction inverters manufacture common mode voltage, reducing the strain of the load and don't harm the load.

5.2 Input Current:

construction inverters will draw input current with low distortion

5.3 switch Frequency:

The construction electrical converter will operate at each elementary switch frequencies that are higher switch frequency and lower switch frequency. It ought to be noted that the lower switch frequency means that lower switch loss and better potency is achieved.

5.4 Reduced harmonic distortion:

Selective harmonic elimination technique at the side of the multi-level topology results the overall harmonic distortion becomes low within the output wave while not victimization any filter circuit.

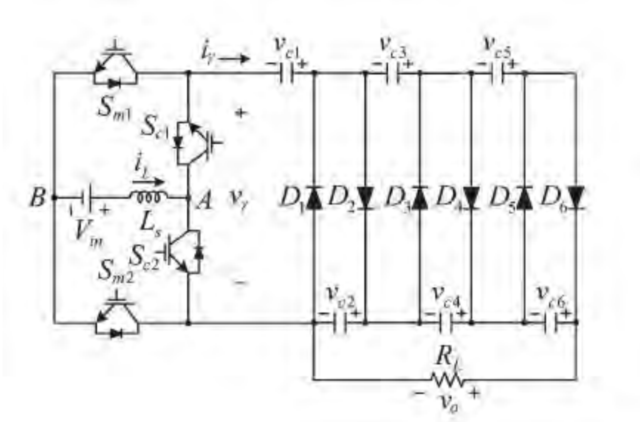


Figure 1: *CW Voltage Multiplier Circuit.*

6 Proposed three stage CW multiplier Diagram

7 Circuit Operations and Principle

In order to change the analysis of circuit operation, the projected convertor with a three-stage CW voltage number, as shown in Fig. 7, is used. Before analyzing, some assumptions area unit created as follows.

1. All of the circuit parts area unit ideal, and there's no power loss within the system.
2. once a high-frequency periodic electrical energy is fed into the CW circuit, and every one of the capacitors within the CW voltage number area unit sufficiently massive, the free fall and ripple of every electrical condenser voltage will be neglected underneath an affordable load condition. Thus, the voltages across all capacitors area unit equal, except the primary electrical condenser whose voltage is one 1/2 the others.
3. The projected convertor is working in CCM and within the steady-state condition.
4. once the inductance transfers the stored energy to the CW circuit, just one of the diodes within the CW circuit is conducted.
5. Some safe commutation states area unit neglected [7–15].

1. *State I*: Sm1 and Sc1 area unit turned on, and Sm2, Sc2, and every one CW diodes area unit turned off, as shown in Fig. 9(a). The input dc supply charges the boost inductance, the even cluster capacitors C6, C4, and C2 provide the load, and also the odd -group capacitors C5, C3, and C1 area unit floating.
2. *State II*: Sm2 and Sc1 area unit turned on, Sm1 and Sc2 area unit turned off, and also the current i√ is positive. The boost inductance and input dc supply transfer energy to the CW voltage number through totally different even diodes, state II-A, D6 is conducting; therefore, the even-group capacitors C6, C4, and C2 area unit charged, and also the odd-group capacitors C5, C3, and C1 area unit discharged by i√. State II-B, D4 is conducting. Thus, C4 and C2 area unit charged, C3 and C1 area unit discharged by i√, C6 provides load current, and C5 is floating. State II-C, D2 is conducting. Thus, C2 is charged, C1 is discharged by i√, C6 and C4 provide load current, and C5 and C3 area unit floating.
3. *State III* Sm2 and Sc2 area unit turned on, and Sm1, Sc1, and every one CW diodes area unit turned off. The input dc supply charges the boost inductance, the even cluster capacitors C6, C4, and C2 provides the load, and also the odd-group capacitors C5, C3, and C1 area unit floating. 4) State IV: Sm1 and Sc2 area unit turned on, Sm2 and Sc1 area unit turned off, and also the current i√ is negative. The boost inductance and input dc supply transfer energy to the CW voltage number through totally different odd diodes. State IV-A, D5 is conducting. Thus, the even-group capacitors, except C6 that provides load current, area unit discharged, and also the odd-group capacitors C5, C3, and C1 area unit charged by i√.
4. *State IV-B*, D3 is conducting. Thus, C2 is discharged, C3 and C1 area unit charged by i√, C6 and C4 provide load current, and C5 is floating. State IV-C, D1 is conducting. Thus, C1 is charged by i√, all even capacitors offer load current, and C5 and C3 area unit floating [11–20].

Table 1.

System Specifications of the Prototype

Output power, P_0	200W
Output voltage, V_0	450V
Input dc voltage, V_{in}	42-54V
Modulation frequency, f_{sm}	60kHz
Alternating frequency, f_{st}	1kHz
Resistive load, R_L	1kΩ
Stage number, n	3

Table 2.

COMPONENT LIST FOR THE PROTOTYPE

Components Description	Symbol	Value/Part no.
Control IC	-	ICE1PCS01
CPLD	-	LC4256V
Boost inductor	L_s	1.5mH
Power switches	S_{m1}, S_{m2}, S_{c1}, S_{c2}	IRF640
Capacitors	$C_1 \sim C_6$	470μF/400V
Diodes	$D_1 \sim D_6$	SF20L60U
Gate driver	-	HCPL-3120

8 Capacitance of CW Voltage Multiplier

A major advantage of the quality CW voltage number is that the voltage gain is on paper proportional to the number of cascaded stages. Inside the previous section, the most effective voltage gain (unloaded) is assumed to switch the Circuit analysis. Sadly, once a load is connected to the load side of the system, the free fall and ripple across every electrical condenser can't be unremarked. Voltage-fed mode, throughout that the input terminal of the CW voltage number was fed by a recurved voltage provide, was used for analyzing free fall and ripple for CW multipliers in most works of literature, whereas only a few publications mentioned current fed mode. Throughout this paper, for analyzing the free fall and ripple, constant discontinuous-pulse-type current provide is fed into the CW voltage number. In step with the current-fed mode analytical principle given inside the drop and ripple associated with each capacitance area unit usually found by the charge-discharge behavior of capacitors beneath the steady-state condition.

9 Input Inductance

The value of the boost electrical device may be calculated by

$$L_s = V_{\text{in}} \frac{DT_{\text{sm}}}{K_I I_{\text{pk}}}$$

.

where KI is that the expecting proportion of the most peak to-peak current ripple in the inductor.

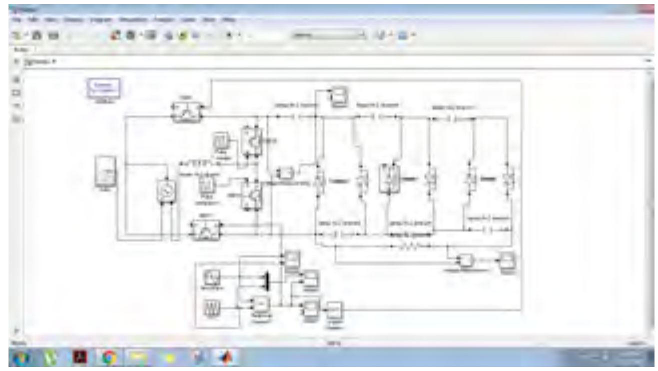


Figure 2: *simulation diagram.*

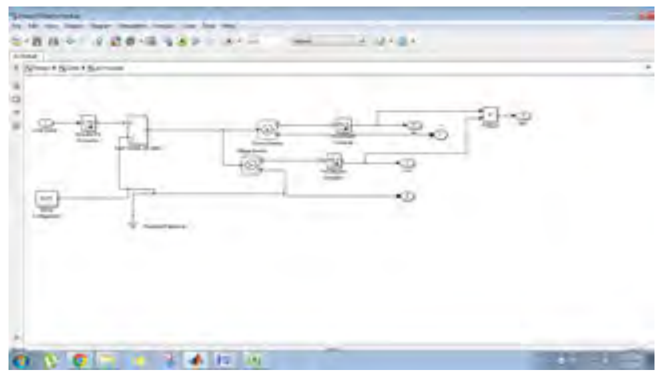


Figure 3: *solar module.*

10 Simulation And Experimental Results

Math work Simulink is applied to estimate the mathematic model and management strategy of the planned device. Some selected waveforms of the planned device at Po = two hundred W, Vin = 48 V, and Vo = 450 V for each simulation and experiment are shown in fig. The shift signals of simulation for the four switches, within which Sc1 and Sc2 are operated at fsc and Sm1 and Sm2 are operated at fsm. Moreover, the simulation results of the output voltage vo, the input current iL, the terminal voltage v√, and current i√ of the CW voltage multiplier factor are shown. The experimental waveforms of the shift signals, vo, iL, v√, and i√. The simulation results well trust the experimental results. In the theoretical analysis, the input current ripple frequency (fsc) is unheeded as a result of the very fact that the electrical condensers are assumed giant enough to get stable capacitor voltages with no voltage ripple within the CW voltage multiplier factor. However, the voltage ripple exists much altogether capacitors. In alternative words, the input current and also the output voltage have a similar ripple frequency (fsc). The results of conjointly

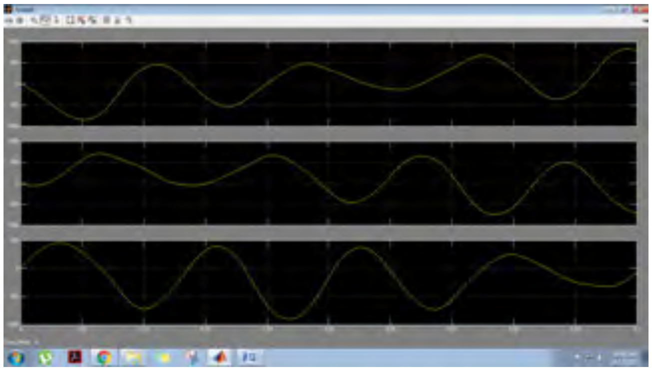


Figure 4: *output voltage diagram.*

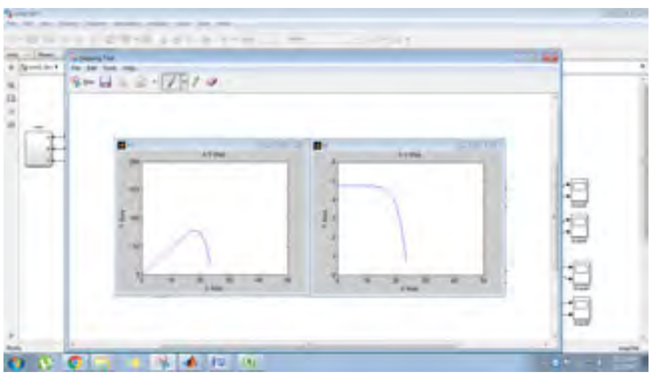


Figure 5: *solar pv, iv graph.*

influence the terminal voltage v√ and current i√ of the CW voltage multiplier factor [20–22].

11 Conclusion

In this paper, a high increase dc-dc device supported the CW voltage multiplier factor while not a line- or high-frequency step up electrical device has been given to get a high voltage gain. Since the voltage stress on the active switches, diodes, and capacitors isn't laid low with the number of cascaded stages, power components with a similar voltage rating will be selected. The techniques gate operation are thought-about during this paper. The planned management strategy employs 2 freelance frequencies, one in all that operates at high frequency to attenuate the scale of the electrical device whereas the opposite one operates at a comparatively low frequency in step with the specified output voltage ripple. Finally, the simulation and experimental results tested the validity of the theoretical analysis and also the practicableness of the planned device. In future work, the influence of loading on the output voltage of the planned device is Derived for finishing the steady-state analysis.

References

[1] X. Hu, C. Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Power Management of a Hybrid Solar- Wind Energy System" International Journal of Engineering Research & Technology vol. 3(2) pp.1988–1992, 2014.

[3] M. Siva Ramkumar, M. Sivaram Krishnan, A. Amudha. "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239–245, 2017.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc " in International Journal of Control Theory and Applications, 10 (2) pp 333–344, 2017.

[5] M Siva RamKumar, Dr. A Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485–6488, 2016.

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763–769,2014.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361–1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2),2014

[9] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1–10, September 2016.

[10] D. Kavitha, Dr. C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973–4562 Vol. 10 No.20 (2015), pg. 17749–17754.

[11] D. Manoharan, Dr. A. Amudha. "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973–4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, Dr. A. Amudha. A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973–4562 Volume 10, Number 3 (2015) pp. 6233–6240.

[13] Dr. A. Amudha. "Enhancement of Available Transfer Capability using FACTS controller" in International journal of Applied Mechanics and Materials, Vol. 573, pp 340–345

[14] K. Balachander, Dr. P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035–2042.

[15] K. Balachander, Dr. P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, Dr. P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839–847.

[17] K. Balachander, Dr. P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, Dr. Vijayakumar Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179–186.

[19] K. Balachander, Dr. Vijayakumar Ponnusamy, 'Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research', Volume 7, Number 3 (2012), pp. 247–256.

[20] K. Balachander, S. Kuppusamy, Dr. Vijayakumar Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111–118.

[21] M. Sivaram Krishnan, A. Amudha, M. Siva Ramkumar, 'Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms', International journal of Pure and Applied Mathimatics,118 (11), pp 609–617,2018 DOI:10.12732/ijpam.v118i11.79

[22] S. Motapon, L. Dessaint, K. AI-Haddad, "A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, " IEEE Trans. Ind. Electron., vo1.61, no.3, pp.1320,1334, March 2014.

DESIGN AND IMPLEMENTATION OF SERIES Z-SOURCE MATRIX CONVERTERS

S. Vivekanandan, M.S. Ramkumar, A. Amudha, M.S. Krishan, D. Kavitha

ABSTRACT: Series Z-Source network, Associate in Nursing enlargement of the favored conception of Z-source dc link, was initially projected for enhancing the output voltage of power electronic inverters. Throughout this paper, that concept is extended on a three-phase indirect matrix converter. The converter depends on the ultra-sparse matrix topology characterized by the minimum vary of semiconductor switches. The series Z-source network is placed between the three-switch input rectifier stage and additionally the six-switch output electrical converter stage, in either the positive or negative rail. A short shoot-through state produces the voltage boost. Associate in Nursing optimum pulse breadth modulation technique is developed for higher boosting capability of the converter and reduce of switch losses. A comparison is made between the matrix converters mistreatment series and customary cascade Z-source networks. The inpouring current and Z-source capacitor's voltage are reduced inside the series Z-source matrix converter.

Keywords: ac-ac converters, matrix converter, z source converter.

1 Introduction

A direct AC-AC device is projected in reference [1] known as the Matrix device. A matrix device (MC) consists of bifacial switches that give bifacial power conversion. MCs have received respectable interest as a result of the supply many blessings over back to back device, like the dearth of a dc link electrical condenser, bifacial power-flow capability, curved input/output undulation, manageable input-power issue, lightweight weight style, and long life [2], [3], [4], but with this blessings, Matrix device still have some issues got to be solved, like input filters, multistep commutation techniques, a sway algorithmic rule below unbalanced input voltages, common mode voltage (CMV) lead to motor winding failures, and magnetic attraction interference [5], [6], [7]. The thought of a matrix device was initially conferred by Gyugi in 1970 [8], and later in 1976 [9], that was delineated as a force commuted cyclo-converters. In [1], the primary modulation strategy permits full management of the output voltages and input power issue. During this projected algorithmic rule the most voltage transfer magnitude relation is restricted to zero. 5 and for dominant the input power issue data of the output power issue is needed. This voltage transfer magnitude relation has been accumulated up to zero.866, with the inclusion of third harmonics within the input and output voltage waveforms [2]. This worth of voltage transfer magnitude relation represents an associate intrinsic limitation of the three-phase matrix device. An equivalent technique has been extended in [3] with input power issue management having powerful modulation strategy known as optimum Jewish calendar month methodology. The modulation algorithmic rule projected in [4] supported a unique approach, offers performance like the optimum Jewish calendar month methodology. With a feature of the fictional dc link algorithmic rule, there's a wise increase of the most voltage transfer magnitude relation up to one.053 conferred in [5]. This indirect matrix device strategy consists of the modulation as a ballroom dance method, rectification, and inversion. Once this some PWM and SVM technique is developed. The remainder of the report is as follows: Section a pair of explores the matrix device elementary. Sections three and four describe the technological problems and application of matrix device. Finally, the conclusion is given.

2 Matrix Converter

The 3ph-3ph matrix convertor theme is shown in Figure one. The matrix convertor consists of 9 bidirectional switches. Victimization bidirectional switches it's doable to attach any of input facet phases a, b, or c to any of output facet phases A, B, or C at any moment. The input phases of matrix convertor shouldn't be shorted because of the input voltage sources, and also the output phases shouldn't be opened because of the inductive nature of the load.

3 Types of Matrix Converter:

Two basic varieties of AC-AC matrix device structures are projected in literature, the Direct Matrix device (DMC) and therefore the Indirect Matrix device

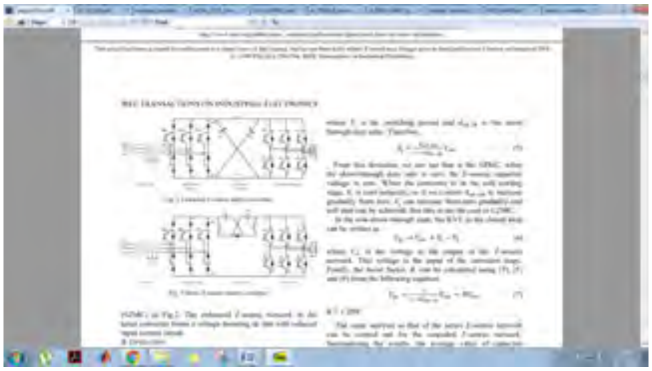


Figure 1: *Three Phase AC-AC Matrix converter [10].*

(IMC). Each converter uses an identical range of power devices and might reach same quality of input current and output voltage if controlled mistreatment same form of modulation, which implies that they have identical input filters to realize identical performance on the road current [2–4]. Conjointly each converter has same limitations, primarily relating to the most output voltage on the market and power issue correction particularly at low output power. The most variations between the 2 converters square measure potency and losses distribution among the devices, given in [10], [11]. The matrix converters square measure any classified into many varieties [12].

1. Distributed Matrix Converter-In this sort of matrix device, the numbers of needed switches square measure less, therefore the quality of the gate drive circuit is reduced. The operate is a twin of direct matrix device. Eighteen diodes and fifteen switches square measure needed for the distributed sort matrix device.

2. distributed Matrix Converter-In this sort, the range and diodes square measure exaggerated and correspondingly the number of switches is reduced as compared to the distributed matrix device. though' gate drive quality is reduced thanks, however, to increase within the range of diodes, the losses square measure exaggerated.

3. Radical distributed Matrix Converter-Only simplex switches square measure utilized in the input stage of ultra-sparse matrix device. So, these varieties of matrix converters square measure used for the variable speed drives that square measure of low dynamics. The topology of ultra-sparse matrix device introduces section displacement between input voltages and input currents. Solely twelve diodes and nine switch devices square measure needed for this sort of matrix device Hybrid Matrix Converters-The hybrid matrix device convert AC/DC/AC, however, doesn't use any dc link or reactive components like condenser or electrical device. The hybrid matrix converters square measure any classified into 2 varieties reckoning on their operation. If the hybrid matrix device converts each voltage and current commutation in the same stage, then this can be known as hybrid direct matrix converters. If the current and voltages square measure reborn in numerous steps, then these square measure is known as hybrid indirect matrix device [15].

The management of the matrix device topology is complex. 2 modulation strategies are:

- Pulse dimension Modulation (PWM) and
- Space Vector Modulation (SVM).

Space vector modulation techniques for matrix device are classified into 2 different strategies: Indirect house vector modulation that takes advantage of a virtual dc link associate degree Direct house vector modulation that has direct conversion [10][11].

4 Pulse breadth Modulation:

1. Pulse breadth modulation could be a technique within which a message or a sign is encoded in such some way that it takes the shape of a rhythmical signal. This method is employed to encipher any info which will be used for transmission. One of the most use of PWM is that the management of power which will be provided to the load. By perpetually turning on and off the change device between load and also the supply, the worth of voltage needed is achieved. This development is applied at high change frequency by varying the duty cycle of the PWM signal; the number of power provided to the load is varied. Owing to perpetually on and off the change device the specified output undulation won't be sleek. So, to stay the output undulation sleek, the change frequency ought to be as high as attainable. The change frequency of a PWM signal is incredibly high that allows the ability of electronic change devices to be saturated hardly. So, between on and off state of the change the transition interval is incredibly short and thence, change losses is less. Throughout off state of a controlled switch, there's no flow of current, and through on state, the forward free fall is nearly zero. So, exploitation PWM signal for change the change losses square measure virtually zero. Reckoning on the necessity, breadth of the heartbeat is modulated. The term duty cycle is outlined because of the magnitude relation of on time of the signal to the whole fundamental quantity of the signal. Duty cycle is diagrammatical in share like fifty%, means that on for 1/2 the time and off for 1/2 the time,

100% duty cycle defines entirely on [12], because the output of the matrix device is made in harmonics. There square measure PWM techniques given [43] to cut back harmonics particularly curving pulse breadth modulation (SPWM), delta modulation (DM), and quadrangle modulation (TM).

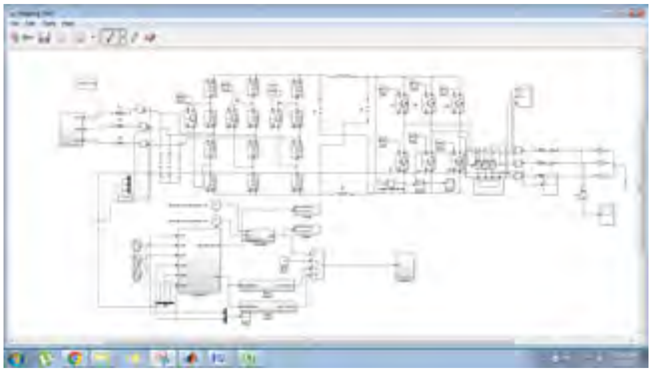


Figure 2: *simulation diagram.*

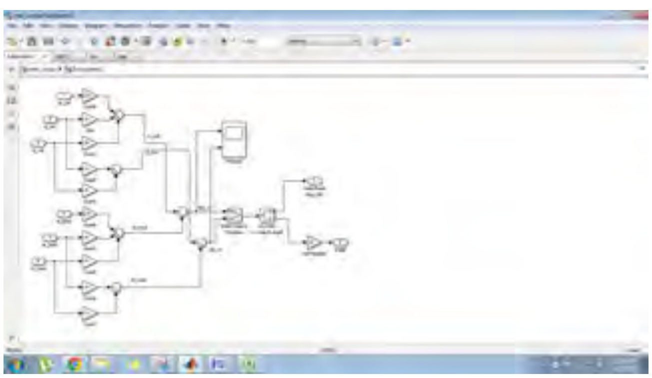


Figure 3: *control diagram.*

5 Space Vector Modulation:

Space vectors represent a 3 section ac system of your time variant quantities like voltage, current or flux in an exceedingly complex plane and were originally accustomed model the dynamic behavior of ac machines. However, they will be accustomed describe any quite three-phase system, e.g., 3 section power electronic converters and their modulation. Additionally, house vector theory is employed within the management of ac machines. The generated 3 section voltages vary from one another by one hundred twenty degrees with the frequency same as of reference signal. The reference signal may be varied by variable the period Ts as Ts = 1/fs, wherever fs is shift frequency. The reference signal may be generated from a 3 section victimization d-q or α-β-$\sqrt{}$ transformation. Varied combos exist for choosing

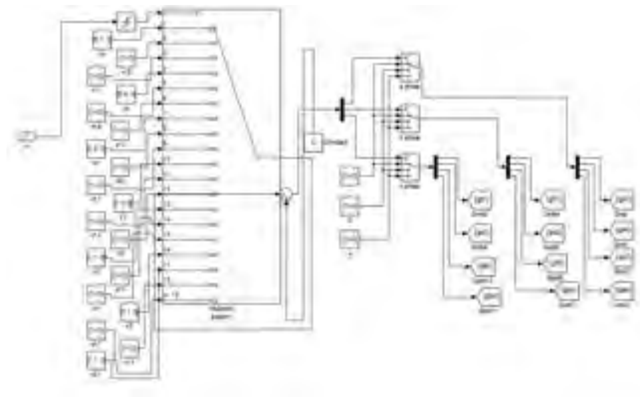


Figure 4: *pulse generation.*

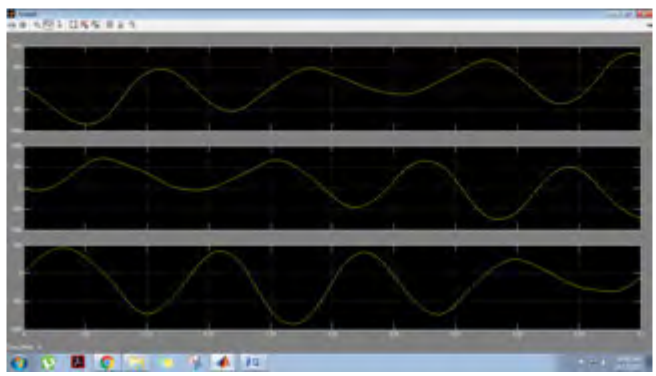


Figure 5: *output voltage.*

the shift sequence of switches however every strategy has its shift losses. Per the kind of masses, house vector topology provides the most effective appropriate shift sequence like rhythmic load, non-linear load and static load etc [21–22].

The advantages of SVM are: THD of the output voltage is low, SVM offers low peak currents in controlled switches as compared to PWM, Higher performance, potency, and dependableness are achieved victimization SVM as compared to PWM primarily based inverters of a comparable kind [13–22].

The SVM approach was at first planned in [6] to manage solely the output voltages, that has been in turn developed in [7]–[10] to manage the input power issue no matter the output power issue, to cut back the number of switch commutations in every cycle amount and to totally utilize the input voltages. Also, it permits an instantaneous comprehension of the modulation method, a fictitious dc link, and not includes the third-harmonic parts. As common mode voltage (CMV) is found mutually of the key drawback with matrix convertor (MCs). There square measure many house vector modulation ways square measure introduced in recent years to suppress this herpes virus of MCs. In [13], [14] current

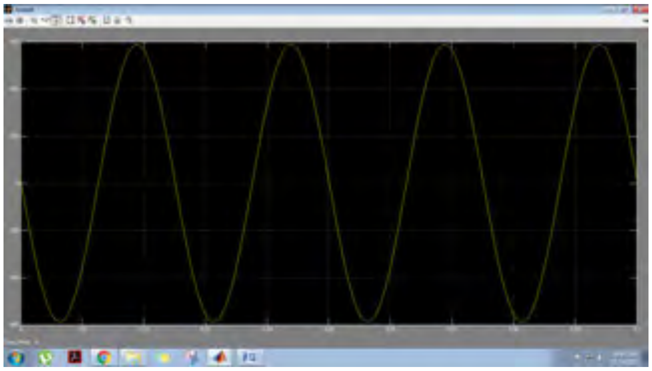


Figure 6: *grid voltage.*

management uses prognostic management to cut back herpes virus by adding a replacement quality operate. Space-vector modulation includes a clear comprehension of the modulation method and a comparatively easy formula [15]. Thus it's a widely used herpes virus reduction technique for MCs. The SVM technique is classed into 2 categories:

1. Indirect house Vector Modulation (ISVM) and
2. Direct house Vector Modulation (DSVM).

In the ISVM technique, the herpes virus is reduced to thirty-four % by victimization zero vectors [16] or by victimization four active vectors [17] to get the specified output voltage. The DSVM technique given in [18] is a lot of enticing attributable to the turning away of extra third-harmonic parts for herpes virus reduction in MCs. In DSVM technique, use of vectors from an entirely different cluster are introduced in recent years to limit this peak price of herpes virus to forty-two %, by replacement zero vectors with active vectors [19], or by replacement zero vectors with rotating vectors [20], or by victimization 2 lower input line-to-line voltages [21]. In [22] zero herpes virus has been achieved by victimization solely rotating vectors; however, voltage transfer magnitude relation is prescribed up to zero.5 only. All the previous ways cut back herpes virus. However, they additionally increase the shift losses. In [23], authors propose a replacement technique that suppresses shift losses still as herpes virus. This technique uses 3 pairs of active vectors to get the specified output-voltage vector. This technique is compared with the opposite herpes virus reduction ways in [19] and [20], which give the full voltage transfer magnitude relation among the ways in [19]–[22].

6 Matrix convertor Technology:

The matrix convertor is Associate in Nursing ac to ac power convertor technology supported duplex semiconductor switches with the minimal passive element. The management and modulation of a matrix convertor could be an important analysis subject field. Once the modulation functions properly and also the convertor output voltage follows the demanded voltage, the management of current and speed is the same as compared to a VSI electrical converter. As a result of the absence of a large dc link element, these management strategies give some attributes of this convertor technology like the governable input power issue, curved input and output current. Since there's no energy storage element, any power pulsation at the output of the convertor also will be a gift at the input. Therefore, the Matrix convertor won't be the ideal resolution for periodical masses once the input power quality is vital for the appliance. It's exceptionally suited for constant power masses like curved motor drives like induction machines or magnet synchronous machines. The reliableness of matrix convertor is a smaller amount than that of rectifier-inverter topologies as a result of the rise within the range of semiconductor used. The failure rate for the matrix convertor is magnified as a result of the magnified range of devices; however the voltage stress on matrix convertor devices is far reduced compared to the VSI topologies. Another advantage of matrix convertor is input filters size. A generally sized input inductance for a matrix convertor can nearly smaller than the equivalently rated input inductance of a PWM rectifier. The input capacitors may be organized in either a delta or star arrangement. The advantage in an exceeding delta arrangement is that capacitance of 1/3 of that of the star arrangement may be used whereas higher voltages should be sustained. The input inductance may be realized as a 3-phase reactor or three individual inductances. The three-phase reactor offers a smaller resolution however minimal common mode attenuation. Though this can be not necessary, it's going to be vital if Associate in nursing electro-magnetic interference (EMI) filter is to be integrated.

7 Application of Matrix Converter:

In [4], a quick technique to discover and localize a faulty power device employing a correlation of the protecting clamp circuit current and also the output part currents is conferred. The convertor then uses a fourth leg of the convertor to continue the operation of the motor. In [21], a period fault identification strategy supported the output current magnitudes and also the input voltage sector is delineated alongside a modulation strategy to avoid the utilization of the unsuccessful device. Fault-tolerant four-leg detection and modulation schemes square measure conferred in [20]. These methods are often used to continue satisfactory operation once a failure has occurred. The potential size and weight benefits of the matrix convertor and also the elevated temperature capability thanks to the dearth of dc-link parts lend themselves to craft applications. In [7], image craft mechanism comes are reported during this application wherever matrix convertor was chosen in as a result of its ability to be driven from a frequency wild offer. A deep ocean remotely operated vehicle (ROV) matrix convertor drive application was the topic conferred in [8]. As a result of the acute pressure knowledgeable by ROVs and also the lack of substantial dc-link parts, the matrix convertor was chosen as a possible topology for the appliance. Analysis into the consequences of high gas pressure on the constituent components of typical drive systems was disbursed at three hundred bars. The paper conjointly mentioned the utilization of observer-based sensor-less management of a PMSM mistreatment the matrix convertor. The matrix convertor has conjointly been applied to drive the rotor circuit of a doubly fed induction generator in turbine applications mistreatment direct [19] and indirect matrix converters [10], with a plus that a comparatively low power four-quadrant power convertor are often accustomed management a high-octane generator system. In [11] analysis into the soundness of such systems is conferred, and also the effects of rotor-side harmonics in a very similar system were conferred in [12]. A 3 part to 2 part matrix convertor (reduced) was accustomed management a turbine generator associate degree to drive one part electrical device that was then connected through an ac rectifier to a dc cable conferred in [16]. The potency comparison of this reduced matrix convertor beneath entirely different

The application of the matrix convertor in poly-phase generator systems has been investigated in [16] and [17]. During this case, with the input frequency and voltage, the matrix convertor conjointly rework the number of phases. Because the matrix convertor circuit is standard, any variety of input and output phases are often enforced. In [18], protection methods for the matrix convertor once used as a grid offer convertor square measure mentioned. A small rotary engine generation system was delineating in [19]. The challenge here was the high input frequency of 2221 rate. A replacement shift technique is planned to reduce the number of shift events whereas maintaining harmonic performance. Use of a matrix convertor mistreatment solely unofficial switches was delineating in [20], to drive associate degree induction machine. Since mistreatment 9 unofficial switches, the present will solely flow in one direction and current commutation method becomes inherently safe. Another one application of an unofficial matrix convertor was to drive a five-phase fault-tolerant brushless dc (BLDC) motor for the pump in associate degree electro-hydraulics mechanism. A unifacial matrix convertor was conjointly accustomed drive a switched reluctance motor (SRM) in [18]. In, structure inversion strategy is conferred. During this study the primary objective was to scale back harmonics by observant stator coil current and speed-torque characteristics, considering load as associate degree induction motor [22].

8 Conclusion

In this analysis, it's found that the output of the matrix convertor is made in harmonics and also the voltage transfer quantitative relation contains a limitation of the most worthy of zero.866. The higher limit of the vary of variation of the output frequency is less than the input frequency. A number of the ways that area unit utilized for harmonic reduction area unit supported modulation techniques and traditional filter systems. With the modulation technique, PWM and SVM primarily based 3 phases AC to AC matrix converters are developed. It's pointed out that PWM and SVM primarily based matrix convertor may be deployed to realize any desired output and input characteristics. These converters area unit extremely applicable for adjustable speed drives or variable frequency drives attributable to variable desired frequency may be earned. Secondly, any desired output voltage may be achieved. Therefore, interconnected systems may be freed from synchronization problems by using these converters.

References

[1] X. Hu, C. Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Power Management of a Hybrid Solar- Wind Energy System" International Journal of Engineering Research & Technology vol. 3(2) pp.1988–1992, 2014.

[3] M. Siva Ramkumar, M. Sivaram Krishnan, A. Amudha. "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239–245, 2017.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc " in International Journal of Control Theory and Applications, 10 (2) pp 333–344, 2017.

[5] M Siva RamKumar, Dr. A Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power

Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485–6488, 2016.

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763–769,2014.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361–1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2),2014

[9] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1–10, September 2016.

[10] D. Kavitha, Dr. C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973–4562 Vol. 10 No.20 (2015), pg. 17749–17754.

[11] D. Manoharan, Dr. A. Amudha. "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973–4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, Dr. A. Amudha. A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973–4562 Volume 10, Number 3 (2015) pp. 6233–6240.

[13] Dr. A. Amudha. "Enhancement of Available Transfer Capability using FACTS controller" in International journal of Applied Mechanics and Materials, Vol. 573, pp 340–345

[14] K. Balachander, Dr. P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035–2042.

[15] K. Balachander, Dr. P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, Dr. P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839–847.

[17] K. Balachander, Dr. P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, Dr. Vijayakumar Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179–186.

[19] K. Balachander, Dr. Vijayakumar Ponnusamy, 'Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research', Volume 7, Number 3 (2012), pp. 247–256.

[20] K. Balachander, S. Kuppusamy, Dr. Vijayakumar Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111–118.

[21] M. Sivaram Krishnan, A. Amudha, M. Siva Ramkumar, 'Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms', International journal of Pure and Applied Mathimatics,118 (11), pp 609–617,2018 DOI:10.12732/ijpam.v118i11.79

[22] S. Motapon, L. Dessaint, K. AI-Haddad, "A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, " IEEE Trans. Ind. Electron., vo1.61, no.3, pp.1320,1334, March 2014.

DTC-SVM MANAGEMENT OF INDUCTION MACHINE FED BY 3 LEVEL NPC MATRIX CONVERTOR

A. Thirugnanaselvi, M.S. Ramkumar, A. Amudha, M.S. Krishan, K. Balachander

Abstract: This work proposes a DTC-SVM management rule supported computer coordinate transformation to manage associate induction machine fed by a three-level Neutral purpose clamped matrix converter. The rule is simulated on Matlab Simulink to verify its performance. It provides reasonable performance usually. The results are mentioned, and a study of the results of the variation of computer resistance is projected jointly.

Keywords: Multilevel Inverter, DTC, Active Neutral Point Clamped, SVM.

1 Introduction

Because of the growing demand on the renewable strength assets, grid-connected convertor structures are getting Associate in Nursing increasing sort of vital than ever previous [1,2]. For grid -linked operation, the convertor ought to meet following needs [1–6].

1. The convertor ought to generate a pure curvilineal output voltage.
2. The convertor output current has to be compelled to be compelled to own low general harmonic distortion (THD).

Traditionally, two-stage PWM convertor is utilized for grid-tied operation. Just in case of a -stage convertor, the shift frequency have to be compelled to be excessive, or the inductance of the output filter device has to be compelled to be large enough to satisfy the desired academic degree. To handle the issues associated with the two-degree convertor, multi-level electrical converters (MLIs) unit of measurement was brought for the grid-connected electrical converter. Various MLI topologies had been advised up to currently and that they are going to be significantly categorized as 3 sorts in Fig. 1; neutral issue clamped (NPC), a flying capacitor (FC), and cascaded kind. The gain of the MLIs is that their switch frequency and device voltage rating is additionally tons decrease than those of at more two-degree convertor for a similar output voltage. Consequently, IGBT switch loss is shriveled significantly and so the convertor device efficiency is additionally expanded. In this paper, a circuit supported an H-bridge topology with four switches coupled to the dc-link is projected as an MLI topology. Fig. a illustrates the projected MLI. Besides, it is simple as a result of the projected PWM technique makes use of one provider sign for producing PWM signals. Similarly, the switch assortment considering the voltage stability of dc-link was projected. Afterwards, the projected topology of the multi-level convertor is verified by implies that of showing the practicability via the simulation and thus the take a glance at [7–15].

2 Existing system:

NPC convertor makes use of diodes to clamp the voltage ranges generated on the dc-hyperlink capacitors to the output. Excessive vary of diodes, unbalanced operation of dc-link's resistance capacitors, and stormy distribution of loss among switches are foremost issues with this topology. The disadvantages of FC-ANPC are high varying switches, assortment association of high voltage switches, and negative loss distribution [16–21].

3 Proposed system:

This work proposes a DTC-SVM management formula supported robot coordinate transformation to manage Associate in Nursing induction machine fed by a three-level Neutral purpose clamped matrix device. The formula is simulated on Matlab Simulink to verify its performance. This paper proposes a contemporary five-stage hybrid topology primarily based all on FC and administrative body inverters. The goal of the projected topology is to beat the shortcomings of the quality FC-ANPC. Therefore, relatively, the projected topology offers higher loss distribution, avoids direct series association of high voltage switches, and eliminates a combine of switches in step with section leg. These edges come back on the value of a further condenser and half-dozen diodes. Though, the amount of every condenser is anticipated to extend as results of the 0.5 cycle operation and cut back rams trendy. Vary of devices of the projected multi-stage convertor is decrease than that of the quality multi-degree inverters. Consequently, the projected device is more dependable and worth aggressive than the quality two-degree and construction inverters. Inside the H-bridge device unit of measurement operated at Associate in Nursing occasional frequency (e.g., sixty Hz) frequency. Therefore, shift loss of the four switches nearly negligible. Handiest one carrier signal is required to return up with the PWM signals. The projected topology may even be just prolonged to 5-stage or higher level with reduced spirited device issue bear in mind [22].

4 Operation of projected topology:

The projected topology consists of a dc-hyperlink this is (often—this can be) often common in most of the 3 phases. The dc-hyperlink offers three voltage degrees +2E, zero, and -2E for the section legs. Since all the stages have a similar configuration, best one section leg of the projected topology has been shown in Fig. 1. All the additives shown inside the tell apart have equal in operation voltage E, i.e., one-fourth of the dc-link voltage Vdc. The flying capacitors CA1 and CA2 square measure controlled to stay charged at the goal voltage E. The to be had states of one part leg square measure shown in table I. to come back up with level 2E, all of the highest arm switches SA1, SA2, SA3, SA4 ought to activate. For stage E, alternatives square measure to be had, i.e., either via dc-link's fine purpose (EP) or through dc-link's neutral issue (E0). This redundancy is going to be wont to stability the voltage of CA1. Degree zero is generated via clamping the dc link's neutral purpose to the output (00). Dangerous states to boot generated equally as a result of the symmetry of the topology. The operation of this topology is, in essence, the same as topologies that embody stacked multi-cell (SMC) device, whereby the positive and negative stacks operate severally. Later, the good stack device CA1 is utilized and balanced throughout the very good cycle and rest for the amount of the terrible cycle, whereas the terrible stack electrical deviceCA2 is utilized and balanced at some purpose of the terrible cycle and relaxation throughout the superb cycle. So, the flying electrical devices will see the switching frequency in preference to line frequency and so the electrical condenser size is not overlarge. Terribly the same as the 3-degree agency converter, if the 3 phases of the load space unit balanced, the neutral purpose voltage is regular in essence. However, the voltage might barely waft away as a result of the imbalance inside the elements' discharge gift day. Additionally, although little, there's often a handful of imbalance among the stages. A gradual voltage goes alongside the flow, although very little, can cause higher voltage throughout a locality of the devices which can be fatal. This waft is going to be paid via injecting a tiny low common mode to the 3 phases [30–35]. A significant feature of the projected topology is that the even distribution of transitions amongst switches gadgets. Therefore, switching loss that's that the predominant limiting part of inverter's thermal performance is shipped form of the switches. As results of the essential result, the trade-off between switch frequency and trendy dreading is progressed. This offers the possibility to every can increase the rated trendy and energy of the converter or growth the switch frequency resulting in decrease device size and improved voltage wave type exceptional [16–22].

Figure 1: *circuit diagram.*

5 Carrier primarily based modulation:

Provider set's association and reference waveform's kind unit of measurement the foremost resources of sorts in service-based entire modulation techniques for construction inverters. As for provider set's arrangement, stage shifted companies LSC and section shifted vendors p.c unit of measurement the two predominant categories that may be severally acceptable for diode-clamped and Multi-mobile structures. Two members among the LSC circle of relatives, likelihood part opposition disposition APOD and section disposition element unit of measurement proverbial to urge the satisfactory outcomes for single-segment and three half programs, severally. [40–45]Within the course of its authentic sort has been shown to urge a PWM wave kind that matches with APOD. Together a modified model of ethical with dynamic half shift has been tested to suit with the element. The reference for unmarried-section programs is mostly a straightforward arc form wave kind. For 3-section packages, a variety of reference waveforms unit of measurement to be had because of the prospect of common mode injection in 3-section structure. This ability has been accustomed to serve one-of-a-kind functions like improved dc link usage, decrease degree, lower Loss, and impartial issue voltage manipulates. For the planned convertor, a hybrid modulation approach is required as a result of the hybrid type of the topology. Parent 3 illustrates the modulation technique for the single-phase case. It's intuitive to separate the operation to effective and negative cycles, seeing that every cycle is generated with a 3-degree FC stack. The gate signals for every FC has then generated the employment of moral to provide seasoning voltage reconciliation for the flying capacitors. The generated output PWM wave kind fits the APOD theme [16–52].

6 Non-carrier modulation:

For non-carrier-primarily based modulation strategies that embody SVM and he or she or he, the output PWM wave are generated initial thus rotten to the required amendment signals. Make sure four illustrates the required manner to induce the gate signals for each section leg. The 5-level PWM wave is initially separated to advantageous and international organization healthy cycle 3-stage PWMs. Exploitation nation system decoder, each cycle is then rotten to a pair of 2-level PWMs i.e., the specified gate indicators for each FC mobile. It's method very important to word that this procedure is impartial of the followed modulation methodology. Consequently, it ought to be used with carrier-primarily based modulation strategies. This might otherwise be a reference voltage at any time will synthesize smart numerous once the quality of the service based mostly on methodology is massively excessive, e.g., for chemical element theme [1–10].

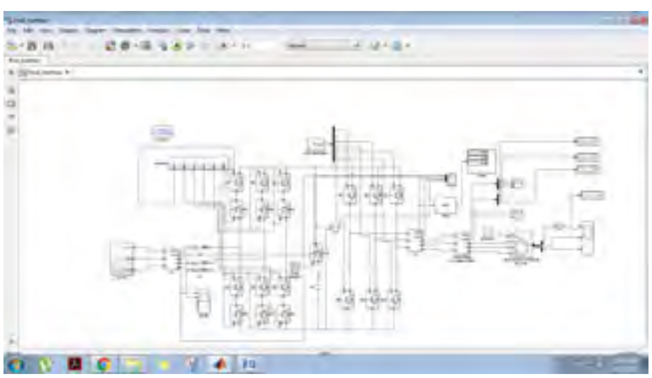


Figure 2: *simulation diagram.*

7 Comparison with alternative Topologies:

An analysis among the projected topology and distinctive 5-degree topologies in phrases of issue count selection and loss distribution is listed in Table II. The 5-stage agency has low switch count, however, the predominant issues unit unbalanced operation of dc-hyperlink capacitors, terrible loss distribution among switches, and steep vary of diodes. 5-degree FC offers low transfer matter and fantastic loss distribution but desires high kind of flying capacitors which will adversely have a bearing on the initial fee, preservation and substitute surcharges, and reliability of the converter. Capacitors' Recharge demand in some programs is likewise a drawback of this topology. The five-level SMC prime logy provides decrease capacitance swear as compared to FC and prime loss distribution. However, excessive transfer count and excessive frequency switch non-Parallel Square live the principle issues with this topology. The five-stage FC ANPC presents a fantastic balance between the number of semiconductors and capacitors. The foremost trouble with this topology is that the negative loss distribution many of the switches. The topology projected throughout this paper affords an exchange between distinct issue counts to appreciate a decent loss distribution, avoid direct series association of semiconductor gadgets, hold the balanced operation of dc link capacitors whereas protecting the variability of highly-priced elements in conjunction with capacitors and switches as very little as viable.

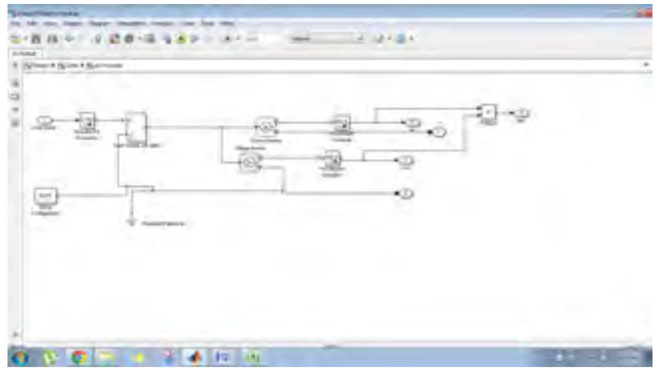


Figure 3: *solar module.*

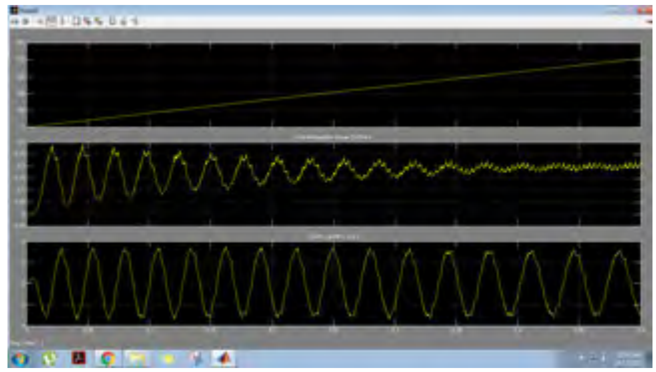


Figure 4: *output waveform*

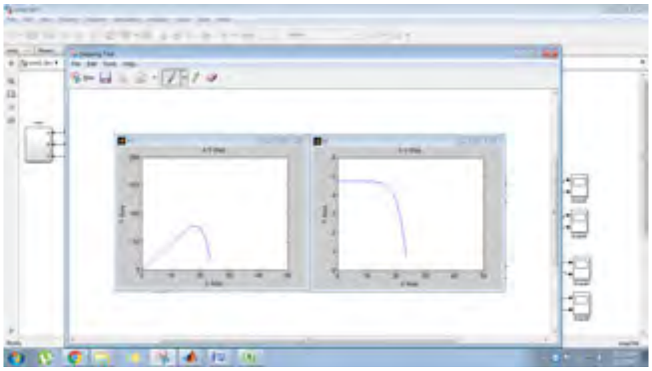


Figure 5: *solar pv, iv graph*

COMPARISON OF DIFFERENT TOPOLOGIES

Topology	Flying Capacitors	Switches	Diodes	Loss Distribution
5L-NPC	0	8	12	Poor
5L-FC	6	8	0	Excellent
5L-SMC	2	12	0	Good
5L-FC-ANPC	1	12	0	Fair
Proposed Topology	2	10	6	Good

Table 1 topologies

8 Conclusion:

A DTC-SVM management algorithmic program supported the stator coordinate transformation to manage induction machine fed by three level workplace matrix devices TLMC is planned and simulated exploitation Matlab –Simulink. The algorithmic management program with TLMC offers wise performance in every temporary and permanent mode, and it follows the references of speed and flux. Inside constant time it uses a robust and quick switch frequency, so one disadvantage of the classic DTC is resolved. The force and flux error bandwidths unit very little and that they unit proportional to the switch frequency. The most harmonics of the input current unit around the change frequency and it's multiple so as that they unit filtered by the input filter. The DTC-SVM management is sensitive to the variation of the mechanical device resistance notably once Rm¿Rs. throughout this case, the management can diverge [11–22].

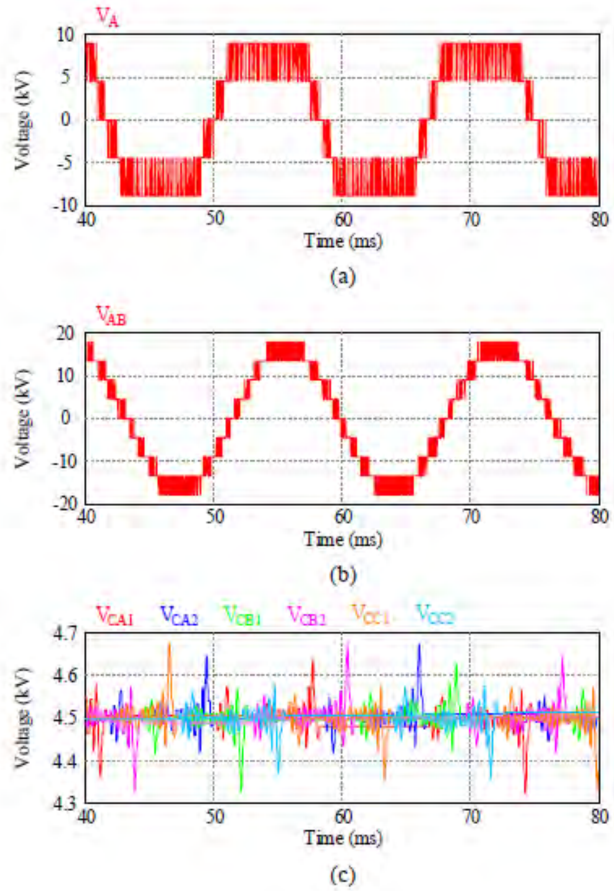


Figure 6: *voltage waveforms*

References

[1] X. Hu, C. Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Power Management of a Hybrid Solar- Wind Energy System" International Journal of Engineering Research & Technology vol. 3(2) pp.1988–1992, 2014.

[3] M. Siva Ramkumar, M. Sivaram Krishnan, A. Amudha. "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239–245, 2017.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc " in International Journal of Control Theory and Applications, 10 (2) pp 333–344, 2017.

[5] M Siva RamKumar, Dr. A Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485–6488, 2016.

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763–769,2014.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361–1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2),2014

[9] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1–10, September 2016.

[10] D. Kavitha, Dr. C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973–4562 Vol. 10 No.20 (2015), pg. 17749–17754.

[11] D. Manoharan, Dr. A. Amudha. "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973–4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, Dr. A. Amudha. A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973–4562 Volume 10, Number 3 (2015) pp. 6233–6240.

[13] Dr. A. Amudha. "Enhancement of Available Transfer Capability using FACTS controller" in International journal of Applied Mechanics and Materials, Vol. 573, pp 340–345

[14] K. Balachander, Dr. P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035–2042.

[15] K. Balachander, Dr. P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Vol. 2, Issue 11(2013), pp. 174–184.

[16] K. Balachander, Dr. P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839–847.

[17] K. Balachander, Dr. P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, Dr. Vijayakumar Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January–April (2012), pp. 179–186.

[19] K. Balachander, Dr. Vijayakumar Ponnusamy, 'Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research', Volume 7, Number 3 (2012), pp. 247–256.

[20] K. Balachander, S. Kuppusamy, Dr. Vijayakumar Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111–118.

[21] M. Sivaram Krishnan, A. Amudha, M. Siva Ramkumar, 'Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms', International journal of Pure and Applied Mathematics, 118 (11), pp 609–617, 2018 DOI:10.12732/ijpam.v118i11.79

[22] S. Motapon, L. Dessaint, K. AI-Haddad, "A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, " IEEE Trans. Ind. Electron., vo1.61, no.3, pp.1320,1334, March 2014.

A PHOTOVOLTAIC GENERATION SYSTEM BASED ON HYBRID MULTILEVEL INVERTER IN ORDER TO REDUCE SWITCHING FOR DC MICRO GRIDS

C. Karunamoorthy, A. Amudha, K. Balachander, M. Siva Ramkumar

Abstract: In this paper, a photovoltaic (PV) generation system based on Hybrid Multilevel inverter is proposed. Hybrid multilevel inverter gives multilevel operation by using hybrid source, hybrid configuration or hybrid device in such a way to produce output with reduced number of DC sources, high speed capability, low output switching frequency, low switching loss, high conversion efficiency, flexibility to enhance and various topologies for different applications. Simulations and analysis are done by the use of MATLAB /SIMULINK software

Keywords: Photovoltaic system, Hybrid Multilevel Inverter.

1 Introduction

How can we increase the amount of photovoltaic (PV) generation? From this viewpoint, we are over viewing electric facilities from power plants to electric appliances in demand sites. PV modules generate DC electric power. The power should be converted to AC that is synchronized with commercial grids to be transmitted and distributed to demand sites. To reduce energy dissipation through the transmission, the power is sent near the demand site after being raised the electric voltage to 66 kV or higher. The power is transformed to 100 V and provided to residential outlets after multi-processed reduction in voltage at substations and pole-mounted transformers. Therefore, we should consider how we can establish efficient transmission and distribution systems for PV generation in addition to cost, efficiency and lifetime for generation facilities, if we utilize the power source as infrastructure. Transmission facilities for PV generation often stay idle as well as generation facilities themselves, because they do not yield electricity during night and poor weather. If contribution from solar power were much smaller than transfer capability, existing facilities could take care of it. To understand this problem easily, we assume a huge PV farm comparable to a nuclear power plant with a giga wattage class output. PV generation, which has poor yield for its footprint, needs vast ground to generate such a big power. Consequently, the generation facilities must be set up in sites far from consuming regions. Transmission facilities must have enough large capacity for maximum current which can be generated under the best weather condition. They do not work during off-generating time such as at night and under poor sunshine. If PV plants supplied constant huge power as dam type hydraulic or nuclear plants, we would make choice of a far-reaching transmission system that connects distant sources and a consuming centre. Electric power storage devices, such as batteries, can absorb fluctuation of PV generation and equalize power transmission. However, this scheme reduces capacity of transmission facilities and requires rather huge additional cost for the huge accumulators. Therefore, until drastically reduced cost is available for storage devices, we cannot adopt this method. Then, put gas turbines together, with which we are able to adjust output power rather rapidly. The combined plant can absorb the fluctuation of PV generation, and consequently, improve the operation ratio for transmissions. However, it requires a parallel established thermal power plant comparable to the PV, which is a roundabout way for our initial goal, the introduction of a large amount of PV. As mentioned above, large scale PV plants in remote sites have a serious problem on economic efficiency. We need a new power system that enables the introduction of a massive amount of distributed PV units in demand sites. This article proposes DC micro grid systems as an option for such a purpose. The conventional electrical system in place today sees our electrical devices powered by AC mains. But as renewable technologies such as solar photovoltaics and wind power become more prevalent at a household level, DC microgrids could be a cheaper and more efficient alternative. Take lighting and ‘gadgets’ for example. Lighting is widely considered to account for around 20% of global electricity consumption, and a recent report from the International Energy Agency estimates that up to 15% of domestic energy is consumed through ‘gadgets’ - i.e. computers and consumer electronics. LEDs are emerging as a preferred option for high efficiency lighting, and they run on DC power. Similarly, most gadgets operate on DC power, so these two sectors alone add significant and increasing global consumption of electricity by DC devices. But these are presently powered by AC mains via multitudinous individual transformers. Fuel cells and many small scale renewable natively generate low voltage DC power. Most of these generators supply power to AC mains networks and require costly and inefficient power invertors; even where the power may ultimately be delivered to a DC device. A possible solution is to install a DC network linking DC devices to DC power supplies. Such networks have not yet emerged because of the higher electrical losses associated with transmitting a fixed amount of power as low voltage DC, rather than higher voltage AC. But with the proliferation of low power electronic devices, bringing the potential for LEDs to reduce lighting loads by a up to a factor of 10 and the potential for efficient distributed power generation, localised DC networks – or DC microgrids - may finally be practical. Aside from reducing resource and financial costs, a key advantage of DC microgrids is that the low risk of dangerous electric shocks from low voltage DC makes plug-and-play grids a possibility. This greatly reduces the installation cost of micro-generation, and could empower end users to take responsibility for understanding and controlling their individual energy consumption. Adding intelligence and internet connectivity to DC micro-grid controllers further enables consumer engagement with AC mains devices - through smart metering and ultimately with dynamic demand management. And this could reduce costs associated with periods of high and low power consumption. A DC microgrid comprises:

- DC power generation (i.e. fuel cell, solar PV panels, or micro wind turbines);
- DC electrical storage (i.e. battery or super capacitor);
- DC power distribution (i.e. wiring and control);
- DC gadgets (i.e. laptops, telephones, satellite TV controllers);
- DC lighting (i.e. LEDs).

Whilst homes generally require an AC supply for inherently "high" power devices such as washing machines, kettles and hairdryers, there are a surprising number of environments, such as site offices and outdoor events, where these devices are not used. In such cases a DC microgrid could be the sole power provider. The elimination of inverter cost, simplified installation and reduced fuel costs yielded by a DC microgrid system potentially make it cost effective to operate independently of the electricity grid and conventional mains-power generators. The Photovoltaic (PV) system provides secure, clean and reliable in renewable energy sources with the added advantageous of zero fuel cost, no moving parts, low running cost, minimum maintenance and long-life time. These points of interest make the utilization of PV in many places and also in off-grid installations. Multilevel Inverter (MLI) topologies are proved as substantial global attention by the researchers and front-end industries in various medium and high power applications because of their ability to generate high quality of output waveforms, reducing switching stress across the switches, and reducing switching frequency. In recent years, many topologies have emerged in the field of grid connected MLI in renewable energy application. The basic classification of MLI is Diode-Clamped MLI (DCMLI), Flying Capacitor (FCMLI) and Cascaded H-Bridge MLI (CHBMLI). Although these types of basic MLIs are noticeable in high power applications regardless they have few demerits like components count and voltage balancing problem expect CHBMLI. To overcome this problem, reduced switch MLI topologies are developed in past decades. Many topologies in MLI are ended with DC source, but only a few topologies are integrated with PV applications.

2 PHOTOVOLTAIC SYSTEM

Converting solar energy into electrical energy by PV installations is the most recognized way to use solar energy. Since solar photovoltaic cells are semiconductor devices, they have a lot in common with processing and production techniques of other semiconductor devices such as computers and memory chips. As it is well known, the requirements for purity and quality control of semiconductor devices are quite large. With today's production, which reached a large scale, the whole industry production of solar cells has been developed and, due to low production cost, it is mostly located in the Far East. Photovoltaic cells produced by the majority of today's most large producers are mainly made of crystalline silicon as semiconductor material. Solar photovoltaic modules, which are a result of combination of photovoltaic cells to increase their power, are highly reliable, durable and low noise devices to produce electricity. The fuel for the photovoltaic cell is free. The sun is the only resource that is required for the operation of PV systems, and its energy is almost inexhaustible. A typical photovoltaic cell efficiency is about 15%, which means it can convert 1/6 of solar energy into electricity. Photovoltaic systems produce no noise, there are no moving parts and they do not emit pollutants into the environment. Taking into account the energy consumed in the production of photovoltaic cells, they produce several tens of times less carbon dioxide per unit in relation to the energy produced from fossil fuel technologies. Photovoltaic cell has a lifetime of more than thirty years and is one of the most reliable semiconductor products. Most solar cells are produced from silicon, which is non-toxic and is found in abundance in the earth's crust. Figure 1 shows the photovoltaic cell.

Figure 1: *Photovoltaic cell.*

Photovoltaic systems (cell, module, network) require minimal maintenance. At the end of the life cycle, photovoltaic modules can almost be completely recycled. Photovoltaic modules bring electricity to rural areas where there is no electric power grid, and thus increase the life value of these areas. Photovoltaic systems will continue the future development in a direction to become a key factor in the production of electricity for households and buildings in general. The systems are installed on existing roofs and/or are integrated into the facade. These systems contribute to reducing energy consumption in buildings. A series of legislative acts of the European Union in the field of renewable energy and energy efficiency have been developed, particularly promoting photovoltaic technology for achieving the objectives of energy savings and CO2 reduction in public, private and commercial buildings. Also, photovoltaic technology, as a renewable energy source, contributes to power systems through diversification of energy sources and security of electricity supply. By the introduction of incentives for the energy produced by renewable sources in all developed countries, photovoltaic systems have become very affordable, and timely return of investment in photovoltaic systems has become short and constantly decreasing. In recent years, this industry is growing at a rate of 40% per year and the photovoltaic technology creates thousands of jobs at the local level.

2.1 Types of vehicle charging equipment

The word photovoltaic consists of two words: photo, a greek word for light, and voltaic, which defines the measurement value by which the activity of the electric field is expressed, i.e. the difference of potentials. Photovoltaic systems use cells to convert sunlight into electricity. Converting solar energy into electricity in a photovoltaic installation is the most known way of using solar energy. The light has a dual character according to quantum physics. Light is a particle and it is a wave. The particles of light are called photons. Photons are massless particles, moving at light speed. In metals and in the matter generally, electrons can exist as valence or as free. Valence electrons are associated with the atom, while the free electrons can move freely. In order for the valence electron to become free, he must get the energy that is greater than or equal to the energy of binding. Binding energy is the energy by which an electron is bound to an atom in one of the atomic bonds. In the case of photoelectric effect, the electron acquires the required energy by the collision with a photon. Part of the photon energy is consumed for the electron getting free from the influence of the atom which it is attached to, and the remaining energy is converted into kinetic energy of a now free electron. Free electrons obtained by the photoelectric effect are also called photoelectrons. The energy required to release a valence electron from the impact of an atom is called a work out Wi, and it depends on the type of material in which the photoelectric effect has occurred.

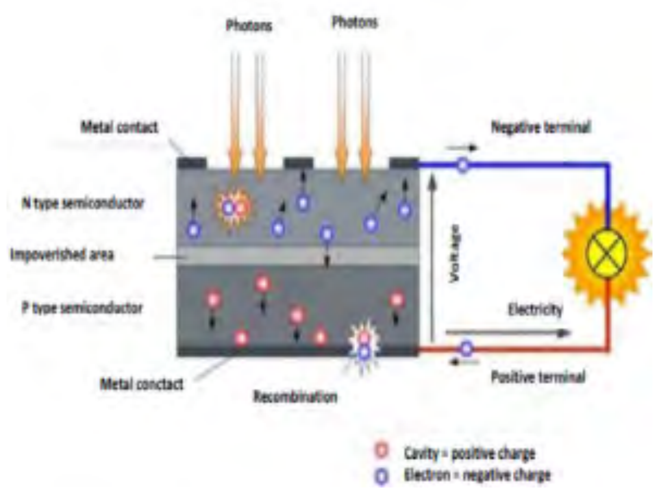


Figure 2: *Functioning of PV cell.*

The previous equation shows that the electron will be released if the photon energy is less than the work output. The photoelectric conversion in the PV junction. PV junction (diode) is a boundary between two differently doped semiconductor layers; one is a P-type layer (excess holes), and the second one is an N-type (excess electrons). At the boundary between the P and the N area, there is a spontaneous electric field, which affects the generated electrons and holes and determines the direction of the current. To obtain the energy by the photoelectric effect, there shall be a directed motion of photoelectrons, i.e. electricity. All charged particles, photoelectrons also, move in a directed motion under the influence of electric field. The electric field in the material itself is located in semiconductors, precisely in the impoverished area of PV junction (diode). It was pointed out for the semiconductors that, along with the free electrons in them, there are cavities as charge carriers, which are a sort of a byproduct in the emergence of free electrons. Cavities occurs whenever the valence electron turns into a free electron, and this process is called the generation, while the reverse process, when the free electron fills the empty spaces - a cavity, is called recombination. If the electron-cavity pairs occur away from the impoverished areas it is possible to recombine before they are separated by the electric field. Photoelectrons and cavities in semiconductors are accumulated at opposite ends, thereby creating an electromotive force. If a consuming device is connected to such a system, the current will flow and we will get electricity. In this way, solar cells produce a voltage around 0,5-0,7 V, with a current density of about several tens of mA/cm2 depending on the solar radiation power as well as on the radiation spectrum. The usefulness of a photovoltaic solar cell is defined as the ratio of electric power provided by the PV solar cells and the solar radiation power. The usefulness of PV solar cells ranges from a few percent to forty percent. The remaining energy that is not converted into electrical energy is mainly converted into heat energy and thus warms the cell. Generally, the increase in solar cell temperature reduces the usefulness of PV cells. Standard calculations for the energy efficiency of solar photovoltaic cells are explained below. Energy conversion efficiency of a solar photovoltaic cell (η "ETA") is the percentage of energy from the incident light that actually ends up as electricity. This is calculated at the point of maximum power, Pm, divided by the input light irradiation (E, in W/m2), all under standard test conditions (STC) and the surface of photovoltaic solar cells (AC in m2). STC - standard test conditions, according to which the reference solar radiation is 1.000 W/m2, spectral distribution is 1.5 and cell temperature 250C

2.2 Energy depreciation of PV ells

The period of energy depreciation of photovoltaic cells is the time period that must pass using a photovoltaic system to return the energy that has been invested in the construction of all parts of the system, as well as the energy required for the breakdown after the lifetime of a PV system. Of course, the energy depreciation time is different for different locations at which the system is located, thus it is a lot shorter on locations with a large amount of irradiated solar energy, up to 10 or more times shorter than its lifetime. South Istria has approximately 1.700 kWh/m2 annual radiation, while the northern part of Istria has somewhere around 1.500 kWh/m2. The figure 3 shows the available data on the energy depreciation for the various technologies of photovoltaic cells, with their respective efficiencies in given years of production. In relation to the south of Istria, which is shown in Figure 2.7, the energy depreciation in the city of Zagreb is, for example, about 20% longer, in southern Dalmatia is 10 to 15% shorter than in Istria, which corresponds to solar radiation intensity-insolation map.

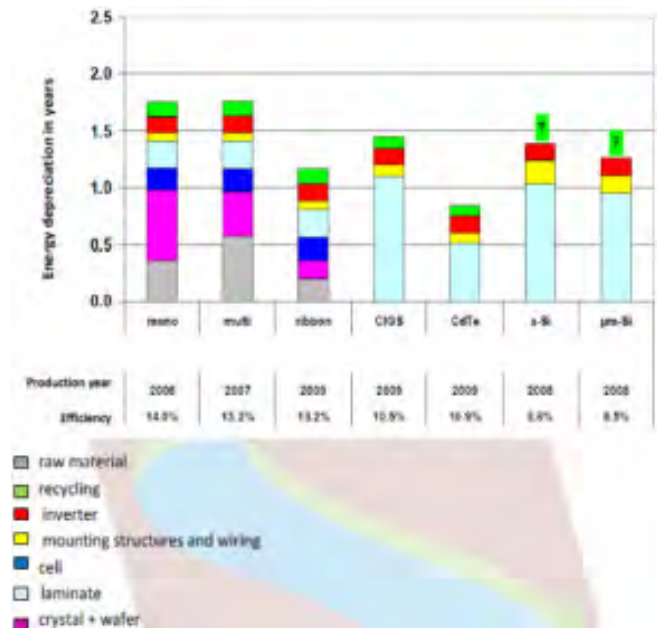


Figure 3: *Availability of energy.*

3 DC MICRO GRID

Electricity demand has been significantly increasing over the past few years due to many factors. In countries such as the United States, Energy production will play an important role because of its power based civilization. Thermal, hydro and nuclear power plants are the major sources of electricity to date. But the limited availability of resources like coal and nuclear energy made us to concentrate on renewable sources such as wind and solar energy. Even though there has been a rapid development going on in wind and solar power technology to make use of renewable sources efficiently and to increase the stability of the system, there are many problems associated with these time- and environment- dependent sources. Because of the variations in parameters such as wind speed, intensity of sunlight, etc., the power extracted from these sources varies accordingly which in turn imposes series problems on the stability of the main grid system. The problems include voltage fluctuations, oscillations in frequency, harmonics, and imbalances in power generation and load demand etc. The best way to shield this problem is to move towards the smarter localized grid system which is called as a microgrid (MG). Microgrid can act as backup power when there is a shortage of supply from the main grid which in turn reduces the voltage fluctuations caused by high demand. Microgrid can also operate in an islanded mode during power blackouts to supply power to localized loads. Microgrids are connected to the main grid through the point of common coupling (PCC). Circuit Breakers are used to isolate MG from the main grid during faulty conditions. Power systems currently undergo considerable change in operating requirements mainly as a result of deregulation and due to an increasing amount of distributed energy resources (DER). In many cases DERs include different technologies that allow generation in small scale (microsources) and some of them take advantage of renewable energy resources (RES) such as solar, wind or hydro energy. Having microsources close to the load has the advantage of reducing transmission losses as well as preventing network congestions. Moreover, the possibility of having a power supply interruption of end-customers connected to a low voltage (LV) distribution grid (in Europe 230 V and in the USA 110 V) is diminished since adjacent microsources, controllable loads and energy storage systems can operate in the islanded mode in case of severe system disturbances. This is identified nowadays as a microgrid.

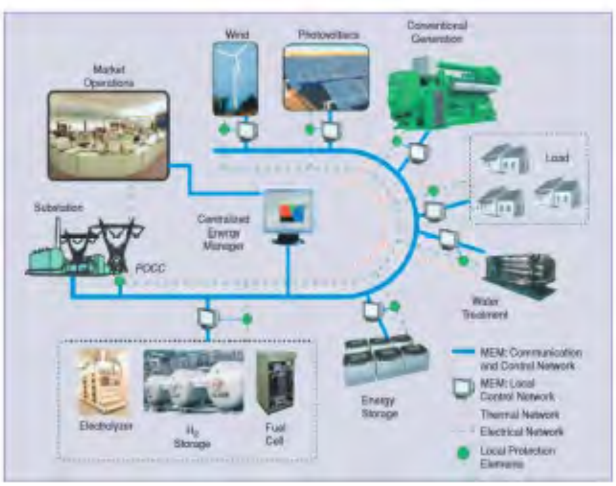


Figure 4: *Microgrid power system.*

Figure 4 depicts a typical microgrid. The distinctive microgrid has the similar size as a low voltage distribution feeder and will rare exceed a capacity of 1 MVA and a geographic span of 1 km. Generally more than 90% of low voltage domestic customers are supplied by underground cable when the rest is supplied by overhead lines. The microgrid often supplies both electricity and heat to the customers by means of combined heat and power plants (CHP), gas turbines, fuel cells, photovoltaic (PV) systems, wind turbines, etc. The energy storage systems usually include batteries and flywheels. The storing device in the microgrid is equivalent to the rotating reserve of large generators in the conventional grid which ensures the balance between energy generation and consumption especially during rapid changes in load or generation. From the customer point of view, microgrids deliver both thermal and electricity requirements and in addition improve local reliability, reduce emissions, improve power excellence by supportive voltage and reducing voltage dips and potentially lower costs of energy supply. From the utility viewpoint, application of distributed energy sources can potentially reduce the demand for distribution and transmission facilities. Clearly, distributed generation located close to loads will reduce flows in transmission and distribution circuits with two important effects: loss reduction and ability to potentially substitute for network assets. In addition, the presence of generation close to demand could increase service quality seen by end customers. Microgrids can offer network support during the time of stress by relieving congestions and aiding restoration after faults. The development of microgrids can contribute to the reduction of emissions and the mitigation of climate changes. This is due to the availability and developing technologies for distributed generation units are based on renewable sources and micro sources that are characterized by very low emissions. There are various advantages offered by microgrids to end-consumers, utilities and society, such as: improved energy efficiency, minimized overall energy consumption, reduced greenhouse gases and pollutant emissions, improved service quality and reliability, cost efficient electricity infrastructure replacement. Technical challenges linked with the operation and controls of microgrids are immense. Ensuring stable operation during network disturbances, maintaining stability and power quality in the islanding mode of operation necessitates the improvement of sophisticated control strategies for microgrid's inverters in order to provide stable frequency and voltage in the presence of arbitrarily varying loads. In light of these, the microgrid concept has stimulated many researchers and attracted the attention of governmental organizations in Europe, USA and Japan. Nevertheless, there are various technical issues associated with the integration and operation of microgrids.

3.1 Electric grid

An electrical grid is an interconnection of generating stations, transmission lines and distribution lines, which provide power supply to customers. At generating stations, electric power is produced from renewable or non-renewable sources. Then the electric power is carried from one place to other by the transmission lines. Finally, electric power is distributed among consumers with the help of distribution feeders.

3.2 Concept of microgrid

Microgrid is defined as the "localized grid that interconnects distributed energy resources with organized loads and normally operates connected to traditional centralized grid synchronously. During faulty conditions can act in islanded mode i.e. disconnected from the centralized grid". The sources in the microgrid are called as micro sources, which can be battery storage, Solid oxide fuel cell, wind, solar, diesel generator, etc. Each source is controlled in the respective manner to connect it to distribution network. Loads are connected to the distributed network whose power demand is met by micro sources and main grid. Micro grid can operate in two modes.

1. Grid connected mode: During normal operating conditions, the microgrid is connected to main grid through the point of common coupling (PCC) and a Circuit Breaker (CB). Voltage and frequency of the microgrid are synchronized with the main grid. Different control strategies are used to maintain the synchronization at PCC. Power delivered to the distributed load is shared by main grid and the microgrid. The microgrid sources can deliver excess power to balance the load when there is power shortage from the main grid. Similarly, if there is any fault occurred at one of the micro sources, main grid delivers the excess power along with remaining active micro sources to balance the power shortage caused by faulty source.

2. Islanded mode: During faulty conditions on the main grid, MG is disconnected from the main grid at PCC by operating the circuit breaker which separates MG with main grid. After disconnection from main grid, MG operates on its own to supply power to the load by stepping up the power delivered from all the micro sources according to the control strategies that are pre-defined. In this way, the load is powered up even during the power blackouts. In islanded mode, some of the non-emergency loads can be disconnected if the load demand exceeds the micro sources capacity. The grid voltage and frequency are maintained by operating at least one converter in V/f control. After fault clearance, to reconnection of MG with the main grid is possible only when error in voltage is below 3%, error in frequency is below 0.1Hz and error in phase angle is below 100.

3.3 Technical challenges in microgrid

Protection system is one of the major challenges for microgrid which must react to both main grid and microgrid faults. The protection system should cut off the microgrid from the main grid as rapidly as necessary to protect the microgrid loads for the first case and for the second case the protection system should isolate the smallest part of the microgrid when clears the fault. A segmentation of microgrid, i.e. a design of multiple islands or sub microgrids must be supported by microsource and load controllers. In these conditions problems related to selectivity (false, unnecessary tripping) and sensitivity (undetected faults or delayed tripping) of protection system may arise. Mainly, there are two main issues concerning the protection of microgrids, first is related to a number of installed DER units in the microgrid and second is related to an availability of a sufficient level of short-circuit current in the islanded operating mode of microgrid since this level may substantially drop down after a disconnection from a stiff main grid. In the authors have made short-circuit current calculations for radial feeders with DER and studied that short-circuit currents which are used in over-current (OC) protection relays depend on a connection point of and a feed-in power from DER. The directions and amplitudes of short circuit currents will vary because of these conditions. In reality the operating conditions of microgrid are persistently varying because of the intermittent microsources (wind and solar) and periodic load variation. Also the network topology can be changed frequently which aims to minimize loss or to achieve other economic or operational targets. In addition controllable islands of different size and content can be formed as a result of faults in the main grid or inside microgrid. In such situations a loss of relay coordination may happen and generic OC protection with a single setting group may become insufficient, i.e. it will not guarantee a selective operation for all possible faults. Hence, it is vital to ensure that settings chosen for OC protection relays take into account a grid topology and changes in location, type and amount of generation. Otherwise, unwanted operation or failure may occur during necessary condition. To deal with bi-directional power flows and low short-circuit current levels in microgrids dominated by microsources with power electronic interfaces a new protection philosophy is essential, where setting parameters of relays must be checked/updated periodically to make sure that they are still appropriate.

4 ARDUINO

Many multilevel inverter topologies have been proposed during the last three decades. Modern research has engaged novel inverter topologies and unique modulation schemes. Three different major multilevel inverter structures have been reported in the literature: cascaded H-bridges inverter with separate DC sources, diode clamped (neutral clamped) and flying capacitors (capacitor clamped). The first topology introduced was the series H-bridge design. This was followed by the diode-clamped multilevel inverter which utilizes a bank of series capacitors to split the DC bus voltage. After few years the flying-capacitor (or capacitor clamped) topology was introduced in which instead of series connected capacitors floating capacitors are used to clamp the voltage levels. Another multilevel design, slightly different from the previous ones, involves parallel connection of inverter outputs through inter-phase reactors. In this design the switches must block the entire reverse voltage, but share the load current. Various combinatorial designs have also emerge and been implemented by cascading the fundamental topologies such designs come under hybrid topologies category. These designs can create higher power quality for a given number of semiconductor devices than the fundamental topologies due to a multiplying effect of the number of levels. Moreover, number of modulation techniques and control techniques have been developed for multilevel inverters such as sinusoidal pulse width modulation (SPWM), selective harmonic elimination (SHE-PWM), space vector modulation (SVM), multicarrier modulation and others. In the beginning multilevel inverters were introduced to drive high voltage as in High Voltage Direct Current (HVDC) applications to make the front-end connection between DC and AC lines. In this way the limits on the maximum voltage tolerable by the semiconductor switches were overtaken and the inverters were able to drive directly the line voltage without a transformer. Nowadays it is possible to find multilevel applications even in low voltage field like motor drive because of the high quality of the AC output. In particular back-to-back multilevel systems can drive motors with very good performance concerning the line voltage and current distortions and also reduces the losses. Recent advances in power electronics have made the multilevel concept practical. In fact the concept is so advantageous that several major drive manufacturers have obtained patents on multilevel power inverter and associated switching techniques. In addition, many multilevel inverter applications focus on industrial medium voltage motor drives utility interface for renewable energy systems flexible ac transmission system (FACTS) and traction drive systems.

4.1 Classification of HMLI

Hybrid multilevel inverters are classified on basis of types of power devices used, number of power supplies used, magnitude of the power supplies used and how power devices are connected in circuit. Thus broad classification of hybrid multilevel inverter is as follows:

- Asymmetric Hybrid Multilevel Inverter
- Hybrid Multilevel Inverter Based on Half-Bridge Modules
- New Symmetrical Hybrid Multilevel Inverters
- Hybrid Clamped Five-Level Inverter Topology
- Distinct Series Connected cells Hybrid Multilevel Inverter
- Hybrid Medium-Voltage Inverter based on a NPC Inverter
- New Hybrid Asymmetrical Multilevel H-bridge Inverter
- Hybrid Multilevel Inverter with Single DC Source

4.2 HMLI with single DC source

This inverter includes a standard full bridge 3-leg inverter (one leg for each phase) and an H-bridge in series with each inverter leg as shown in figure 5. It uses only a single DC power source to supply a standard 3-leg inverter along with three full H-bridges supplied by capacitors or batteries. Traditionally, each H-bridge requires a DC power source. The inverter can be used in electric vehicles (EV) / hybrid electric vehicles (HEV) to drive electric motor. And it can be applied for utility interface. As shown in figure 6 the output voltage v1 of single leg (with respect to the ground) is either +Vdc (S5 closed) or - Vdc (S6 closed). This leg is connected in series with a full H-bridge which in turn is supplied by capacitor voltage. If the capacitor is used and kept charged to Vdc, then the output voltage of the H-bridge can take on the values + Vdc (S1, S4 closed), 0 (S1, S2 closed or S3, S4 closed), or - Vdc (S2, S3 closed).

Figure 7 shows an output voltage example. The capacitor's voltage regulation control method consists of monitoring the output current and the capacitor voltage so that during periods of zero voltage output either the switches S1, S4, and S6 are closed or the switches S2, S3, S5 are closed depending on whether it is necessary to charge or discharge the capacitor. This method depends on the voltage and current not being in phase. That means one needs positive (or negative) current when the voltage is passing through zero in order to charge or discharge the capacitor. Consequently the amount of capacitor voltage the scheme can regulate depends on the phase angle difference of output voltage and current.

As figure 8 illustrates, this method of regulating the capacitor voltage depends on the voltage and current not

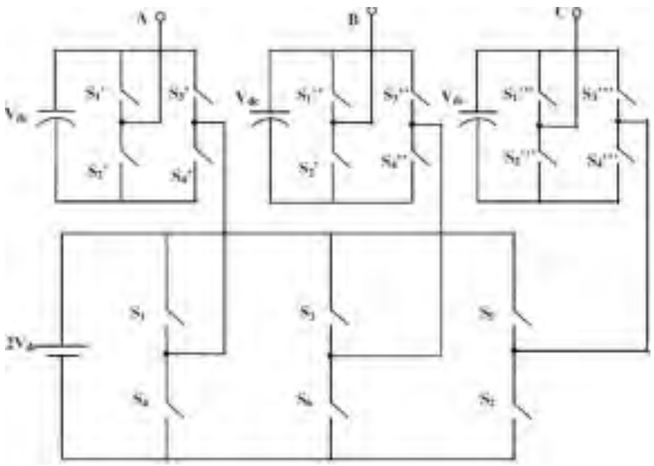


Figure 5: *Three level HMLI with single DC source.*

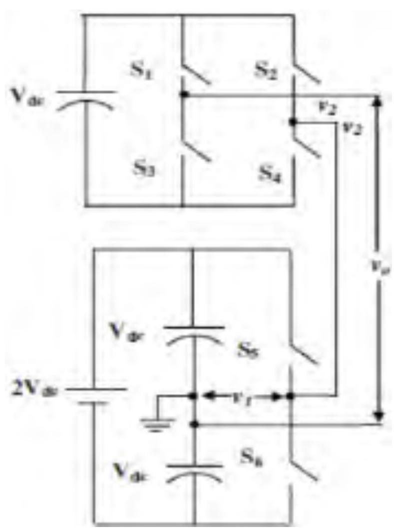


Figure 6: *Single phase HMLI with single DC source.*

being in phase. That is, one needs positive (or negative) current when the voltage is passing through zero in order to charge or discharge the capacitor. Consequently, the amount of capacitor voltage the scheme can regulate depends on the power factor. Thus by maintaining the regulation of the capacitor voltage simultaneously achieves an output voltage waveform which is 25% higher than that obtained using a standard 3-leg inverter by itself.

5 PROPOSED SYSTEM

Figure 9 shows the block diagram of the use of Hybrid multilevel inverter to integrate the Photovoltaic system based DC grid with the main grid in order to reduce the switches.

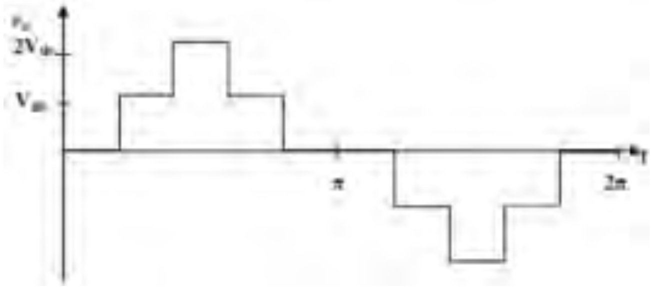


Figure 7: *Output voltage for single phase HMLI with single DC source.*

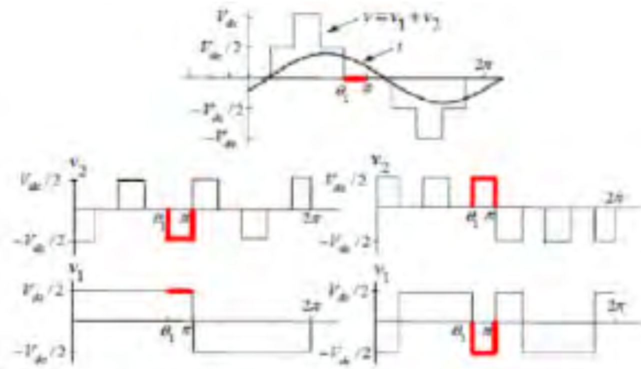


Figure 8: *Capacitor voltage regulation.*

5.1 PV system based on HMLI

Photovoltaic modules are usually series connected for higher voltage and power level. However, the I-V characteristics mismatch among PV modules due to partial shading, thermal gradients and manufacturing variability may lead to large deviation from MPPs for some PV modules, with severe power loss. Hybrid Multilevel Inverter (HMLI) is an effective solution that has been researched for a long time.

5.2 PV array

A PV Array consists of a number of individual PV modules or panels that have been wired together in a series and/or parallel to deliver the voltage and amperage a particular system requires. An array can be as small as a single pair of modules, or large enough to cover acres.The performance of PV modules and arrays are generally rated according to their maximum DC power output (watts) under Standard Test Conditions (STC). Standard Test Conditions are defined by a module (cell) operating temperature of 25oC (77 F), and incident solar irradiant level of 1000 W/m2 and under Air Mass 1.5 spectral distribution. Since these conditions are not always typical of how PV modules and arrays operate in the field, actual performance is usually 85 to 90 percent

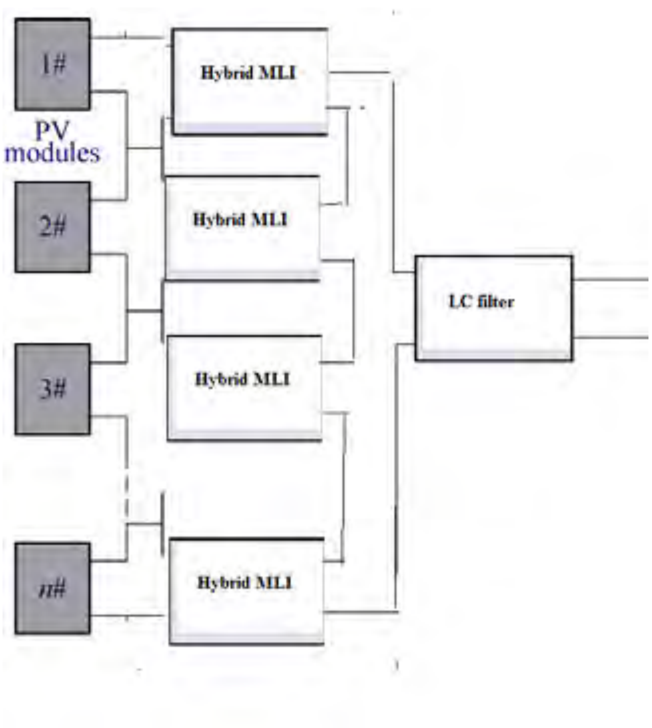


Figure 9: *Block diagram of proposed system.*

of the STC rating. The simulation of PV system used in proposed work is shown in figure 10.

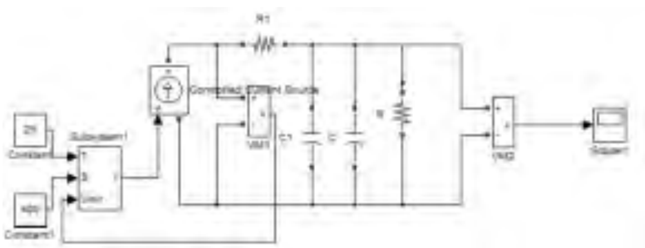


Figure 10: *Simulation diagram of PV system.*

5.3 P & O algorithm

The most commonly used MPPT algorithm is P&O method. This algorithm uses simple feedback arrangement and little measured parameters. The module voltage is periodically given a perturbation and the corresponding output power is compared with that at the pervious perturbing cycle as shown in figure 11.

In this method the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This is called the perturb and observe method and is most common, although this method can result in oscillations of power

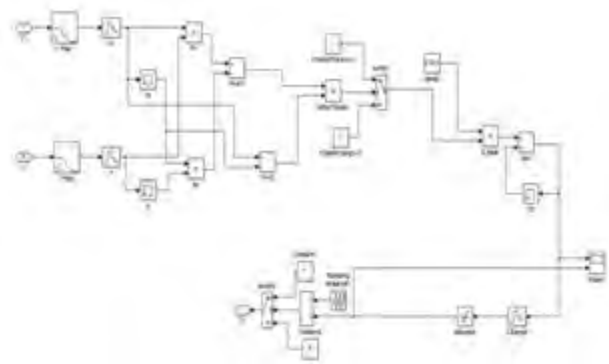


Figure 11: *P & O algorithm.*

output. It is referred to as a hill climbing method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Perturb and observe is the most commonly used MPPT method due to its ease of implementation. Perturb and observe method may result in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is adopted. Both perturb and observe, and incremental conductance, are examples of "hill climbing" methods that can find the local maximum of the power curve for the operating condition of the PV array, and so provide a true maximum power point. The perturb and observe method requires oscillating power output around the maximum power point even under steady state irradiance. The PV system with this MPPT is shown in figure 12. The pulse pattern to the algorithm is shown in figure 13.

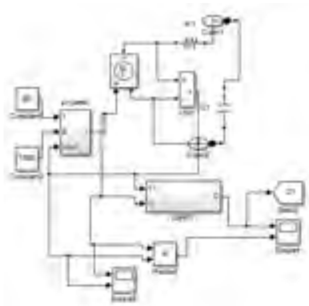


Figure 12: *PV system with MPPT.*

The overall system that is the photovoltaic generation based on hybrid multilevel inverter in order to reduce the switch for DC micro grid is shown in figure 14.

6 RESULT

The behavior of the complete proposed system that is high efficient semi-z-source inverter which is supplied by photovoltaic system when connected with power grid is

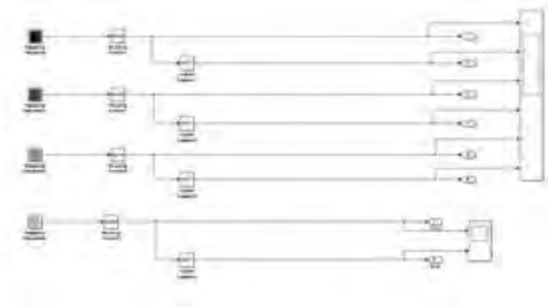


Figure 13: *Pulse patternPulse pattern.*

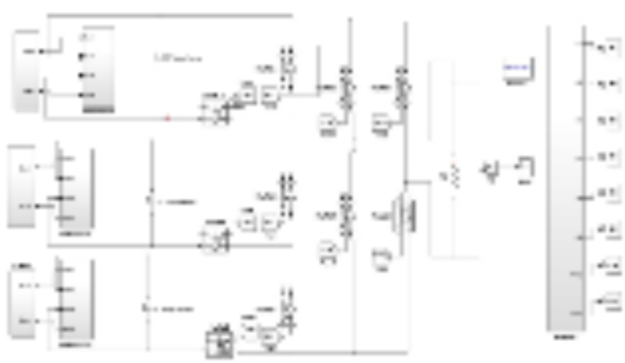


Figure 14: *Overall system simulation .*

discussed in this chapter. There are multiple PV system is used in proposed work. The simulation result of one of the PV systems is discussed here. The output voltage of the PV is shown in figure 15.

Figure 15: *PV output voltage.*

The MPPT algorithm used in proposed system is P & O algorithm. The duty cycle of the P& O algorithm is shown in figure 16.

The sinusoidal that is the AC voltage which is inverted from DC output of Photovoltaic system by hybrid multilevel inverter is shown in figure 17.

Figure 16: *Duty cycle of P & O algorithm.*

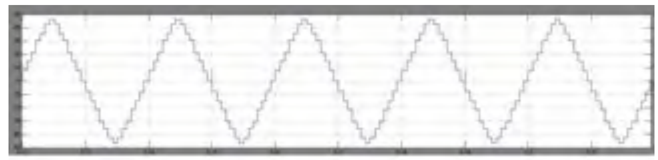


Figure 17: *Output voltage of hybrid multilevel inverter .*

7 CONCLUSION

This paper has presented a single phase grid connected MLI with a reduced number of switch count and DC sources integrated with PV panel. Perturb and Observer method MPPT method is utilized. The isolated DC source is replaced by PV panel with boost converter and it boosting voltage based on the asymmetric conditions values. Sinusoidal pulse width modulation technique is used for generating the switching pulses. From the results it is concluded that proposed hybrid MLI is well suited for PV based grid application.

References

[1] Abdul Mannan Rauf and Vinod Khadkikar, "Integrated Photovoltaic and Dynamic Voltage Restorer System Configuration," IEEE Transactions on Sustainable Energy, Vol. 6, No. 2, pp.400-410, April 2015.

[2] Erickson RW, Maksimovic D. Fundamentals of power electronics. 2nd ed. Norwell, MA: Kluwer; 200 I.

[3] A. Amudha, , M. Siva Ramkumar , M. Sivaram Krishnan "Perturb and Observe Based Photovoltaic Power Generation System For Off-Grid Using Sepic Converter" International Journal of Pure and Applied Mathematics , 114(7), pp. 619-628 , 2017 .

[4] M. Siva Ramkumar, M. Sivaram Krishnan, A. Amudha, "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[5] M. Siva Ramkumar, M. Sivaram Krishnan, A. Amudha, "Impedance Source Inverter and Permanent Magnet Synchronous Generator For Variable Speed Wind Turbine " International Journal of Computer & Mathematical Sciences, 6 (9) pp 98-105, 2017.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017.

[8] M.Subramanian, M. Siva Ramkumar, A. Amudha, , K.Balachander and D.Kavitha "Power Quality Improvement In Low Voltage Transmission System Using Static Compensator" in International Journal of Control Theory and Applications (IJCTA) 10 (38) pp 247-261, 2017.

[9] M. R. Latha, S. Kuppusamy, A. Amudha, K. Balachander, M. Siva Ramkumar " An Efficient Single Stage Converter Based Pv-Dvr For Improving Voltage Quality" in International Journal of Control Theory and Applications, 10 (38) pp 177-193, 2017.

[10] M. Sivaram Krishnan, M. Siva Ramkumar, "Power Management of a Hybrid Solar-Wind Energy System, International Journal of Engineering Research & Technology, 2 (1) pp 1988-1992.

[11] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[12] Emayavaramban. G, Amudha. A, 'Recognition of sEMG for Prosthetic Control using Static and Dynamic Neural Networks', International Journal of Control Theory and Applications,Vol.2 (6), pp.155-165, September 2016.

[13] D. Manoharan, A. Amudha. "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)

[14] D. Manoharan, A. Amudha. A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6233-6240.

[15] K. Balachander, "Design and Hardware Implementation of Speed Control of Induction Motor using Z - Source Inverter", International Journal of Electronics Engineering Research, Vol. 9(6), pp. 931-937.

[16] K. Balachander, A. Amudha," Design and Hardware Implementation of Interleaved Boost Converter Using Sliding Mode Approach", International Journal of Electronics Engineering Research, Volume 9, Number 5 (2017) pp. 745-750

[17] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[18] K. Balachander, P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[19] K. Balachander, V. Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[20] K. Balachander, S. Kuppusamy, V. Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[21] K. Balachander, S. Kuppusamy, V. Ponnusamy, '" Comparative Study of Hybrid Photovoltaic-Fuel Cell System / Hybrid Wind-Fuel Cell System for Smart Grid Distributed Generation System" Proceedings of IEEE International Conference on Emerging Trends in Science, Engineering and Technology at JJ College of Engineering, Trichy on 13 th and 14 th December 2012. DOI: 10.1109/ INCOSET. 2012.6513950, pp.462-466

[22] O. Ibrahim, N. Thanh-Hai, D.-C. Lee, and S.-C. Kim, "A fault ride-through technique of DFIG wind turbine systems using dynamic voltage restorers," IEEE Trans. Energy Converts., vol. 26, no. 3, pp. 871–882, September 2011.

[23] F. Lima, A. Luna, P. Rodriguez, E. Watanabe, and F. Blaabjerg, "Rotor voltage dynamics in the doubly fed induction generator during grid faults," IEEE Trans. Power Electron., vol. 25, no. 1, pp. 118–130, January 2010.

[24] P. Zhou,Y. He, and D. Sun, "Improved direct power control of a dfig-based wind turbine during network unbalance," IEEE Trans. Power Electron., vol. 24, no. 11, pp. 2465–2474, November 2009.

[25] J. Lopez, E. Gubia, E. Olea, J. Ruiz, and L. Marroyo, "Ride through of wind turbines with doubly fed induction generator under symmetrical voltage dips," IEEE Trans. Ind. Electron., vol. 56, no. 10, pp. 4246–4254, October 2009.

TRANSIENT STABILITY IMPROVEMENT IN POWER SYSTEM WITH SMES AND BATTERY ENERGY STORAGE SYSTEM

C. Chinnusamy, G.Emayavaramban, A. Amudha, K. Balachander, M. Siva Ramkumar

Abstract: In recent years constraints forced by the environment, right of way and energy costs have resulted in power systems operating with considerably reduced stability margins. Consequently, modern power systems depend strongly on stabilizing devices to keep reliable and stable operation. These devices should provide sufficient damping in the system, during the transient period following a system disturbance, such as line switching, load changes and fault clearance. To avoid collapse of the system due to loss of synchronism or voltage instability, countermeasures such as power system stabilizers, optimal turbine governor control systems and phase shifters have been used. This concept presents the transient stability analysis of a power grid, which integrates both Superconducting Magnetic Energy Storage (SMES) and Gridable Vehicles (GVs). Also, Vehicle-to Grid (V2G) operation is devised to control GVs to charge power from or discharge to the grid. SMES and GVs to adjust the active power and reactive power to support the System. Simulations of both balanced and unbalanced faults such as 3LG fault, LG fault, LLG fault are carried. The system model is established and simulated using the Matlab/Simulink. The results of load angle response and system voltage response are given to illustrate that both SMES and GVs can enhance transient stability of the power grid. Moreover, the simultaneous use of SMES and GVs can further improve the system dynamic performances.

Keywords: Voltage Superconducting Magnetic Energy Storage (SMES), Girdable Vehicle (GV), Dynamic Voltage Restorer (DVR).

1 Introduction

Electrical energy is generated in power station and transmitted through transmission line and substation to load. The main objective of the power station is maintain to supply the quality power to the consumer and also maintain the system stability. Stability is the major part in the power system environment. Power system stability defined as the property of power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to disturbances. In stability in a power system manifested in many different ways depending on the system configuration and operating mode. The stability problem has been one of maintaining synchronous operation. Since power systems rely on synchronous machines for generation of electrical power, a necessary condition for satisfactory system operation is that all synchronous machines remain in synchronism. Stability is the behavior of the power system when subjected to a transient disturbance. The disturbance may be small or large. Small disturbances in the form of load changes continually and the system adjust itself to the changing conditions. The system must be able to operate satisfactorily under these conditions and successfully supply the maximum amount of load this system stability called as small signal stability. The large disturbances such as short circuit on a transmission line, loss of large generator or load or loss of tie between two sub systems. The system response to such disturbances involves large excursions of generator rotor angles, power flows, bus voltages and other system variables. The ability of the power system to maintain a synchronism when subjected to a large disturbance. This system stability called as transient stability. The power system stability problem mainly caused by voltage and frequency changes during a fault contingency. This concept analyses the transient stability of a system with SMES and BES. Integration of both SMES and BES to adjust the active power and reactive power to support the system. Superconducting Magnetic Energy Storage (SMES) is based on a superconducting inductor or coil which is capable of storing energy in the magnetic field. The most important merit of SMES is that the time delay during charge/discharge is short. Due to its rapid discharge capabilities the technology has been implemented on electric power systems for system stability applications SMES is the combination of three fundamental principles(current with no resistive losses; magnetic field; and energy storage in magnetic field) provides potential for the highly efficient storage of electrical energy in a superconducting coil. SMES is different from other storage technologies in that a continuously circulating current within the superconducting coil produces the stored energy. In addition, the only conversion process in the SMES system is from AC to DC. As a result, there are none of the inherent thermodynamic losses associated with conversion of one type of energy to another. The SMES includes superconducting coil, refrigerator, power conditioning system and control system. The superconducting SMES coil must be maintained at a temperature sufficiently low to maintain a superconducting state in the wires. Reaching and maintaining this temperature is accomplished by a special cryogenic refrigerator that uses helium as the coolant. Gridable BATTERYs (BES), including Electric BATTERYs (BEs) and plug-in hybrid electric BATTERYs (PHBEs),draw power from the grid to charge their batteries for vehicular Operation .BATTERY-to-grid (B2G) technology is dBEseloped which allows BES to absorb power from the grid or delivery power back to the grid. BATTERY to grid (B2G) describes a system in which plug in electric BATTERYs (BBEs) and plug in hybrids (PHBEs), communicate with the power grid to sell demand response services by either delivering electricity into the grid or by throttling their charging rate. The concept allows B2G BATTERYs to provide power to help balance loads by "valley filling" (charging at night when demand is low) and "peak shaving" (sending power back to the grid when demand is high) It can enable utilities new ways to provide regulation services (keeping voltage and frequency stable) and provide spinning reserves (meet sudden demands for power).Particularly, BES can help improve the power quality such as the transient stability at the local power system with the charging/discharging facilities such as the parking lots, public areas and communities. In order to analyze the system performance, both balanced and unbalanced faults are conducted using both SMES and BES. The system model is established and simulated using the Matlab/Simulink. The results of voltage response and load angle response are given to illustrate the validity of the proposed SMES and BES.[1-5]

2 TRANSIENT STABILITY

Each generator operates at the same synchronous speed and frequency of 50 hertz while a delicate balance between the input mechanical power and output electrical power is maintained. When generation is less than the actual consumer load, the system frequency falls. On the other hand, when the generation is more than the actual load, the system frequency rise. The generators are also interconnected with each other and with the loads they supply via high voltage transmission line. An important feature of the electric power system is that electricity has to be generated when it is needed because it cannot be efficiently stored. Hence using a sophisticated load forecasting procedure generators are scheduled for hour in day to match the load. In addition, generators are also placed in active standby to provide electricity in times of emergency. This is referred as spinning reserved. The power system is routinely subjected to a variety of disturbances. The act of switching on an appliance in the house can be regarded as a disturbance. However, given the size of the system and the scale of the perturbation caused by the switching of an appliance in comparison to the size and capability of the interconnected system, the effects are not measurable. Large disturbance do occur on the system. These includes lightning strikes, loss of transmission line carrying bulk power due to overloading. The ability of power system to survive the transition following a large disturbance and reach an acceptable operating condition is called transient stability. The physical phenomenon following a large disturbance can be described as follows. Any disturbance in the system will cause the imbalance between the mechanical power input to the generator and electrical power output of the generator to be affected. As a result, some of the generators will tend to speed up and some will tend to slow down. If, for a particular generator, this tendency is too great, it will no longer remain in synchronism with the rest of the system and will be automatically disconnected from the system. This phenomenon is referred to as a generator going out of step. Acceleration or deceleration of these large generators causes mechanical stresses. Generators are also expensive. Damage to generators results in costly overhaul and long downtimes for repair. As a result, they are protected with equipment safety in mind. As soon as a generator begins to go out-of-step, sensor in the system sense the out-of-step condition and trip the generators. In addition, since the system is interconnected through transmission lines, the imbalance in the generator electrical output power and mechanical input power is reflected in a change in the flows of power on transmission lines. As a result, there could be large oscillations in the flows on the transmission lines as generator try to overcome the imbalance and their output swing with respect to each other.[6-10]

2.1 Elementary view of transient stability

Consider the very simple power system of figure 1, consisting of a synchronous generator supplying power to a synchronous motor over a circuit composed of series inductive reactance XL. Each of the synchronous machines may be represented, at least approximately, by a constant-voltage source in series with a constant reactance. Thus the generator is represented by Eg and Xg; and the motor, by EM and XM. Upon combining the machine reactance and the line reactance into a single reactance, we have an electric circuit consisting of two constant-voltage sources, Eg and EM, connected through reactance X =XG + XL + XM. It will be shown that the power transmitted from the generator to the motor depends upon the phase difference 8 of the two voltages EG and EM. Since these voltages are generated by the flux produced by the field windings of the machines, their phase difference is the same as the electrical angle between the machine rotors.

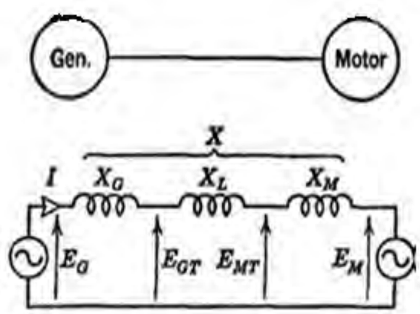


Figure 1: *Simple two machine power system.*

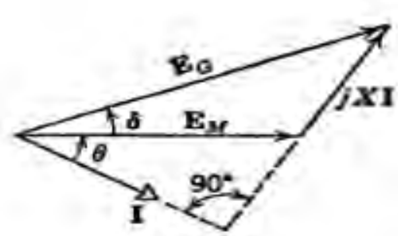


Figure 2: *Phasor diagram of the different parameters.*

The vector diagram of voltages is shown in figure 2 Vectorially,

$$EG = EM + Jxi \tag{1}$$

Hence the current is

$$I = (EG - EM)/jx \tag{2}$$

The power output of the generator and likewise the power input of the motor, since there is no resistance in the line is given by

$$P = Re(EgI) \tag{3}$$

Now let

$$EM = EM\llcorner 0 \tag{4}$$

$$EG = EG\llcorner \delta \tag{5}$$

$$P = Re(EG\llcorner -\delta(EGL\delta - EML0/xL90)) \tag{6}$$

$$= (EGEM/x)\sin\delta \tag{7}$$

This equation shows that the power P transmitted from the generator to the motor varies with the sine of the displacement angle between the two rotors, as plotted in figure 2.2. The curve is known as a power angle curve. The maximum power that can be transmitted in the steady state with the given reactance X and the given internal voltages EG and EM is

$$PM = \frac{EGEM}{X} \tag{8}$$

and occurs at a displacement angle 8 = 90°. The value of maximum power may be increased by rising either of the internal voltages or by decreasing the circuit reactance.

2.2 Swing equation

The electromechanical equation describing the relative motion of the rotor load angle (δ) with respect to the stator field as a function of time is known as Swing equation.

$$M\frac{d^2\delta}{d^2l} = Pt - Pu \tag{9}$$

M = Inertia constant PT = Shaft power input corrected for rotational losses Pu = Pm sinδ electric power output corrected for rotational losses Pm = Amplitude for the power angle curve δ = Rotor angle with respect to synchronously rotating reference Figure 3 shows the Response to a step change in mechanical power input[17].

3 SEPARATE ENERGY STORAGE DEVICE

SMES systems store energy in the magnetic field created by the flow of direct current in a superconducting coil which has been cryogenically cooled to a temperature below its superconducting critical temperature. A typical SMES system includes three parts: superconducting coil, Power Conversion System (PCS) and cryogenically cooled refrigerator. Once the superconducting coil is charged, the current will not decay and the magnetic energy can be stored indefinitely. The stored energy can be released back to the network by discharging the coil. The PCS uses an inverter/rectifier to transform AC power to direct current or convert DC back to AC power. The inverter/rectifier accounts for about 2–3% energy loss in each direction. SMES loses the least amount of electricity in the energy storage process compared to other methods of storing energy. SMES systems are highly efficient; the round-trip efficiency is greater than 95%. Due to the energy requirements of refrigeration and the high cost of superconducting wire, SMES is

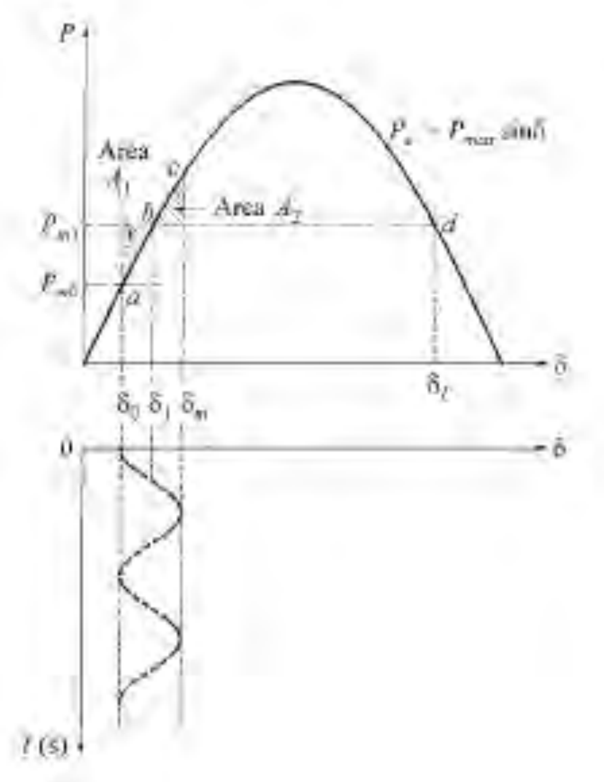


Figure 3: *Response to a step change in mechanical power input.*

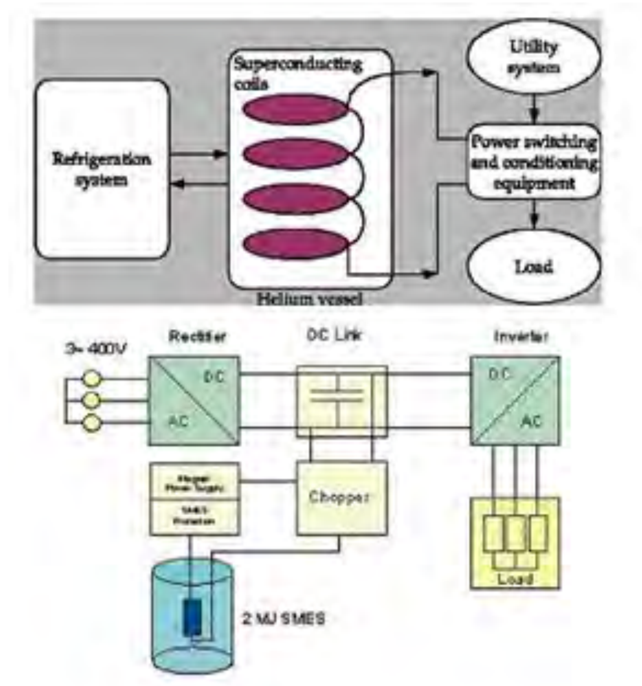


Figure 4: *Superconducting Magnetic Energy Storage.*

currently used for short duration energy storage. Therefore, SMES is most commonly to improving power quality. If SMES were to be used for utilities it would be a diurnal storage, charged from base load power at night and meeting peak loads during the day.

3.1 Components of SMES

Independent of capacity and size a SMES system always includes a superconducting coil, a refrigerator, a PCS, and a control system. Each of these components is discussed in this section.

The coil and superconductor: The superconducting coil, the heart of the SMES system, stores energy in the magnetic field generated by a circulating current. The maximum stored energy is determined by two factors: a) the size and geometry of the coil, which determines the inductance of the coil. The larger the coil, the greater the stored energy; and b) the characteristics of the conductor, which determines the maximum current. Superconductors carry substantial currents in high magnetic fields (EPRI, 2002). [3-11] All practical SMES systems installed to date use a superconducting alloy of niobium and titanium (Nb-Ti), which requires operation at temperatures near the boiling point of liquid helium, about 4.2 K (-269°C or -452°F) – 4.2 centigrade degrees above absolute zero. Some research-based SMES coils use High-Temperature Superconductors (HTS). HowBEser, the state of these materials today is such that they are not cost effective for SMES. Since only a few SMES coils have been constructed and installed, there is little experience with a generic design. This is true BEsen for the small or micro-SMES units for power-quality applications, where sBEseral different coil designs have been used. A primary consideration in the design of a SMES coil is the maximum allowable current in the conductor. It depends on: conductor size, the superconducting materials used, the resulting magnetic field, and the operating temperature. The magnetic forces can be significant in large coils and must be reacted by a structural material. The mechanical strength of the containment structure within or around the coil must withstand these forces. Another factor in coil design is the withstand voltage, which can range from 10 kV to 100 kV (EPRI, 2002). Cryogenic refrigerator: The superconducting SMES coil must be maintained at a temperature sufficiently low to maintain a superconducting state in the wires. As mentioned, for commercial SMES today this temperature is about 4.5 K (-269°C, or -452°F). Reaching and maintaining this temperature is accomplished by a special cryogenic refrigerator that uses helium as the coolant. Helium must be used as the so called "working fluid" in such a refrigerator because it is the only material that is not a solid at these temperatures. Just as a conventional refrigerator requires power to operate, electricity is used to power the cryogenic refrigerator (EPRI, 2002). As a result, there is a tremendous effort in the design of SMES and other cryogenic systems to lower losses within the superconducting coils and to minimize heat flow into the cold environment from all sources. The refrigerator consists of one or more compressors for gaseous helium and a vacuum enclosure called a “cold-box”, which receives the compressed, ambient-temperature helium gas and produces liquid helium for cooling the coil (EPRI, 2002).[5-16] Power conversion system: Charging and discharging a SMES coil is different from that of other storage technologies. The coil carries a current at any state of charge. Since the current always flows in one direction, the PCS must produce a positive voltage across the coil when energy is to be stored, which causes the current to increase. Similarly, for discharge, the electronics in the PCS are adjusted to make it appear as a load across the coil. This produces a negative voltage causing the coil to discharge. The product of this applied voltage and the instantaneous current determine the power. SMES manufacturers design their systems so that both the coil current and the allowable voltage include safety and performance margins. Thus, the PCS power capacity typically determines the rated capacity of the SMES unit (EPRI, 2002). The PCS provides an interface between the stored energy (related to the direct current in the coil) and the AC in the power grid. Control system: The control system establishes a link between power demands from the grid and power flow to and from the SMES coil. It receives dispatch signals from the power grid and status information from the SMES coil. The integration of the dispatch request and charge lBEsel determines the response of the SMES unit. The control system also measures the condition of the SMES coil, the refrigerator, and other equipment. It maintains system safety and sends system status information to the operator. Modern SMES systems are tied to the Internet to provide remote observation and control.

3.2 Thyristor based SMES

Figure 5 shows the basic configuration of a thyristor-based SMES unit, which consists of a Wye-Delta transformer, an ac/dc thyristor controlled bridge converter, and a superconducting coil or inductor. The converter impresses positive or negative voltage on the superconducting coil. Charge and discharge are easily controlled by simply changing the delay angle that controls the sequential firing of the thyristors . If α is less than 90o , the converter operates in the rectifier mode (charging) If α is greater than 90o, the converter operates in the inverter mode (discharging). As a result, power can be absorbed from or released to the power system according to requirement. At the steady state, SMES should not consume any real or reactive power.

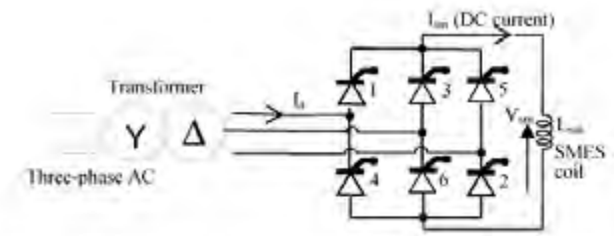


Fig. 1. SMES unit with six-pulse bridge ac/dc thyristor controlled converter.

Figure 5: *SMES unit with six-pulse bridge ac/dc thyristor controlled converter.*

The voltage Vsm of the dc side of the converter is expressed by

$$V_{sm} = V_{smo} \cos\alpha \tag{10}$$

where Vsmo is the ideal no-load maximum dc voltage of the bridge. The current and voltage of superconducting inductor are related as

$$I_{sm} = \frac{1}{Lsm} \int V_{sm} dT + I_{smo} \tag{11}$$

where Ismo is the initial current of the inductor. The real power Psm absorbed or delivered by the SMES can be given by

$$P_{sm} = V_{sm} I_{sm} \tag{12}$$

Since the bridge current Ism is not rBEsersible, the bridge output power Psm is uniquely a function of α, which can be positive or negative depending on Vsm. If Vsm is positive, power is transferred from the power system to the SMES unit. While if Vsm is negative, power is released from the SMES unit. The energy stored in the superconducting inductor is

$$W_{sm} = W_{smo} + \int P_{sm} dT \tag{13}$$

(13) where Wsmo=0.5Lsm I2smo is the initial energy in the inductor C. VSC based SMES Figure 3.3 shows the basic configuration of the VSC-based SMES unit, which consists of a Wye-Delta transformer, a six-pulse PWM rectifier/inverter using IGBT, a two-quadrant dc-dc chopper using IGBT, and a superconducting coil or inductor. The PWM converter and the dc-dc chopper are linked by a dc link capacitor. The superconducting

coil is charged or discharged by a two-quadrant dc-dc chopper. The dc-dc chopper is controlled to supply positive (IGBT is turned ON) or negative (IGBT is turned OFF) voltage to SMES coil and then the stored energy can be charged or discharged. Therefore, the superconducting coil is charged or discharged by adjusting the average voltage across the coil which is determined by the duty cycle of the two-quadrant dc-dc chopper. When the duty cycle is larger than 0.5 or less than 0.5, the stored energy of the coil is either charging or discharging. In order to generate the PWM gate signals for the IGBT of the chopper, the reference signal is compared with the triangular signal.[11-22]

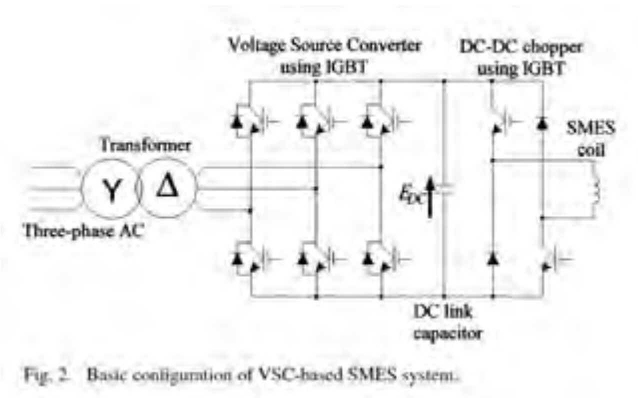


Figure 6: *Basic configuration of VSC based SMES system.*

3.3 CSC based SMES

Figure 7 shows the basic configuration of the Current Source Converter (CSC) based SMES unit. The dc side of CSC is directly connected with the superconducting coil, and its ac side is connected to the power line. A bank of capacitors connected to a CSC input terminal is utilized to buffer the energy stored in line inductances in the process of commutating direction of ac line current. Furthermore, the capacitors can filter the high-order harmonics of the ac line current. In CSC, through regulating the trigger signals of the switching dBEsices, the current in the superconducting coil can be modulated to generate controllable three-phase PWM current at the ac side. As the SMES system is inherently a current system, the transfer of both active and reactive powers between the CSC and power network is very fast.[11-19]

In case of 12-pulse CSC-based SMES, to improve the Total Harmonics Distortion (THD) of the ac source currents, an optimal PWM switching strategy is used to minimize the 5th, 7th, 11th, and 13th harmonics. It has been proved that the 5th, 7th, 11th, and 13th harmonics can be minimized to zero with the modulation index ranging from 0.2 to 1. Compared to a 6-pulse CSC, the 12-pulse CSC has smaller voltage ripples on the dc side, which means a further reduction of the ac losses in the SMES coil. For the magnet training, a dc current control algorithm is applied.[10-18]

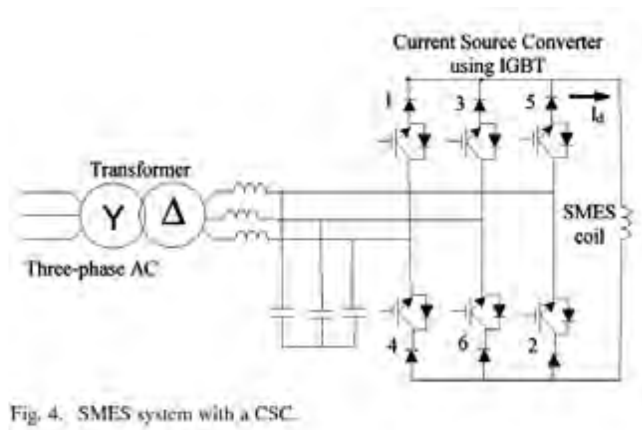


Figure 7: *SMES system with a CSC.*

3.4 Chopper operation

There are three different modes of operation of the SMES coil. The first mode of operation is the charging of the SMES coil. The SMES coil charges relatively fast to its rated current. The second mode is the stand-by mode. In this mode the current in the SMES coil effectively circulates in a closed loop, which can also be called as a freewheeling mode. The third mode is the discharge mode, during which the SMES coil discharges into the dc-link capacitor. The three modes are shown in figure 8, 9 and 10.

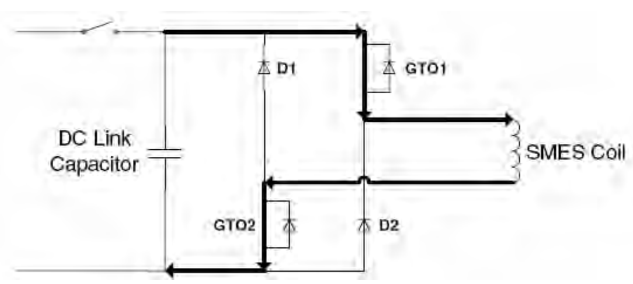


Figure 8: *Charging Mode.*

Before discussing the different modes, a GTO in ON state means that the duty cycle of that particular GTO is 1 and a GTO in OFF state means that the duty ratio is 0. All the three modes of operation are explained as follows.

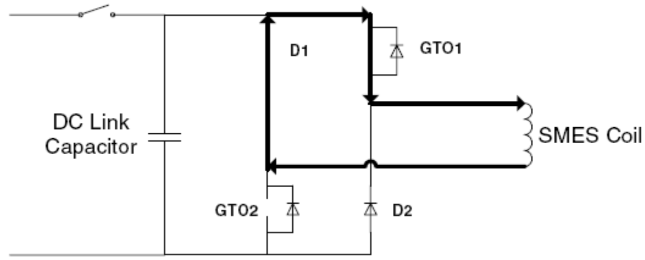


Figure 9: *Freewheeling Mode.*

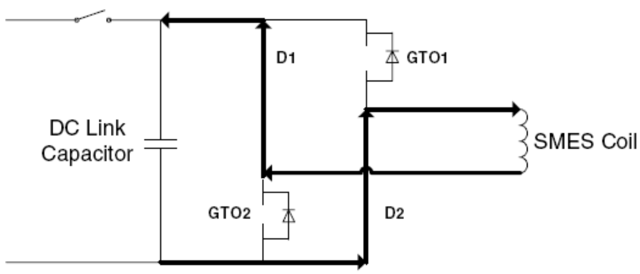


Figure 10: *Discharging Mode.*

3.5 Charging mode

In this mode, the SMES coil is charged to its rated capacity. During charging mode, GTO2 is always in the ON state. GTO1 can be switched ON or OFF in BEsery cycle. The SMES coil charges when the GTO1 is also in the ON state. When the SMES coil is charging, the relationship between the voltage across the SMES coil and the voltage across the dc link capacitor can be given as

$$V_{smes} = DV_{dc} \tag{14}$$

Where, Vsmes is the voltage across the SMES coil Vdc is the voltage across the dc link capacitor and D is the duty cycle of the GTO1 (defined as the ratio of the GTO ON time to the total time for a complete cycle) In this particular case, the duty cycle (D) of the GTO1 is kept constant at 1 so that the SMES coil charges at the maximum charging rate possible.

3.6 Freewheeling mode

The second mode of operation is called the freewheeling mode. In this mode, the current circulates in a closed loop. This is also called the standby mode. When the SMES coil is in the freewheel mode, one of the two GTO's is OFF. In Figure 4.6, it was shown that GTO1 is ON and GTO2 is OFF. During this period, there is no significant amount of loss, as the current through the SMES coil is circulating in a closed loop. Hence, the current remains fairly constant.

3.7 Discharging mode

The final mode of operation is the discharge cycle. The current in the SMES coil discharges into the dc link capacitor in this mode of operation. In this mode, the GTO2 is always in the OFF state and the duty cycle of GTO1 can be varied depending on the rate of discharge requirement. During the discharge cycle, to have the maximum rate of discharge, both the GTOs are kept in OFF state. The rate of discharge of the SMES coil can be controlled by making the duty cycle of one of the GTOs to be non-zero. The voltage relationship between the SMES coil and the dc link capacitor during the discharge cycle is given as,

$$V_{smes} = (1 - D)V_{dc} \tag{15}$$

In order to have the maximum discharge rate of the SMES coil into the dc link capacitor, the duty cycle of the GTO1 is kept at 0 in the present simulation. I. Battery to grid technology According to the 2012 energy outlook, with the current trend the transportation sector's share in total oil consumption will raise from 40% in 2008 up to 54% by 2035 Forecasts by the Energy Information Agency (EIA) anticipate rising oil prices over the next two decades, which in a high price scenario may surpass $5.5 per US gallon. Therefore, technologies related to reducing the oil consumption of the transportation section such as Plug-in Hybrid Electric BATTERYs or all Electric BATTERYs are starting to take their share in the BATTERY market and will potentially replace combustion engine BATTERYs in the future. Some economic studies anticipate that depending on the future oil price and the relative purchase price of internal combustion engine BATTERYs, BEs may take up to 86% of new light-BATTERY sales by 2030. BEs have higher production cost compared to combustion engine BATTERYs, which makes them not the first choice for a large percentage of consumers at the moment. Further, with the relatively slow improvement of battery technology comparing to other technologies, the total production cost of the BEs will not decrease substantially in the near future. Some industrial reports claim that the total cost of ownership of Li-ion powered BEs, which includes initial price and also fuel, maintenance, and other costs over the life of the car is less than the combustion engine BATTERYs. Unfortunately, the majority of consumers tend to focus more on initial cost, not total cost of ownership, when they make BATTERY purchasing decisions Therefore, government or private companies should provide incentives or financing to consumers to make BEs marketable. [20-22] In 2012, a provider named "Better Place" demonstrated the World's first switchable battery electric taxi for urban areas in Japan In switchable batteries transportation systems, network operators finance the cost of the battery by offering electric car drivers pay-per-mile service contracts. These contracts also include the price of charging infrastructure as well as charging electricity price. Financing the BES battery with a service contract has a number of advantages. First, a switchable battery eliminates the up-front cost of the battery for the customer. Second, it allows new battery technology to be installed in older BEs. Third, it eliminates the risk of purchasing a car whose battery life is shorter than the life of the BES. Fourth, switchable batteries contract opens the door for BATTERY to Grid (B2G) services since if the utility owns the battery, it is easier to convince the customer to use the BES battery for B2G. BEs have the potential to serve the grid as distributed energy storage. Most BATTERYs are parked an average of 95% of the time and remain connected to the grid in charging or idle mode. Thus, their batteries and chargers could be used to let active and reactive power flow from the car and internal capacitors back to the power lines and to the grid. Therefore, the BES charger can be designed to be able to support the grid during critical conditions, namely, active power ride-through, regulation of reactive power, and sending active power back to the grid for peak shaving. In addition, the chargers can be coordinated to start charging during low peak hours of the local distribution system. In this case, BEs indirectly support the grid with intelligent charging. B2G can be implemented using either hybrid BATTERYs or pure electric BATTERYs. Moreover, charging of the BES can be slowed or stopped according to demand response contracts, and emergency load curtailment. The possibility of B2G services has been studied for more than a decade and it is gaining more and more popularity as percentage of battery based PHBEs and BEs penetration into the grid is increasing.[15-20] The ability to use BEs and PHBEs as a resource depends on appropriate supporting infrastructure, and customers who are willing to provide the services as well as presence of bidirectional chargers. SBEseral studies have discussed bidirectional charger topologies as well as different control methods to use the BES as a potential distributed energy resource. These topologies allow the charger to send active and sometimes reactive power in both directions, i.e., from BATTERYs to the grid and from the grid to the BATTERYs. The active power markets of B2G can be divided into four general groups. These four groups are base load, peak, spinning reserves, and regulation. Base load power is defined as the bulk power generation that is running most of the time. As B2G for base load power requires a large amount of battery charge, it is not discussed here. Peak shaving occurs during predictable highest power demand hours. Spinning reserves are supplied by fast generators ready to respond in case of equipment or power supplier failures. Spinning reserves should be included in system power design to meet contract requirements and are typically called around 20 times a year. The duration of supply by a spin reserve is typically around 10 min but the source must be able to last up to 1 hour. Active regulation is used to keep the frequency and voltage steady. Regulation is called for only a few minutes at a time, but the number of times can be up to 400–500 times per day. The utility pays spinning reserves and regulation sources in part for just being available, per hour availability; how BE, base load and peak shaving are paid per kWh generated. The Power quality services can be classified into motor starting, active filtering, and general reactive power regulation. Large induction motors or combinations of medium size motors starting at the same time require a large amount of instantaneous reactive power for a short period of time during their acceleration. The reactive power can be injected locally through the BEs charger to compensate for the reactive power need during motor start up. BES charging stations can be used as shunt active filter to improve power quality of girds integrating wind generation. Reactive regulation is required frequently during power system operation. Reactive power is usually supplied locally by capacitor banks or other reactive compensators. Due to the presence of BES charging stations in the distribution system, BEs are possible source of reactive power for the distribution system.

4 PROPOSED SYSTEM

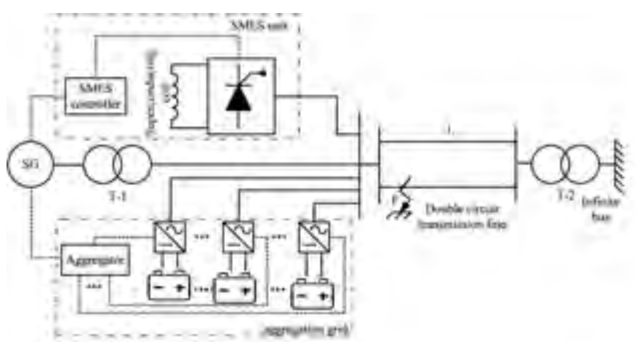


Figure 11: *Block diagram of proposed SMES.*

This system consists of the main grid, the GV aggregation grid and the SMES unit. In the main grid, a synchronous generator (SG) feeds an infinite bus through a double circuit transmission line as shown in figure 11. The SMES unit and the GV aggregation grid are connected to the main grid at the generator terminal bus so that the power flow at transient state can be effectively regulated. The SMES unit consists of a thyristor-based

SMES and a SMES controller. The GV aggregation grid consists of an aggregation of BES and an aggregator. Each GV is connected to the power grid through a DC/AC power converter. Both the SMES controller and aggregator communicate with the main grid operator. They control the SMES and BES to charge or discharge a certain amount of energy according to the power grid demands. The faults are assumed to occur at point F on the transmission line. Synchronous generator is taken as test system of having 200MVA,13.8KV as shown in figure 12 connected to the grid. The SMES and BES are integrated into the grid for improving transient stability.[41-50]

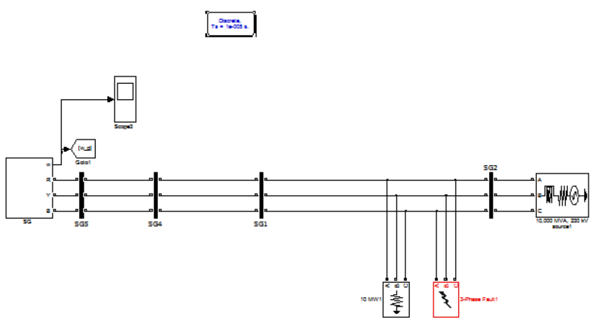


Figure 12: *Test system without SMES and GV.*

As shown in figure 13 SMES is connected to the generator terminal. Speed and voltage of the generator are measured by SMES controller.

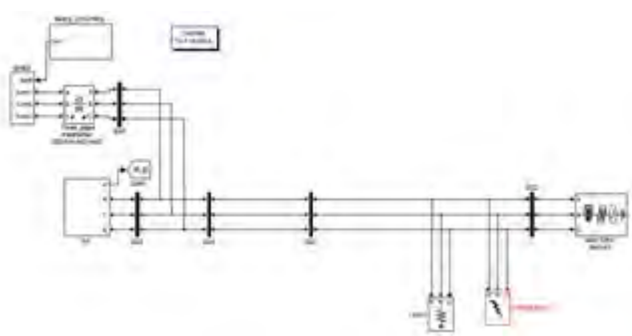


Figure 13: *Synchronous generator with SMES.*

SMES and BES are connected to the generator terminal as shown in figure 14. During fault condition SMES and BES supports active and reactive power to the system.

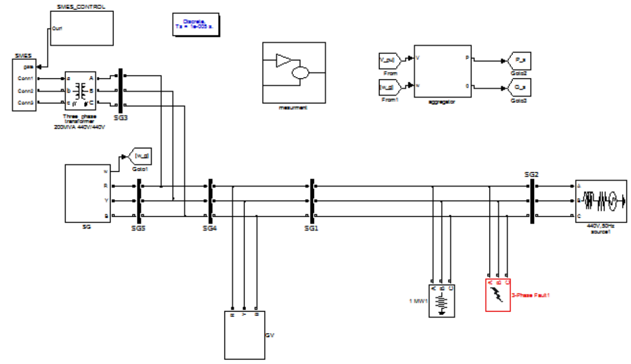


Figure 14: *Integration of SMES and BES.*

5 RESULT

The behavior of the complete system of integration of SMES with battery energy storage system to improve the transient stability of the power system. Considering three phase fault in the power system which occurs of 1sec. Figure 15 shows the load angle response of the system under three phase fault. The system voltage response during fault is shown in figure 16.[1-7]

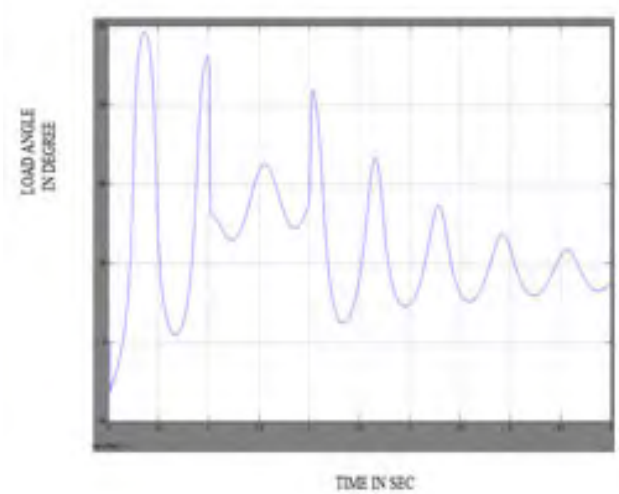


Figure 15: *Load angle response during three phase fault.*

The response of the power system for three phase fault after the implementation of proposed SMES with BES system is shown in figure 16.

Considering LLG fault in the power system which occurs of 1sec. Figure 17 shows the load angle response of the system under LLG fault. The system voltage response during fault is shown in figure 18.

The response of the power system for three phase fault after the implementation of proposed SMES with BES system is shown in figure 19.

Considering LG fault the fault duration is 1 sec. The fault is cleared automatically after one sec. During this fault period synchronous generator voltage get reduced and load angle get increased. At the time SMES and

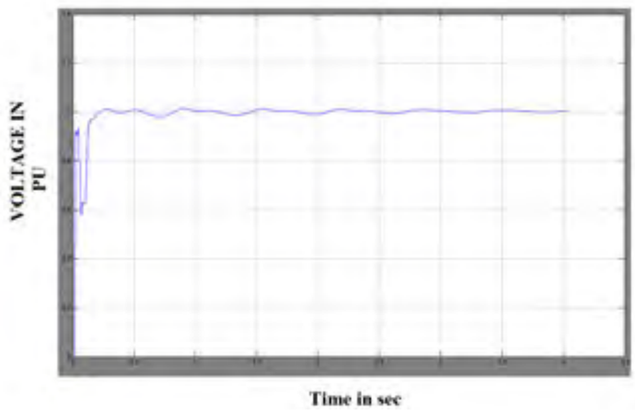


Figure 16: *System voltage during three phase fault without SMES.*

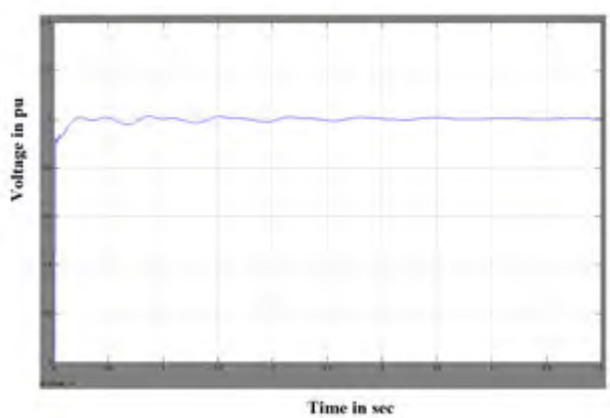


Figure 17: *System voltage during three phase fault with SMES.*

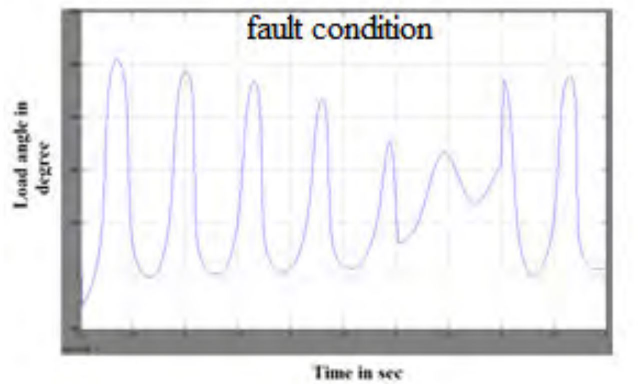


Figure 18: *Load angle response during LLG fault.*

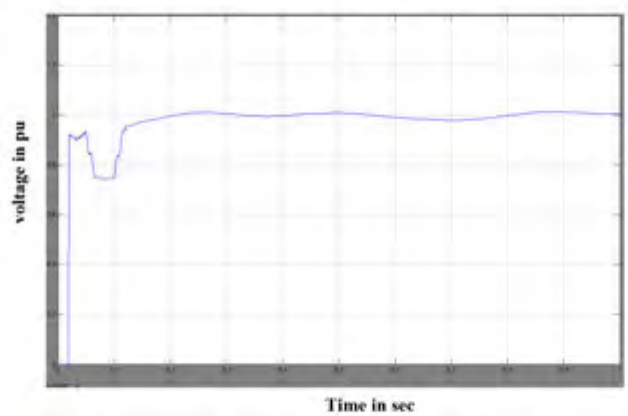


Figure 19: *System voltage during LLG fault without SMES.*

BES provide active and reactive power to the system for reaching fast steady state condition. The load angle response under LG fault is shown in figure 20. The system voltage response during LG fault with the proposed system is shown in figure 21.

6 CONCLUSION

This paper has analyzed the transient stability of the proposed power system integrated with SMES and BES. SMES and BES adjust the active and reactive power to the system.SMES is very efficient in transient stability enhancement. The system model is established to carry out computer simulations under both LG and LG, LL faults. The results of load angle response and system voltage response are given to illustrate the system dynamic performances. It can be found that both SMES and BES can enhance the transient stability of the power grid.

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Power Management of a Hybrid Solar- Wind Energy System" International Journal of Engineering Research & Technology vol. 3(2) pp.1988-1992, 2014.

[3] M. Siva Ramkumar, M. Sivaram Krishnan, A. Amudha, "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc " in Interna-

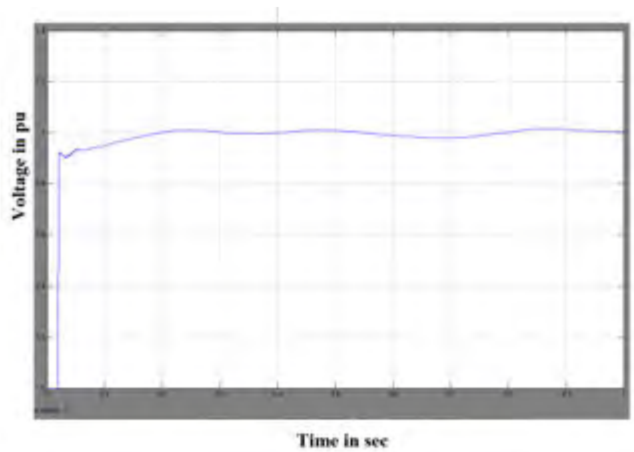


Figure 20: *System voltage during LLG fault with SMES.*

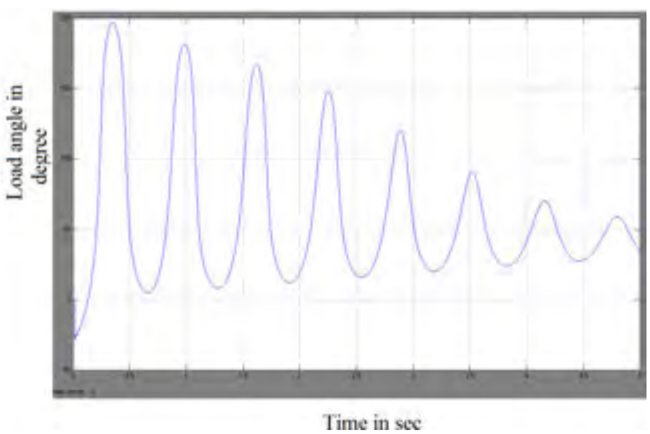


Figure 21: *Load angle response during LG fault.*

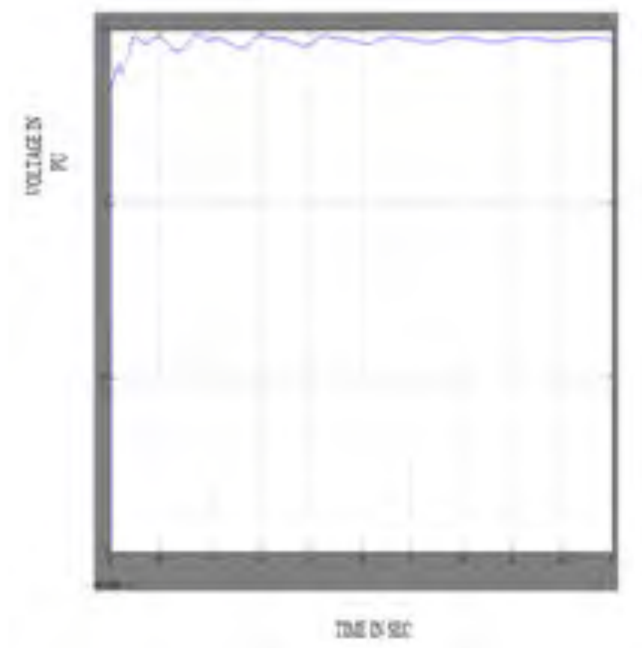


Figure 22: *System voltage during LG fault with SMES.*

tional Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[5] M Siva RamKumar, A. Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016. .

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763-769,2014.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2),2014

[9] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[10] D. Kavitha, C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.20 (2015), pg. 17749-17754.

[11] D. Manoharan, A. Amudha. "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, A. Amudha. A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6233-6240.

[13] A. Amudha. "Enhancement of Available Transfer Capability using FACTS controller" in International journal of Applied Mechanics and Materials, Vol. 573, pp 340-345

[14] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035-2042.

[15] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[17] K. Balachander, P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, V. Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[19] K. Balachander, V. Ponnusamy, 'Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research', Volume 7, Number 3 (2012), pp. 247-256. .

[20] K. Balachander, S. Kuppusamy, V. Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[21] M. Sivaram Krishnan, A. Amudha, , M. Siva Ramkumar, 'Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms', International journal of Pure and Applied Mathimatics,118 (11), pp 609-617,2018 DOI:10.12732/ijpam.v118i11.79

[22] S. Motapon, L. Dessaint, K.AI-Haddad, "A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, " IEEE Trans. Ind. Electron. , vo1.61, no.3, pp.1320,1334, March 2014.

ACHIEVING EFFICIENT AND SECURE DATA ACQUISITION FOR CLOUD-SUPPORTED INTERNET OF THINGS IN GRID CONNECTED SOLAR, WIND AND BATTERY SYSTEMS

M. Jayaprakash, D. Kavitha, M. Siva Ramkumar, K. Balachander, M. Sivaram Krishnan

Abstract: Lack of resources established in the present world is initiating everyone towards energy efficient technologies. Among all these resources, power is one which needs to be monitored and controlled as per the need since electricity consumption is increasing day-by day. In this project, we have described an effective implementation of an intelligent remote monitoring system for solar Photovoltaic (PV), Wind Energy Conversion System (WECS) and battery which are used in a greenhouse environment. The proposed system design can be installed in solar PV, WECS and battery in order to solve management problems, maintenance and shortens the mean time to repair. We have designed a smart remote monitoring system based on internet of thing for monitoring Solar PV, WECS and Battery. This system had incorporated remote monitoring for solar PV, WECS and battery through internet using host, network GPRS (Global Positioning Radio Service), embedded system gateway and Arduino. The result of our demonstration shows that the system can monitor store and manipulate data from solar PV, WECS and battery. Thus, the remote monitoring functions are realized in real-time.

Keywords: Cloud computing, Internet of Things (IOT), Photovoltaic system (PV), Wind Energy Conversion System (WECS), Battery, Data acquisition.

1 Introduction

Electricity is the most basic need of everyone in this modern world. Energy consumption graph is increasing day by day whereas the resources of energy are diminishing parallel. Usage of power is growing drastically paving the way for energy efficient technologies and digging for renewable energy sources. Since prevention is better than cure awareness of energy consumption should be brought into every place before resources get extinguished. Industrial users consume about 37 percent of the total energy, personal and commercial transportation consumes 20 percent whereas residential appliances consume 11 percent; and commercial uses amount to 5 percent of the total energy and remaining 27 percent of the world's energy is lost in energy transmission and generation. [1-10] The designed system will help in reducing the energy wastage by continuously monitoring and controlling the electrical appliances. Among all the microcontrollers, mbed is selected because of the features it has like simplicity, online compiler, comfortable start-up and peripheral libraries. Since mbed has 10/100MBit Ethernet compatibility, it can be interfaced to Ethernet modem in order to implement IoT. The monitored values from sensors can be continuously stored and updated in a cloud database. There are many open source cloud platforms such as Ubidots, Xively and Thing Speak etc. for several dashboard devices. Xively provides libraries and BSP files to mbed. This is the reason for choosing Xively as storage platform for monitored data from current measuring sensors. Controlling of the devices is the other task that could be done to save energy. Relays can be used as actuators in order to turn on and turn off the appliances as per the needs. Automation system online makes user to operate the system even when user is not in vicinity of the automation system. In this context, IoT concept has been initiated. IoT represents integration of devices through internet which implies that the devices utilize IP(Internet Protocol) address as unique identifier. When interfaced to Ethernet, each mbed generates unique IP address. Depending upon the necessity and number of rooms' present in house, user can provide controllers to each room. An energy-efficient solution using new concept of CPS (Communicating Power Supplies) to facilitate the information transfer about energy and control the information between the device and building management system. The components of CPS are an mbed controller to control all the information and a RF transceiver to communicate to user. All the data obtained can be stored in the cloud data base using IoT platform. The system is tested on three devices i.e. Television, video player and LED light. CPS devices are integrated into the product to provide native controls and automatically include product identity information. A hardware system that consists of Smart Home Energy Management System (SHEMS) including applications such as communication, sensing technology and a machine-learning algorithm. SHEMS includes sensors which are used detect human activities and with the help of this data, machine-learning algorithm is executed consequently. This execution reduces the total electricity bills for consumers without any need of human's presence. [11-16] Home control and security system based on the field programmable array, the FPGA used is Nios development board cyclone-II edition which provides hardware platform for developing embedded systems based on Altera cyclone-II devices.The model of the proposed system is designed and the correlation of software and hardware is carried out. The logics for controlling are designed in FPGA and communicated to the user through web server. The web server is created by using HTML or java based script. User alerts are given through web server designed in PHP and thereby placing switch modules and controlling them through controller provides the entire security system. Smart home interfaces and device definitions to allow interoperability among ZigBee devices produced by various manufacturers of electrical equipment, meters and smart energy enabling products. ZigBee can be utilized for transferring the information about the power and energy of home appliances. For monitoring the solar panels, power-line communication is utilized. This protocol establishes the wireless network, based on the Kruskal's algorithm value measured from the RF radio. A photovoltaic system management to improve home energy management based on PLC that consists of PLC modem, Renewable Energy Gateway (REG) and smart device source. The PLC modems communicate with the REG through the power line which transmits the DC power generated by PV modules to the grid-connected inverter. The REG stores and processes the received status value. The smart device application provides the status of the entire PV system and this method allows clients to limit the failures and quickly fix them.[17-22]

2 HYBRID ENERGY SYSTEM

We all know that the world is facing a major threat of fast depletion of the fossil fuel reserves. Most of the present energy demand is met by fossil and nuclear power plants. A small part is met by renewable energy technologies such as the wind, solar, biomass, geothermal etc. There will soon be a time when we will face a severe fuel shortage. As per the law of conservation of energy, "Energy can neither be created, nor be destroyed, but it can only be converted from one form to another". Most of the research now is about how to conserve the energy and how to utilize the energy in a better way. Research has also been into the development of reliable and robust systems to harness energy from nonconventional energy resources. Among them, the wind and solar power sources have experienced a remarkably rapid growth in the past 10 years. Both are pollution free sources of abundant power. [13-16] With high economic growth rates and over 17 percent of the world's population, India is a significant consumer of energy resources. Despite the global financial crisis, India's energy demand continues to rise. India consumes its maximum energy in Residential, commercial and agricultural purposes in comparison to China, Japan, and Russia. Solar energy is energy from the Sun. It is renewable, inexhaustible and environmental pollution free. Solar charged battery systems provide power supply for complete 24 hours a day irrespective of bad weather. By adopting the appropriate technology for the concerned geographical location, we can extract a large amount of power from solar radiations. More over solar energy is expected to be the most promising alternate source of energy. The global search and the rise in the cost of conventional fossil fuel is making supply-demand of electricity product almost impossible especially in some remote areas. Generators which are often used as an alternative to conventional power supply systems are known to be run only during certain hours of the day, and the cost of fuelling them is increasingly becoming difficult if they are to be used for commercial purposes. Wind energy is the kinetic energy associated with the movement of atmospheric air. It has been used for hundreds of years for sailing, grinding grain and for irrigation. Wind energy systems convert this kinetic energy to more useful forms of power. Wind energy systems for irrigation and milling have been in use since ancient times and at the beginning of the 20th century it is being used to generate electric power. Windmills for water pumping have been installed in many countries particularly in the rural areas. Wind turbines transform the energy in the wind into mechanical power, which can then be used directly for grinding etc. or further converting to electric power to generate electricity. Wind turbines can be used singly or in clusters called 'wind farms.[17-21]

2.1 Wind Energy Conversion System

Figure 1 represents the complete wind energy conversion systems (WECS), which converts the energy present in the moving air (wind) to electric energy. The wind passing through the blades of the wind turbine generates a force that turns the turbine shaft. The rotational shaft turns the rotor of an electric generator, which converts mechanical power into electric power. The major components of a typical wind energy conversion system include the wind turbine, generator, interconnection apparatus and control systems. The power developed by the wind turbine mainly depends on the wind speed, swept area of the turbine blade, density of the air, rotational speed of the turbine and the type of connected electric machine.

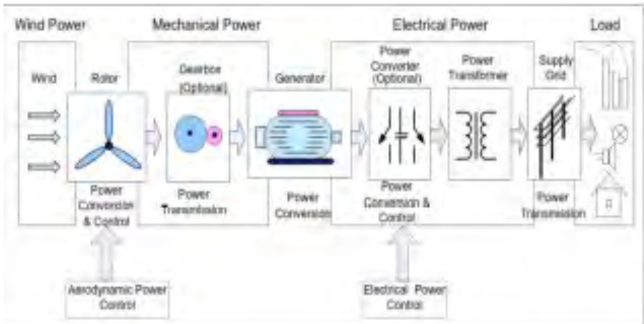


Figure 1: *Wind Energy Conversion System.*

As shown in figure 1, there are primarily two ways to control the WECS. The first is the Aerodynamic power control at either the Wind Turbine blade or nacelle, and the second is the electric power control at an interconnected apparatus, e.g., the power electronics converters. The flexibility achieved by these two control options facilitates extracting maximum power from the wind during low wind speeds and reducing the mechanical stress on the wind turbine during high wind speeds. [12-19]

2.2 PV system

The word photovoltaic consists of two words: photo, a greek word for light, and voltaic, which defines the measurement value by which the activity of the electric field is expressed, i.e. the difference of potentials. Photovoltaic systems use cells to convert sunlight into electricity. Converting solar energy into electricity in a photovoltaic installation is the most known way of using solar energy. The light has a dual character according to quantum physics. Light is a particle and it is a wave. The particles of light are called photons. Photons are massless particles, moving at light speed. In metals and in the matter generally, electrons can exist as valence or as free. Valence electrons are associated with the atom, while the free electrons can move freely. In order for the valence electron to become free, he must get the energy that is greater than or equal to the energy of binding. Binding energy is the energy by which an electron is bound to an atom in one of the atomic bonds. In the case of photoelectric effect, the electron acquires the required energy by the collision with a photon. Part of the photon energy is consumed for the electron getting free from the influence of the atom which it is attached to, and the remaining energy is converted into kinetic energy of a now free electron. Free electrons obtained by the photoelectric effect are also called photoelectrons. The energy required to release a valence electron from the impact of an atom is called a work out Wi, and it depends on the type of material in which the photoelectric effect has occurred.

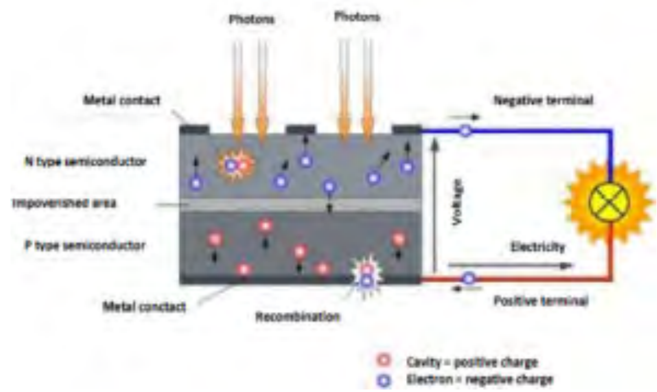


Figure 2: *Functioning of PV cell.*

The previous equation shows that the electron will be released if the photon energy is less than the work output. The photoelectric conversion in the PV junction. PV junction (diode) is a boundary between two differently doped semiconductor layers; one is a P-type layer (excess holes), and the second one is an N-type (excess electrons). At the boundary between the P and the N area, there is a spontaneous electric field, which affects the generated electrons and holes and determines the direction of the current. To obtain the energy by the photoelectric effect, there shall be a directed motion of photoelectrons, i.e. electricity. All charged particles, photoelectrons also, move in a directed motion under the influence of electric field. The electric field in the material itself is located in semiconductors, precisely in the impoverished area of PV junction (diode). It was pointed out for the semiconductors that, along with the free electrons in them, there are cavities as charge carriers, which are a sort of a byproduct in the emergence of free electrons. Cavities occurs whenever the valence electron turns into a free electron, and this process is called the generation, while the reverse process, when the free electron fills the empty spaces - a cavity, is called recombination. If the electron-cavity pairs occur away from the impoverished areas it is possible to recombine before they are separated by the electric field. Photoelectrons and cavities in semiconductors are accumulated at opposite ends, thereby creating an electromotive force. If a consuming device is connected to such a system, the current will flow and we will get electricity. In this way, solar cells produce a voltage around 0,5-0,7 V, with a current density of about several tens of mA/cm2depending on the solar radiation power as well as on the radiation spectrum. The usefulness of a photovoltaic solar cell is defined as the ratio of electric power provided by the PV solar cells and the solar radiation power. The usefulness of PV solar cells ranges from a few percent to forty percent. The remaining energy that is not converted into electrical energy is mainly converted into heat energy and thus warms the cell. Generally, the increase in solar cell temperature reduces the usefulness of PV cells. Standard calculations for the energy efficiency of solar photovoltaic cells are explained below. Energy conversion efficiency of a solar photovoltaic cell (η "ETA") is the percentage of energy from the incident light that actually ends up as electricity. This is calculated at the point of maximum power, Pm, divided by the input light irradiation (E, in W/m2), all under standard test conditions (STC) and the surface of photovoltaic solar cells (AC in m2). STC - standard test conditions, according to which the reference solar radiation is 1.000 W/m2, spectral distribution is 1.5 and cell temperature 250C.

2.3 Battery

The storage battery or secondary battery is such battery where electrical energy can be stored as chemical energy and this chemical energy is then converted to electrical energy as when required. The conversion of electrical energy into chemical energy by applying external electrical source is known as charging of battery. Whereas conversion of chemical energy into electrical energy for supplying the external load is known as discharging of secondary battery. During charging of battery, current is passed through it which causes some chemical changes inside the battery. This chemical changes absorb energy during their formation. When the battery is connected to the external load, the chemical changes take place in reverse direction, during which the absorbed energy is released as electrical energy and supplied to the load. [14]

3 IoT AND CLOUD COMPUTING

3.1 IoT

In analogy to the definition that a universe is commonly defined as the totalityof existence, an Internet of Things universe might potentially connect everything.As a further analogy to new theories about parallel universes, differentInternet of Things worlds might develop and exist in parallel, potentially overlapand possess spontaneous or fixed transfer gates.These forward-looking considerations do certainly convey a slight touchof science fiction, but are thought to stimulate the exploration of future livingworlds. The overall scope is to create and foster ecosystems of platforms forconnected smart objects, integrating the future generation of devices, networktechnologies, software technologies, interfaces and other evolving ICT innovations,both for the society and for people to become pervasive at home, at-work and while on the move. These environments will embed effective andefficient security and privacy mechanisms into devices, architectures, platforms,and protocols, including characteristics such as openness, dynamicexpandability, interoperability of objects, distributed intelligence, and costand energy-efficiency. Whereas the forthcoming Internet of Things related research in the scopeof Horizon 2020 and corresponding national research programs will addressthe above matters, challenges from a societal and policy perspective remain equally important, in particular the following: Fostering of a consistent, interoperable and accessible Internet ofThings across sectors, including standardisation. Directing effort and attention to important societal applicationareas such as health and environment, including focus on lowenergy consumption. Offering orientation on security, privacy, trust and ethical aspectsin the scope of current legislation and development of robust andfuture-proof general data protection rules. Providing resources like spectrum allowing pan-European service-provision and removal of barriers such as roaming.[15] Maintaining the Internet of Things as an important subject for internationalcooperation both for sharing best practises and developingcoherent strategies.

3.2 Cloud computing

Cloud computing is an information technology (IT) paradigm, a model for enabling ubiquitous access to shared pools of configurable resources (such as computer networks, servers, storage, applications and services), which can be rapidly provisioned with minimal management effort, often over the Internet. Cloud computing allows users and enterprises with various computing capabilities to store and process data either in a privately-owned cloud, or on a third-party server located in a data center - thus making data-accessing mechanisms more efficient and reliable. Cloud computing relies on sharing of resources to achieve coherence and economy of scale, similar to a utility. Advocates note that cloud computing allows companies to avoid or minimize up-front IT infrastructure costs. As well, third-party clouds enable organizations to focus on their core businesses instead of expending resources on computer infrastructure and maintenance. Proponents also claim that cloud computing allows enterprises to get their applications up and running faster, with improved manageability and less maintenance, and that it enables IT teams to more rapidly adjust resources to meet fluctuating and unpredictable business demand. Cloud providers typically use a "pay-as-you-go" model. This could lead to unexpectedly high charges if administrators are not familiarized with cloud-pricing models. In 2009 the availability of high-capacity networks, low-cost computers and storage devices as well as the widespread adoption of hardware virtualization, service-oriented architecture and autonomic and utility computing led to a growth in cloud computing. Companies can scale up as computing needs increase and then scale down again when demands decrease. In 2013 it was reported that cloud computing had become a highly demanded service or utility due to the advantages of high computing power, cheap cost of services, high performance, scalability, and accessibility - as well as availability. Some cloud vendors experience growth rates of 50% per year, but while cloud computing remains in a stage of infancy, it has pitfalls that need to be addressed to make cloud-computing services more reliable and user-friendly. Though service-oriented architecture advocates "everything as a service" (with the acronyms EaaS or XaaS, or simply aas), cloud-computing providers offer their "services" according to different models, of which the three standard models per NIST are Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). These models offer increasing abstraction; they are thus often portrayed as a layers in a stack: infrastructure-, platform- and software-as-a-service, but these need not be related. For example, one can provide SaaS implemented on physical machines (bare metal), without using underlying PaaS or IaaS layers, and conversely one can run a program on IaaS and access it directly, without wrapping it as SaaS. This service models are shown in figure 3 as a layers in a stack.[11-20]

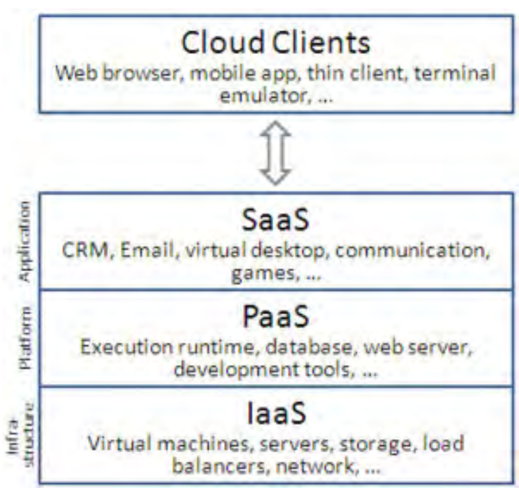


Figure 3: *Cloud computing service models.*

The NIST's definition of cloud computing defines the service models as follows: Software as a Service (SaaS): The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email), or a program interface. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.[9-22] Platform as a Service (PaaS): The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment. Infrastructure as a Service (IaaS): The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components (e.g., host firewalls).[12-20]

3.3 Data aquisition

Data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition systems, abbreviated by the acronyms DAS or DAQ, typically convert analog waveforms into digital values for processing. The components of data acquisition systems include: Sensors, to convert physical parameters to electrical signals. Signal conditioning circuitry, to convert sensor signals into a form that can be converted to digital values. Analog-to-digital converters, to convert conditioned sensor signals to digital values. Data acquisition applications are usually controlled by software programs developed using various general purpose programming languages such as Assembly, BASIC, C, C++, C#, Fortran, Java, LabVIEW, Lisp, Pascal, etc. Stand-alone data acquisition systems are often called data loggers. There are also open-source software packages providing all the necessary tools to acquire data from different hardware equipment. These tools come from the scientific community where complex experiment requires fast, flexible and adaptable software. Those packages are usually custom fit but more general DAQ package like the Maximum Integrated Data Acquisition System can be easily tailored and is used in several physics experiments worldwide.10-14]

4 ARDUINO

The Arduino is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

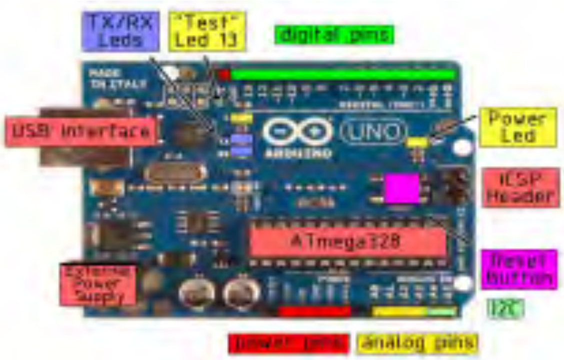


Figure 4: *Arduino UNO.*

The differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter. It is shown in figure 4.

4.1 Arduino Mega 2560

Figure 5: *Arduino Mega 2560.*

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila. It is shown in figure 5.

4.2 Arduino Duemilanove and NG

Both the Diecimila and NG have a jumper next to the USB port and require manual selection of either USB or battery power. The Arduino NG requires that you hold the rest button on the board for a few seconds prior to uploading a program. The figures 6 and 7 shows arduino duemianove and NG respectively.

Figure 6: *Arduino duemilanove.*

Figure 7: *Arduino NG.*

4.3 Arduino lilypad

The LilyPad was designed for wearable and e-textile applications. It is intended to be sewn to fabric and connected to other sewable components using conductive thread. This board requires the use of a special FTDI-USB TTL serial programming cable. For more information, the Arduino LilyPad page is a decent starting point. It is shown in figure 8.

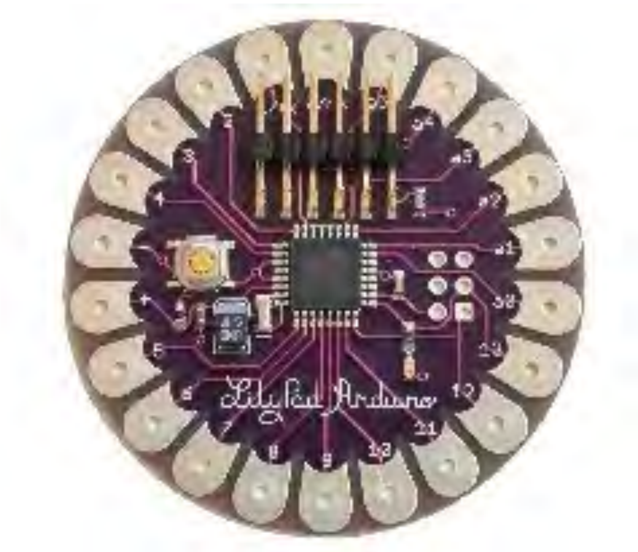


Figure 8: *Arduino lilypad.*

4.4 Microcontroller

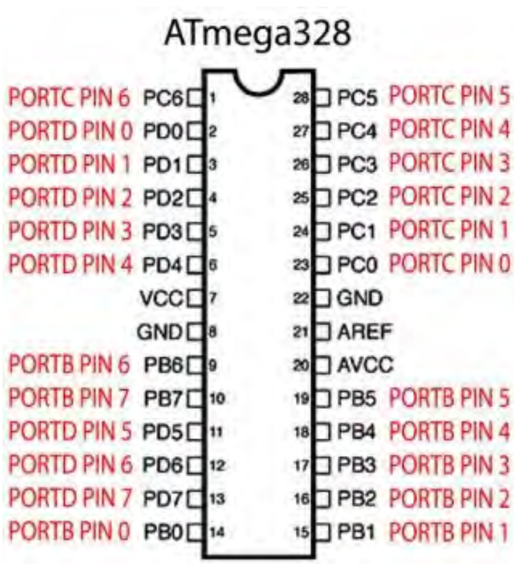


Figure 9: *PIN diagram.*

The ATmega328 is a single chip micro-controller created by Atmel and belongs to the megaAVR series. The device operates between 1.8-5.5 volts. The device achieves throughputs approaching 1 MIPS per MHz. The Atmel 8-bit AVR RISC-based microcontroller combines 32 KB ISP flash memory with read-while-write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8-channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The PIN diagram is shown in figure 9.[12-22]

5 PROPOSEDSYSTEM

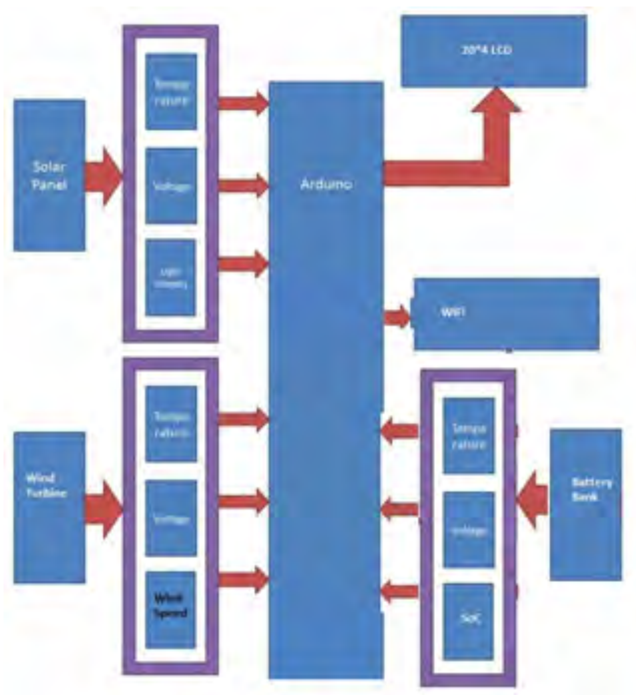


Figure 10: *Block diagram of proposed system.*

Figure 10 shows the block diagram of Achieving Efficient and Secure Data Acquisition for Cloud-supported Internet of Things in Grid connected Solar, Wind and Battery Systems.

5.1 Monitoring solar system

Most photovoltaic systems contain parts such as the solar modules (panels) to provide the electrical power, a battery charger for converting the panel output to the battery voltage, a battery pack to store energy during the day and provide it during the night time, an inverter to transform the battery voltage to the proper line voltage for operating home appliances and an line source selector to switch between the solar and grid power. When the sun is shining during the daytime, the solar photovoltaic cells convert the sunlight falling on them into electricity. Although the efficiency of the conversion may be only about 17%, solar power can easily reach 1KW/m2 and suitable panels can produce 5000 Watts in these conditions. Solar panels typically produce a high voltage, 120V DC being a common figure. The battery charger has to convert this to match the battery voltage, generally 48V DC. Solar light power charges the batteries continuously during the daytime; therefore, the charger has to keep tracking the maximum power point to optimize the yield of the system. As the charger has to charge the battery also, this device forms the most elaborate part of the system. With the above arrangement, the solar panels charge the battery during the daytime and the battery discharges during the night. The size of the battery depends on one day of consumption plus some extra to tide over an overcast day. That also decides the size of the solar panel. Batteries are essentially heavy and the lead-acid types generally have a lifespan of about 7 years. The batteries feed the inverter, which converts the 48V DC into the line voltage – usually 230V AC or 110V AC. With a 5KW continuous rating, inverters can essentially run almost all household appliances such as the clothes dryer, the washing machine, the dishwasher and the electric kitchen oven. When the inverter is supplying a large load, the battery current may climb up to 200A. Multiple sensors measure the solar field power from and temperature of the solar modules divided into arrays. The information comes to a PV panel via a CAN bus, which unites all the sensors. The PV panel also acts like a gateway between the CAN bus and a single board computer.

5.2 Voltage Measurement in PV

Voltage Measurement of the Solar Panel is very easy which is up to 5 volts. But if we want to measure more than 5 volts then we have to use some additional circuitry like Voltage Divider. This circuitry changes according to Voltage, which means How Much Voltage we have to Measure. It is shown in figure 11.

Let us suppose if we want to measure 5 volts, then there is no need for any Additional Circuitry. Just connect the Solar Panel Output Voltage to Analog pin of Arduino and convert that in Digital and Display result on LCD or Computer. For measuring Voltage we have to follow the given Formula: Voltage= (Analog value / resistor factor) * reference Voltage Where: Analog value= Analog output of Voltage divider Resistor factor= 1023.0/(R2/R1+R2) Reference Voltage= 5 volts And let suppose: R1= 1K R2=1K Resistor factor= 1023.0 * (1000/1000+1000) Resistor factor=1023.0 * 0.5

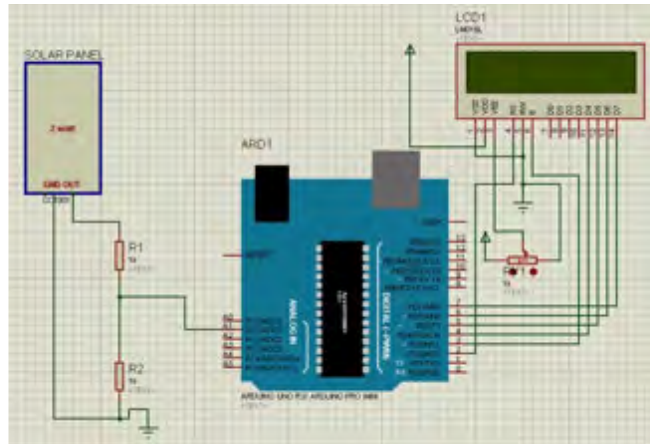


Figure 11: *Monitoring PV system with Arduino.*

5.3 Monitoring wind energy system

Wind turbine downtime is particularly costly during winter, for two reasons. First, November to April is the period over which most such plants around the world produce around two thirds of their electricity yield. The wind farms depend on the availability of wind, which in turn depends on the season. Second, logistical costs for maintenance during this time of year are high. So turbine failure at this time must be avoided at all costs. Condition monitoring, perhaps integrated with programmable logic control, can help a plant maintain its energy availability over this crucial period. As such a system enables the detection of impending mechanical damage in advance and during operation, a plant can use a condition monitoring system (CMS) to avoid the sudden failure of a bearing on the gear shaft.[21] Here replacement of the component requires a crane to be used, the cost of which is large, particularly in the case of offshore installations. The turbine also has to be shut down for around three to four days, but in the case of a sudden failure caused after wear damage has failed to be detected in good time, the downtime can easily be 10 times longer since material and personnel first have to be organized and brought to the plant. Sudden failures are also often due to higher wind loads in times of strong wind and therefore high yields, and if consequential damage occurs to components whose dimensions mean they can only be partially repaired at the plant, additional expenditure is incurred.

5.4 Vibration Monitoring

A CMS supplies the technical operational management team with a continuous stream of data, mostly based on vibration monitoring. 'For this, vibration or body-sound sensors are fitted at critical locations along the drive train of a wind turbine,' explains Holger Fritsch, CEO of Bachmann Monitoring. Other meaningful, physical variables such as temperatures or lubricant consistency can also be measured. Changes in the vibration behavior of the monitored components enable the detection of impending mechanical damage, and a comparison with reference measurements, such as those taken directly after erection of the installation allows conclusions to be drawn about the actual condition of gears, generators, roller bearings, rotors and other elements. The key advantage of a CMS is the permanent automatic monitoring and evaluation of trends under comparable operating conditions. These are therefore superior to vibration measurements taken at specific points, which are not referenced to any defined operating conditions, and thus involve a considerably greater degree of variance, and are hardly suitable for comparison.[22] "With a CMS plant shutdowns required for repair and maintenance can thus be planned and prepared systematically, plants can be kept longer on the grid, and consequential damage prevented," Fritsch emphasizes. He adds: "The average difference between planned and unplanned repair times can be up to 30 percent and more - depending on the type of wind turbine".

5.5 Maintenance Planning

Another benefit of condition monitoring is that it allows condition-based maintenance. Instead of replacing components after fixed time intervals based on empirical values, they can be replaced only when required, such as when signs of wear are detected. A CMS also supports the technical plant manager in controlling the maintenance intervals and in setting priorities systematically. By taking seasonal conditions into account, maintenance schedules, personnel and materials can be planned cost-effectively. "The results also help to improve medium-term maintenance strategies and forecast the expected operating costs and yield of a plant more clearly," Axel Ringhandt, wind sector manager at Bachmann Electronic, says.[20]

5.6 Integrated Solution

The key benefit of an integrated solution is the linking of the CMS's measured values with other operating parameters of the wind turbine. This increases the diagnostic reliability of the condition monitoring. Fault patterns can be compared with the current operating situation and interpreted with greater accuracy. Selective control of the plant even enables mechanical loads to be reduced. In this way, adjusted operating conditions can extend the lifespan of partly damaged parts up to the next plannable maintenance date. "Nowadays a plant would be shut down for safety reasons if there was any damage to the gears," explains Fritsch. "If the controller is provided with additional sensor data that enables the damage to be restricted, it would be possible to keep the wind turbine plant connected to the grid at a suitably reduced power output - with further continuous monitoring and the agreement of all involved, right through to the insurers. This makes it possible to considerably reduce a loss in yield."[15-21] The additional data available enables the monitoring centre to perform more precise diagnostics. The plant manager not only receives a verified fault message, but also an assessment of the operational relevance and specific action recommendations. Any reserves available can be identified in conjunction with technical operational management by combining the information from the automation system and the currently prevailing environmental conditions, such as wind speed or ambient temperature, with the evaluation of the load on relevant components. This enables the plant manager to further exploit the potential of the wind turbine and run it safely and at optimum yield for the operator or investor. Wind turbines are complex systems that are continuously exposed to changing operating conditions. Therefore it makes sense to tailor the CMS to the special characteristics of the turbine type and parameterise accordingly. Monitoring via remote access is possible through the use of state-of-the-art communications media, so that competent and fast support is ensured when required. There are, for example, condition monitoring centers which specialize in internet-based remote service.[5-12] The monitoring centre consolidates and analyses the data coming from the plants it oversees. In the event of a fault, the staff of the remote monitoring service more closely examines the automatically formed characteristic values and compare them with other characteristic values and trends until a consistent fault pattern is formed. "In our experience it is already possible at this stage to give the plant operator indications about the cause of the fault," says Fritsch. "This then enables the use of additional examination techniques such as video endoscopy to be carried out selectively and efficiently."[11-20]

5.7 Certification Guidelines for CMS Systems

Guidelines from Germanischer Lloyd and the Allianz Center for Technology for the certification of CMSs that monitor wind turbines require that at least the main bearings, main gears, generator and nacelle including the tower should be covered by condition monitoring. Monitoring of the main bearings, main gears and the generator requires at least six acceleration sensors. For the nacelle and tower one such sensor is required in each axial wind direction as well as perpendicular to it. In all cases, Germanischer Lloyd's guidelines for wind incorporate the state-of-the-art in technology. They therefore stipulate the most important basic conditions for the development, installation and operation of these systems. They also represent a basis for the testing of CMSs. Monitoring centers must, for example, explain how limit values are determined and why they are selected in this form. This ensures that the complex CMS data is evaluated and interpreted in a sufficiently qualified way. In drawing up the guidelines, Germanischer Lloyd Wind contacted wind farm operators that operate different systems, the manufacturers of wind turbines and CMSs, and the insurance sector. This ensured the greatest possible neutrality and acceptance of the guidelines across the industry. The guidelines also form the basis for the development and installation of CMSs and regulate the use of measured values, such as how they are evaluated, interpreted and stored. They also describe the operating procedures when specified limit values are exceeded.

6 RESULTS

The behavior of the complete system of the Maximum Power Point Tracking for a wind energy conversion system with supercapacitor connected photovoltaic system which supports the distribution power grid is explained by the simulation results. The system comprises two energy sources such as wind energy source and photovoltaic source. The simulation of monitoring PV system is shown in figure 12.

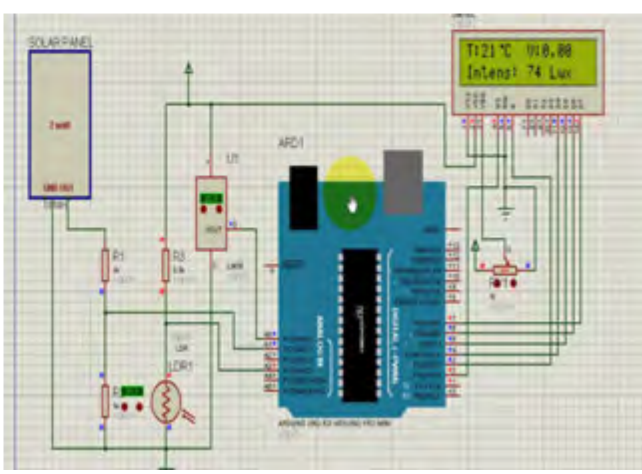


Figure 12: *PV Data Monitoring.*

The figure 13 shows the Battery Charger Circuit of Proteus Simulation

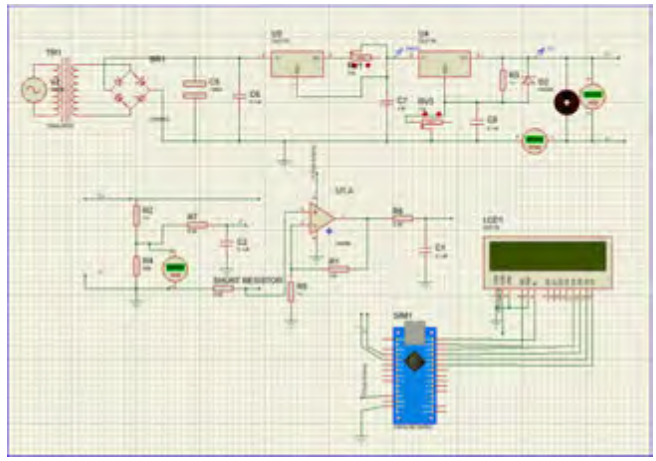


Figure 13: *Battery Charger Circuit.*

Voltage and current measurement using arduino is shown in figure 14.

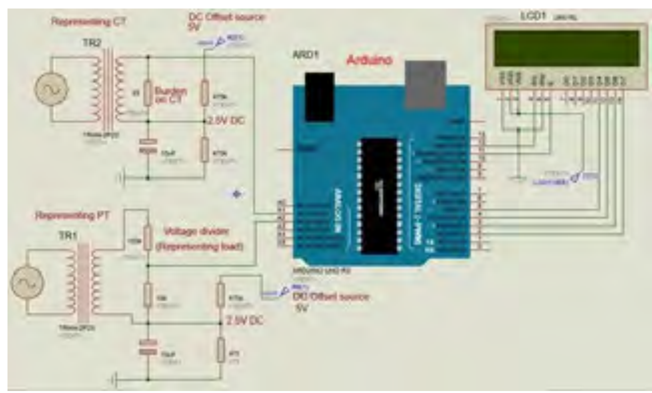


Figure 14: *voltage and current measurement.*

The overall system of WiFi 8266 is shown in figure 15 and the system of data transfer is shown in figure 16.

7 CONCLUSION

The solar PV, WECS and battery monitoring using Internet of Things with arduino has been experimentally proven to work satisfactorily by monitoring the parameters successfully through the internet. The designed system not only monitors the parameter of solar PV, WECS and battery but it also manipulate the data and produce the report according to the requirement, for example calculate unit plot and generate total units generated per month. It also stores all the parameters in the cloud in a timely manner. This will help the user to analyse the condition of various parameters in the solar PV, Wind Energy Conversion System and battery.

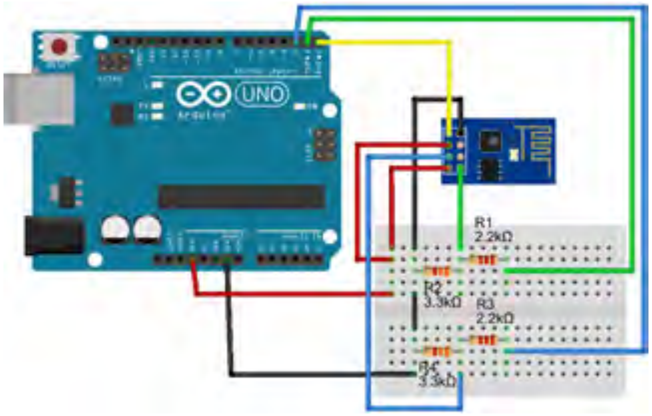


Figure 15: *WiFi Connected Arduino.*

Figure 16: *Data Storing in Cloud.*

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Power Management of a Hybrid Solar- Wind Energy System" International Journal of Engineering Research & Technology vol. 3(2) pp.1988-1992, 2014.

[3] M. Siva Ramkumar, M. Sivaram Krishnan, A. Amudha, "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc " in International Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[5] M Siva RamKumar, A. Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016. .

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763-769,2014.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2),2014

[9] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[10] D. Kavitha, C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.20 (2015), pg. 17749-17754.

[11] D. Manoharan, A. Amudha. "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, A. Amudha. A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6233-6240.

[13] A. Amudha. "Enhancement of Available Transfer Capability using FACTS controller" in International journal of Applied Mechanics and Materials, Vol. 573, pp 340-345

[14] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035-2042.

[15] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[17] K. Balachander, P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, V. Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[19] K. Balachander, V. Ponnusamy, 'Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research', Volume 7, Number 3 (2012), pp. 247-256. .

[20] K. Balachander, S. Kuppusamy, V. Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[21] M. Sivaram Krishnan, A. Amudha, , M. Siva Ramkumar, 'Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms', International journal of Pure and Applied Mathimatics,118 (11), pp 609-617,2018 DOI:10.12732/ijpam.v118i11.79

[22] S. Motapon, L. Dessaint, K.AI-Haddad, "A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, " IEEE Trans. Ind. Electron. , vo1.61, no.3, pp.1320,1334, March 2014.

GRID CONNECTED WIND ENERGY CONVERSION SYSTEM WITH UNIFIED POWER QUALITY CONDITIONER (UPQC) BY FUZZY LOGIC

M. Mohammed Shaheeth, D. Kavitha, A. Amudha, M. Siva Ramkumar, K. Balachander, G.Emayavaramban

Abstract: Unified Power Quality Conditioner (UPQC) device combines a shunt active filter together with a series active filter in a back-to-back configuration, to simultaneously compensate the supply voltage and the load current. The Three phase four wire system is realized from a three phase three wire system. In three phases, four wire system electrical loads are connected from line to neutral of the three phases. Neutral current in three-phase power systems is often thought to be only the result of the imbalance of the phase currents. Unbalance is a serious power quality problem, mainly affecting low-voltage distribution systems, as for instance encountered in office buildings with abundant PCs and lighting. In an ideal balanced sinusoidal three-phase power system, the neutral current is the vector sum of the three phase currents, should be equal to zero. Under normal operating condition, some phase unbalance occurs resulting in a small neutral current. A new control strategy to balance the unbalanced load currents is presented. The neutral current that may flow towards transformer neutral point is compensated by using a four-leg voltage source inverter topology in shunt part of the inverter. Hysteresis controller is mainly used to control the gating pulses of the inverter. The series transformer neutral will be at virtual zero potential during all operating conditions. The simulation results based on MATLAB/Simulink are presented to show the effectiveness of the proposed UPQC-based three phases four wire distribution system.

Keywords: Unified Power Quality Conditioner, 3-Phase 4-Wire system, Power Quality.

1 Introduction

Power quality has different meanings to different people. Institute of Electrical and Electronic Engineers (IEEE) Standard IEEE1100 defines power quality as "the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment". There is a broad range of power quality problems associated with power systems based on time such as long duration variations, short duration variations and other disturbances. All electrical devices are prone to failure or malfunction when exposed to one or more power quality problems. [1-6] The main reasons for concern with power quality (PQ) are as following: End user devices become more sensitive to PQ due to many microprocessor based controls. Large computer systems in many businesses facilities. Power electronics equipment used for enhancing system stability, operation and efficiency. These are major sources of bad Power Quality. Continuous development of high performance equipment: Such equipment is more susceptible to power disturbances. The users always demand higher power quality. Some basic criterions for power quality are constant rms value, constant frequency, symmetrical three-phases, pure sinusoidal wave shape and limited THD. The word "Power Quality" is the most important facets of any power delivery system. Low quality power affects electricity consumers in many ways. The lack of quality power can cause loss of damage of equipment, production or appliances, increased in power losses, interference with communication lines. The widespread use of power electronics equipment has produced a significant impact on quality of electric power supply by generating harmonics in voltages and currents. Therefore, it is a very important to maintain a high standard of power quality. In recent years, Power engineers are increasingly concerned over the quality of the electrical power. In modern industries, load equipment uses electronic controllers which are sensitive to poor voltage quality and will shut down if the supply voltage is depressed and may mal-operate in other ways if harmonic Distortion of the supply voltage is excessive. Most of this modern load equipment uses electronic switching devices which can contribute to poor network voltage quality. The competition in electrical energy supply has created greater commercial awareness of the issues of power quality while equipment is readily available to measure the quality of the voltage waveform and so quantify the problem. [7-14] Along with advance technology, the organization of the worldwide economy has evolved towards globalization and the profit margins of many activities tend to decrease. The increased sensitivity of the vast majority of processes like (industrial, services and even residential) to PQ problems turn the availability of electric power with quality a crucial factor for competitiveness in every sector. The continuous process industry and the information technology services are most critical area. Due to disturbance, a huge amount of financial losses may happen, with the consequent loss of productivity and competitiveness. Many efforts have been taken by utilities to fulfil consumer requirement, some consumers require a higher level of power quality than the level provided by modern electric networks. This implies that some measures must be taken so that higher levels of Power Quality can be obtained. [15-21] The FACTS devices and Custom power devices are introduced to electrical system to improve the power quality of the electrical power. DVR, DSTATCOM, ACTIVE FILTERs, UPQC etc are some of the devices used to improve the power quality of the voltage and current. With the help of these devices we are capable to reduce the problems related to power quality. Although all devices can improve the power quality but in this the focus is on UPQC.UPQC is a power electronic device consisting of both DVR and D-STATCOM, former is connected in series and latter is connected in parallel to protect the sensitive load from all disturbances. The modern power distribution system is becoming highly vulnerable to the different power quality problems. The extensive use of nonlinear loads is further contributing to increased current and voltage harmonics issues. Furthermore, the penetration level of small/large-scale renewable energy systems based on wind energy, solar energy, fuel cell, etc., installed at distribution as well as transmission levels is increasing significantly. This integration of renewable energy sources in a power system is further imposing new challenges to the electrical power industry to accommodate these newly emerging distributed generation systems. To maintain the controlled power quality regulations, some kind of compensation at all the power levels is becoming a common practice. At the distribution level, UPQC is a most attractive solution to compensate several major power quality problems. The word active power filter (APF) is a widely used terminology in area of a power quality improvement. Conventional power quality mitigation equipment use passive elements and do not always respond correctly as a nature of power system condition change. One modern solution that deals with both load current and supply voltage imperfections is the UPQC. The UPQC is a one of the APF family members.The UPQC is a combination of series and shunt active filters connected in cascade via a common DC link capacitor. The main purpose of a UPQC is to compensate for supply voltage power quality issues such as swells, sags, harmonics, unbalance, flicker, and for load current power quality problems such as, unbalance, harmonics, reactive current and neutral current.[17] Modern power system comprises of complex networks, where many generating stations and load centers are interconnected through long power transmission and distribution networks. Utility distribution networks, critical commercial operations and sensitive industrial loads all suffer from various types of outages and interruptions which can lead to significant financial loss, loss of production, idle work forces etc. Today due the changing trends and restructuring of power systems, the consumers are looking forward to the quality and reliability of power supply at the load centers. A power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure or a miss-operation of end use equipment. As nonlinear loads, these solid state converters draw harmonic and reactive power components of current from ac mains. In three phase systems, they could also cause unbalance and draw excessive neutral currents. The injected harmonics, reactive power burden, unbalance, and excessive neutral currents cause low system efficiency and poor power factor. They also cause disturbance to other consumers and interference in nearby communication networks. The power-electronics-based devices have been used to overcome the major power quality problems. To provide a balance, distortion-free, and constant magnitude power to sensitive load and, at the same time, to restrict the harmonic, unbalance, and reactive power demanded by the load and hence to make the overall power distribution system more healthy, the unified power quality conditioner (UPQC) is one of the best solutions. Proposed project proposes a new topology/structure that can be realized in UPQC-based applications, in which the series transformer neutral used for series inverter can be used to realize a three phase four wire system even if the power supplied by utility is three phase three-wire (3P3W). The new functionality using UPQC could be useful in future UPQC-based distribution systems. The unbalanced load currents are very common and yet an important problem in three phases four wire distribution systems. Proposed project deals with the unbalanced load current problem with a new control approach, in which the fundamental active powers demanded by each phase are computed first, and these active powers are then redistributed equally on each of the phases. The UPQC, also known as the active power line conditioner, consists of a combination of a series type and shunt type APF topologies.[18-20]

2 POWER QUALITY

Since the discovery of electricity 400 years ago, the generation, distribution and use of electricity have evolved steadily. New and innovative means to generate and use electricity fuelled the industrial revolution and since then the scientists and engineers have contributed to its continuing evolution. In the beginning, electrical machines and devices consumed large amounts of electricity and performed well. The machines were designed with cost concerns secondary to performance considerations. However, in the last 50 years, the industrial age led to the need for products to be economically competitive. Increased demand for electricity created extensive power generation and distribution grids. Industries demanded larger and larger shares of the generated power, which along with the growing use of electricity in the residential sector, stretched electricity generation to the limit. Today, electrical utilities are no longer independently operated entities. They are a part of a large network of utilities tied together in a complex grid. The combinations of these factors have created the electrical systems requiring power quality. As per IEEE standard 1100 power quality is defined as "the concept of powering and grounding sensitive electronic equipment in a manner that is suitable to the operation of that equipment". Parameters of power quality are as follows:

- Variation in voltage magnitude
- Harmonic content in the waveform for ac power
- Transient voltages and currents.
- Continuity of service.

These days, power systems are complex in nature. Hundreds of generating stations and load centres are interconnected. The major concerns for the customers are the reliability and quality of power supply at the load centres. Power generation in most of the well developed countries is reliable but quality of supply is not. Customers should be provided with uninterrupted supply of energy. [16] A power quality problem is defined as any manifested problem in voltage or current of leading to frequency deviations that result in failure or mis-operation of customer equipment. Power quality has serious implications for the consumers. Power system, especially the distribution system, has numerous non-linear loads which significantly affect the quality of power supply. These loads may distort the supply waveform. Some system events also contribute power quality problems like capacitor switching, starting of motors and faults. The consequence of power quality problems includes a large economic loss. [3-5] Power quality problems are also associated with extensive number of electromagnetic phenomena in power systems with broad ranges of time frames such as long duration variations, short duration variations and other disturbances. Short duration variations are mainly caused by either fault conditions or energisation distance related to impedance type of grounding and connection of transformer between the faulted location and node, there can be temporary load of voltage reduction (sag) or voltage rise (swell) at different nodes of the system. Both, electric utilities and end users of electrical power are becoming increasingly concerned about the quality of electric power. Sensitive loads such as computers, programmable logic controllers (PLC), variable speed drives (VSD) etc. need high quality supplies. Modernization and automation of industry involves increasing use of computers, microprocessors and power electronic systems such as adjustable speed drives. The power electronic systems also contribute to power quality problem (generated harmonics). The electronic devices are very sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics.[4-8]

2.1 Power quality problems

Power Quality concerns about the utility ability to provide uninterrupted power supply. The quality of electric power is characterized by parameters such as "continuity of supply, voltage magnitude variation, transients and harmonic contents in electrical signals". Synchronization of electrical quantities allows electrical systems to function properly and without failure or malfunction of an electric device.

2.1.1 Voltage sag:

It is also referred to as a voltage dip as shown in figure1. This is the most common power quality problem. It is defined as a decrease of rms voltage to a value between 0.1 p.u. to 0.9 p.u. and lasts for duration between 0.5 cycles to 1 minute. The voltage sag magnitude depends on various factors like the type of fault, the location of the fault and the fault impedance. The duration of voltage sag basically depends on how fast the fault is cleared by the protective device. In short, voltage sag will last till the fault is cleared. Although the effect of voltage sag is only for a short duration, sensitive equipments like PLC's may malfunction. This affects the production and leads to revenue loss.

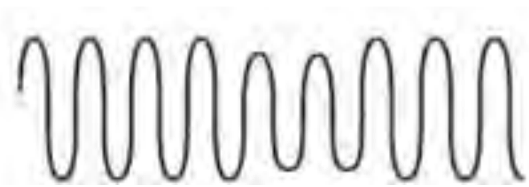


Figure 1: *Voltage Sag.*

2.1.2 Voltage swell:

A voltage swell is defined as an increase in rms voltage between 1.1 and 1.8 p.u. at the power frequency for duration between 0.5 cycles to 1 minute. A voltage swell (like sag) is characterized by its magnitude (RMS) and duration. The main causes for voltage swell are switching of large capacitors or start/stop of heavy loads. Voltage swell is less common in distribution systems. It is shown in figure 2.

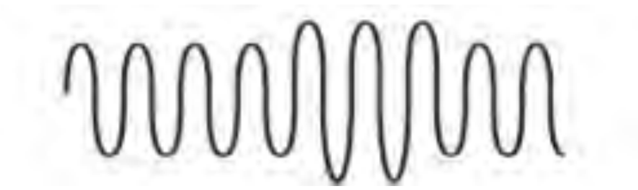


Figure 2: *Voltage Swell.*

2.1.3 Voltage interruption:

A voltage interruption is a large decrease in rms voltage to less than a small percentile of the nominal voltage, or a complete loss of voltage as shown in figure 3. Voltage interruptions may come from accidents like faults and component malfunctions, or from scheduled downtime. Short voltage interruptions are typically the result of a malfunction of a switching device or a deliberate or inadvertent operation of a fuse, circuit breaker, or reclosure in response to faults and disturbances. Long voltage interruptions are usually the result of scheduled downtime, where part of an electrical power system is disconnected in order to perform maintenance or repairs.

Figure 3: *Voltage Interruption.*

2.1.4 Spikes:

Spikes are a sudden, short surge in voltage. Voltage spikes can be caused by lightning, power outages, short circuits, or power transitions in large equipment on the same power line. [11-19]

2.1.5 Transients:

Transients are also known as surge. Transients are power quality disturbances that involve destructive high magnitudes of current and voltage or even both. It may reach thousands of volts and amps even in low voltage systems. However, such phenomena only exist in a very short duration from less than 50 nanoseconds to as long as 50 milliseconds. Voltage fluctuations and flickers: Voltage fluctuations are systematic variations of the voltage envelope or a series of random changes in the voltage magnitude (which lies in the range of 0.9 p.u. to 1.1 p.u.). High power loads that draw fluctuating current, such as large motor drives and arc furnaces, cause low frequency cyclic voltage variations that result in flickering of light sources (incandescent and fluorescent lamps) which can cause significant physiological discomfort or irritation in human beings. The typical frequency spectrum of voltage flicker lies in the range from 0 Hz to 30 Hz.

2.1.6 Waveform distortion:

This is defined as a steady-state deviation from an ideal sine wave of power frequency. Different types of waveform distortion are as follows

2.1.7 Harmonics:

A harmonic is any sinusoidal frequency, which is a multiple of the fundamental frequency. Harmonic frequencies can be even or odd multiples of the sinusoidal fundamental frequency. The main causes for harmonic distortion are rectifiers and all non-linear loads, such as power electronics equipment. [21-22]

2.1.8 Notching:

Notching is a periodic voltage disturbance caused by the normal operation of power electronic devices when current is commutated from one phase to another which is shown in figure 4.

2.1.9 Noise:

Noise is defined as unwanted electrical signal as shown in figure 5 with broadband spectral content lower than 200 kHz superimpose upon the power system voltage or current in phase conductors, or found on neutral conductors or signal lines. Noise power systems can be due to power electronic devices, control circuits, arcing equipment, loads with solid state rectifiers and switching power supplies.

2.2 Solutions to improve the power quality

The solution to the power quality can be done from customer side or from utility side. Approaches that are used to improve the power quality are as follows: Load conditioning: It ensures that the equipment is less sensitive to power disturbances, allowing the operation even

Figure 4: *Notching.*

Figure 5: *Noise.*

under significant voltage distortion. Line conditioning systems: They suppress or counteract the power system disturbances. To achieve improve power quality is to use passive filters connected at the sensitive load terminals. The challenge is to regulate the sensitive load terminal voltage so that its magnitude remains constant and any harmonic distortion is reduced to an acceptable level.[11-20]

3 CUSTOM POWER DEVICES

For improving the system performance for distribution system and with the growing development of the power semiconductor technology, the concepts of custom power was introduced to distribution systems. The concept describes the value-added power that electric utilities will offer their customers in the future, focusing on the quality of power flow and reliability. Due to this increasing demand and the rapid development of the high power semiconductor technology, the custom power solutions are taking place rapidly. In a custom power system customer receives specified power quality from a utility or a service provider or at-the-fence equipment installed by the customer in coordination with the utility, which includes an acceptable combination of the following features:

- No (or rare) power interruptions
- Magnitude and duration of voltage reductions within specified limits.
- Low harmonic voltage.
- Low phase unbalance.

This can be done on the basis of an individual, large customer, industry or a supply for a high tech community on a wide area basis.

3.1 Need of custom power

The increased use of automated equipment, like adjustable speed drives, programmable logic controllers, switching power supplies, arc furnaces, electronic fluorescent lamp ballasts, automated production lines are far more vulnerable to disturbances than were the previous generation equipment and less automated production and information systems. Even though the power generation in most advanced country is fairly reliable, the distribution is not always so. It is however not only reliability that the consumers want these days, quality too is very important for them. With the deregulation of the electric power energy market, the awareness regarding the quality of power is increasing day by day among customers. Power quality is an issue that is becoming increasingly important to electricity consumers at all levels of usage. [17-22] In the several processes such as semiconductor manufacturing or food processing plants, a batch of product can be ruined by a voltage dip of very short duration. Even short dips are sufficient to cause contactors on motor drives to drop out. There are other loads which are very sensitive such as hospitals, processing plants, air traffic control and numerous other data processing and service providers that require clean and uninterrupted power. Thus in this scenario in which customers increasingly demand power quality, the term power quality attains increased significance. The factors mentioned point out the problems faced by the industry and awareness of consumers about quality of power due to which it has increasingly become important to provide the consumers with the reliable as well as superior power quality. Thus the development of custom power has gained so much of widespread attention nowadays.

3.2 Custom power devices

There are many types of Custom Power devices. Some of these devices include Active Power Filters (APF), Surge Arresters (SA). Battery Energy Storage Systems (BESS), Super conducting Magnetic Energy Systems (SMES), Static Electronic Tap Changers (SETC), Solid State Fault Current Limiter (SSFCL), Solid-State Transfer Switches (SSTS), Static VAR Compensator (SVC), Distribution Series Capacitors (DSC), Dynamic Voltage Restorer (DVR), Distribution Static synchronous Compensators (DSTATCOM) and Uninterruptible Power Supplies (UPS) , Unified power quality conditioner(UPQC). The classification of custom power devices can be done into two major categories, one is network configuring type and the other is compensating type. The network configuring type devices changes the configuration of the power system network for power quality enhancement. SSCL (Solid State Current Limiter), SSCB (Solid State Circuit Breaker)and SSTS (Solid State Transfer Switch) are the most representative in this category. The compensating type devices are used for active filtering; load balancing, power factor correction and voltage regulation. The family of compensating devices include DSTATCOM (Distribution Static compensator), DVR (Dynamic voltage restorer) and Unified power quality conditioner (UPQC). DSTATCOM is connected in shunt with the power system while DVR is a series connected device that injects a rapid series voltage to compensate the supply voltage. Though there are many different methods to mitigate voltage sags and swells, but the use of a custom power device is considered to be the most efficient method to serve for different purposes. The term Custom Power pertains to the use of power electronic controllers in a distribution system to deal with various power quality problems. It makes sure that customers get pre-specified quality and reliability of power supply that may include a single or the combination of the specifications like no power interruptions, low phase unbalance, low harmonic distortion in load voltage, low flicker at the load voltage, acceptance of fluctuations, magnitude and duration of overvoltage and under voltages within specified limits and poor factor loads without significant effect on the terminal voltage.[15-19]

4 THREE PHASE FOUR WIRE SYSTEM

Generally, a 3P4W distribution system is realized by providing a neutral wire along with three phase three wire distribution line from generation station or by using a three-phase δ–Y transformer at distribution level. Figure 6 shows a 3P4W network in which the neutral wire is provided from the generating station itself, whereas in figure 6 shows a 3P4W distribution network considering a δ–Y transformer at the distribution line. Assume a plant where three-phase three-wire UPQC is already installed to protect a sensitive loads and to restrict any entry of distortion from load side toward utility, as shown in figure 6.

If we want to upgrade the system from 3P3W to 3P4W due to installation of single-phase loads and if the distribution transformer is close to the plant under consideration, we would easily provide the neutral conductor from this transformer without major investment. In certain

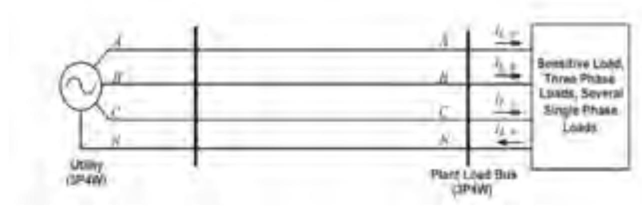


Figure 6: *3-phase four wire distribution systems.*

cases, this may be an uneconomical because the distribution transformer may not be nearer to load centres.

4.1 Inverter

The main objective of studying small signal model is to predict low frequency component present in the output voltage. The magnitude and phase of this component depend not only on the duty cycle variation but also frequency response of the converter. Figure 7 shows a typical DC/AC inverter, there are 6 IGBTs in this inverter, which inverts a DC power input into a controlled 3 phase AC power output based on the control signals applied on the gate circuits of IGBTs.

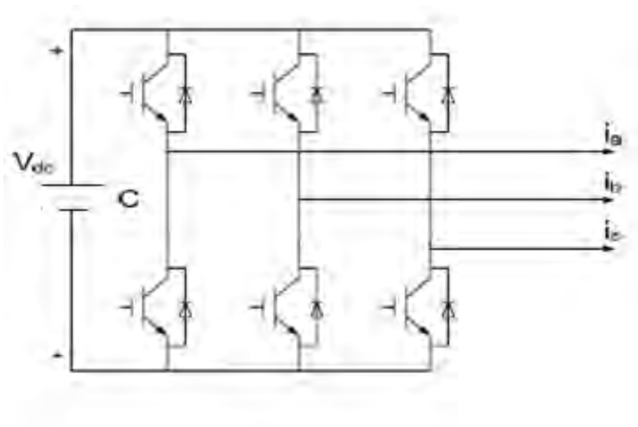


Figure 7: *Typical DC/AC Inverter.*

The control signals used for the gate circuits of IGBT are usually generated through a PWM signal generator. The simplest way to get a PWM signal requires a repetitive switching-frequency sawtooth or triangular waveform and a comparator. In order to produce a sinusoidal output voltage waveform, a sinusoidal control signal is compared with a triangular waveform. The amplitude Vtri of the triangular waveform is always kept as constant value such as 1 V. When the value of the sinusoidal control signal is greater than the triangular waveform value, the PWM generator output is in high state, otherwise it is in low state. The frequency of the triangular waveform creates the inverter switching frequency and the fundamental output voltage waveform frequency is the same as the frequency of the sinusoidal control signal. Two terms are defined in PWM algorithm, one is called amplitude modulation ratio, and the other is called frequency modulation ratio. The amplitude modulation ratio ma is defined as

$$m_a = \frac{V_{control}}{V_{tri}} \tag{1}$$

Where V_{tri} is the amplitude of the triangular waveform, and $V_{control}$ is the amplitude of the sinusoidal control signal. The frequency modulation ratio is defined as

$$m_f = \frac{f_{tri}}{f_{control}} \tag{2}$$

Where f_{tri} is the frequency of the triangular waveform (also called carrier frequency), and $f_{control}$ is the frequency of the sinusoidal control signal.

4.2 Description and implementation of series active power filter

In series APF the Inverter injects a voltage in series with the line which feeds the polluting load through a transformer. The injected voltage will be mostly harmonic with a small amount of sinusoidal component which is in-phase with the current flowing in the line. The small sinusoidal in-phase (with line current) component in the injected voltage results in the right amount of active power flow into the Inverter to compensate for the losses within the Series APF and to maintain the D.C side capacitor voltage constant. Obviously the D.C voltage control loop will decide the amount of this in-phase component. Series active power filter compensate current system distortion caused by nonlinear load by imposing a high impedance path to the harmonic current.

4.3 Description and implementation of shunt active power filter

The active filter concept uses power electronics to produce harmonic current components that cancel the harmonic current components that cancel the harmonic current components from the non- linear loads. The active filter uses Power electronic switching to generate

Harmonic currents that cancel the harmonic currents from a non-linear load. In this configuration, the filter is connected in parallel with the load being compensated. Therefore the configuration is often referred to as an active parallel or shunt filter.

The figure 8 illustrates the concept of the harmonic current cancellation so that the current being supplied from the source is sinusoidal. The voltage source inverter

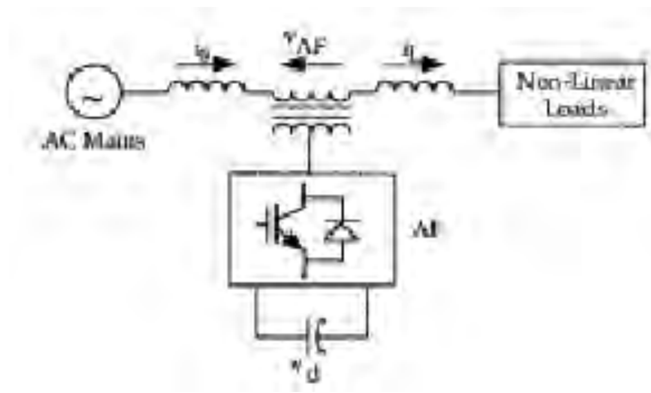


Figure 8: *Line diagram of series active power filter.*

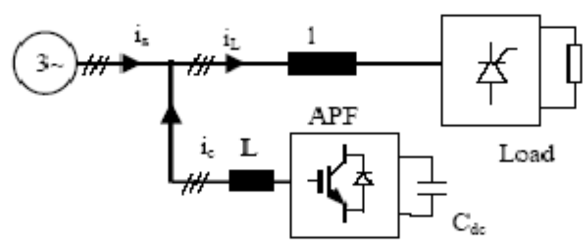


Figure 9: *Shunt active power filter.*

used in the active filter makes the harmonic control possible. This inverter uses dc capacitors as the supply and can switch at a high frequency to generate a signal that will cancel the harmonics from the non-linear load. The control algorithm for series APF is based on unit vector template generation scheme .Whereas the control strategy for shunt APF is discussed in this section. Based on the load on the 3P4W system, the current drawn from the utility can be unbalanced. In this paper, the concept of single phase P-Q theory. According to this theory, a single phase system can be defined as a pseudo two-phase system by giving lead or lag that is each phase voltage and current of the original three phase systems. These resultant two phase systems can be represented in α-β coordinates, and thus P-Q theory applied for balanced three phase system can also be used for each phase of unbalanced system independently. In order to eliminate these limitations, the reference load voltage signals extracted for series APF are used instead of actual load voltage.[11-19]

4.4 Need for shunt active filter

The growing number of power electronics base equipment has produced an important impact on the quality of electric power supply. Both high power industrial loads and domestic loads cause harmonics in the network voltages. At the same time, much of the equipment causing the disturbances is quite sensitive to deviations from the ideal sinusoidal line voltage. Therefore, power quality problems may originate in the system or may be caused by the consumer itself. Harmonic distortion has traditionally been deal with by the use of passive LC filters. However, the application of passive filters for harmonic reduction may result in parallel resonances with the network impedance, over compensation of reactive power at fundamental frequency, and poor flexibility for dynamic compensation of different frequency harmonic components. Switching compensators called Active filters or active power line conditioners provide an effective alternative to the conventional passive LC filers. They are able to compensate current and voltage harmonics and reactive power, regulate terminal voltage, suppress flicker, and improve voltage balance in three phase systems. The advantage of active filtering is that it automatically adapts to changes in the network and load fluctuations.[5-12]

4.5 Shunt active filter with instantaneous p-q theory

The concept of Shunt Active Filtering was first introduced by Gyugyi and Strycula in 1976. Nowadays, a Shunt Active Filter is not a dream but a reality, and many SAFs are in commercial operation all over the world. The controllers of the Active Filters determine in real time the compensating current reference, and force the power converter to synthesize it accurately. In this way, the Active Filtering can be selective and adaptive. In other words, a Shunt Active Filter can compensate only for the harmonic current of a selected nonlinear load, and can continuously track changes in its harmonic content. The Instantaneous active and reactive power theory or simply the p-q theory is based on a set of instantaneous values of active and reactive powers defined in the time domain. There are no restrictions on the voltage or current waveforms, and it can be applied to three-phase systems with or without a neutral wire for three-phase generic voltage and current waveforms. Thus, it is valid not only in the steady state, but also in the transient state. This theory is very efficient and flexible in designing controllers for power conditioners based on power electronics devices. Other traditional concepts of power are characterized by treating a three-phase system as three single-phase circuits. The p-q Theory first uses Clarke transformation to transforms voltages and currents from the abc to $\alpha\beta 0$ coordinates, and then defines instantaneous power on these coordinates. Hence, this theory always considers the three-phase system as a unit, not a superposition or sum of three single-phase circuits.[12-21]

4.6 Proposed 3P4W distribution using UPQC

Generally, a 3P4W distribution system is realized by providing a neutral wire along with three phase three wire distribution line from generation station or by using a three-phase δ–Y transformer at distribution level. Fig. 1 shows a 3P4W network in which the neutral wire is provided from the generating station itself, whereas in Fig. 2 shows a 3P4W distribution network considering a δ–Y transformer at the distribution line. Assume a plant where three-phase three-wire UPQC is already installed to protect a sensitive loads and to restrict any entry of distortion from load side toward utility, as shown in figure 9. If we want to upgrade the system from 3P3W to 3P4W due to installation of single-phase loads and if the distribution transformer is close to the plant under consideration, we would easily provide the neutral conductor from this transformer without major investment. In certain cases, this may be an uneconomical because the distribution transformer may not be nearer to load centers. Recently, the utility service providers are putting more restrictions on current total harmonic distortion (THD) limits, drawn by nonlinear loads (that maybe single phase or three phase loads), to control the power distribution system harmonic pollution. At the same time, the use of sensitive equipment/load has increased significantly, and it needs clean power for its proper operation. Therefore, in future distribution systems and the plant/load centers, application of UPQC would be necessary. Fig. 4 shows the proposed structure of 3P4W topology that can be realized from a 3P3W system. This proposed system has all the advantages of general UPQC and easy expansion of 3P3W system to 3P4W system. Thus, the proposed topology may play an vital role in the future 3P4W distribution system for more advanced UPQC based plants installation, where utilities would be having an additional option to realize a 3P4W system just by providing a 3P3W supply.

4.7 Modelling of UPQC controller

The control algorithm for series active power filter (APF) is based on unit vector template generation scheme, whereas the control strategy for shunt APF is discussed in this section. Based on the load on the 3P4W system, the current drawn from the utility can be unbalanced. In this paper, a new control strategy is proposed to compensate the current unbalance present in the load currents by expanding the concept of single phase p–q theory. According to this theory, a signal phase system can be defined as a pseudo two-phase system by giving $\pi/2$ lead or $\pi/2$ lag, i.e., each phase voltage and current of the original three-phase system can be considered as three independent two-phase systems. These resultant two phase systems can be represented in α–β coordinates, and thus, the p–q theory applied for balanced three-phase system can also be used for each phase of unbalanced system independently. The actual load voltages and load currents are considered as α-axis quantities, whereas the $\pi/2$ lead load or $\pi/2$ lag voltages and $\pi/2$ lead or $\pi/2$ lag load currents are considered as β-axis quantities. In this paper, $\pi/2$ lead is considered to achieve a two-phase system for each phase. The major disadvantage of p–q theory is that it gives poor results under distorted and/or unbalanced input/utility voltages. In order to eliminate these limitations, the reference load voltage signals extracted for series APF are used instead of actual load voltages. For phase a, the load voltage and current in α–β coordinates can be represented by $\pi/2$ lead as where v[??]La(ωt) represents the reference load voltage and VLmrepresents the desired load voltage magnitude. Similarly, for phase b, the load voltage and current in α–β coordinates can be represented by $\pi/2$ lead.[14-22]

4.8 3phase four 4wire distributions

Recently, the utility service providers are putting more restrictions on current total harmonic distortion (THD) limits, drawn by nonlinear loads (that maybe single phase or three phase loads), to control the power distribution system harmonic pollution. At the same time, the use of sensitive equipment/load has increased significantly, and it needs clean power for its proper operation. Therefore, in future distribution systems and the plant/load centers, application of UPQC would be necessary. Figure 10 shows the proposed structure of 3P4W topology that can be realized from a 3P3W system. This proposed system has all the advantages of general UPQC and easy expansion of 3P3W system to 3P4W system. Thus, the proposed topology may play an vital role in the future 3P4W distribution system for more advanced UPQC based plants installation, where utilities would be having an additional option to realize a 3P4W system just by providing a 3P3W supply.

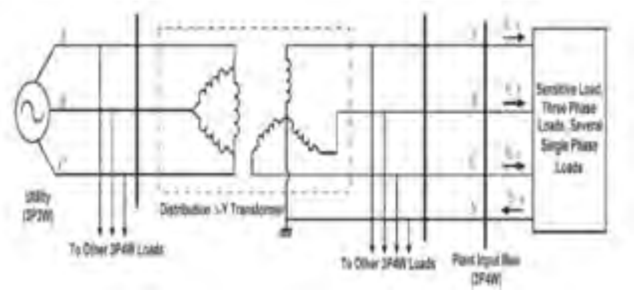


Figure 10: *3P4W distribution (neutral: δ–Y transformer).*

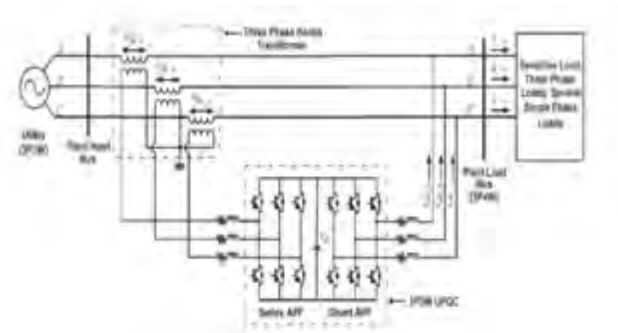


Figure 11: *3P3W distribution system with UPQC.*

As shown in figure 11, the UPQC should necessarily consist of 3-phase series transformer in order to connect one of the inverters in the series with the line to function as a controlled voltage source. If we could use the neutral of 3-phase series transformer to connect a neutral wire to realize the 3P4W system, then 3P4W system can easily be achieved from a 3P3W system (Figure 12). The neutral current, present if any, would flow through this fourth wire toward transformer neutral point. This neutral current can be compensated by using a split capacitor topology or a four-leg voltage-source inverter (VSI) topology for a shunt inverter (in our project the neutral current is compensated by using 4-leg VSI). The 4-leg VSI topology requires one additional leg as compared to the split capacitor topology. The neutral current compensation in the 4-leg VSI structure is much easier than that of the split capacitor because the split capacitor topology essentially needs two capacitors and an extra control loop to maintain a zero voltage error difference between both the capacitor voltages, resulting in a more complex control loop to maintain the dc bus voltage at constant level. [8-15] The four-leg VSI topology is considered to compensate the neutral current flowing toward the transformer neutral point. A fourth leg is added on the existing 3P3W UPQC, such that the transformer neutral point will be at virtual zero potential (i.e. Vn=0v). Thus, the proposed structure would help to realize a 3P4W system from a 3P3W system at distribution load end. This would be easily expansion from 3P3W to 3P4W systems.

The four-leg VSI topology is considered to compensate the neutral current flowing toward the transformer neutral point. A fourth leg is added on the existing 3P3W UPQC, such that the transformer neutral point will be at virtual zero potential. Thus, the proposed structure would help to realize a 3P4W system from a 3P3W system at distribution load end. This would eventually result in easy expansion from 3P3W to 3P4W systems. A new control strategy to generate balanced reference

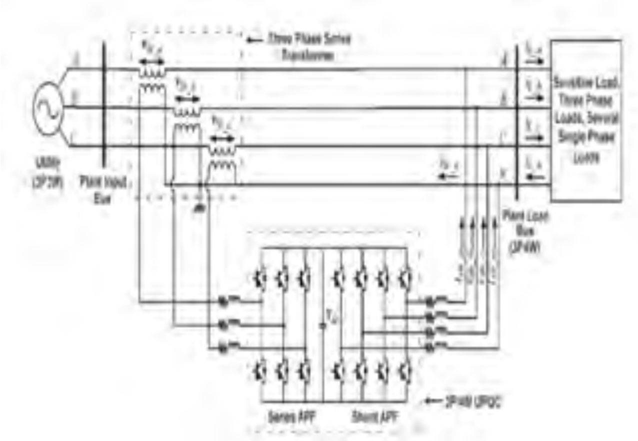


Figure 12: *3P4W distribution.*

source currents under unbalanced load condition is also proposed.[14]

5 PROPOSED SYSTEM

The UPQC should necessarily consist of three-phase series transformer in order to connect one of the inverters in the series with the line to function as a controlled voltage source. If we could use the neutral of three-phase series transformer to connect a neutral wire to realize the 3P4W system, then 3P4W system can easily be achieved from a 3P3W system. The neutral current, present if any, would flow through this fourth wire toward transformer neutral point. This neutral current can be compensated by using a split capacitor topology or a four leg voltage source inverter (VSI) topology for a shunt inverter.

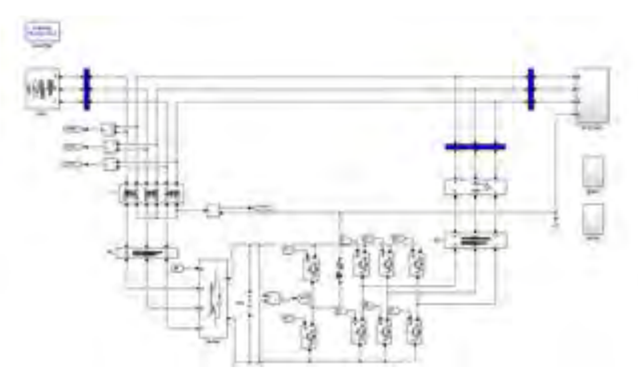


Figure 13: *Simulation model of overall system.*

The four-leg VSI topology requires one additional leg as compared to the split capacitor topology's structure is much easier than that of the split capacitor .But here going through the UPQC design by using P-Q theory and it is connected to 3P4W system. It is shown in figure 13.

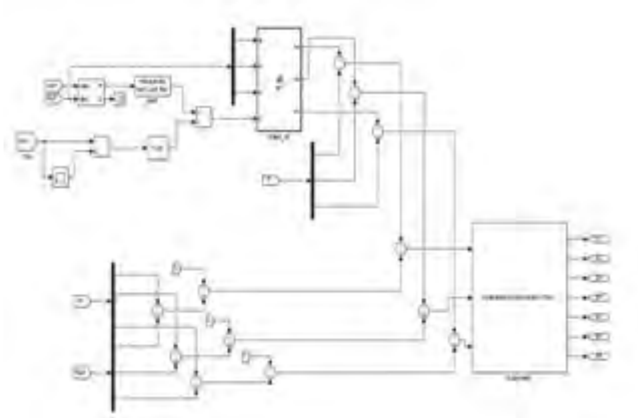


Figure 14: *Simulation model of controller .*

The above model that is figure 14 explains the control block diagram of UPQC with hysteresis controller. The gating pulse of the circuit is controlled by hysteresis controller. DC link capacitor voltage is controlled by PI controller. Actual and reference value is compared and given to the inverter. Moving active filter is used in order to take few samples for taking reference value. Positive sequence extraction is taken from load for the generation of output pulses. Both the actual and reference value is taken from the circuit block itself for the purpose of simplification of circuit. Hence hysteresis is advance method of controlling gating pulse of the inverter. The neutral current is taken as an input for the fourth leg inverter in order to avoid sending back to the source. This prevents distortion of the source and hence circuit is protected.

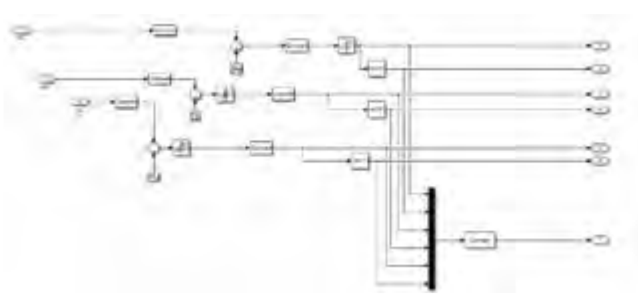


Figure 15: *Simulation model of pulse generation system.*

The above model that is figure 15 explains about the pulse generation system. The actual and reference value are compared and given to the inverter gating circuit. Since we are using constant frequency in overall system, same pulses are given to the series as well as for shunt part.

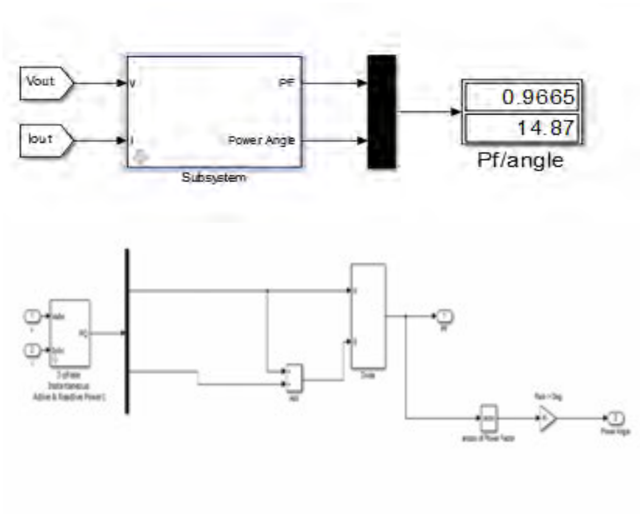


Figure 16: *Simulation of power factor calculation.*

In the overall system, the power factor must be maintained unity, for this purpose the power factor is calculated and simulated as shown in figure 16.[22]

6 RESULT

The behaviour of the complete system of three phase four wire system with UPQC for power quality improvement in the system. Considering three phase four wire system without any compensation devices. The fault occurred for the interval 0.1sec to 0.9sec. Due to the fault the dip occurred in the system voltage as shown in figure 17.

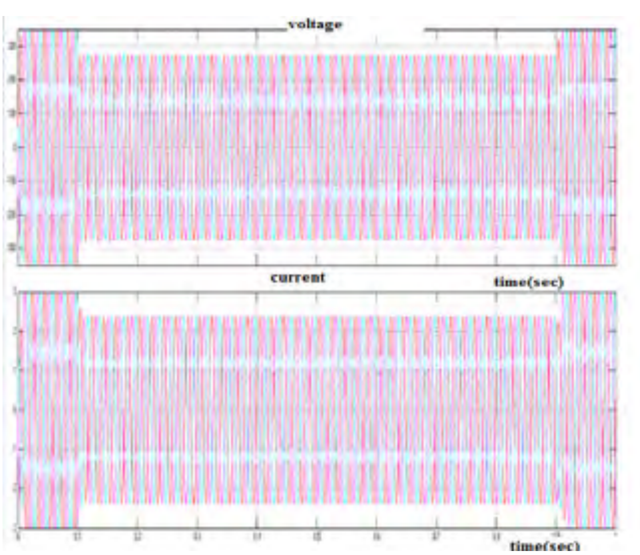


Figure 17: *Output waveform before compensation.*

The figure 18 shows the waveform of the system voltage after the voltage sag compensation which is occurred due to the system fault by the custom power device called unified Power Quality Conditioner.

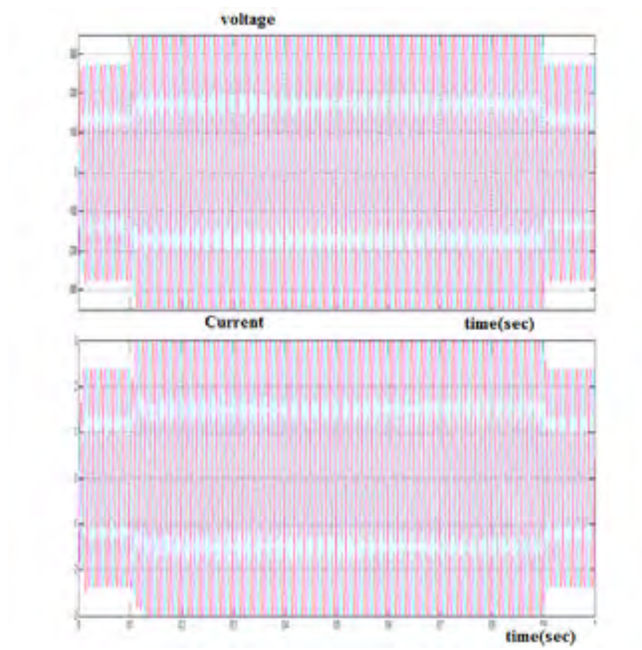


Figure 18: *Output waveform after compensation.*

7 CONCLUSION

This paper presents control and performance of UPQC intended for installation on a transmission line with the help of hysteresis controller. A control system is simulated in unbalanced condition with series inverter and shunt four leg inverter. Simulation results show the effectiveness of UPQC in active filtering and controlling unbalance in voltage and current through the line. AC voltage regulation and power factor of the transmission line also improved.

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Power Management of a Hybrid Solar- Wind Energy System" International Journal of Engineering Research & Technology vol. 3(2) pp.1988-1992, 2014.

[3] M.Siva Ramkumar, M.Sivaram Krishnan, Dr.A. Amudha "Resonant Power Converter Using GA For

PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc" in International Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[5] M Siva RamKumar, Dr. A Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016. .

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763-769,2014.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2),2014

[9] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[10] D. Kavitha, Dr. C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.20 (2015), pg. 17749-17754.

[11] D. Manoharan, Dr. A. Amudha "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, Dr. A. Amudha A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6233-6240.

[13] Dr. A. Amudha "Enhancement of Available Transfer Capability using FACTS controller" in International journal of Applied Mechanics and Materials, Vol. 573, pp 340-345.

[14] K. Balachander, Dr. P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035-2042.

[15] K. Balachander, Dr. P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, Dr. P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[17] K. Balachander, Dr. P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, V. Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[19] K. Balachander, V. Ponnusamy, 'Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research', Volume 7, Number 3 (2012), pp. 247-256. .

[20] K. Balachander, S. Kuppusamy, V. Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[21] M.Sivaram Krishnan, Dr.A. Amudha, M.Siva Ramkumar, 'Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms', International journal of Pure and Applied Mathimatics,118 (11), pp 609-617,2018 DOI:10.12732/ijpam.v118i11.79

[22] S. Motapon, L. Dessaint, K.AI-Haddad, "A Comparative Study of Energy Management Schemes for a

Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, " IEEE Trans. Ind. Electron. , vo1.61, no.3, pp.1320,1334, March 2014.

INTEGRATED DC/DC PARALLEL MAXIMUM POWER POINT TRACKING BASED PHOTOVOLTAIC SYSTEM ARCHITECTURE FOR COMMON DC BUS

V. Akiladevi, A. Amudha, K. Balachander, M. Siva Ramkumar, S. Divyapriya

Abstract: Concerns over environment and increased demand of energy have led the world to think about alternate energy sources such as wind, hydro, solar and fuel cells. Out of these, photovoltaic (PV) power generation systems have become increasingly important all over the world due its availability, cleanness, low maintenance cost and inexhaustible nature. But power produced by the photovoltaic system is stochastic in nature due to the variation of solar irradiation and cell temperature throughout the day. In order to track the varying power, a DC-DC converter with maximum power point tracker (MPPT) is used. Different MPPT algorithms have been proposed for tracking peak power from the PV panel. Selection of adequate DC-DC converter is also an important factor since it has an influence on overall performance of the PV system. This paper presents a comparative study on the characteristics of different non-isolated DC-DC converters and highlights the various research works that has been done on DC-DC converters based MPPT PV system. Study shows that selection of converter also has an impact on the overall performance of the PV system. Based on the survey and comparative study, selection criteria to choose DC-DC converter for PV system is described in this paper.

Keywords: DC-DC converter, PV system, Maximum Power Point Tracking (MPPT), DC-DC converter.

1 Introduction

For economic development of any country energy is one of the major inputs. Number of industries, vehicles, domestic users has been increased by a large number in last decade; this in turn led to increase the global energy consumption also. Industries uses major share of energy produced in the world with a share of 33%, while residential, transport, service and other sectors follows with share of 29%, 26%, 9% and 3% respectively. Majority of energy is used in form of electricity and huge amount of electric energy is required by world to fulfill daily demand. By 2030 global electric energy demand is estimated to be doubled [1-3]. Electric energy demands in fast developing countries are estimated to triple by this period. Majority of electric energy in the world is produced from coal with a share of 40.4% followed by natural gas, large hydro, nuclear, oil and renewable energy with a share of 22.5%, 16.2%, 10.9%, 5% and 5% respectively. Fossil fuel deposit on earth is depleting day by day and the atmospheric pollution and global temperature is increasing due to increased use of fossil fuels. Renewable energy tracking has become one of the interesting area in recent years due increased energy demand and issues related to environment. Out of all renewable energy sources, solar energy has gained much more attention due to its availability, cleanness and inexhaustible nature. Tracking solar power is difficult due to non-linear current – voltage (I-V) characteristics of panel with a unique maximum power point (MPP). Power produced by PV panel varies with variation in atmospheric conditions such as solar irradiation and cell temperature. MPP of solar panel also varies with the variation in atmospheric conditions. So in order to extract maximum power, PV panel must be operated at a voltage corresponding to MPP (VMPP). Maximum power point trackers are used to achieve this. MPPT is an art of extracting maximum power from PV panel and it is regarded as the critical component of SPV system. Internal resistance of PV panel also varies with the variation in atmospheric conditions, but load resistance remains the same. Converter controlled with MPPT algorithm is used to achieve load matching and extracting maximum power from PV panel. In order ensure that the PV system is operating near MPP, a DC-DC converter along with an MPPT controller is inserted in between the load and PV module. Various MPPT algorithms such as short circuit current based, open circuit current based, ripple correlation control (RCC), slide mode control technique, perturb and observe (P & O), incremental conductance (INC), fuzzy logic controller (FLC), artificial neural network (ANN) based approaches have been already proposed. DC-DC converters have drawn attraction these days, and are being used extensively with modern electronic systems. Since most of the renewable energy resources produce dc voltage, a DC-DC converter is used to transfer the power from source to load [4]. For tracking solar and wind power, which are stochastic in nature, DC-DC converters are used as an impedance matching unit. DCDC converters act as an impedance matching unit in between the PV panel and load. By controlling converter duty ratio, input impedance of the converter is made equal to output impedance of the PV panel and load matching is achieved. Information regarding different converter topologies is mostly available on power electronics, simulation, and other electrical journals and detailed review on application of DC-DC converter topologies on solar power tracking is not available [5-7]. Since the application of non-isolated DC-DC converters on PV power tracking is increasing these days, it is the time to compile the work that has been already carried out in this area for the reference of researchers. This is the main motive behind this project. This project describes the working of DC-DC converters along with its merits and demerits on solar power tracking.

2 PHOTOVOLTAIC CELL

Converting solar energy into electrical energy by PV installations is the most recognized way to use solar energy. Since solar photovoltaic cells are semiconductor devices, they have a lot in common with processing and production techniques of other semiconductor devices such as computers and memory chips. As it is well known, the requirements for purity and quality control of semiconductor devices are quite large. With today's production, which reached a large scale, the whole industry production of solar cells has been developed and, due to low production cost, it is mostly located in the Far East. Photovoltaic cells produced by the majority of today's most large producers are mainly made of crystalline silicon as semiconductor material [8-10]. Solar photovoltaic modules, which are a result of combination of photovoltaic cells to increase their power, are highly reliable, durable and low noise devices to produce electricity. The fuel for the photovoltaic cell is free. The sun is the only resource that is required for the operation of PV systems, and its energy is almost inexhaustible. A typical photovoltaic cell efficiency is about 15%, which means it can convert 1/6 of solar energy into electricity. Photovoltaic systems produce no noise, there are no moving parts and they do not emit pollutants into the environment [11]. Taking into account the energy consumed in the production of photovoltaic cells, they produce several tens of times less carbon dioxide per unit in relation to the energy produced from fossil fuel technologies. Photovoltaic cell has a lifetime of more than thirty years and is one of the most reliable semiconductor products. Most solar cells are produced from silicon, which is non-toxic and is found in abundance in the earth's crust. Figure 1 shows the photovoltaic cell.

Figure 1: *Photovoltaic cell.*

Photovoltaic systems (cell, module, network) require minimal maintenance. At the end of the life cycle, photovoltaic modules can almost be completely recycled. Photovoltaic modules bring electricity to rural areas where there is no electric power grid, and thus increase the life value of these areas. Photovoltaic systems will continue the future development in a direction to become a key factor in the production of electricity for households and buildings in general [19]. The systems are installed on existing roofs and/or are integrated into the facade. These systems contribute to reducing energy consumption in buildings. A series of legislative acts of the European Union in the field of renewable energy and energy efficiency have been developed, particularly promoting photovoltaic technology for achieving the objectives of energy savings and CO2 reduction in public, private and commercial buildings. Also, photovoltaic technology, as a renewable energy source, contributes to power systems through diversification of energy sources and security of electricity supply. By the introduction of incentives for the energy produced by renewable sources in all developed countries, photovoltaic systems have become very affordable, and timely return of investment in photovoltaic systems has become short and constantly decreasing. In recent years, this industry is growing at a rate of 40% per year and the photovoltaic technology creates thousands of jobs at the local level.

2.1 Types of vehicle charging equipment

The word photovoltaic consists of two words: photo, a greek word for light, and voltaic, which defines the measurement value by which the activity of the electric field is expressed, i.e. the difference of potentials. Photovoltaic systems use cells to convert sunlight into electricity. Converting solar energy into electricity in a photovoltaic installation is the most known way of using solar energy. The light has a dual character according to quantum physics. Light is a particle and it is a wave. The particles of light are called photons. Photons are massless particles, moving at light speed [12-15]. In metals and in the matter generally, electrons can exist as valence or as free. Valence electrons are associated with the atom, while the free electrons can move freely. In order for the valence electron to become free, he must get the energy that is greater than or equal to the energy of binding. Binding energy is the energy by which an electron is bound to an atom in one of the atomic bonds. In the case of photoelectric effect, the electron acquires the required energy by the collision with a photon. Part of the photon energy is consumed for the electron getting free from the influence of the atom which it is attached to, and the remaining energy is converted into kinetic energy of a now free electron. Free electrons obtained by the photoelectric effect are also called photoelectrons. The energy required to release a valence electron from the impact of an atom is called a work out Wi, and it depends on the type of material in which the photoelectric effect has occurred [16-18].

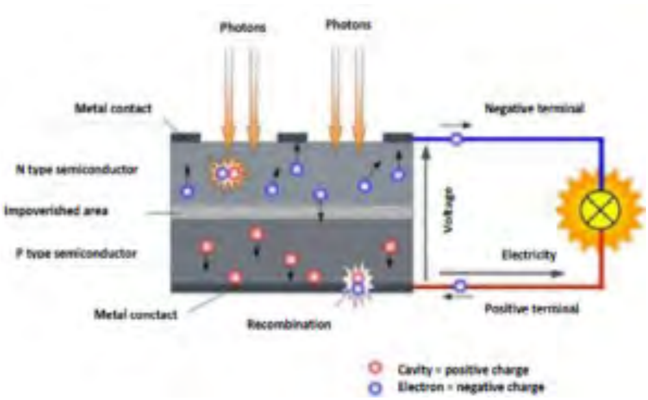


Figure 2: *Functioning of PV cell.*

The previous equation shows that the electron will be released if the photon energy is less than the work output. The photoelectric conversion in the PV junction. PV junction (diode) is a boundary between two differently doped semiconductor layers; one is a P-type layer (excess holes), and the second one is an N-type (excess electrons). At the boundary between the P and the N area, there is a spontaneous electric field, which affects the generated electrons and holes and determines the direction of the current [20-21]. To obtain the energy by the photoelectric effect, there shall be a directed motion of photoelectrons, i.e. electricity. All charged particles, photoelectrons also, move in a directed motion under the influence of electric field. The electric field in the material itself is located in semiconductors, precisely in the impoverished area of PV junction (diode). It was pointed out for the semiconductors that, along with the free electrons in them, there are cavities as charge carriers, which are a sort of a byproduct in the emergence of free electrons. Cavities occurs whenever the valence electron turns into a free electron, and this process is called the generation, while the reverse process, when the free electron fills the empty spaces - a cavity, is called recombination. If the electron-cavity pairs occur away from the impoverished areas it is possible to recombine before they are separated by the electric field. Photoelectrons and cavities in semiconductors are accumulated at opposite ends, thereby creating an electromotive force. If a consuming device is connected to such a system, the current will flow and we will get electricity. In this way, solar cells produce a voltage around 0,5-0,7 V, with a current density of about several tens of mA/cm2 depending on the solar radiation power as well as on the radiation spectrum. The usefulness of a photovoltaic solar cell is defined as the ratio of electric power provided by the PV solar cells and the solar radiation power. The usefulness of PV solar cells ranges from a few percent to forty percent. The remaining energy that is not converted into electrical energy is mainly converted into heat energy and thus warms the cell. Generally, the increase in solar cell temperature reduces the usefulness of PV cells. Standard calculations for the energy efficiency of solar photovoltaic cells are explained below. Energy conversion efficiency of a solar photovoltaic cell (η "ETA") is the percentage of energy from the incident light that actually ends up as electricity. This is calculated at the point of maximum power, Pm, divided by the input light irradiation (E, in W/m2), all under standard test conditions (STC) and the surface of photovoltaic solar cells (AC in m2). STC - standard test conditions, according to which the reference solar radiation is 1.000 W/m2, spectral distribution is 1.5 and cell temperature 250C.

2.2 Energy depreciation of PV ells

The period of energy depreciation of photovoltaic cells is the time period that must pass using a photovoltaic system to return the energy that has been invested in the construction of all parts of the system, as well as the energy required for the breakdown after the lifetime of a PV system. Of course, the energy depreciation time is different for different locations at which the system is located, thus it is a lot shorter on locations with a large amount of irradiated solar energy, up to 10 or more times shorter than its lifetime. South Istria has approximately 1.700 kWh/m2 annual radiation, while the northern part of Istria has somewhere around 1.500 kWh/m2. The figure 3 shows the available data on the energy depreciation for the various technologies of photovoltaic cells, with their respective efficiencies in given years of production. In relation to the south of Istria, which is shown in Figure 2.7, the energy depreciation in the city of Zagreb is, for example, about 20% longer, in southern Dalmatia is

10 to 15% shorter than in Istria, which corresponds to solar radiation intensity-insolation map.

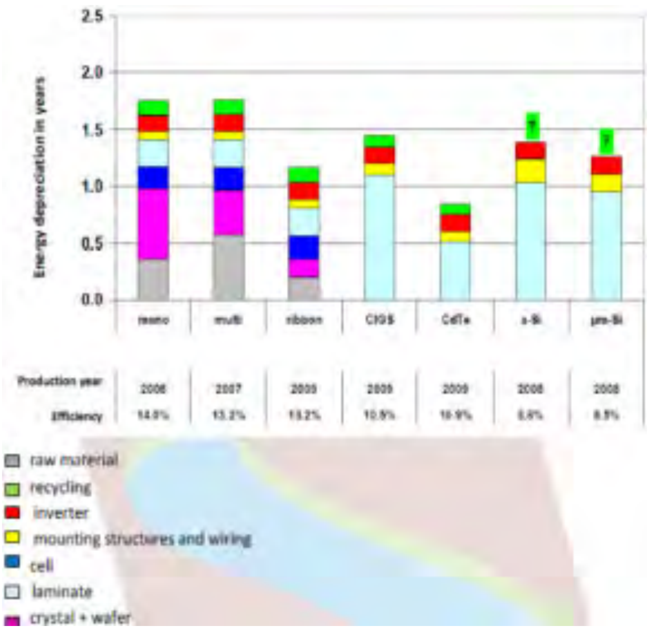


Figure 3: *Availability of energy.*

3 MAXIMUM POWER POINT TRACING

MPPT or **Maximum Power Point Tracking** is algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage). Maximum power varies with solar radiation, ambient temperature and solar cell temperature. A MPPT, or maximum power point tracker is an electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid. To put it simply, they convert a higher voltage DC output from solar panels (and a few wind generators) down to the lower voltage needed to charge batteries. (These are sometimes called "power point trackers" for short - not to be confused with PANEL trackers, which are a solar panel mount that follows, or tracks, the sun). The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient voltage (maximum power point). That is to say: MPPT checks output of PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current into battery. It can also supply power to a DC load, which is connected directly to the battery. MPPT is most effective under these conditions:

- Cold weather, cloudy or hazy days: Normally, PV module works better at cold temperatures and MPPT is utilized to extract maximum power available from them.
- When battery is deeply discharged: MPPT can extract more current and charge the battery if the state of charge in the battery is lowers.

Panel tracking is where the panels are on a mount that follows the sun. The most common are the Zomeworks and Wattsun. These optimize output by following the sun across the sky for maximum sunlight. These typically give you about a 15% increase in winter and up to a 35% increase in summer. This is just the opposite of the seasonal variation for MPPT controllers. Since panel temperatures are much lower in winter, they put out more power. And winter is usually when you need the most power from your solar panels due to shorter days. Maximum Power Point Tracking is electronic tracking usually digital. The charge controller looks at the output of the panels, and compares it to the battery voltage. It then figures out what is the best power that the panel can put out to charge the battery. It takes this and converts it to best voltage to get maximum AMPS into the battery. (Remember, it is Amps into the battery that counts). Most modern MPPT's are around 93-97% efficient in the conversion. You typically get a 20 to 45% power gain in winter and 10-15% in summer. Actual gain can vary widely depending weather, temperature, battery state of charge, and other factors. Grid tie systems are becoming more popular as the price of solar drops and electric rates go up. There are several brands of grid-tie only (that is, no battery) inverters available. All of these have built in MPPT. Efficiency is around 94% to 97% for the MPPT conversion on those. Solar cells are neat things. Unfortunately, they are not very smart. Neither are batteries - in fact batteries are downright stupid. Most PV panels are built to put out a nominal 12 volts. The catch is "nominal". In actual fact, almost all "12 volt" solar panels are designed to put out from 16 to 18 volts. The problem is that a nominal 12 volt battery is pretty close to an actual 12 volts - 10.5 to 12.7 volts, depending on state of charge. Under charge, most batteries want from around 13.2 to 14.4 volts to fully charge quite a bit different than what most panels are designed to put out.

3.1 Working of MPPT

Here is where the optimization, or maximum power point tracking comes in. Assume battery is low, at 12 volts. A MPPT takes that 17.6 volts at 7.4 amps and converts it down, so that what the battery gets is now 10.8 amps at 12 volts. Now you still have almost 130 watts. Ideally, for 100% power conversion you would get around 11.3 amps at 11.5 volts, but you have to feed the battery a higher voltage to force the amps in. And this is a simplified explanation - in actual fact the output of the MPPT charge controller might vary continually to adjust for getting the maximum amps into the battery. A MPPT tracks the maximum power point, which is going to be different from the STC (Standard Test Conditions) rating under almost all situations. Under very cold conditions a 120 watt panel is actually capable of putting over 130+ watts because the power output goes up as panel temperature goes down - but if you don't have some way of tracking that power point, you are going to lose it. On the other hand under very hot conditions, the power drops - you lose power as the temperature goes up. That is why you get less gain in summer. MPPT's are most effective under these conditions

- Winter, and/or cloudy or hazy days - when the extra power is needed the most.
- Cold weather - solar panels work better at cold temperatures, but without a MPPT you are losing most of that. Cold weather is most likely in winter - the time when sun hours are low and you need the power to recharge batteries the most.
- Low battery charge - the lower the state of charge in your battery, the more current a MPPT puts into them - another time when the extra power is needed the most. You can have both of these conditions at the same time.
- Long wire runs - If you are charging a 12 volt battery, and your panels are 100 feet away, the voltage drop and power loss can be considerable unless you use very large wire. That can be very expensive. But if you have four 12 volt panels wired in series for 48 volts, the power loss is much less, and the controller will convert that high voltage to 12 volts at the battery. That also means that if you have a high voltage panel setup feeding the controller, you can use much smaller wire.

The Power point tracker is a high frequency DC to DC converter. They take the DC input from the solar panels, change it to high frequency AC, and convert it back down to a different DC voltage and current to exactly match the panels to the batteries. MPPT's operate at very high audio frequencies, usually in the 20-80 kHz range. The advantage of high frequency circuits is that they can be designed with very high efficiency transformers and small components. The design of high frequency circuits can be very tricky because the problems with portions of the circuit "broadcasting" just like a radio transmitter and causing radio and TV interference. Noise isolation and suppression becomes very important. There are a few non-digital (that is, linear) MPPT's charge controls around. These are much easier and cheaper to build and design than the digital ones. They do improve efficiency somewhat, but overall the efficiency can vary a lot - and we have seen a few lose their "tracking point" and actually get worse. That can happen occasionally if a cloud passed over the panel - the linear circuit searches for the next best point, but then gets too far out on the deep end to find it again when the sun comes out. Thankfully, not many of these around anymore. The power point tracker (and all DC to DC converters) operates by taking the DC input current, changing it to AC, running through a transformer (usually a toroid, a doughnut looking transformer), and then rectifying it back to DC, followed by the output regulator. In most DC to DC converters, this is strictly an electronic process - no real smarts are involved except for some regulation of the output voltage. Charge controllers for solar panels need a lot more smarts as light and temperature conditions vary continuously all day long, and battery voltage changes.

3.2 Boost Converter

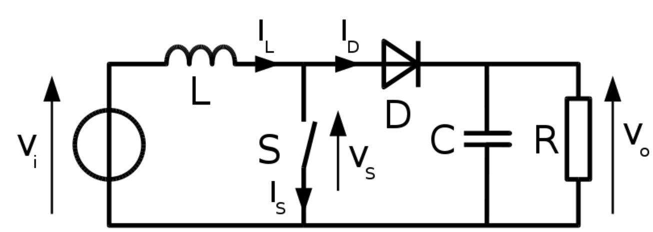


Figure 4: *Circuit Diagram of Boost Converter.*

The boost converter converts an input voltage to a higher output voltage. The boost converter is also called a step-up converter. A boost converter is a DC-to-DC power converter .with an output voltage greater than its input voltage. It is a class of switched mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor and at least one energy storage element, a capacitor C, inductor L or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. Power for the boost converter can come from any suitable DC sources,. A process that changes low DC voltage to a high DC voltage is called DC to DC conversion .It "steps up" the source voltage. Since power must be conserved the output current is lower than the source current.

3.3 Operating Principle

The principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. A schematic of a boost power stage is shown in figure 4. (a) When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive in figure 5. (b) When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current flow towards the load. Thus the polarity will be reversed. As a result two sources will be in series causing a higher voltage to charge the capacitor through the diode D in figure 5. If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. Also while the switch is opened, the capacitor in parallel with the load is charged to this combined voltage. When the switch is then closed and the right hand side is shorted out from the left hand side, the capacitor is therefore able to provide the voltage and energy. The basic principle of a Boost converter consists of 2 distinct states

1) In the On-state, the switch S is closed, resulting in an increase in the inductor current 2) In the Off-state, the switch is open and the only path offered to inductor current is through flyback diode D, the capacitor C and the load R. This results in transferring the energy accumulated during the On-state into the capacitor. 3) The input current is the same as the inductor current as can be seen in figure 3.1. So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter.

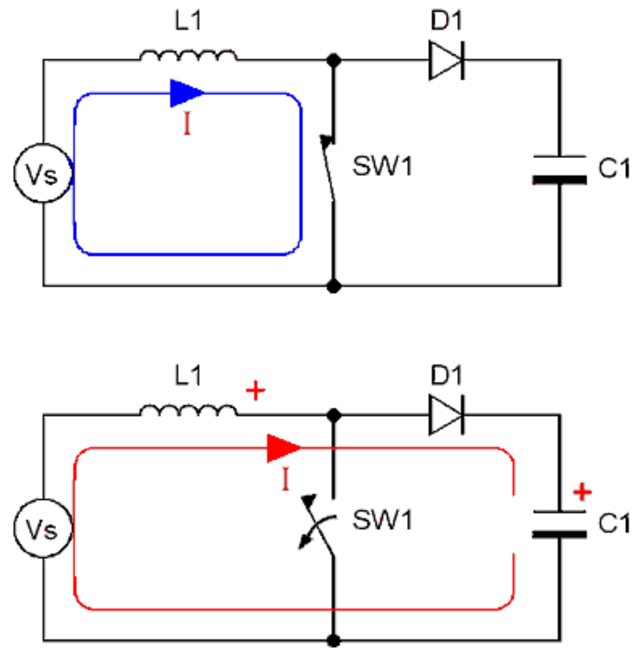


Figure 5: *Operating Mode of the Boost Converter.*

3.4 Controllers for MPPT

The controller should keep testing if the PV system is operating at the PV maximum power point. It should force the system to track this MPP. Continuous measuring of the voltage and current from the PV array, and then performing either voltage or power feedback control is the method used.

3.4.1 Voltage Feedback Control

The control variable here is the PV array terminal voltage. The controller forces the PV array to operate at its MPP by changing the array terminal voltage. It neglects, however, the variation in the temperature and insulation level.

3.4.2 Power Feedback Control

The control variable here is the power delivered to the load. To achieve maximum power the quantity dp/dvis forced to zero. This control scheme is not affected by the characteristics of the PV array, yet it maximizes power to the load and not power from the PV array. Fast shadows cause trackers to lose the MPP momentarily, and the time lost in seeking it again, because the point has moved away quickly and then moved back to the original position, equating to the energy lost while the array is off power point. On the other hand, if lighting conditions do change, the tracker needs to respond within a short amount of time to the change to avoid energy loss. Thus the controller should be capable of adjusting and keeping the PV at its MPPT. Several algorithms were proposed to accomplish MPPT controller. Published MPPT methods include: 1) Perturb and Observe (PAO) , 2) Incremental Conductance Technique (ICT), and 3) Constant Reference Voltage/Current.

4 Proposed System

4.1 DC/DC parallel MPPT for PV system

MPPT or Maximum Power Point Tracking is calculation that incorporated into charge controllers utilized for removing most extreme accessible power from PV mod-

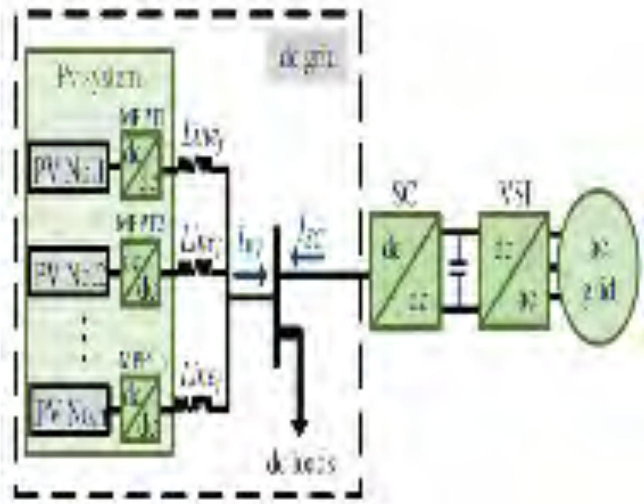


Figure 6: *Block diagram of proposed system.*

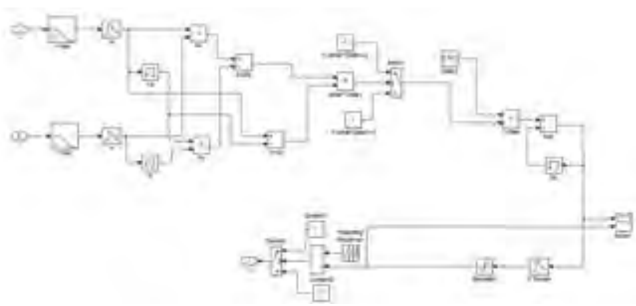


Figure 7: *Simulation of MPPT.*

ule under specific conditions. The voltage at which PV module can deliver most extreme power is called 'greatest power point' (or pinnacle control voltage). Most extreme power differs with sunlight based radiation, encompassing temperature and sun based cell temperature. A MPPT, or most extreme power point tracker is an electronic DC to DC converter that streamlines the match between the sun powered exhibit (PV boards), and the battery bank or utility framework. Basically, they change over a higher voltage DC yield from sun based boards (and a couple of twist generators) down to the lower voltage expected to charge batteries. (These are some of the time called "control point trackers" for short - not to be mistaken for PANEL trackers, which are a sun powered board mount that takes after, or tracks, the sun). The simulation of MPPT is shown in figure 8.

The significant standard of MPPT is to separate the greatest accessible power from PV module by influencing them to work and no more productive voltage (most extreme power point). In other words: MPPT checks yield of PV module, thinks about it to battery voltage at

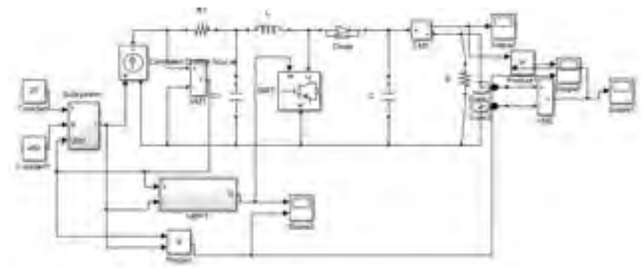


Figure 8: *Simulation of PV system with MPPT.*

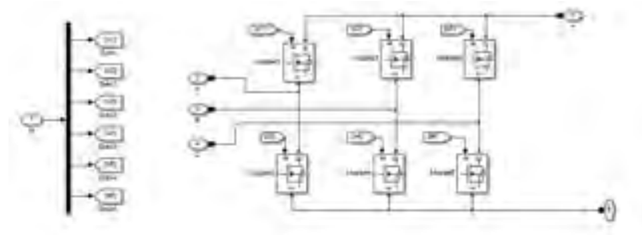


Figure 9: *Bridge inverter.*

that point fixes what is the best power that PV module can deliver to charge the battery and believers it to the best voltage to get most extreme current into battery. It can likewise supply energy to a DC stack, which is associated specifically to the battery.

4.2 PV Array

A PV Array consists of a number of individual PV modules or panels that have been wired together in a series and/or parallel to deliver the voltage and amperage a particular system requires. An array can be as small as a single pair of modules, or large enough to cover acres.The performance of PV modules and arrays are generally rated according to their maximum DC power output (watts) under Standard Test Conditions (STC). Standard Test Conditions are defined by a module (cell) operating temperature of 25oC (77 F), and incident solar irradiant level of 1000 W/m2 and under Air Mass 1.5 spectral distribution. Since these conditions are not always typical of how PV modules and arrays operate in the field, actual performance is usually 85 to 90 percent of the STC rating. The simulation of PV system with MPPT used in proposed work is shown in figure 8.

4.3 Inverter

An inverter is an electrical device which converts DC voltage, almost always from batteries, into standard household AC voltage so that it is able to be used by common appliances. In short, an inverter converts direct current into alternating current. Direct current is

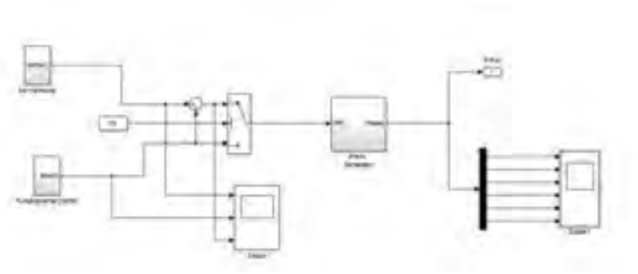


Figure 10: *PWM controller.*

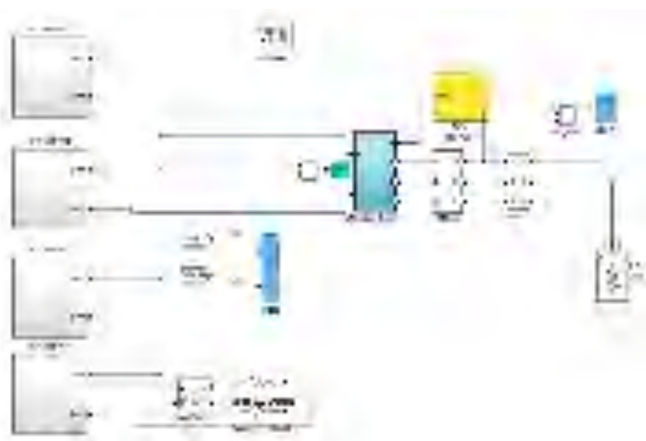


Figure 11: *Overall system timetable.*

used in many of the small electrical equipment such as solar power systems, since solar cells is only able to produce DC. They are also used in places where a small amount of voltage is to be used or produced such as power batteries which produce only DC. Other than these fuel cells and other power sources also produce DC. The switching arrangements of the inverter that is bridge inverter is shown in figure 9. The controller used to control the switches in the inverter is PWM controller which is shown in figure 9.

The overall system of the integrated DC/Dc parallel Maximum Power Point Tracking system for photovoltaic system is shown in figure 10. Overall system simulation diagram is shown in figure 11.

5 Results

The behavior of the complete proposed system that the DC/DC parallel Maximum Power Point Tracking for photovoltaic system is explained here with the simulation results. The system comprises of multiple PV sources and parallel DC/DC maximum power point tracking system which connected with each PV source. The overall PV system is connected with the DC bus. The inverter controlled by PWM technique is used to convert the DC voltage of DC bus to AC voltage which

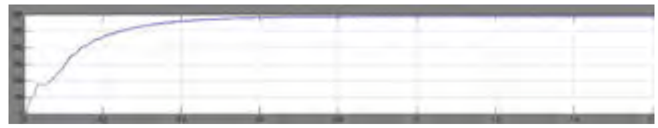


Figure 12: *Output voltage of PV system.*

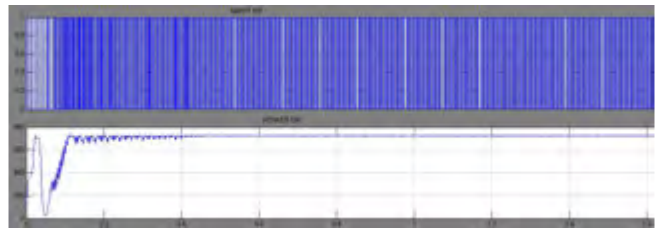


Figure 13: *Output voltage and power of PV with MPPT.*

can be utilized by the loads. The output voltage of the single PV source is shown in figure 6.1. The output voltage and power of the PV system with Proposed MPPT technique is shown in figure 12.

This DC voltage is converted into AC which is required to drive the AC sources. The controlling signal for the inverter switches is shown in figure 13.

The AC output of the proposed DC/DC parallel maximum power point tracking system for photovoltaic system is shown in figure 15.

6 Conclusion

This project provides a comprehensive study on various non-isolated DC-DC converters which are used for MPPT of solar power. DC-DC converters are found attractive due to the ability it to step up the low voltage produced by PV panel and the ability achieve load matching between PV panel and load. Selection crite-

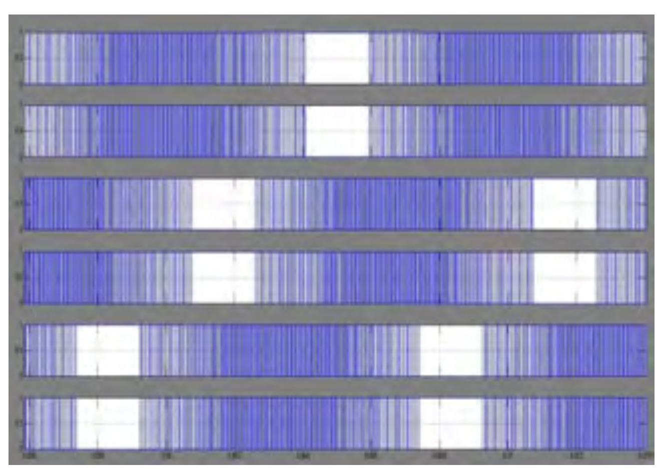


Figure 14: *Inverter switching pulses.*

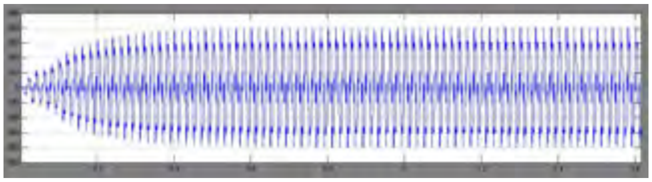


Figure 15: *Output AC voltage of the proposed system.*

ria for choosing an adequate converter for solar power tracking has been also presented based on the study and survey. Advantages and disadvantages of each converter is discussed in detail. To determine the characteristic of converter different parameters are analyzed. Working principle, merits and demerits of various DC-DC converter is described in detail.

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] K. Govindaraju, V. Bhavithira, D. Kavitha, S. Kuppusamy, and K. Balachander, "Improvement of Voltage Profile and Loss Minimization in IEEE 14 Bus System using FACTS Devices" in International Journal of Control Theory and Applications, ISSN: 0974-5572 Vol. 10 No.38 (2017), pg. 213-224.

[3] A. Amudha, , M. Siva Ramkumar , M. Sivaram Krishnan "Perturb and Observe Based Photovoltaic Power Generation System For Off-Grid Using Sepic Converter" International Journal of Pure and Applied Mathematics , 114(7), pp. 619-628 , 2017 .

[4] M. Siva Ramkumar, M. Sivaram Krishnan, A. Amudha, "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[5] M. Siva Ramkumar, M. Sivaram Krishnan, A. Amudha, "Impedance Source Inverter and Permanent Magnet Synchronous Generator For Variable Speed Wind Turbine " International Journal of Computer & Mathematical Sciences, 6 (9) pp 98-105, 2017.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017.

[8] M.Subramanian, M. Siva Ramkumar, A. Amudha, , K.Balachander and D.Kavitha "Power Quality Improvement In Low Voltage Transmission System Using Static Compensator" in International Journal of Control Theory and Applications (IJCTA) 10 (38) pp 247-261, 2017.

[9] V.Chandra Prabha , A. Amudha, , K.Balachander, M. Siva Ramkumar " MPPTAlgorithm For Grid Integration of Variable Speed Wind Energy Conversion System" in International Journal of Control Theory and Applications, 10 (38) pp 237-246, 2017.

[10] R. Yuvaraj, K. Balachander, A. Amudha, S. Kuppuamy, M. Siva Ramkumar " Modified Interleaved Digital Power Factor Correction Based On The Sliding Mode Approach" in International Journal of Control Theory and Applications, 10 (38) pp 225-235, 2017.

[11] R. Ravichandran, K. Balachander, A. Amudha, M. Siva Ramkumar, S.Kuppusamy " Estimation Of Electrical Parameter Using Fuzzy Logic Controller Based Induction Motor" in International Journal of Control Theory and Applications, 10 (38) pp 205-212 , 2017.

[12] K. R. Jeyakrishna, A. Amudha. ,K. Balachander, M. Siva Ramkumar " Electric Vehicle Battery Charging Station Using Dual Converter Control" in International Journal of Control Theory and Applications, 10 (38) pp 195-203, 2017.

[13] M. R. Latha, S. Kuppusamy, A. Amudha, K. Balachander, M. Siva Ramkumar " An Efficient Single Stage Converter Based Pv-Dvr For Improving Voltage Quality" in International Journal of Control Theory and Applications, 10 (38) pp 177-193, 2017.

[14] N. Sivakumar, D. Kavitha, M. Siva Ramkumar, V.Bhavithira, S. Kalaiarasi, "A Single Stage High Gain Converter For Gird Interconnected Renewable Application Using Perturb And Observe" in International Journal of Control Theory and Applications, 10 (38) 161-175 , 2017.

[15] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc " in International Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[16] M Siva RamKumar, A. Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016. .

[17] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in

'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763-769,2016.

[18] R. Sudhakar, M. Siva Ramkumar, "Boosting With SEPIC" in 'International Journal of Engineering and Science' 3 (4) pp 14-19,2014.

[19] M. Sownthara, M. Siva Ramkumar, "Wireless Communication Module To Replace Resolver Cable In Welding Robot" in International Journal of Advanced Information Science and Technology on 23(23) pp 230-235,2014.

[20] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2)

[21] M. Sivaram Krishnan, M. Siva Ramkumar, "Power Management of a Hybrid Solar-Wind Energy System, International Journal of Engineering Research & Technology, 2 (1) pp 1988-1992.

[22] M. Sivaram Krishnan, M. Siva Ramkumar, "Power Quality Analysis In Hybrid Energy Generation System" in 'International Journal of Advance Research in Computer Science and Management Studies 2 (1) pp 188-193

INTEGRATION OF VARIOUS RENEWABLE ENERGY SYSTEMS WITH BATTERY ENERGY STORAGE SYSTEM USING OPTIMAL ENERGY MANAGEMENT SYSTEM

G. Sumathi, A. Amudha, K. Balachander

Abstract: Hybrid power production units seems to be an interesting alternative for supplying isolated sites. This project proposes a new supervision strategy in order to ensure an optimized energy management of the hybrid unit which includes a wind generator (WG), a fuel cell (FC), an electrolyzer (EL) and a battery. An overall power supervision approach was designed to guarantee the power flow management between the energy sources and the storage elements. The aim of the control system is to provide a permanent supply to the isolated site by adapting production to consumption according to the storage level. The performance of the control strategy for an optimal management of the hybrid power production unit under different scenarios of power generation and load demand was illustrated using MATLAB/SIMULINK software.

Keywords: Wind Generator (WG), Fuel Cell (FC), Electrolyzer (EL), Energy Management System (EMS)

1 Introduction

An energy management scheme for a WECS based power system with hybrid energy storage units is proposed. It is shown that, the EMS chooses the operating mode of three sources based on their states and determines the reference power for each of the individual source. In a renewable grid integrated hybrid energy management scheme was reported with main focus on high battery state of charge and overcharge limits. In an effective power management strategy was proposed for the renewable grid integrated system with battery ESS and it is demonstrated that the power management scheme (PMS) provides fast DC link voltage regulation compared with AC line current regulation method. However, the battery current and voltage undergo sudden changes during renewable/load variation, which affects battery life span in the long term. In a model predictive based power management scheme was proposed for battery hybrid in a DC microgrid environment. The main advantage of this scheme is that, it provides a uniform approach to design a control system that ensures the operation of the fuel cell battery hybrid within predefined limits. However, the DC link voltage is assumed to be constant throughout the work. Moreover, the classical model predictive control (MPC) that relies on a discrete model of the control system and a cost function makes it computationally intensive [1-3]. A control strategy is devised to balance the power flow in a DC microgrid environment under renewable side variations and load as well. However, this scheme does not allow to divert transient powers to the supercapacitor units. In Power management of a stand-alone wind/photovoltaic/fuel cell energy system, power management strategies have been developed for islanded microgrids that include PV and battery units. These strategies require that the energy management system (EMS) has access to the power measurements at every distributed generation unit and load node. Therefore, all load nodes and local loads must be equipped with power measurement and communication modules, which are not practical or readily available in most conventional distribution networks. Otherwise, the central EMS may make an undesirable decision if the power measurements are not available from one or more loads. A power management strategy is presented in Supervisory control of an adaptive regulated DC micro grid with battery management capability, for islanded DC micro grids that includes PV and battery storage units. A state machine of four modes is used in the supervisory EMS, where the battery voltage is used as a measure of the SOC to switch between modes.

2 HYBRID ENERGY SYSTEM

We all know that the world is facing a major threat of fast depletion of the fossil fuel reserves. Most of the present energy demand is met by fossil and nuclear power plants. A small part is met by renewable energy technologies such as the wind, solar, biomass, geothermal etc. There will soon be a time when we will face a severe fuel shortage. As per the law of conservation of energy, "Energy can neither be created, nor be destroyed, but it can only be converted from one form to another". Most of the research now is about how to conserve the energy and how to utilize the energy in a better way. Research has also been into the development of reliable and robust systems to harness energy from non-conventional energy resources. Among them, the wind and solar power sources have experienced a remarkably rapid growth in the past 10 years. Both are pollution free sources of abundant power [4-5]. With high economic growth rates and over 17 percent of the world's population, India is a significant consumer of energy resources. Despite the global financial crisis, India's energy demand continues to rise. India consumes its maximum energy in Residential, commercial and agricultural purposes in comparison to China, Japan, and Russia. Solar energy is energy from the Sun. It is renewable, inexhaustible and environmental pollution free [6]. Solar charged battery systems provide power supply for complete 24 hours a day irrespective of bad weather. By adopting the appropriate technology for the concerned geographical location, we can extract a large amount of power from solar radiations. More over solar energy is expected to be the most promising alternate source of energy. The global search and the rise in the cost of conventional fossil fuel is making supply-demand of electricity product almost impossible especially in some remote areas [7-9]. Generators which are often used as an alternative to conventional power supply systems are known to be run only during certain hours of the day, and the cost of fuelling them is increasingly becoming difficult if they are to be used for commercial purposes. Wind energy is the kinetic energy associated with the movement of atmospheric air. It has been used for hundreds of years for sailing, grinding grain and for irrigation. Wind energy systems convert this kinetic energy to more useful forms of power. Wind energy systems for irrigation and milling have been in use since ancient times and at the beginning of the 20th century it is being used to generate electric power. Windmills for water pumping have been installed in many countries particularly in the rural areas. Wind turbines transform the energy in the wind into mechanical power, which can then be used directly for grinding etc. or further converting to electric power to generate electricity. Wind turbines can be used singly or in clusters called 'wind farms.

2.1 Wind Energy Conversion System

Figure 1 represents the complete wind energy conversion systems (WECS), which converts the energy present in the moving air (wind) to electric energy. The wind passing through the blades of the wind turbine generates a force that turns the turbine shaft. The rotational shaft turns the rotor of an electric generator, which converts mechanical power into electric power. The major components of a typical wind energy conversion system include the wind turbine, generator, interconnection apparatus and control systems. The power developed by the wind turbine mainly depends on the wind speed, swept area of the turbine blade, density of the air, rotational speed of the turbine and the type of connected electric machine.

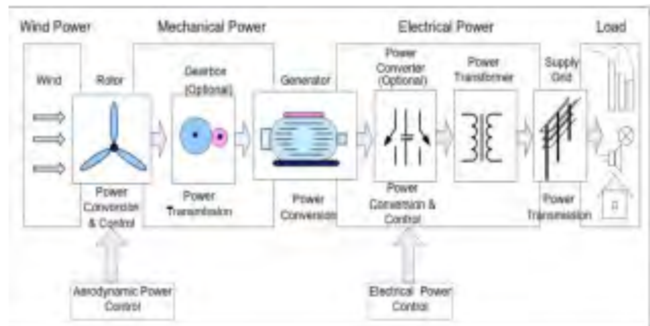


Figure 1: *Wind Energy Conversion System.*

As shown in figure 1, there are primarily two ways to control the WECS. The first is the Aerodynamic power control at either the Wind Turbine blade or nacelle, and the second is the electric power control at an interconnected apparatus, e.g., the power electronics converters. The flexibility achieved by these two control options facilitates extracting maximum power from the wind during low wind speeds and reducing the mechanical stress on the wind turbine during high wind speeds [10-12].

2.2 Fuel cell technology

A fuel cell is an energy conversion device that converts the chemical energy of a fuel directly into electricity without any intermediate thermal or mechanical processes. Energy is released whenever a fuel reacts chemically with the oxygen in air. In an internal combustion engine, the reaction occurs combustivelyand the energy is released in the form of heat, some of which can be used to do useful work by pushing a piston. In a fuel cell, the reaction occurs electrochemically and the energy is released as a combination of low-voltage DC electrical energy and heat. The electrical energy can be used to do useful work directly while the heat is either wasted or used for other purposes. In galvanic (or "voltaic") cells, electrochemical reactions form the basis in which chemical energy is converted into electri-cal energy. A fuel cell of any type is a galvanic cell, as is a battery. In contrast, in electrolytic cells, electrical energy is converted into chemical energy, such as in an electrolyzer or electroplater. A basic feature of fuel cells is that the electric current load determines the consumption rate of hydrogen and oxygen. In an actual systems application, a variety of electrical loads may be applied to the fuel cell [13]. In a fuel cell, the fuel and the oxidant gases themselves comprise the anode and cathode respectively.

Thus, the physical structure of a fuel cell is one where the gases are directed through flow channels to either side of the electrolyte. The electrolyte is the distinguishing feature between different types of fuel cells. Different electrolytes conduct different specific ions. Electrolytes can be liquid or solid; some operate at high temperature, and some at low temperature. Low-temperature fuel cells tend to require a noble metal catalyst, typically platinum, to encourage the electrode reactions whereas high-temperature fuel cells do not. Most fuel cells suitable for automotive applications use a low temperature solid electrolyte that conducts hydrogen ions as shown in figure 2.

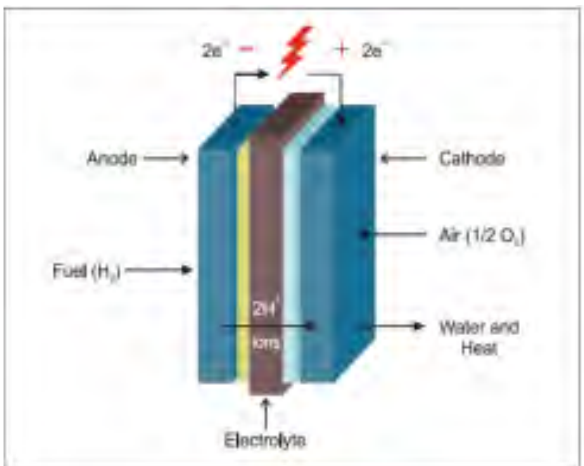


Figure 2: *Fuel cell operation.*

In principle, a fuel cell can operate using a variety of fuels and oxidants. Hydrogen has long been recognized as the most effective fuel for practical fuel cell use since it has higher electrochemical reactivity than other fuels, such as hydrocarbons or alcohols. Even fuel cells that operate directly on fuels other than hydrogen tend to first decompose into hydrogen and other elements before the reaction takes place. Oxygen is the obvious choice of oxidant due to its high reactivity and its abundance in air [14-16].

2.3 Battery

The storage battery or secondary battery is such battery where electrical energy can be stored as chemical energy and this chemical energy is then converted to electrical energy as when required. The conversion of electrical energy into chemical energy by applying external electrical source is known as charging of battery. Whereas conversion of chemical energy into electrical energy for supplying the external load is known as discharging of secondary battery [17]. During charging of battery, current is passed through it which causes some chemical changes inside the battery. This chemical changes absorb energy during their formation. When the battery is connected to the external load, the chemical changes take place in reverse direction, during which the absorbed energy is released as electrical energy and supplied to the load.

3 ENERGY MANAGEMENT

Energy management includes planning and operation of energy production and energy consumption units. Objectives are resource conservation, climate protection and cost savings, while the users have permanent access to the energy they need. It is connected closely to environmental management, production management, logistics and other established business functions [18-20]. The VDI-Guideline 4602 released a definition which includes the economic dimension: "Energy management is the proactive, organized and systematic coordination of procurement, conversion, distribution and use of energy to meet the requirements, taking into account environmental and economic objectives".

3.1 Steps for energy management

1. Energy management as Policy and Commitment.
2. Selection of energy manager and defining his responsibilities;
   (a) Energy planning
   (b) Monitoring energy consumption
   (c) Planning energy conservation
   (d) Implementing energy conservation measures
   (e) Achieve energy conservation objectives
3. Formulation energy strategy and energy conservation plan
4. Bring awareness and involvement at various levels by means of training programmes, workshops, communication, in-house journals
5. Introduce suggestion scheme and award scheme
6. Appoint energy audit team/consultants
7. Obtain report on energy conservation measures
8. Establish practice of monitoring energy consumption and effectiveness of energy conservation measures
9. Adopt new technology measures
10. Adopt recycling of scrap, avoid wastage etc
11. Carry out modifications, retrofitting or replacement of existing plant/machinery so as to save energy.

3.2 Objectives of supply side

To formulate energy strategies, plan energy supply on short term, mid-term and long term basis and to ensure adequate supply of various forms of secondary (usable) energy to various consumers in the allocated geographical zone with minimum cost and minimum environmental pollution, to regulate energy flow.

3.3 Objectives of End-user side

To select optimum energy forms for consumption and to optimize energy consumption of each form of energy for reducing energy costs and for improving productivity, standard of living and environment . In accordance with this generic objective, every end-user organisation should have an energy objective statement in written form as a management policy statement. This is an obligatory function for every organisation on supply side and demand side in individual and national interest.

3.4 Energy strategies

A long-term energy strategy should be part of the overall strategy of a company. This strategy may include the objective of increasing the use of renewable energies. Furthermore, criteria for decisions on energy investments, such as yield expectations, are determined.[15] By formulating an energy strategy companies have the opportunity to avoid risks and to assure a competitive advance against their business rivals.

3.5 Potential energy strategies

According to Kals there are the following energy strategies: 1. Passive Strategy: There is no systematic planning. The issue of energy and environmental management is not perceived as an independent field of action. The organization only deals with the most essential subjects. 2. Strategy of short-term profit maximization: The management is concentrating exclusively on measures that have a relatively short payback period and a high return. Measures with low profitability are not considered. 3. Strategy of long-term profit maximization: This strategy includes that you have a high knowledge of the energy price and technology development. The relevant measures (for example, heat exchangers or power stations) can have durations of several decades. Moreover, these measures can help to improve the image and increase the motivation of the employees. 4. Realization of all financially attractive energy measures: This strategy has the goal to implement all measures that have a positive return on investment. 5. Maximum strategy: For the climate protection one is willing to change even the object of the company. In reality, you usually find hybrid forms of different strategies.

3.6 Energy strategies of companies

Many companies are trying to promote its image and time protect the climate through a proactive and public energy strategy. General Motors (GM) strategy is based on continuous improvement. Furthermore they have six principles: e.g. restoring and preserving the environment, reducing waste and pollutants, educating the public about environmental conservation, collaboration for the development of environmental laws and regulations. Nokia created its first climate strategy in 2006. The strategy tries to evaluate the energy consumption and greenhouse gas emissions of products and operations and sets reduction targets accordingly.[19]Furthermore, their environmental efforts is based on four key issues: substance management, energy efficiency, recycling, promoting environmental sustainability. The energy strategy of Volkswagen (VW) is based on environmentally friendly products and a resource-efficient production according to the "Group Strategy 2018". Almost all locations of the Group are certified to the international standard ISO 14001 for environmental management systems. When looking at the energy strategies of companies it is important to you have the topic greenwashing in mind. This is a form of propaganda in which green strategies are used to promote the opinion that an organization's aims are environmentally friendly.

3.7 Energy strategies of politics

Even many countries formulate energy strategies. The Swiss Federal Council decided in May 2011 to resign nuclear energy medium-dated. The nuclear power plants will be shut down at the end of life and will not be replaced. In Compensation they put the focus on energy efficiency, renewable energies, fossil energy sources and the development of water power. The European Union has clear instructions for its members. The "20-20-20-targets" include, that the Member States have to reduce greenhouse gas emissions by 20% below 1990 levels, increase energy efficiency by 20% and achieve a 20% share of renewable energy in total energy consumption by 2020.

3.8 Ethical basis of the energy strategies

The basis of every energy strategy is the corporate culture and the related ethical standards applying in the company.[19] Ethics, in the sense of business ethics, examines ethical principles and moral or ethical issues that arise in a business environment. Ethical standards can appear in company guidelines, energy and environmental policies or other documents. The most relevant ethical ideas for the energy management are: Utilitarianism: This form of ethics has the maxim that the one acts are good or right, whose consequences are optimal for the welfare of all those affected by the action (principle of maximum happiness). In terms of energy management, the existence of external costs should be considered. They do not directly affect those who profit from the economic activity but non-participants like future generations. This error in the market mechanism can be solved by the internalization of external costs. Argumentation Ethics: This fundamental ethical idea says that everyone who is affected by the decision, must be involved in decision making. This is done in a fair dialogue, the result is completely uncertain. Deontological ethics: The deontological ethics assigns individuals and organizations certain obligations. A general example is the golden rule: "One should treat others as one would like others to treat oneself." Therefore everyone should manage their duties and make an energy economic contribution.

4 FUZZY LOGIC CONTROLLER

Fuzzy logic is a soft computing tool for embedding structured human knowledge into workable algorithms. The idea of fuzzy logic was introduced by Dr.LoftiZadeh of UC/Berkley in 1960's as a means of model of uncertainty of natural languages. Fuzzy logic is considered as a logical system that provides a model for human reasoning modes that are approximate rather than exact. The fuzzy logic system can be used to design intelligent systems on the basis of knowledge expressed in human language. There is practically no area of human activity left untouched by intelligent systems as these systems permits the processing of both symbolic and numerical information. The systems designed and developed based on fuzzy logic methods have been proved to be more efficient than those based on conventional approaches. Fuzzy logic has been recently applied in process control, modeling, estimation, identification, stock market prediction, diagnostics, military science, agriculture and so on. One of the pioneering applications of fuzzy logic is in control systems. Fuzzy logic based control is used in various applications. During the past several years, fuzzy logic based control has emerged as one of the most active and fruitful areas for research in the application of fuzzy logic theory, especially in wide range of industrial process which lacks quantitative data regarding the input-output relations. Some important systems for which fuzzy logic based controllers have been extensively used are water quality control system, elevator control system, automatic train operation system, automatic transmission control, nuclear reactor control system, washing machine etc.

4.1 Basics of fuzzy logic theory

Fuzzy logic is another form of artificial intelligence, but its history and applications are more recent than artificial intelligence based expert systems. Fuzzy logic is based on the fact that human thinking does not always follow crispy "YES" – "NO" logic, but it is often vague, uncertain, and indecisive. Fuzzy logic deals with problems that have vagueness, uncertainty, imprecision, approximations or partial truth or qualitative mess. The fuzzy logic is based on fuzzy set theory in which a particular object or variable has a degree of membership in a given set which may be anywhere in the range of 0 to 1. This is different from conventional set theory based on Boolean logic in which a particular object or variable is either a member (logic 1) of a given set or it is not (logic 0). The basic set operations like union (OR), intersection (AND) and complement (NOT) of Boolean logic are also valid for fuzzy logic.

4.2 Basics of Fuzzy Logic Control

Fuzzy logic provides a non-analytic alternative to the classical analytical control theory. Hence, fuzzy logic control is a powerful control tool for systems or processes which are complex and precise mathematical modeling are not possible. Fuzzy logic control is inherently robust and does not require precise, noise free inputs or the measurement or computation of change of parameters. Since the fuzzy logic controller uses defined rules governing the target systems, it can be tuned easily to improve system performance. The fuzzy logic controller is a suitable candidate for the control of multiple input-multiple output systems as it can accept many feedback inputs and generate many control outputs and it needs less storage of data in the form of membership functions and rules than the conventional look up table for non-linear controllers. The block diagram of a closed loop fuzzy logic controller is shown in figure 3.

In fuzzy logic control of a process or a system, there are two links between the fuzzy logic controller and the process or the system under control, namely the input and output links. The inputs of fuzzy logic controller are linked to the process through sensors and the outputs of the fuzzy logic controller are linked to the process through actuators. The fuzzy logic controller comprises of fuzzification, inference mechanism and defuzzification which are executed using information stored in the knowledge.

4.3 Knowledge Base

The knowledge base can be divided into two sub-blocks namely the Data Base and Rule Base. The data base consists of the information required for fuzzifying

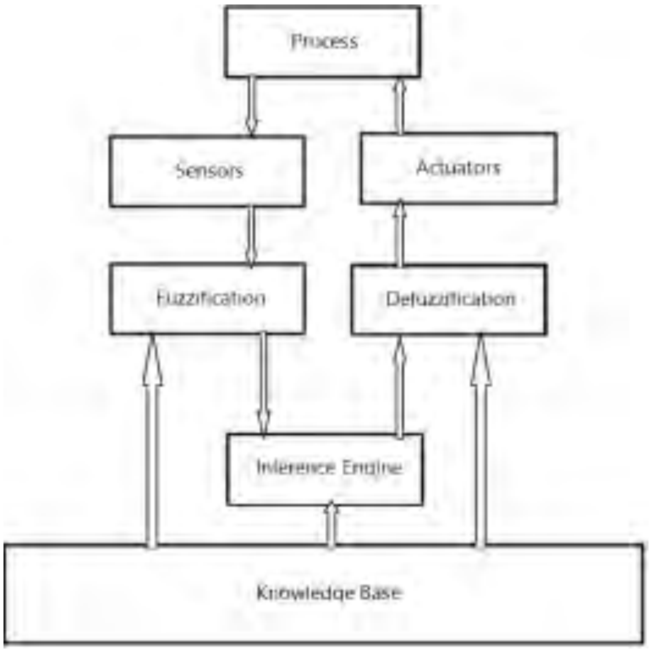


Figure 3: *Fuzzy logic controller.*

the crisp input and later defuzzifying the fuzzy outputs to a crisp output. It consists of the membership functions for various fuzzy variables or sets used in the controller design. The rule base consists of a set of rules, which are usually formulated from the expert knowledge of the system. The rules are typically of the form "If. . . . ., then. . . . ." rules. The antecedent part of the rule may be a simple statement or a compound statement using connectives like "and", "or" etc. The consequent part may contain a fuzzy set (Mamdani type and Tsukamoto type) or a linear or a quadratic function of the crisp input variables (Sugeno type). The knowledge base is the heart of fuzzy logic based system it has to be designed with utmost care and requires a lot of expertise in the knowledge of the system into which fuzzy logic controller is being incorporated.

4.4 Fuzzification

As the inputs of fuzzy logic controller are from sensors and the data from sensors are crisp in nature, the fuzzy logic controller cannot use this data directly. Hence, there exists the need for converting this data to the form comprehensible to the fuzzy system. Fuzzification is the process of converting a real scalar crisp value into a fuzzy quantity. This is done by assigning appropriate membership values to each input. The data required to change the crisp value to the fuzzy quantity is stored in the knowledge base in the form of membership functions associated with various linguistic fuzzy variables. A membership function is a function that defines how each point or object in the universe of discourse is assigned a degree of membership or membership value between 0 and 1. The membership function can be an arbitrary curve that is suitable in terms of simplicity, convenience, speed and efficiency. Though a membership function can be an arbitrary curve, there are eleven standard membership functions that are commonly used in engineering applications. These membership functions can be built from several basic functions: piecewise linear functions, sigmoid curve, Gaussian distribution function, and quadratic and cubic polynomial curves. The simplest membership functions can be formed using straight lines. They may be triangular membership function which is a collection of three points forming a triangle or trapezoidal membership function which has a flat top and is just a truncated triangle curve. These membership functions built out of straight lines have the advantage of simplicity. The examples of triangular and trapezoidal membership functions are given in figure 4 and figure 5 respectively. Two types of membership functions can be built using Gaussian distribution curve, a simple Gaussian curve shown in figure 6 and a two sided composite of two different Gaussian curves. The generalized bell membership function is specified by three parameters as shown in figure 7.

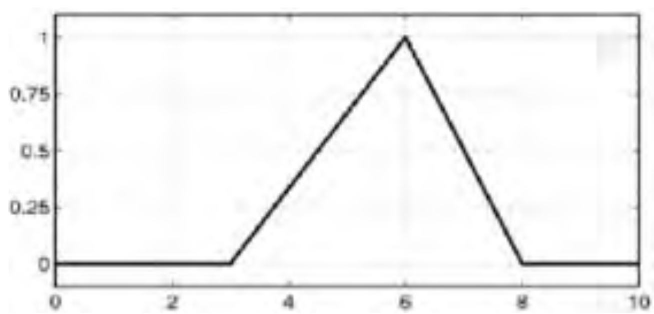


Figure 4: *Triangular membership function.*

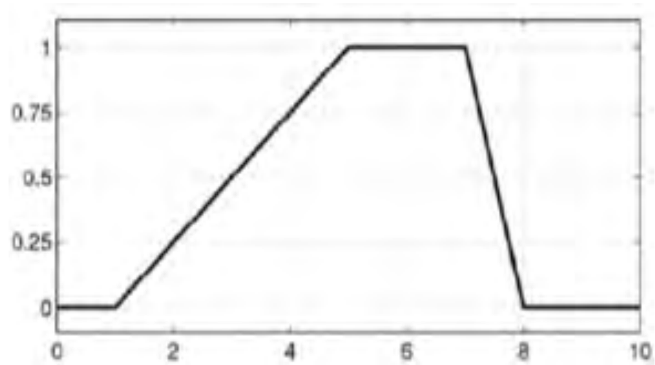


Figure 5: *Trapezoidal membership function.*

Because of their smoothness and nonzero values at all points, Gaussian and bell membership functions are popular membership functions for specifying fuzzy sets. However, they are unable to specify asymmetric membership functions, which are important in many applications. Three types of membership functions are built using sigmoid curves- left open, right open and closed. Two types of closed sigmoid membership functions can be synthesized using two sigmoid functions. They are d-sigmoid membership function using difference between two sigmoid functions, p-sigmoid membership function using the product of two sigmoid functions. The membership functions based on sigmoid curves are asymmetric.

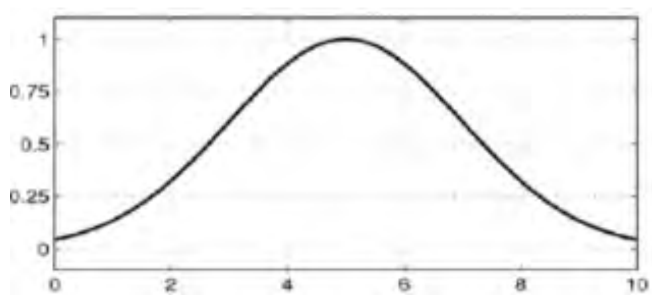


Figure 6: *Gaussian membership function.*

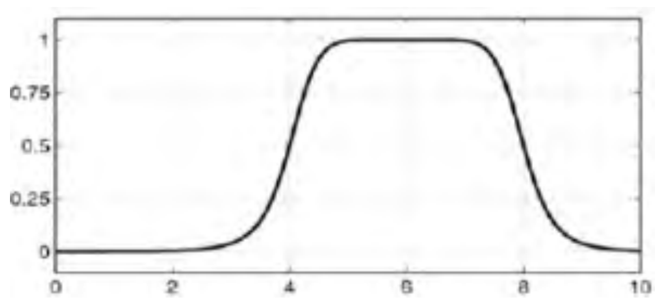


Figure 7: *Generalized bell membership function.*

Z-shaped membership functions, S-shaped membership functions and Pi-shaped membership functions are the asymmetrical membership functions which can be built using polynomial based curves. The Z-shaped membership function is the polynomial curve open to the left, S-shaped membership function is the polynomial curve open to the right, and Pishaped membership function has zero on both extremes with a rise in the middle. There is a wide choice of membership function types when a membership function is to be selected. There is no hard and strict rule on the selection of membership functions. The membership functions can be selected to suit the applications in terms of simplicity, convenience, speed and efficiency. The following principles should be adopted for designing membership functions for fuzzy logic controllers. Each membership function overlaps only with the closest neighbouring membership functions. For any input data, the sum of its membership values in all the fuzzy sets (membership functions) should be 1

4.5 Defuzzification

The outputs from the inference engine (Mamdani type) are fuzzyand they need to be converted to crisp outputs before sending themtoactuators to control the process. The conversion of a fuzzy quantity to a crisp value is called defuzzification. Some of the commonly used defuzzification methods are discussed here. Centroid method, Center of largest area method, Height method, First of maxima method, Last of maxima method, Mean of maxima method are based on aggregated fuzzy output, ie., all fuzzy outputs corresponding to different rules are aggregated using a union operator (max operator) to an aggregated fuzzy output before defuzzification. The Weighted average method and Center of sums method are based on individual output fuzzy sets. Centroid method or center of gravity method is the most commonly used defuzzification method as this method is very accurate and gives smooth output. In centroid defuzzification method. The center of largest area defuzzification can be used if the aggregate fuzzy set has at-least two convex sub-regions (convex region is the region in which the membership values are strictly monotonically increasing or strictly monotonically decreasing or strictly monotonically increasing and then strictly monotonically decreasing with increasing values of points in the universe). The performance of the defuzzification methods are measured using five criteria. The first one is continuity which means that a small change in the input should not produce a large change in the output. The second criterion is disambiguity which means that the defuzzification method should always result in a unique defuzzified value. The center of largest area method does not satisfy this criterion as there is ambiguity in selecting a defuzzified value when the aggregate membership function has two or more convex sub-regions with the largest area. The third criterion is plausibiltiy which means that the defuzzified value should lie approximately in the middle of the support region and should have high membership degree. The centroid method does not satisfy this criterion as the defuzzified value determined using centroid method may not have high membership degree in the aggregate membership function though the value lies in the middle of the support region. The fourth one is computational simplicity. The first of maxima method, last of maxima method, mean of maxima method and height method are computationally simpler than centroid method and weighted methods. The fifth criterion is weighting method. The weighted average method is computationally efficient than center of sums method.

5 PROPOSEDSYSTEM

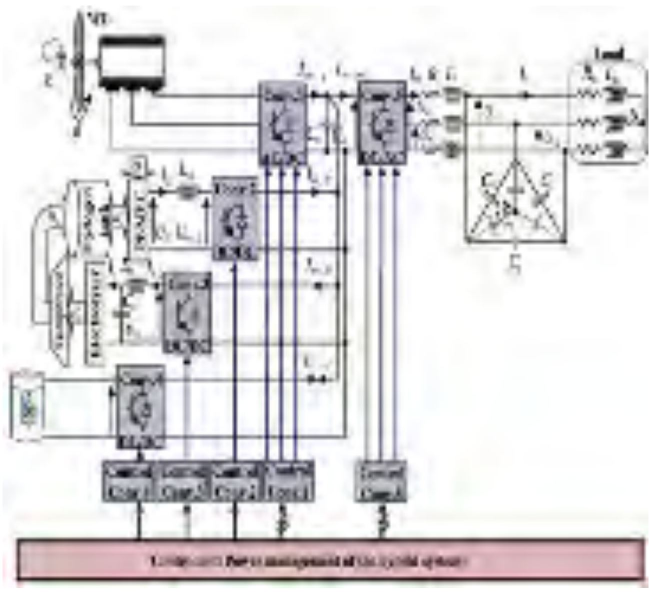


Figure 8: *Block diagram of proposed system.*

Figure 8 shows the block diagram of the proposed energy management system with various renewable energy sources and battery storage system.

5.1 Energy management

The proposed energy management system which comprises the PMSG based Wind Energy Conversion System, Fuel cell and battery storage system with boost converter. The controller used to control this proposed energy management system is an embedded controller. It controls the sources according the demand of loads.

5.2 WECS

WECS which converts the energy present in the moving air (wind) to electric energy. The wind passing through the blades of the wind turbine generates a force that turns the turbine shaft. The rotational shaft turns the rotor of an electric generator, which converts mechanical power into electric power. The major components of a typical wind energy conversion system include the wind turbine, generator, interconnection apparatus and control systems. The power developed by the wind turbine mainly depends on the wind speed, swept area of the turbine blade, density of the air, rotational speed of the turbine and the type of connected electric machine.

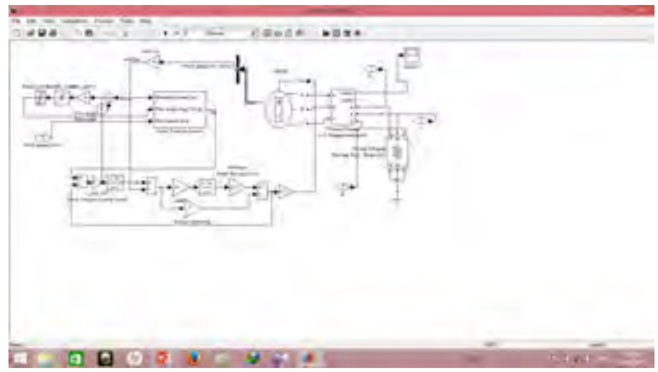


Figure 9: *Wind turbine model.*

This turbine model is shown in figure 9. The simulation diagram of PMSG wind turbine is shown in figure 10.

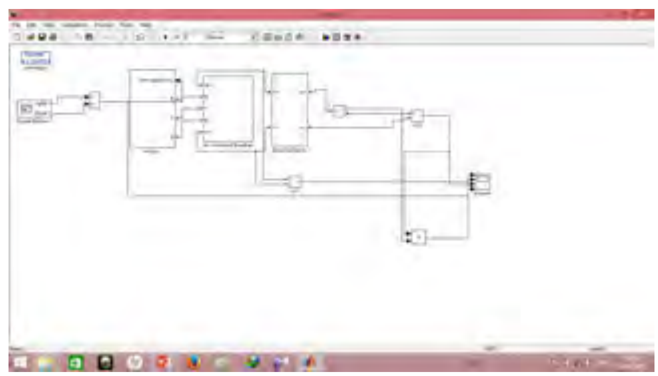


Figure 10: *PMSG based WECS.*

5.3 Electrolyzer

Electrolyzers are devices that use an electric current to provide the energy that splits a water molecule (H2O) into hydrogen (H2) and oxygen (O2). Electrolyzers have a positive and negative side, like a magnet or a battery. Hydrogen gas is generated on the negative side while oxygen gas is generated on the positive. If we attach empty tubes or cylinders to either side, we can collect these gases and use them in experiments. The model of electrolyser and electrolyzer simulation diagram is shown in figure 11 and figure 12 respectively.

5.4 Fuel cell

A fuel cell is an electrochemical cell that converts the chemical energy from a fuel into electricity through an electrochemical reaction of hydrogen-containing fuel with oxygen or another oxidizing agent.[1] Fuel cells are different from batteries in requiring a continuous source of fuel and oxygen (usually from air) to sustain the chemical reaction, whereas in a battery the chemical energy

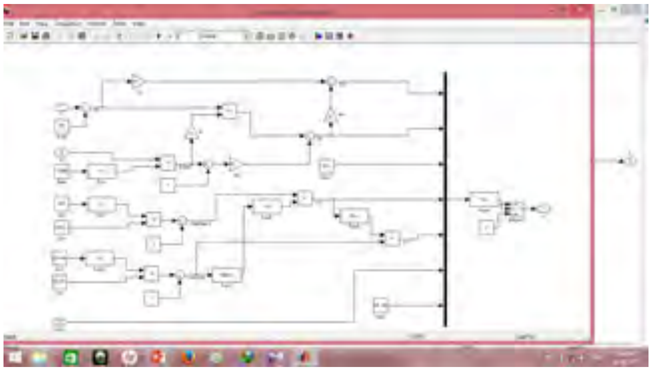


Figure 11: *Model of electrolyzer.*

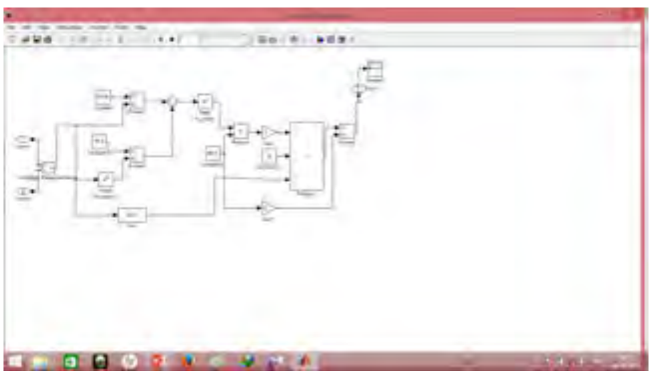


Figure 12: *Simulation of electrolyzer.*

comes from chemicals already present in the battery. Fuel cells can produce electricity continuously for as long as fuel and oxygen are supplied. Simulation diagram of this fuel cell is shown in figure 13.

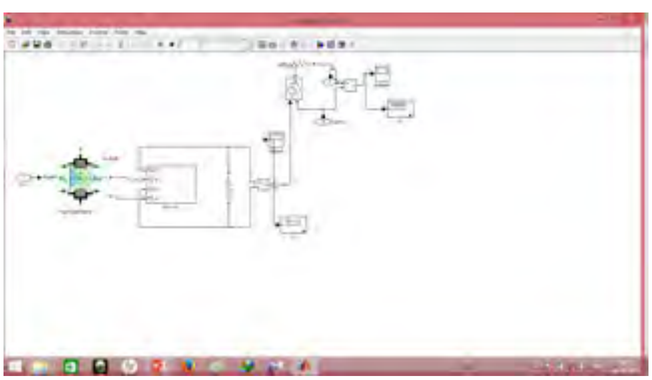


Figure 13: *Fuel cell.*

5.5 Battery

Solar panels cannot produce energy at night or during cloudy periods. But rechargeable batteries can store electricity: the photovoltaic panels charge the battery during the day, and this power can be drawn upon in the evening. Residential systems usually use deep-cycle batteries that last for about ten years and can repeatedly charge and discharge about 80 percent of their capacity. While batteries can be expensive, in remote areas it can often be more cost effective to use batteries rather than extending an electricity cable to the grid. But if choosing to go off the grid in this way, the batteries must be sized correctly, with a storage capacity sufficient to meet electricity needs. In most cases, though, purchasing electricity from the grid is cheaper than opting for batteries. The simulation of this battery charger is shown in figure 14.

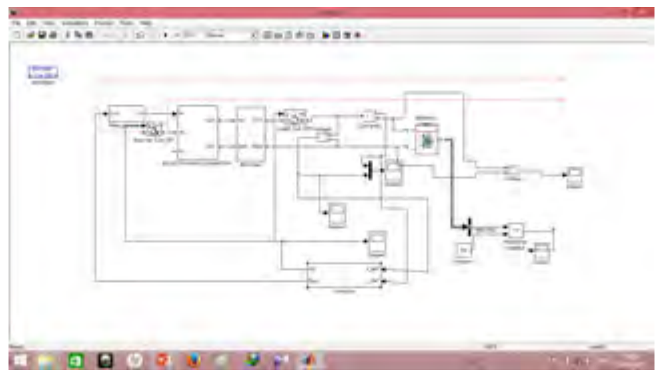


Figure 14: *Battery charger.*

The simulation of the overall proposed system is shown in figure 15.

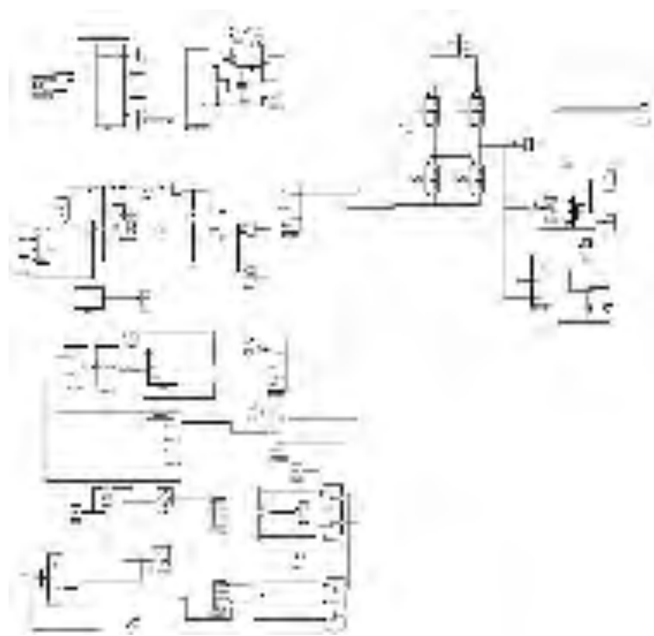


Figure 15: *Overall simulation diagram of proposed system.*

6 RESULTS

The behavior of the complete system of energy management with the integration of various source such as wind energy conversion system, fuel cell and battery storage system.

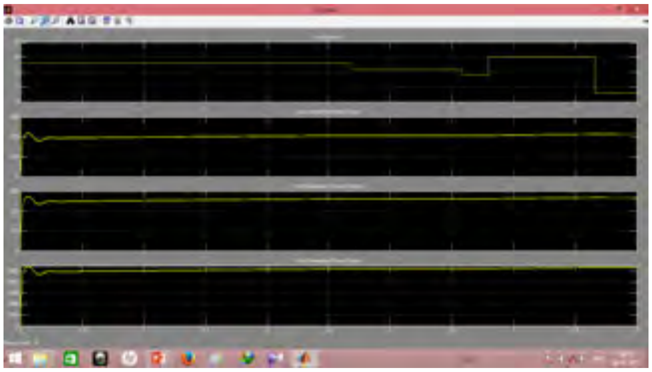


Figure 16: *Output of WECS.*

The speed of the wind turbine, the voltage generated by that speed and the power produced from the wind energy conversion system is shown in figure 16. The fuel cell is another source of this energy system. The voltage generated by the fuel cell, current and power produced by the fuel cell sis shown in figure 17.

Figure 17: *Output of fuel cell.*

The output voltage and power of the battery storage system is shown in figure 18.

7 CONCLUSION

This paper proposes optimized energy management algorithm for the hybrid power system. The hybrid power system comprises of a wind turbine, a fuel cell, an electrolyzer and battery. The performance of the control strategy is evaluated under different source and load condition. The proposed control system is implemented in the MATLAB/SIMULINK and tested under various source and load condition. Results are presented and

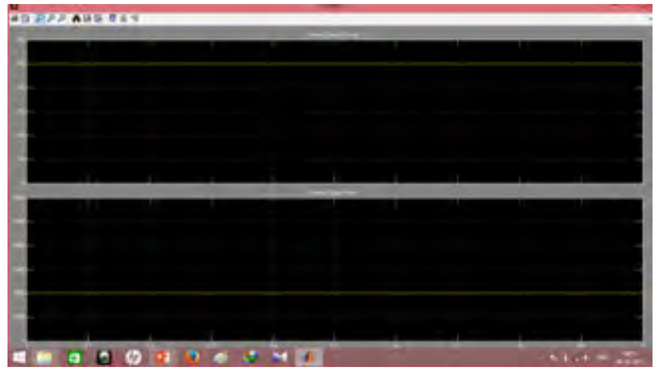


Figure 18: *Output of Battery.*

discussed. The main aim of the control strategy is to provide permanent supply to the load.

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] K. Govindaraju, V. Bhavithira, D. Kavitha, S. Kuppusamy, and K. Balachander, "Improvement of Voltage Profile and Loss Minimization in IEEE 14 Bus System using FACTS Devices" in International Journal of Control Theory and Applications, ISSN: 0974-5572 Vol. 10 No.38 (2017), pg. 213-224.

[3] E.Koutroulis, F.Blaabjerg, "Methodology for the optimal design of transformerless grid-connected PV inverters, " Power Electron., lET , vol.5, no. 8, pp.1491,1499, September 2012.

[4] H. Tao, J. L. Duarte, andM. AM. Hendrix, "Line-interactive UPS using a fuel cell as the primary source," IEEE Trans. lnd. Electron., vol. 55, no. 8, pp. 3012-3021, Aug. 2008.

[5] Erickson RW, Maksimovic D. Fundamentals of power electronics. 2nd ed. Norwell, MA: Kluwer; 200 I.

[6] A. Amudha, ,M. SivaRamkumar , M. Sivaram Krishnan "Perturb and Observe Based Photovoltaic Power Generation System For Off-Grid Using Sepic Converter" International Journal of Pure and Applied Mathematics , 114(7), pp. 619-628 , 2017 .

[7] M. SivaRamkumar, M. Sivaram Krishnan, A. Amudha, "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[8] M. SivaRamkumar, M. Sivaram Krishnan, A. Amudha, "Impedance Source Inverter and Permanent Magnet Synchronous Generator For Variable Speed Wind Turbine " International Journal of Computer & Mathematical Sciences, 6 (9) pp 98-105, 2017.

[10] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017.

[11] M.Subramanian, M. Siva Ramkumar, A. Amudha, , K.Balachander and D.Kavitha"Power Quality Improvement In Low Voltage Transmission System Using Static Compensator" in International Journal of Control Theory and Applications (IJCTA) 10 (38) pp 247-261, 2017.

[12] V.Chandra Prabha , A. Amudha, , K.Balachander, M. Siva Ramkumar " MPPTAlgorithm For Grid Integration of Variable Speed Wind Energy Conversion System" in International Journal of Control Theory and Applications, 10 (38) pp 237-246, 2017.

[13] R. Yuvaraj, K. Balachander, A. Amudha, S. Kuppuamy, M. Siva Ramkumar " Modified Interleaved Digital Power Factor Correction Based On The Sliding Mode Approach" in International Journal of Control Theory and Applications, 10 (38) pp 225-235, 2017.

[14] R. Ravichandran, K. Balachander, A. Amudha, M. Siva Ramkumar, S.Kuppusamy" Estimation Of Electrical Parameter Using Fuzzy Logic Controller Based Induction Motor" in International Journal of Control Theory and Applications, 10 (38) pp 205-212 , 2017.

[15] K. R. Jeyakrishna, A. Amudha. ,K. Balachander, M. SivaRamkumar " Electric Vehicle Battery Charging Station Using Dual Converter Control" in International Journal of Control Theory and Applications, 10 (38) pp 195-203, 2017.

[16] M. R. Latha, S. Kuppusamy, A. Amudha, K. Balachander, M. SivaRamkumar " An Efficient Single Stage Converter Based Pv-Dvr For Improving Voltage Quality" in International Journal of Control Theory and Applications, 10 (38) pp 177-193, 2017.

[17] N. Sivakumar, D. Kavitha, M. Siva Ramkumar, V.Bhavithira, S. Kalaiarasi, "A Single Stage High Gain Converter For Gird Interconnected Renewable Application Using Perturb And Observe" in International Journal of Control Theory and Applications, 10 (38) 161-175 , 2017.

[18] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc" in International Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[19] M Siva RamKumar, A. Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016. .

[20] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763-769,2016.

[21] R. Sudhakar, M. Siva Ramkumar, "Boosting With SEPIC" in 'International Journal of Engineering and Science' 3 (4) pp 14-19,2014.

ANALYSIS AND PARALLEL OPERATION OF NOVEL BIDIRECTIONAL DC-DC CONVERTER FOR DC MICROGRID

K. Kaleeswari, K. Balachander, A. Amudha, M. Siva Ramkumar, D. Kavitha

ABSTRACT: Concerns over environment and increased demand of energy have led the world to think about alternate energy sources such as wind, hydro, solar and fuel cells. Out of these, photovoltaic (PV) power generation systems have become increasingly important all over the world due its availability, cleanness, low maintenance cost and inexhaustible nature. But power produced by the photovoltaic system is stochastic in nature due to the variation of solar irradiation and cell temperature throughout the day. In order to track the varying power, a DC-DC converter have been proposed for the parallel operation of PV panel. The proposed DC/DC converter is designed by a coupled inductor with same winding turns in the primary and secondary sides. In step-up mode, the primary and secondary windings of the coupled inductor are operated in parallel charge and series discharge to achieve high step-up voltage gain. In step-down mode, the primary and secondary windings of the coupled inductor are operated in series charge and parallel discharge to achieve high step-down voltage gain. Thus, the proposed converter has higher step-up and step-down voltage gains than the conventional bidirectional dc–dc boost/buck converter. The proposed converter and the conventional bidirectional boost/buck converter, the average value of the switch current in the proposed converter is less than the conventional bidirectional boost/buck converter.

Keywords: Photovoltaic system (PV), Z-Source Inverter, Modulation strategy.

1 INTRODUCTION

For economic development of any country energy is one of the major inputs. Number of industries, vehicles, domestic users has been increased by a large number in last decade; this in turn led to increase the global energy consumption also. Industries uses major share of energy produced in the world with a share of 33%, while residential, transport, service and other sectors follows with share of 29%, 26%, 9% and 3% respectively. Majority of energy is used in form of electricity and huge amount of electric energy is required by world to fulfil daily demand. By 2030 global electric energy demand is estimated to be doubled. Electric energy demands in fast developing countries are estimated to triple by this period. Majority of electric energy in the world is produced from coal with a share of 40.4% followed by natural gas, large hydro, nuclear, oil and renewable energy with a share of 22.5%, 16.2%, 10.9%, 5% and 5% respectively. Fossil fuel deposit on earth is depleting day by day and the atmospheric pollution and global temperature is increasing due to increased use of fossil fuels. Renewable energy tracking has become one of the interesting area in recent years due increased energy demand and issues related to environment. Out of all renewable energy sources, solar energy has gained much more attention due to its availability, cleanness and inexhaustible nature. Tracking solar power is difficult due to non-linear current – voltage (I-V) characteristics of panel with a unique maximum power point (MPP). Power produced by PV panel varies with variation in atmospheric conditions such as solar irradiation and cell temperature. MPP of solar panel also varies with the variation in atmospheric conditions. So in order to extract maximum power, PV panel must be operated at a voltage corresponding to MPP (VMPP). Maximum power point trackers are used to achieve this. MPPT is an art of extracting maximum power from PV panel and it is regarded as the critical component of SPV system [1-7]. Internal resistance of PV panel also varies with the variation in atmospheric conditions, but load resistance remains the same. Converter controlled with MPPT algorithm is used to achieve load matching and extracting maximum power from PV panel. In order ensure that the PV system is operating near MPP, a DC-DC converter along with an MPPT controller is inserted in between the load and PV module. Various MPPT algorithms such as short circuit current based, open circuit current based, ripple correlation control (RCC), slide mode control technique, perturb and observe (P & O), incremental conductance (INC), fuzzy logic controller (FLC), artificial neural network (ANN) based approaches have been already proposed. DC-DC converters have drawn attraction these days, and are being used extensively with modern electronic systems. Since most of the renewable energy resources produce dc voltage, a DC-DC converter is used to transfer the power from source to load. For tracking solar and wind power, which are stochastic in nature, DC-DC converters are used as an impedance matching unit. DCDC converters act as an impedance matching unit in between the PV panel and load [8-14]. By controlling converter duty ratio, input impedance of the converter is made equal to output impedance of the PV panel and load matching is achieved. Information regarding different converter topologies is mostly available on power electronics, simulation, and other electrical journals and detailed review on application of DC-DC converter topologies on solar power tracking is not available. Since the application of non-isolated DC-DC converters on PV power tracking is increasing these days, it is the time to compile the work that has been already carried out in this area for the reference of researchers. This is the main motive behind this project. This project describes the working of DC-DC converters along with its merits and demerits on solar power tracking [15-21].

2 PHOTOVOLTAIC SYSTEM

Converting solar energy into electrical energy by PV installations is the most recognized way to use solar energy. Since solar photovoltaic cells are semiconductor devices, they have a lot in common with processing and production techniques of other semiconductor devices such as computers and memory chips. As it is well known, the requirements for purity and quality control of semiconductor devices are quite large. With today's production, which reached a large scale, the whole industry production of solar cells has been developed and, due to low production cost, it is mostly located in the Far East. Photovoltaic cells produced by the majority of today's most large producers are mainly made of crystalline silicon as semiconductor material [22-25]. Solar photovoltaic modules, which are a result of combination of photovoltaic cells to increase their power, are highly reliable, durable and low noise devices to produce electricity. The fuel for the photovoltaic cell is free. The sun is the only resource that is required for the operation of PV systems, and its energy is almost inexhaustible. A typical photovoltaic cell efficiency is about 15%, which means it can convert 1/6 of solar energy into electricity. Photovoltaic systems produce no noise, there are no moving parts and they do not emit pollutants into the environment. Taking into account the energy consumed in the production of photovoltaic cells, they produce several tens of times less carbon dioxide per unit in relation to the energy produced from fossil fuel technologies. Photovoltaic cell has a lifetime of more than thirty years and is one of the most reliable semiconductor products. Most solar cells are produced from silicon, which is non-toxic and is found in abundance in the earth's crust. Figure 1 shows the photovoltaic cell.

Figure 1: *Photovoltaic cell.*

Photovoltaic systems (cell, module,network) require minimal maintenance. At the end of the life cycle, photovoltaic modules can almost be completely recycled. Photovoltaic modules bring electricity to rural areas where there is no electric power grid, and thus increase the life value of these areas. Photovoltaic systems will continue the future development in a direction to become a key factor in the production of electricity for households and buildings in general. The systems are installed on existing roofs and/or are integrated into the facade. These systems contribute to reducing energy consumption in buildings. A series of legislative acts of the European Union in the field of renewable energy and energy efficiency have been developed, particularly promoting photovoltaic technology for achieving the objectives of energy savings and CO2 reduction in public, private and commercial buildings. Also, photovoltaic technology, as a renewable energy source, contributes to power systems through diversification of energy sources and security of electricity supply. By the introduction of incentives for the energy produced by renewable sources in all developed countries, photovoltaic systems have become very affordable, and timely return of investment in photovoltaic systems has become short and constantly decreasing. In recent years, this industry is growing at a rate of 40% per year and the photovoltaic technology creates thousands of jobs at the local level.

2.1 Functioning of the PV cells

The word photovoltaic consists of two words: photo, a greek word for light, and voltaic, which defines the measurement value by which the activity of the electric field is expressed, i.e. the difference of potentials. Photovoltaic systems use cells to convert sunlight into electricity. Converting solar energy into electricity in a photovoltaic installation is the most known way of using solar energy. The light has a dual character according to quantum physics. Light is a particle and it is a wave. The particles of light are called photons. Photons are massless particles, moving at light speed. In metals and in the matter generally, electrons can exist as valence or as free. Valence electrons are associated with the atom, while the free electrons can move freely. In order for the valence electron to become free, he must get the energy that is greater than or equal to the energy of binding. Binding energy is the energy by which an electron is bound to an atom in one of the atomic bonds. In the case of photoelectric effect, the electron acquires the required energy by the collision with a photon. Part of the photon energy is consumed for the electron getting free from the influence of the atom which it is attached to, and the remaining energy is converted into kinetic energy of a now free electron. Free electrons obtained by the photoelectric effect are also called photoelectrons. The energy required to release a valence electron from the impact of an atom is called a work out Wi, and it depends on the type of material in which the photoelectric effect has occurred.

Figure 2 Functioning of PV cell

The previous equation shows that the electron will be released if the photon energy is less than the work output. The photoelectric conversion in the PV junction. PV junction (diode) is a boundary between two differently doped semiconductor layers; one is a P-type layer (excess holes), and the second one is an N-type (excess electrons). At the boundary between the P and the N area, there is a spontaneous electric field, which affects the generated electrons and holes and determines the direction of the current. To obtain the energy by the photoelectric effect, there shall be a directed motion of photoelectrons, i.e. electricity. All charged particles, photoelectrons also, move in a directed motion under the influence of electric field. The electric field in the material itself is located in semiconductors, precisely in the impoverished area of PV junction (diode). It was pointed out for the semiconductors that, along with the free electrons in them, there are cavities as charge carriers, which are a sort of a by-product in the emergence of free electrons. Cavities occurs whenever the valence electron turns into a free electron, and this process is called the generation, while the reverse process, when the free electron fills the empty spaces - a cavity, is called recombination. If the electron-cavity pairs occur away from the impoverished areas it is possible to recombine before they are separated by the electric field. Photoelectrons and cavities in semiconductors are accumulated at opposite ends, thereby creating an electromotive force. If a consuming device is connected to such a system, the current will flow and we will get electricity. In this way, solar cells produce a voltage around 0,5-0,7 V, with a current density of about several tens of mA/cm2 depending on the solar radiation power as well as on the radiation spectrum. The usefulness of a photovoltaic solar cell is defined as the ratio of electric power provided by the PV solar cells and the solar radiation power. The usefulness of PV solar cells ranges from a few percentage to 40 %. The remaining energy that is not converted into electrical energy is mainly converted into heat energy and thus warms the cell. Generally, the increase in solar cell temperature reduces the usefulness of PV cells. Standard calculations for the energy efficiency of solar photovoltaic cells are explained below. Energy conversion efficiency of a solar photovoltaic cell (η "ETA") is the percentage of energy from the incident light that actually ends up as electricity. This is calculated at the point of maximum power, Pm, divided by the input light irradiation (E, in W/m2), all under standard test conditions (STC) and the surface of photovoltaic solar cells (AC in m2). STC - standard test conditions, according to which the reference solar radiation is 1.000 W/m2, spectral distribution is 1.5 and cell temperature 250C.

2.2 Types of solar PV cells

Electricity is produced in solar cells which, as noted, consist of more layers of semiconductive material. When the sun's rays shine down upon the solar cells, the electromotive force between these layers is being created, which causes the flow of electricity. The higher the solar radiation intensity, the greater the flow of electricity. The most common material for the production of solar cells is silicon. Silicon is obtained from sand and is one of the most common elements in the earth's crust, so there is no limit to the availability of raw materials. Solar cell manufacturing technologies are:

- Monocrystalline
- Polycrystalline
- Bar-crystalline silicon
- Thin-film technology

Cells made from crystal silicon (Si), are made of a thinly sliced piece (wafer), a crystal of silicon (monocrystalline) or a whole block of silicon crystals (multicrystalline); their efficiency ranges between 12% and 19%. Monocrystalline Si cells: conversion efficiency for this type of cells ranges from 13% to 17%, and can generally be said to be in wide commercial use. In good light conditions it is the most efficient photovoltaic cell. This type of cell can convert solar radiation of 1.000 W/m2 to 140 W of electricity with the cell surface of 1m2. The production of monocrystalline Si cells requires an absolutely pure semiconducting material. Monocrystalline rods are extracted from the molten silicon and sliced into thin chips (wafer). Such type of production enables a relatively high degree of usability. Expected lifespan of these cells is typically 25-30 years and, of course, as well as for all photovoltaic cells, the output degrades somewhat over the years. It is shown in figure 3. Multicrystalline Si cells: this type of cell can convert solar radiation of 1.000 W/m2 to 130W of electricity with the cell surface of 1m2. The production of these cells is economically more efficient compared to monocrystalline. Liquid silicon is poured into blocks, which are then cut into slabs. During the solidification of materials crystal structures of various sizes are being created, at whose borders some defects may emerge, making the solar cell to have a somewhat lower efficiency, which ranges from 10% to 14%. The lifespan is expected to be between 20 and 25 years.

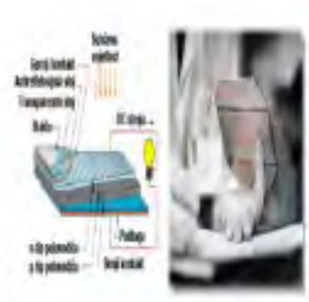


Figure 2: *Typical Monocrystalline cells .*

Ribbon silicon has the advantage in its production process in not needing a wafer cutting (which results in loss of up to 50% of the material in the process of cutting). However, the quality and the possibility of production of this technology will not make it a leader in the near future. The efficiency of these cells is around 11%. In the thin-film technology the modules are manufactured by piling extremely thin layers of photosensitive materials on a cheap substrate such as glass, stainless steel or plastic. The process of generating modules in thin-film technology has resulted in reduced production costs compared to crystalline silicon technology, which is somewhat more intense. Today's price advantage in the production of a thin-film is balanced with the crystalline silicon due to lower efficiency of the thin-film, which ranges from 5% to 13%. The share of thin-film technology on the market is 15% and constantly increasing, it is also expected an increase in years to come and thus reduce the adverse market ratio in relation to the photovoltaic module of crystalline silicon. Lifespan is around 15-20 years. There are four types of thin-film modules (depending on the active material) that are now in commercial use:

- Amorphous silicon (a-Si)
- Cadmium Tellurium (CdTe)
- Copper indium gallium selenide (CIS, CIGS)
- Thermo sensitive solar cells and other organ cells (DSC)

The development of these organic cells is yet to come, since it is still testing and it is not increasingly commercialized. Cell efficiency is around 10%. The tests are going in the direction of using the facade integrated systems, which has proven to be high-quality solutions in all light radiation and all temperature conditions. Also, a great potential of this technology is in low cost compared to silicon cells. There are other types of photovoltaic technologies that are still developing, while others are to be commercialized. Regardless of the lifespan, the warranty period of today's most common commercial photovoltaic modules is 10 years at 90% power output, and 25 years at 80% power output.

2.3 Energy depreciation of PV cells

The period of energy depreciation of photovoltaic cells is the time period that must pass using a photovoltaic system to return the energy that has been invested in the construction of all parts of the system, as well as the energy required for the breakdown after the lifetime of a PV system. Of course, the energy depreciation time is different for different locations at which the system is located, thus it is a lot shorter on locations with a large amount of irradiated solar energy, up to 10 or more times shorter than its lifetime. South Istria has approximately 1.700 kWh/m2 annual radiation, while the northern part of Istria has somewhere around 1.500 kWh/m2.

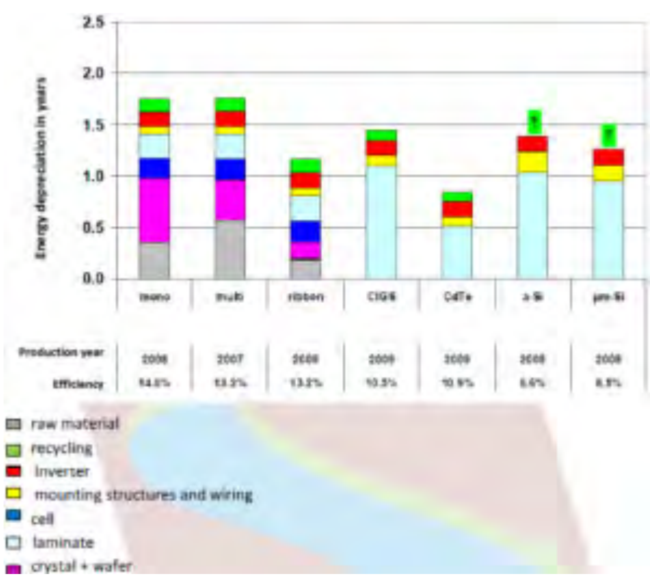


Figure 3: *Availability of energy.*

The figure 4 shows the available data on the energy depreciation for the various technologies of photovoltaic cells, with their respective efficiencies in given years of production. In relation to the south of Istria, which is shown in Figure 2.7, the energy depreciation in the city of Zagreb is, for example, about 20% longer, in southern Dalmatia is 10 to 15% shorter than in Istria, which corresponds to solar radiation intensity-insolation map.

3 DC-MICROGRID

Electricity demand has been significantly increasing over the past few years due to many factors. In countries such as the United States, Energy production will play an important role because of its power based civilization. Thermal, hydro and nuclear power plants are the major sources of electricity to date. But the limited availability of resources like coal and nuclear energy made us to concentrate on renewable sources such as wind and solar energy. Even though there has been a rapid development going on in wind and solar power technology to make use of renewable sources efficiently and to increase the stability of the system, there are many problems associated with these time- and environment- dependent sources. Because of the variations in parameters such as wind speed, intensity of sunlight, etc., the power extracted from these sources varies accordingly which in turn imposes series problems on the stability of the main grid system. The problems include voltage fluctuations, oscillations in frequency, harmonics, and imbalances in power generation and load demand etc. The best way to shield this problem is to move towards the smarter localized grid system which is called as a microgrid (MG). Microgrid can act as backup power when there is a shortage of supply from the main grid which in turn reduces the voltage fluctuations caused by high demand. Microgrid can also operate in an islanded mode during power blackouts to supply power to localized loads. Microgrids are connected to the main grid through the point of common coupling (PCC). Circuit Breakers are used to isolate MG from the main grid during faulty conditions. Power systems currently undergo considerable change in operating requirements mainly as a result of deregulation and due to an increasing amount of distributed energy resources (DER). In many cases DERs include different technologies that allow generation in small scale (microsources) and some of them take advantage of renewable energy resources (RES) such as solar, wind or hydro energy. Having microsources close to the load has the advantage of reducing transmission losses as well as preventing network congestions. Moreover, the possibility of having a power supply interruption of end-customers connected to a low voltage (LV) distribution grid (in Europe 230 V and in the USA 110 V) is diminished since adjacent microsources, controllable loads and energy storage systems can operate in the islanded mode in case of severe system disturbances. This is identified nowadays as a microgrid.

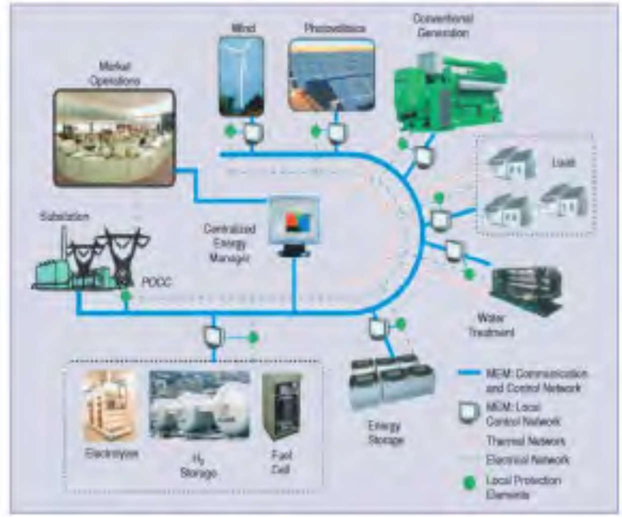


Figure 4: *Microgrid power system.*

Figure 5 depicts a typical microgrid. The distinctive microgrid has the similar size as a low voltage distribution feeder and will rare exceed a capacity of 1 MVA and a geographic span of 1 km. Generally more than 90% of low voltage domestic customers are supplied by underground cable when the rest is supplied by overhead lines. The microgrid often supplies both electricity and heat to the customers by means of combined heat and power plants (CHP), gas turbines, fuel cells, photovoltaic (PV) systems, wind turbines, etc. The energy storage systems usually include batteries and flywheels. The storing device in the microgrid is equivalent to the rotating reserve of large generators in the conventional grid which ensures the balance between energy generation and consumption especially during rapid changes in load or generation. From the customer point of view, microgrids deliver both thermal and electricity requirements and in addition improve local reliability, reduce emissions, improve power excellence by supportive voltage and reducing voltage dips and potentially lower costs of energy supply. From the utility viewpoint, application of distributed energy sources can potentially reduce the demand for distribution and transmission facilities. Clearly, distributed generation located close to loads will reduce flows in transmission and distribution circuits with two important effects: loss reduction and ability to potentially substitute for network assets. In addition, the presence of generation close to demand could increase service quality seen by end customers. Micrograds can offer network support during the time of stress by relieving congestions and aiding restoration after faults. The development of micrograds can contribute to the reduction of emissions and the mitigation of climate changes. This is due to the availability and developing technologies for distributed generation units are based on renewable sources and micro sources that are characterized by very low emissions. There are various advantages offered by microgrids to end-consumers, utilities and society, such as: improved energy efficiency, minimized overall energy consumption, reduced greenhouse gases and pollutant emissions, improved service quality and reliability, cost efficient electricity infrastructure replacement. Technical challenges linked with the operation and controls of microgrids are immense. Ensuring stable operation during network disturbances, maintaining stability and power quality in the islanding mode of operation necessitates the improvement of sophisticated control strategies for microgrid's inverters in order to provide stable frequency and voltage in the presence of arbitrarily varying loads. In light of these, the microgrid concept has stimulated many researchers and attracted the attention of governmental organizations in Europe, USA and Japan. Nevertheless, there are various technical issues associated with the integration and operation of microgrids.

3.1 Electric grid

An electrical grid is an interconnection of generating stations, transmission lines and distribution lines, which provide power supply to customers. At generating stations, electric power is produced from renewable or non-renewable sources. Then the electric power is carried from one place to other by the transmission lines. Finally, electric power is distributed among consumers with the help of distribution feeders.

3.2 Concept of microgrid

Microgrid is defined as the "localized grid that interconnects distributed energy resources with organized loads and normally operates connected to traditional centralized grid synchronously. During faulty conditions can act in islanded mode i.e. disconnected from the centralized grid". The sources in the microgrid are called as micro sources, which can be battery storage, Solid oxide fuel cell, wind, solar, diesel generator, etc. Each source is controlled in the respective manner to connect it to distribution network. Loads are connected to the distributed network whose power demand is met by micro sources and main grid. Micro grid can operate in two modes.

1. Grid connected mode: During normal operating conditions, the microgrid is connected to main grid through the point of common coupling (PCC) and a Circuit Breaker (CB). Voltage and frequency of the microgrid are synchronized with the main grid. Different control strategies are used to maintain the synchronization at PCC. Power delivered to the distributed load is shared by main grid and the microgrid. The microgrid sources can deliver excess power to balance the load when there is power shortage from the main grid. Similarly, if there is any fault occurred at one of the micro sources, main grid delivers the excess power along with remaining active micro sources to balance the power shortage caused by faulty source.

2. Islanded mode: During faulty conditions on the main grid, MG is disconnected from the main grid at PCC by operating the circuit breaker which separates MG with main grid. After disconnection from main grid, MG operates on its own to supply power to the load by stepping up the power delivered from all the micro sources according to the control strategies that are pre-defined. In this way, the load is powered up even during the power blackouts. In islanded mode, some of the non-emergency loads can be disconnected if the load demand exceeds the micro sources capacity. The grid voltage and frequency are maintained by operating at least one converter in V/f control. After fault clearance, to reconnection of MG with the main grid is possible only when error in voltage is below 3%, error in frequency is below 0.1Hz and error in phase angle is below 100.

3.3 Technical challenges in microgrid

Protection system is one of the major challenges for microgrid which must react to both main grid and microgrid faults. The protection system should cut off the microgrid from the main grid as rapidly as necessary to protect the microgrid loads for the first case and for the second case the protection system should isolate the smallest part of the microgrid when clears the fault. A segmentation of microgrid, i.e. a design of multiple islands or submicrogrids must be supported by microsource and load controllers. In these conditions problems related to selectivity (false, unnecessary tripping) and sensitivity (undetected faults or delayed tripping) of protection system may arise. Mainly, there are two main issues concerning the protection of microgrids, first is related to a number of installed DER units in the microgrid and second is related to an availability of a sufficient level of short-circuit current in the islanded operating mode of microgrid since this level may substantially drop down after a disconnection from a stiff main grid. In the authors have made short-circuit current calculations for radial feeders with DER and studied that short-circuit currents which are used in over-current (OC) protection relays depend on a connection point of and a feed-in power from DER. The directions and amplitudes of short circuit currents will vary because of these conditions. In reality the operating conditions of microgrid are persistently varying because of the intermittent microsources (wind and solar) and periodic load variation. Also the network topology can be changed frequently which aims to minimize loss or to achieve other economic or operational targets. In addition controllable islands of different size and content can be formed as a result of faults in the main grid or inside microgrid. In such situations a loss of relay coordination may happen and generic OC protection with a single setting group may become insufficient, i.e. it will not guarantee a selective operation for all possible faults. Hence, it is vital to ensure that settings chosen for OC protection relays take into account a grid topology and changes in location, type and amount of generation. Otherwise, unwanted operation or failure may occur during necessary condition. To deal with bi-directional power flows and low short-circuit current levels in microgrids dominated by microsources with power electronic interfaces a new protection philosophy is essential, where setting parameters of relays must be checked/updated periodically to make sure that they are still appropriate.

4 PROPOSED SYSTEM

DC-DC converters are electronic devices used whenever we want to change DC electrical power efficiently from one voltage level to another. They are needed because unlike AC, DC cannot simply be stepped up or down using a transformer. In many ways, a DC-DC converter is the DC equivalent of a transformer. Typical applications of DC-DC converters are where 24V DC from a truck battery must be stepped down to 12V DC to operate a car radio, CB transceiver or mobile phone; where 12V DC from a car battery must be stepped down to 3V DC, to run a personal CD player; where 5V DC on a personal computer motherboard must be stepped down to 3V, 2V or less for one of the latest CPU chips; where the 340V DC obtained by rectifying 240V AC power must be stepped down to 5V, 12V and other DC voltages as part of a PC power supply; where 1.5V from a single cell must be stepped up to 5V or more, to operate electronic circuitry; where 6V or 9V DC must be stepped up to 500V DC or more, to provide an insulation testing voltage; where 12V DC must be stepped up to +/-40V or so, to run a car hifi amplifier circuitry; or where 12V DC must be stepped up to 650V DC or so, as part of a DC-AC sinewave inverter. In all of these applications, we want to change the DC energy from one voltage level to another, while wasting as little as possible in the process. In other words, we want to perform the conversion with the highest possible efficiency. An important point to remember about all DC-DC converters is that like a transformer, they essentially just change the input energy into a different impedance level. So whatever the output voltage level, the output power all comes from the input; there is no energy manufactured inside the converter. Quite the contrary, in fact. Some is inevitably used up by the converter circuitry and components, in doing their job. We can therefore represent the basic power flow in a converter with this equation:

$$Pin = Pout + Plosses \tag{1}$$

where Pin is the power fed into the converter, Pout is the output power and Plosses is the power wasted inside the converter. Of course if we had a perfect converter, it would behave in the same way as a perfect transformer. There would be no losses, and Pout would be exactly the same as Pin. We could then say that:

$$VinxIin = VoutxIout \tag{2}$$

or by re-arranging, we get:

$$\frac{Vout}{Vin} = \frac{Iin}{Iout} \tag{3}$$

In other words, if we step up the voltage we step down the current, and vice-versa. Of course there is no such thing as a perfect DC-DC converter, just as there are no perfect transformers. So we need the concept of efficiency, where:

$$Efficiency(\%) = \frac{Pout}{Pin} \tag{4}$$

Nowadays some types of converter achieve an efficiency of over 90%, using the latest components and circuit techniques. Most others achieve at least 80-85%, which as you can see compares very well with the efficiency of most standard AC transformers. There are many different types of DC-DC converter, each of which tends to be more suitable for some types of application than for others. For convenience they can be classified into various groups, however. For example some converters are only suitable for stepping down the voltage, while others are only suitable for stepping it up; a third group can be used for either. Another important distinction is between converters which offer full dielectric isolation between their input and output circuits, and those which don't. Needless to say this can be very important for some applications, although it may not be important in many others.

5 PROPOSED SYSTM

Figure 6 shows the parallel operation of bidirectional DC-DC converter for DC micro grids.Simulation in general terms can be defined as the representation of a system in its realistic form. When a computer program

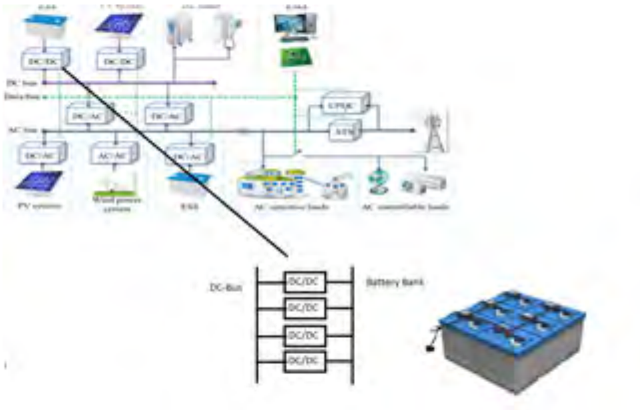


Figure 5: *Block diagram of proposed system.*

is used to create a model to mimic a real world system, then the term 'computer simulation' comes into action such models are called computer simulated models. MATLAB is a software package for high performance numerical computation and visualization. It provides an interactive environment with hundreds of built in function for technical computation, graphics, and animation. Best of all, it also provides easy extensibility with its own high-level programming language. Typical uses include math and computation, algorithm development, data acquisition, modeling, simulation, and prototyping, data analysis, exploration and visualization, scientific and engineering graphics, application development, including graphics user interface building. A simulation model is developed in MATLAB using Simulink and Sim Power System set toolboxes. The simulation is carried out on MATLAB version 8 with ode3 solver. The electrical system is simulated using Sim Power System.

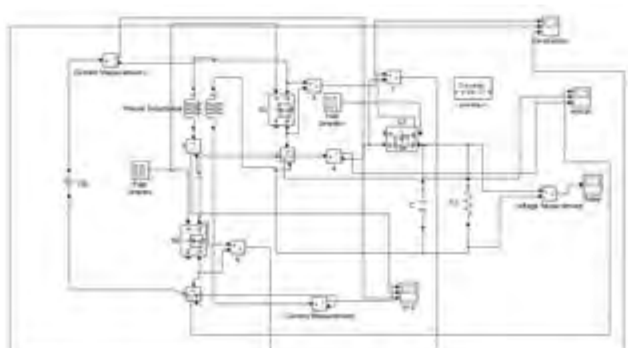


Figure 6: *Step up mode of bidirectional DC-DC converter.*

The proposed system is working in two modes. One mode is step down mode where the voltage of the system is stepped up from one level to higher level. In this mode the primary and secondary windings of the coupled inductor are operated in parallel charge and series discharge to achieve high step-up voltage gain. The simulation diagram of step up mode is shown in figure 7. Another mode of operation is step down operation where the high level voltage is stepped down to low level. In this level the primary and secondary windings of the coupled inductor are operated in series charge and parallel discharge to achieve high step-down voltage gain. The simulation diagram of step down mode is shown in figure 8.

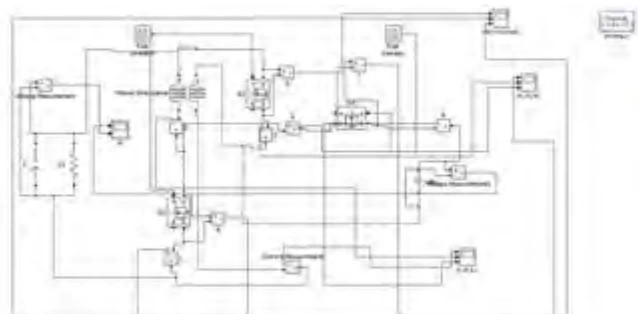


Figure 7: *Step down mode of bidirectional DC-DC converter.*

The parallel operation of bidirectional DC-DC converter is shown in figure 9.

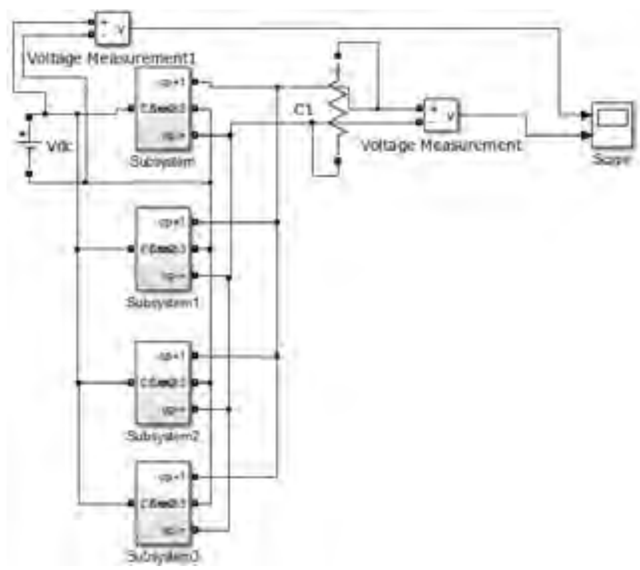


Figure 8: *Parallel operation of bidirectional DC-DC converter.*

6 RESULTS

The behavior of the complete proposed parallel operation of bidirectional DC-DC converter for integrating various DC sources with DC micro grid. There are two modes of operation in proposed bidirectional DC-DC converter. One is step u mode. In this mode the 14V output voltage of DC source is stepped up to 42V of DC as shown in figure 10. In this mode the converter act as a boost converter.

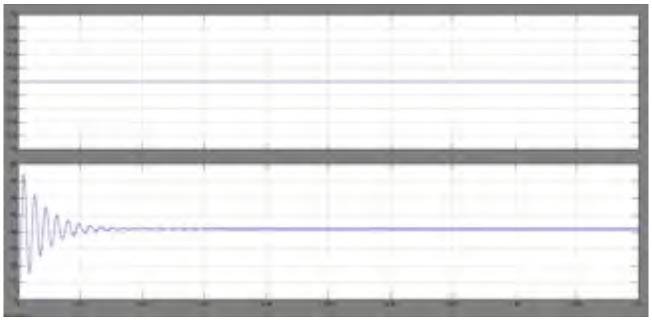


Figure 9: *Step up mode (14V to 42V).*

Another mode is step down mode. Here the 42V of DC voltage is stepped down to 14V of DC as shown in figure 11. In this mode the DC converter is act as a buck converter.

Figure 10: *Step down mode (42V to 14V).*

In the operation of proposed bidirectional DC-DC converter the voltage across the switches and the current through each switch is shown in figure 12 and figure 13 respectively.

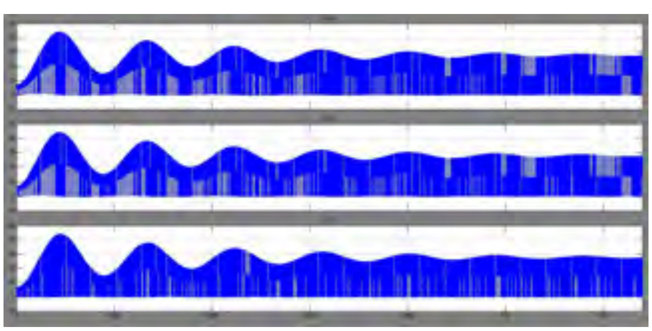


Figure 11: *Voltage across switches.*

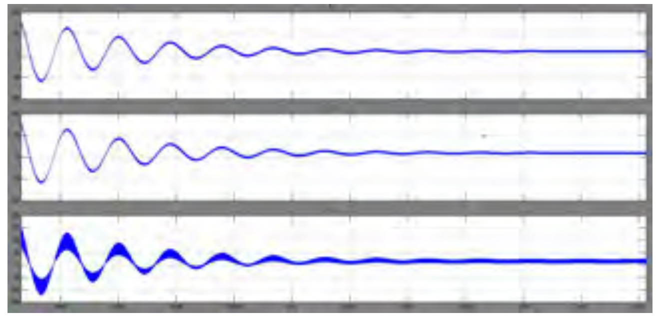


Figure 12: *Block diagram.*Current through the

7 CONCLUSION

This paper provides a comprehensive study on parallel operation of bidirectional DC-DC converter for integrating DC sources with the DC micro grids. DC-DC converters are found attractive due to the ability it to step up the low voltage produced by DC sources and step down the high voltage where it is required to achieve load matching between DC source and load. To determine the characteristic of converter different parameters are analyzed. Working principle, merits and demerits of parallel operation if bidirectional DC-DC converter is described in detail.

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] K. Govindaraju, V. Bhavithira, D. Kavitha, S. Kuppusamy, and K. Balachander, "Improvement of Voltage Profile and Loss Minimization in IEEE 14 Bus System using FACTS Devices" in International Journal of Control Theory and Applications, ISSN: 0974-5572 Vol. 10 No.38 (2017), pg. 213-224.

[3] E.Koutroulis, F.Blaabjerg, "Methodology for the optimal design of transformerless grid-connected PV inverters, " Power Electron., lET , vol.5, no. 8, pp.1491,1499, September 2012.

[4] H. Tao, J. L. Duarte, andM. AM. Hendrix, "Line-interactive UPS using a fuel cell as the primary source," IEEE Trans. lnd. Electron., vol. 55, no. 8, pp. 3012-3021, Aug. 2008.

[5] Erickson RW, Maksimovic D. Fundamentals of power electronics. 2nd ed. Norwell, MA: Kluwer; 200 I.

[6] A. Amudha, ,M. SivaRamkumar , M. Sivaram Krishnan "Perturb and Observe Based Photovoltaic Power

Generation System For Off-Grid Using Sepic Converter" International Journal of Pure and Applied Mathematics , 114(7), pp. 619-628 , 2017 .

[7] M. SivaRamkumar, M. Sivaram Krishnan, A. Amudha, "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[8] R. Ravichandran, K. Balachander, A. Amudha, M. Siva Ramkumar, S.Kuppusamy" Estimation Of Electrical Parameter Using Fuzzy Logic Controller Based Induction Motor" in International Journal of Control Theory and Applications, 10 (38) pp 205-212 , 2017.

[9] K. R. Jeyakrishna, A. Amudha. ,K. Balachander, M. SivaRamkumar " Electric Vehicle Battery Charging Station Using Dual Converter Control" in International Journal of Control Theory and Applications, 10 (38) pp 195-203, 2017.

[10] M. R. Latha, S. Kuppusamy, A. Amudha, K. Balachander, M. SivaRamkumar " An Efficient Single Stage Converter Based Pv-Dvr For Improving Voltage Quality" in International Journal of Control Theory and Applications, 10 (38) pp 177-193, 2017.

[11] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc" in International Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[12] M Siva RamKumar, A. Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016. .

[13] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763-769,2016.

[14] R. Sudhakar, M. Siva Ramkumar, "Boosting With SEPIC" in 'International Journal of Engineering and Science' 3 (4) pp 14-19,2014.

[15] M. Sownthara, M. Siva Ramkumar, "Wireless Communication Module To Replace Resolver Cable In Welding Robot" in International Journal of Advanced Information Science and Technology on 23(23) pp 230-235,2014.

[16] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2)

[17] M. Sivaram Krishnan, M. Siva Ramkumar, "Power Management of a Hybrid Solar-Wind Energy System, International Journal of Engineering Research & Technology, 2 (1) pp 1988-1992.

[18] M. Sivaram Krishnan, M. Siva Ramkumar, "Power Quality Analysis In Hybrid Energy Generation System" in 'International Journal of Advance Research in Computer Science and Management Studies 2 (1) pp 188-193

[19] S. Sriragavi, M. Sivaram Krishnan, M. Siva Ramkumar "Static Compensator In Power Quality Improvement For Lvts" in International Journal of Scientific Research and Review, 6(11) ,pp 51-60

[20] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[21] Ramkumar. S, Emayavaramban. G, Elakkiya. A, 'A Web Usage Mining Framework for Mining Evolving User Profiles in Dynamic Web Sites', International Journal of Advanced Research in Computer Science and Software Engineering, Vol.4 (8), pp.889-894, August 2014.

[22]

[23] Ramkumar. S, Elakkiya. A, Emayavaramban. G, 'Kind Data Transfer Model - Tracking and Identification of Data Files Using Clustering Algorithms', International Journal of Latest Technology in Engineering, Vol.3 (8), pp.13-21, August 2014.

[24] D. Kavitha, C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.20 (2015), pg. 17749-17754.

[25] D. Kavitha, A. Amudha, S. Divyapriya, "Design of Controller for Regenerative Braking using BLDC Motor Applicable for Electric Vehicle" in International Journal of Electronics, Electrical and Computational System- IJEECS, ISSN 2348-117X, Volume 6, Issue 9, September 2017, pg.245-252.

[26] K. Balachander, S. Kuppusamy, V. Ponnusamy, '" Comparative Study of Hybrid Photovoltaic-Fuel Cell System / Hybrid Wind-Fuel Cell System

for Smart Grid Distributed Generation System" Proceedings of IEEE International Conference on Emerging Trends in Science, Engineering and Technology at JJ College of Engineering, Trichy on 13 th and 14 th December 2012. DOI: 10.1109/ INCOSET. 2012.6513950, pp.462-466

AN EFFICIENT HIGH STEP UP CONVERTER FOR AUTOMOBILE APPLICATIONS USING FUZZY LOGIC CONTROL TECHNIQUE

T. Kalimuthu, K. Balachander, A. Amudha, G. Emayavaramban, M. Siva Ramkumar

ABSTRACT: The resonance analysis and soft switching design of the isolated boost converter with coupled inductors are designed in this project. Due to the resonance participated by the voltage doubler capacitor, clamping capacitor, and leakage inductance of coupled inductors, the reverse recovery problem of the secondary diodes is restrained within the whole operation range. By choosing appropriate magnetic inductance of the coupled inductors, zero voltage switching ON of the main MOSFET is obtained collectively at the same working conditions without any additional devices. Moreover the rang of duty ratio is enlarged to achieve soft switching and an optimal operation point is obtained with minimal input current ripple, when duty ratio approaches 0.5,additionally,two kinds of resonances are analyzed and an optimized resonance is utilized to achieve better power density. The high step up conversion is achieved by using soft switching methodology with fuzzy logic system.

Keywords: .

1 INTRODUCTION

The comprehensive resonance analysis and soft switching design of the isolated boost converter with coupled inductors are investigated in this paper. Due to the resonance participated by the voltage doubler capacitor, clamping capacitor, and leakage inductance of coupled inductors, the reverse-recovery problem of the secondary diodes is restrained within the whole operation range. By choosing appropriate magnetic inductance of the coupled inductors, zero-voltage switching ON of the main MOSFETs is obtained collectively at the same working conditions without any additional devices [1-3]. Moreover, the range of duty ratio is enlarged to achieve soft switching and an optimal operation point is obtained with minimal input current ripple, when duty ratio approaches 0.5. Additionally, two kinds of resonances are analyzed and an optimized resonance is utilized to achieve better power density. The simulation is implemented for the vehicle inverter requiring a 150 W output power, input voltage range varying from 16 V, and 132 V output voltage. Simulation results verify the design and show that the minimum efficiency is about 90Another approach, known as synchronous electrical charge extraction, guarantees the independence of harvested power from the output bias and is thu s more suitable for operation with irregular vibrations. In this method, when a voltage peak is detected, the electrical charge is first removed from the transducer through a resonant inductor and then transferred to the output. It is also worth to mention that, although bias-independent, the power harvested is lower than the maximum power achievable and with the newer single supply pre-biasing technique, in which resonant circuits are used for both transferring electrical charge from the transducer to the output in order to harvest energy, and from the output to the transducer in order to provide a favorable voltage bias at the beginning of each elongation.

2 LITERATURE SURVEY

2.1 CIRCUIT CONFIGURATION OF BI DIRECTIONAL DC/DC CONVERTER SPECIFIC FOR SMALL SCALE LOAD LEVELING SYSTEMS

K. Hirachi, M. Yamanaka, et al.,Small scale energy storage system incorporating a battery bank has attracted special interest as a promising load leveling system. Because battery bank voltage of this system is low, it is important to use a bidirectional chopper suitable for large step-up/step-down ratio. In this paper we propose a circuit topology of bidirectional chopper appropriate for small scale load leveling system and present the analytical and experimental results.

2.2 HIGH-EFFICIENCY,HIGH STEP-UP DC–DC CONVERTERS

Q. Zhao and F. C. Lee, DC-DC converters with coupled inductors can provide high voltage gain, but their efficiency is degraded by the losses associated with leakage inductors. Converters with active clamps recycle the leakage energy at the price of increasing topology complexity. A family of high-efficiency, high step-up DC-DC converters with simple topologies is proposed in this paper. The proposed converters, which use diodes and coupled windings instead of active switches to realize functions similar to those of active clamps, perform better than their active-clamp counterparts. High efficiency is achieved because the leakage energy is recycled and the output rectifier reverse-recovery problem is alleviated.

2.3 HIGH-EFFICIENCY DC/DC CONVERTER WITH HIGH VOLTAGE GAIN

R. J. Wai and R. Y. Duan, A high-efficiency converter with high voltage gain applied to a step-up power conversion is presented. In the proposed strategy, a high magnetising current charges the primary winding of the coupled inductor, and the clamped capacitor is discharged to the auxiliary capacitor when the switch is turned on. In contrast, the magnetising current flows continuously to boost the voltage in the secondary winding of the coupled inductor, and the voltages across the secondary winding of the coupled inductor, the clamped capacitor and the auxiliary capacitor are connected in series to charge the output circuit. Thus, the related voltage gain is higher than in conventional converter circuits.

2.4 SWITCHED COUPLED-INDUCTOR CELL FOR DC-DC CONVERTERS WITH VERY LARGE CONVERSION RATIO

B. Axelrod, Y. Berkovich, and A. Ioinovici, A novel switching structure formed by an externally controlled switch, a coupled inductor, and two synchronous switches (diodes) is proposed. The practical implications of the leakage inductance are considered. This structure is inserted into PWM DC-DC buck, boost, and buck-boost converters by replacing their switch and inductor. The results are new converters with very high step-up or step-down voltage gain. The new switching-mode power supplies are analyzed in steady-state. The energy accumulated in the leakage inductance is transferred to the output capacitor in a non-oscillatory manner. The influence of the magnetically-coupling coefficient on the dc gain is studied. Simulation and experimental results confirm the theoretical analysis and the advantages of the proposed converters

2.5 SOFT-SWITCHED INTERLEAVED BOOST CONVERTERS FOR HIGH STEP-UP AND HIGH POWER APPLICATIONS

S. Park, Y. Park, S. Choi,W. Choi, and K. Lee,This paper proposes a generalized scheme of new soft-switching interleaved boost converters that is suitable for high step-up and high-power applications. The proposed converter is configured with proper numbers of series and parallel connected basic cells in order to fulfill the required output voltage and power levels, respectively. This leads to flexibility in device selection resulting in high component availability and easy thermal distribution. Design examples of determining the optimum circuit configuration for given output voltage and power level are presented. Experimental results from a 1.5-kW prototype are provided to validate the proposed concept.

3 PROPOSED MODULE

3.1 PROPOSED SYSTEM

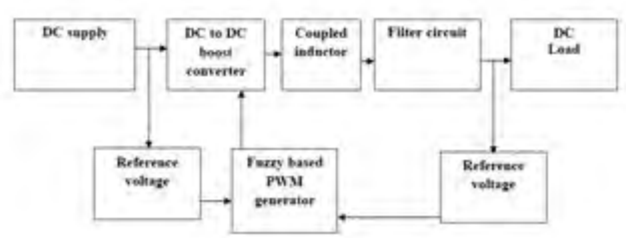


Figure 1: *Block Diagram of Proposed System.*

3.2 BLOCK DIAGRAM DESCRIPTION

Resonance analysis and soft-switching design of the isolated boost converter with coupled inductors are presented. Compared with the former proposed converter, both ZVS on of the main MOSFETs and zero-current switching (ZCS) off of the secondary diodes are obtained collectively at the same working conditions without any additional devices. Moreover, the range of duty ratio is enlarged due to the design and an optimal operation point is obtained when duty ratio approaches 0.5 and the ripple of input current moves in close to zero. The volume of the converter can also be decreased because of smaller transformers and smaller capacitors [4-7]. A dc/dc converter for vehicle inverter is implemented to verify the design. Push–pull topology is widely used in dc/dc stage. Voltage-fed push–pull converter proposed in features high input current ripple because the current in the primary side is discontinuous. A low-pass LC input filter is applied to minimize the ripple. Then it increases the volume of the system for high input current. Moreover, the converter's voltage conversion ratio is only determined by turn ratio of transformer. To achieve a high step up feature, a large turn ratio brings large transformer volume and leakage inductance which degrades power density and circuit performance [8-10]. Current-fed push–pull is suitable for low input voltage, high input current application due to the input inductor. Furthermore, significant topologies are used in battery sourcing application, and active clamping with resonance technology has gained attraction which can realize zero-voltage switching (ZVS) on of MOSFETs or resolve reverse-recovery problem of secondary rectifying diodes [11-13]. With soft-switching characters, the operation frequency can be high enough to obtain not only high power density but also high efficiency. An active-clamping current-fed push–pull converter in has satisfied performance for vehicle inverter application. Optimized resonance will be designed to minimize capacitors volume, and improve power density [14-15].

3.3 BOOST CONVERTER

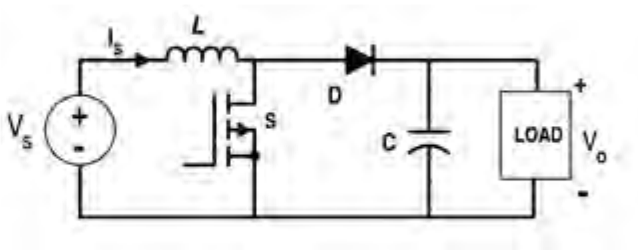


Figure 2: *The Basic Schematic of a Boost Converter.*

A boost converter is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply containing at least two semiconductor switches and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors are normally added to the output of the converter to reduce output voltage ripple [16-18].

The switch is typically a MOSFET, IGBT, or BJT.Power for the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion.. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power must be conserved, the output current is lower than the source current.

3.4 BUCK CONVERTER

The buck is a popular non-isolated power stage topology, sometimes called a step-down power stage. Power supply designers choose the buck power stage because the required output is always less than the input voltage. The input current for a buck power stage is discontinuous, or pulsating, because the power switch current that pulses from zero to IO every switching cycle. The output current for a buck power stage is continuous or non-pulsating because the output current is supplied by the output inductor/capacitor combination. The capacitor equivalent series resistance, RC, and the inductor dc resistance, RL, are included in the analysis. Resistor R represents the load seen by the power supply output. The diode D1 is usually called the catch diode, or freewheeling diode.

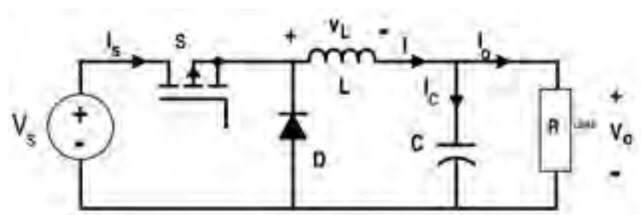


Figure 3: *Buck Power Stage Schematic.*

A power stage can operate in continuous or discontinuous inductor current mode. In continuous inductor current mode, current flows continuously in the inductor during the entire switching cycle in steady-state operation. In discontinuous inductor current mode, inductor current is zero for a portion of the switching cycle. It starts at zero, reaches peak value, and return to zero during each switching cycle [19-20].

3.5 RESONANT CONVERTERS

Resonant converters use a resonant circuit for switching the transistors when they are at the zero current or zero voltage point, this reduces the stress on the switching transistors and the radio interference. We distinguish between ZVS- and ZCS-resonant converters (ZVS: Zero Voltage Switching, ZCS: Zero Current Switching).To control the output voltage, resonant converters are driven with a constant pulse duration at a variable frequency. The pulse duration is required to be equal to half of the resonant period time for switching at the zero-crossing points of current or voltage [21-22].

There are many different types of resonant converters. For example the resonant circuit can be placed at the primary or secondary side of the transformer. Another alternative is that a serial or parallel resonant circuit can be used, depending on whether it is required to turn off the transistor, when the current is zero or the voltage is zero.The technique of resonant converters is described below giving the ZCS-push-pull resonant converter as an example.

3.5.1 ZCS-PUSH-PULL RESONANT CONVERTER

The resonant circuit is formed by L and C. Assume an initial condition of the voltage VC across C equal to zero. If now the transistor T1 is turned on, a sinusoidal current half-swing starts through T1 , L, Tr, C and Cin . This half-swing charges the capacitor C from zero to Vin . If this first half sinusoidal swing is finished, T1 can be switched off without losses and after short delay T2 can be switched and a next half sinusoidal swing starts, this discharges C from Vin back to zero Volts

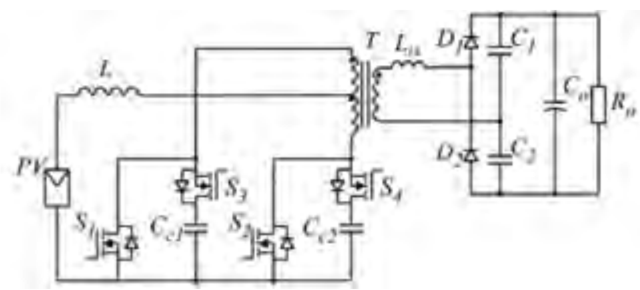


Figure 4: *The ZCS-Push-Pull Resonant Converter.*

Every half sinusoidal swing transfers a certain amount of energy from the primary to the secondary side of the transformer. The transformer Tr operates on its primary side as a voltage source. For the duration of the current swing through the primary winding, the output voltage Vout will be transformed to the primary side

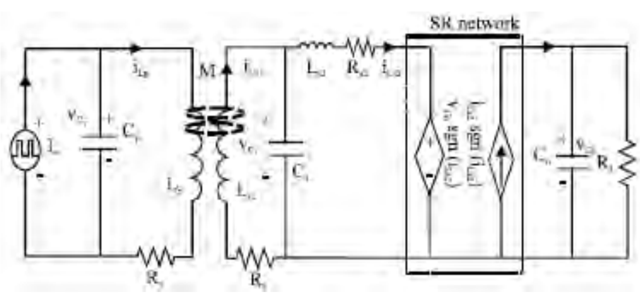


Figure 5: *Equivalent Circuit for One Half Sinusoidal Swing of the ZCS-Push- Pull Converter.*

This leads to the minimum on-time of the transistors. The on-time should be a little higher than half of the resonant period time to ensure that the current reduces to zero. For maximum energy transfer, Vout must be half of Vin . This leads to the turns ratio of the transformer.The maximum output power is achieved if one half current swing instantly follows the next.The transfered energy of each half-swing further depends on the value of C and L. The higher the value of C and the lower the value of L, to maintain a certain resonant frequency, the higher the amount of energy transfer. (see also the peak value of the current in circuit.I addition to the general advantages of resonant converters, having lower switching losses and lower radio interference, this particular resonant converter has two more additional advantages:

The ZCS-push-pull resonant converter can regulate several output voltages using one control circuit, as per the flyback converter. This because several output voltages seem to be parallel connected from the view of the primary side. Due to this the energy always passes to that output, having the lowest voltage value taking into consideration the turns ratio.

The ZCS-push-pull resonant converter is no-load and short-circuit proof without any electronic precaution. The output voltage cannot reach more than twice of the nominal value, because then is Vout =Vin . The current cannot reach more than twice of the nominal output current, because then is Vout = 0 and I =Vin C/L .

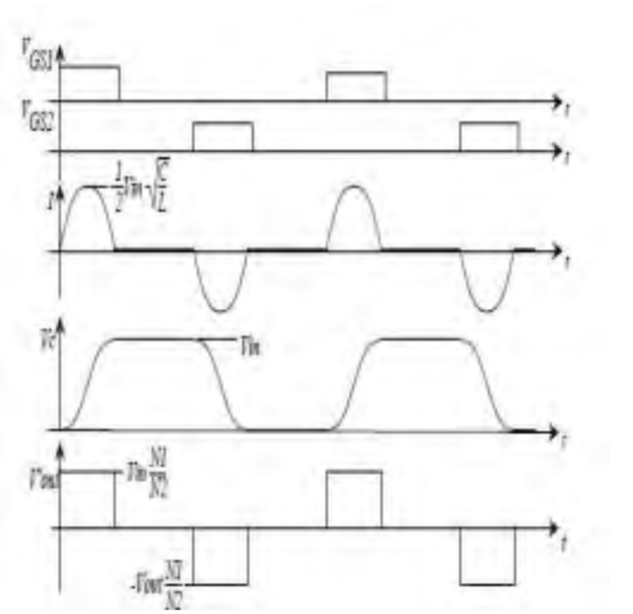


Figure 6: *Voltages and Currents at the ZCS-Push-Pull Resonant Converter.*

Resonant converter, which were been investigated intensively can achieve very low switching loss thus enable resonant topologies to operate at high switching frequency. In resonant topologies, Series Resonant Converter (SRC), Parallel Resonant Converter (PRC) and Series Parallel Resonant Converter (SPRC, also called LCC resonant converter) are the three most popular topologies. The analysis and design of these topologies have been studied thoroughly. In next part, these three topologies will be investigated for front-end application.

3.5.2 SERIES RESONANT CONVERTER

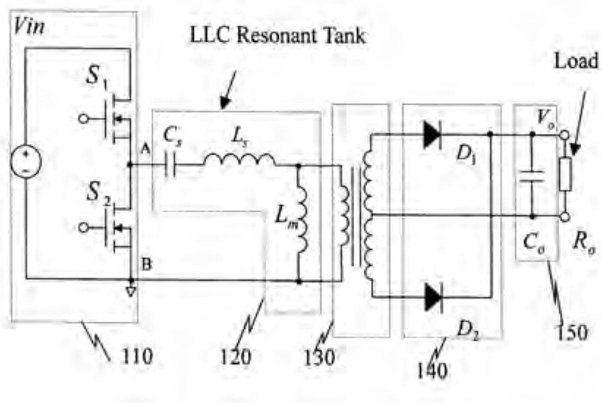


Figure 7: *Half Bridge Series Resonant Converter .*

It is Based on resonant current oscillation. Switching device are placed in series with Load. Thyristor are work in switching device. This type of inverter produces an approximately sinusoidal wave form at a high Frequency ranging from 200Hz to 100KHz.

3.5.3 PARALLEL RESONANT CONVERTER

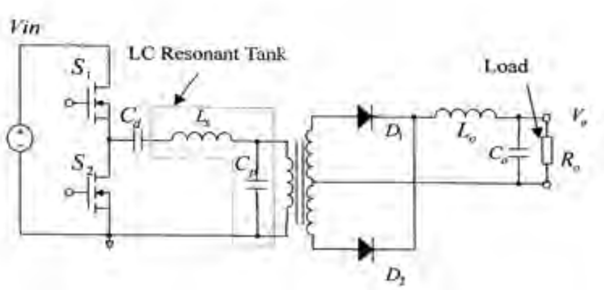


Figure 8: *Half Bridge Parallel Resonant Converter.*

The schematic of parallel resonant converter is shown in Figure. Its DC characteristic is shown in Figure . For parallel resonant converter, the resonant tank is still in series. It is called parallel resonant converter because in this case the load is in parallel with the resonant capacitor. More accurately, this converter should be called series resonant converter with parallel load.

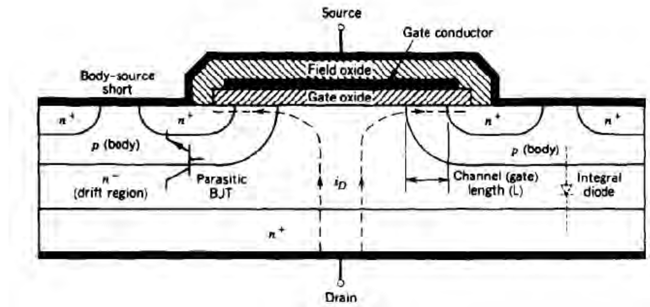


Figure 9: *Power MOSFET Structure.*

3.6 POWER MOSFET

Cross section of a Power MOSFET, with square cells. A typical transistor is constituted of several thousand cells have a different structure than the one presented above. As with most power devices, the structure is vertical and not planar. Using a vertical structure, it is possible for the transistor to sustain both high blocking voltage and high current. The voltage rating of the transistor is a function of the doping and thickness of the N-epitaxial layer, while the current rating is a function of the channel width. In a planar structure, the current and breakdown voltage ratings are both a function of the channel dimensions, resulting in inefficient use of the "silicon estate". Power MOSFETs with lateral structure are mainly used in high-end audio amplifiers and high-power PA systems. Their advantage is a better behavior in the saturated region than the vertical MOSFETs. Vertical MOSFETs are designed for switching applications. DMOS stands for double-diffused metal–oxide–semiconductor. Most power MOSFETs are made using this technology.

3.7 MODULATION TECHNIQUES

In general for a PWM techniques two signals are needed i.e., one is reference signal and other is carrier signal, the reference signal is going to modify, whereas carrier is going to be as triangular wave. Some of the different modified reference signals are as follows.

- Sinusoidal Pulse Width Modulation
- Trapezoidal PWM.
- Stepped PWM
- Stair Case PWM.
- Harmonic Injected PWM
- Space Vector PWM
- Modified Space Vector PWM

3.8 FUZZY LOGIC

Fuzzy logic is a problem solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded microcontrollers to large, networked, multichannel computers or workstation based data acquisition and control systems. It can be implemented in software, hardware or both. It provides a simple way for arriving at a definite conclusion based upon ambiguous, imprecise or missing input information. Fuzzy logic requires some numerical parameters in order to operate such as what is considered significant error and significant rate of change of error, but exact values of these numbers are usually not critical unless very responsive performance is required in which case empirical tuning would determine them. Many control problem use Fuzzy logic because it offers several unique features:

1. It is inherently robust since it does not require precise, noise free inputs and can be programmed to fail safely if a feedback sensor quits or is destroyed. The output control is a smooth control function despite a wide range of input variations.

2. It can be modified and tweaked easily to improve or drastically alter system performance, since the controller processes user defined rules governing the target control.

3. Any data sensor that provides some indication of a system's actions and reactions is sufficient. This allows the sensors to be inexpensive and imprecise thus keeping the overall system cost and complexity low.

4. Because of the rule based operation, any reasonable number of inputs can be processed and numerous outputs generated, although defining the rule base quickly becomes complex if too many inputs and outputs are chosen for a single implementation since rules defining their interrelations must also be defined.

5. It can control nonlinear systems that would be difficult or impossible to model mathematically. This opens doors for control systems that would normally be deemed unfeasible for automation.

3.8.1 APPLICATIONS OF FUZZY LOGIC

Control trains in Japan using fuzzy controllers.

1. Cement Kiln controller.

2. FLOPS is a fuzzy ES rule based shell.

3. Z-II is a fuzzy ES shell used in medical diagnosis and risk analysis.

4. Fuzzy logic has been applied in video camera technology for automatic focusing, automatic exposure, image stabilization and white balancing.

5. Fuzzy logic has been applied in automobiles for cruise control, brake and fuel injection systems.

6. Fuzzy algorithms have been applied for video and audio data compression.

4 SIMULATION RESULTS

4.1 About MATLAB

This paper output is simulated in MATLAB R2009b tool which is user friendly software. MATLAB is a high-level language and interactive environment for numerical computation, visualization, and programming. Using MATLAB, you can analyze data, develop algorithms, and create models and applications. The language, tools, and built-in math functions enable you to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java™. We can use MATLAB for a range of applications, including signal processing and communications, image and video processing, control systems, test and measurement, computational finance, and computational biology. More than a million engineers and scientists in industry and academia use MATLAB, the language of technical computing, Simulink is a data flow graphical programming language tool for modeling, simulating and analyzing multi domain dynamic systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in control theory and digital signal processing for multi domain simulation and Model-Based Design.

4.2 Simulation Diagram of Proposed Method

High step up conversion is possible by the fuzzy logic system used in the above model shown in fig.10. It reduces the distortion and Ripples in the Output voltage. So the proposed method is very efficient using the fuzzy logic system. Fig 11 Shows the Fuzzy logic system used in the proposed method.

Fig 12 depicts the input voltage of the Proposed system. The general conversion gives the four times of the input voltage to the output. But in the Proposed system using the Fuzzy logic gives approximately eight times the input voltage to the output side. Fig 13 depicts that

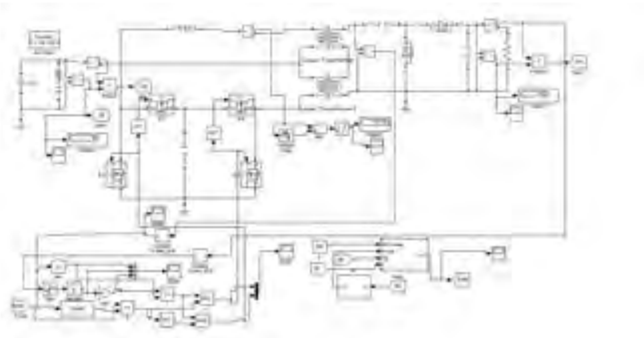


Figure 10: *Simulation Diagram of the Proposed System.*

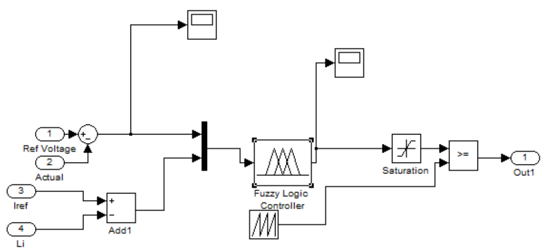


Figure 11: *Simulation Diagram of Fuzzy System.*

the output voltage of the proposed system without the Ripples and Distortion.

5 CONCULSION

Push–pull topology is widely used in dc/dc stage. Voltage-fed push–pull converter proposed in features high input current ripple because the current in the primary side is discontinuous. A low-pass LC input filter is applied to minimize the ripple. Then it increases the volume of the system for high input current. Moreover, the converter's voltage conversion ratio is only determined by turn ratio of transformer. To achieve a high step up feature, a large turn ratio brings large transformer volume and leakage inductance which degrades power density and circuit performance. Because of dc conduction through the rectifier, the harvested power still depends on the operating point and is limited by voltage drops on diodes. Another approach, known as synchronous electrical charge extraction, guarantees the independence of harvested power from the output bias and is thus more suitable for operation with irregular vibrations. In this method, when a voltage peak is detected, the electrical charge is first removed from the transducer through a resonant inductor and then transferred to the output. It is also worth to mention that, although bias-independent, the power harvested is lower than the maximum power achievable and with the newer single supply prebiasing technique, in which resonant circuits are used for both transferring electrical charge from the transducer to the output in order to harvest energy, and from the output to the transducer in order to provide a favourable voltage bias at the beginning of each elongation. Smooth variations is achieved with fuzzy logic control. Efficient Output voltage given by the proposed system proved through the simulation results.

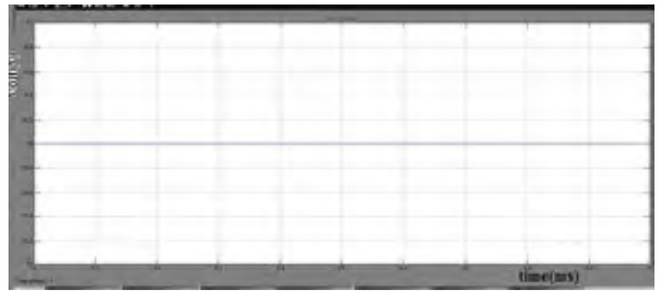


Figure 12: *Input Voltage.*

Figure 13: *Output Voltage.*

References

[1] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2)

[2] M. Sivaram Krishnan, M. Siva Ramkumar, "Power Management of a Hybrid Solar-Wind Energy System, International Journal of Engineering Research & Technology, 2 (1) pp 1988-1992.

[3] M. Sivaram Krishnan, M. Siva Ramkumar, "Power Quality Analysis In Hybrid Energy Generation System" in 'International Journal of Advance Research in Computer Science and Management Studies 2 (1) pp 188-193

[4] S. Sriragavi, M. Sivaram Krishnan, M. Siva Ramkumar "Static Compensator In Power Quality Improvement For Lvts" in International Journal of Scientific Research and Review, 6(11) ,pp 51-60

[5] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[6] Emayavaramban. G, Amudha. A, 'Recognition of sEMG for Prosthetic Control using Static and Dynamic Neural Networks', International Journal of Control Theory and Applications,Vol.2 (6), pp.155-165, September 2016.

[7] Emayavaramban. G, Amudha.A, 'Identifying Hand Gestures using sEMG for Human Machine Interaction', ARPN Journal of Engineering and Applied Sciences, Vol.11 (21), pp.12777-12785, November 2016.

[8] Ramkumar. S, Sathesh Kumar. K, Emayavaramban. G, 'EOG Signal Classification using Neural Network for Human Computer Interaction', International Journal of Control Theory and Applications, Vol.2 (6), pp.173-181, September 2016

[9] Ramkumar. S, Emayavaramban. G, Elakkiya. A, 'A Web Usage Mining Framework for Mining Evolving User Profiles in Dynamic Web Sites', International Journal of Advanced Research in Computer Science and Software Engineering, Vol.4 (8), pp.889-894, August 2014.

[10] D. Manoharan, A. Amudha. "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)

[11] Amudha, Christopher Asir Rajan, "GENCO'S Strategies for Selling Power and Reserve using Hybrid Algorithms of LR, GD and ANN". WULFENIA Journal. Vol. 19, No. 9, pp. 99-118, 2012.

[12] Amudha, Christopher Asir Rajan, "GENCO'S Strategies for Selling Power with effect of Reserve Using Memory Management Algorithm" Archives Des Sciences, Vol. 65, No. 10, pp. 349-358, 2012

[13] K. Balachander, "Design and Hardware Implementation of Speed Control of Induction Motor using Z - Source Inverter", International Journal of Electronics Engineering Research, Vol. 9(6), pp. 931-937.

[14] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035-2042.

[15] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[17] K. Balachander, V. Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[18] K. Balachander, V. Ponnusamy, 'Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research', Volume 7, Number 3 (2012), pp. 247-256. .

[19] K. Balachander, S. Kuppusamy, V. Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[20] K. Balachander, 'A Review of Modeling and Simulation of PV Module', Elixir, Electrical Engineering, 42 (2012) pp. 6798-6802.

[21] S. Kuppusamy, K. Balachander, 'Embedded based capacitance fuel level sensor', Elixir, Electrical Engineering, 43 (2012) pp. 6751-6754

[22] K. Balachander, S. Kuppusamy, V. Ponnusamy, '"Comparative Study of Hybrid Photovoltaic-Fuel Cell System / Hybrid Wind-Fuel Cell System for Smart Grid Distributed Generation System" Proceedings of IEEE International Conference on Emerging Trends in Science, Engineering and Technology at JJ College of Engineering, Trichy on 13 th and 14 th December 2012. DOI: 10.1109/ INCOSET. 2012.6513950, pp.462-466

COMPENSATION OF VOLTAGE VARIATIONS IN DISTRIBUTION SYSTEM DURING FAULT CONDITION BY USING SEPARATE ENERGY STORAGE DEVICE BASED DVR

N.A. Sankar, K. Balachander, A. Amudha, S. Divyapriya, M. Siva Ramkumar

Abstract: The increased asset utilization, facilitates the penetration of renewable sources and improves the flexibility, reliability and efficiency of the grid, Separate Energy Storage Devices (SESD) technology has been progressed. SESD Technology has the potential to bring real power storage characteristic to protect consumer's loads from the grid voltage fluctuations like Long and Short term Voltage variation conditions. This project deals the Design of Decision making Switch and operation principle of the SESD based Dynamic Voltage Restorer (DVR) and its design is based on simple PI control method to compensate voltage Fluctuations. The principle of SESD based DVR is analyzed in this work. The performance of the SESD is validated through simulations using MATLAB SIMULINK and the results reveals that the SESD can be a useful DC source for the DVR.

Keywords: Voltage disturbances, Dynamic Voltage Restorer (DVR), Separate Energy Storage Device (SESD).

1 Introduction

Power Quality in electric networks is one of today's most concerned area of electric power system. The power quality has serious economic implication for consumer, utilities and electrical equipment manufacturers. The impact of power quality problem is increasingly felt by customers-industrial, commercial even residential. Some of the main power quality problems are sag, swell, transient, harmonic and flickers etc. Power system engineers facing challenges seek solutions to operate the system in more a flexible and controller manner. Storage technologies have developed significantly in order to meet the challenges of practical power systems applications. Energy storage devices provide valuable benefits to improve stability, power quality and reliability of supply. Energy storage appears to be beneficial to utilities since it can decouple the instantaneous balancing between the demand and the supply [1-6]. Therefore it allows the increased asset utilization, facilitates the penetration of renewable sources and improves the flexibility, reliability and efficiency of the grid. Nonetheless, there are several high performance storage technologies available today. Energy storage devices are like Flywheel, Pumped hydro, compressed air, Batteries etc. At present, both hydro pump and compressed air are commercial technologies several test sites incorporating batteries have been demonstrated [7-13]. The Separate Energy Storage Device (SESD) systems have found its commercial applications in the area of power quality, though most of them are still under construction. Comparing with other storage technologies, the SESD systems have a unique advantage in two types of application. The first type is the transmission control and stabilization since SESD can respond to power demand very fast and can handle high power demand for longer periods. The second type is the power quality application where SESD can easily be sited near industrial loads [14-17]. The total efficiency of a SESD system can be very high since it does not require energy conversion from electrical to mechanical or chemical energy. The SESD system can respond very rapidly (MWs/milliseconds).The ability of injecting /absorbing real or reactive power can increases the effectiveness of the control, and enhance system reliability and availability [18-21]. To solve the voltage sag problem custom power devices are used. One of those devices is the DVR. Which is the most efficient and effective modern custom power device used in power distribution networks. Its appeal includes lower cost, smaller size and fast dynamic response to the disturbance [22]. The work on the investigation on power with compensating devices is very much diversified. However it is observed that there is a scope to investigate the effectiveness of compensating device for different loads and with different loading conditions in distribution system. As the distribution system locates the end of power system and is connected to the customer directly, so the reliability of power supply mainly depends on distribution system. As the customer's demand for the reliability of power supply is increasing day by day, so the reliability of the distribution system has to be increased. Electrical distribution network failures account for about 90% of the average customer's interruptions. So it is highly required to increase the reliability of the distribution system. The main objectives can be listed as follows

1. The objective of the work is to improve the power quality or reliability in the distribution system with the use of custom power device.

2. Reduction of energy consumption resulting from a reduction of feeder Voltage.

The objective of DVR is to have the customer's voltage at the lowest level consistent with proper operation of equipment and within levels set by regulatory agencies and standards setting organizations [23].

2 POWER QUALITY

While power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause scrambled data, interrupted communications, a frozen mouse, system crashes and equipment failure etc. A power voltage spike can damage valuable components. Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions.

- Voltage dip: A voltage dip is used to refer to short-term reduction in voltage of less than half a second.

- Voltage sag: Voltage sags can occur at any instant of time, with amplitudes ranging from 10 – 90% and a duration lasting for half a cycle to one minute.

- Voltage swell: Voltage swell is defined as an increase in rms voltage or current at power frequency for durations from 0.5 cycles to 1 min.

- Voltage 'spikes', 'impulses' or 'surges': These are terms used to describe abrupt, very brief increases in voltage value.

- Voltage transients: They are temporary, undesirable voltages that appear on the power supply line. Transients are high over-voltage disturbances (up to 20KV) that last for a very short time.

- Harmonics: The fundamental frequency of the AC electric power distribution system is 50 Hz. A harmonic frequency is any sinusoidal frequency, which is a multiple of the fundamental frequency. Harmonic frequencies can be even or odd multiples of the sinusoidal fundamental frequency.

- Flickers: Visual irritation and introduction of many harmonic components in the supply power and their associated ill effects.

2.1 The effects of voltage variation

The nominal system voltage in Australia is now 230/400 volts bringing all 220/380 volt and 240/415 volt systems to a common standard. Under normal service conditions a variation of +10%, -6% is allowed. However the distribution of electricity at the 240/415 volt level with a tolerance of +/-6% still falls within the Australian standards. Electricity supply authorities are required to comply with a nominal supply voltage of 240 volts. Therefore it is necessary to ask whether continuing to operate at the higher 240 volts rather than at 230 volts will eventually cost the consumer more. In a submission to the 2001 Electricity Price Distribution review it was argued that tight controls should be placed on voltage variation above and below the specified value, to maintain adequate supply quality and to discourage energy waste and unfair cost increases for customers. When analyzing the effects of supply voltage variation on power consumption and ultimately cost to the consumer it is found that domestic appliances can be divided into 3 general types i.e. Resistive, Inductive and Electronic. Resistive devices have a prime function to produce light and heat and make up 60% to 80% of most household energy usage. The inductive devices are often those with some form of electric motor whose output is that of mechanical work albeit that work may be used to provide heating or cooling as in the case of refrigerators and air conditioners. These devices contribute between 10% to 40% of household energyuse. The electronic devices form part of entertainment systems in the home but are becoming more common in all appliances where some form of control is required. These are normally low power devices and rarely contribute more than 20% to the energy cost. Various types of lighting fall within the three main categories, however for comparisons it is useful to identify them as a 4th group. The combination of these 4 groups, represent the appliances of a typical domestic installation. Resistive appliances: From an analysis of the basic resistive appliance group it would appear from the outset that the heating devices would produce a predictable outcome. In this case the application of Ohms' law applied to power (P=v2/R) where the change in voltage would produce a change in the power consumption of the square of the voltage change. The graph of figure 1 shows the relative power consumption versus per unit voltage based on a 240 volt supply.

All domestic appliances producing heat behaved predictably when it came to power dissipation, i.e. a rise of 10% in voltage produced slightly less than 21% increase in power. This was due to the higher resistance of the devices as the temperature increased. However when tested for energy usage where the appliance had a thermostat it was found that the increased power could

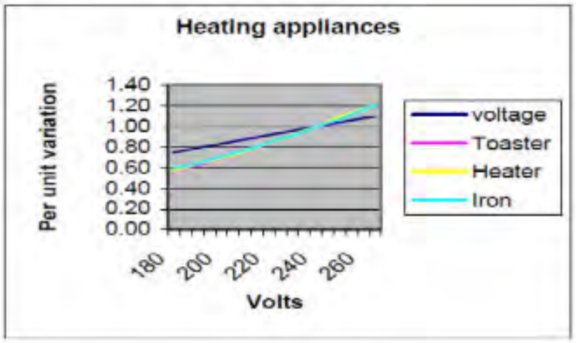


Figure 1: *Relative variations of heating devices.*

actually reduce the cycle time and in the case of the electric fry pan, jug and iron the energy cost of voltage variation is practically zero. There was some erratic behavior in the operation of the thermostats such as in the case of the iron there was a 5% variance in the cycle times at fixed voltage. The testing of the electric jug over a very wide range of voltages showed this to also be the case. A change of approximately 80 degrees Celsius produced no measurable change from the expected value. A further test included repetitively measuring the time taken to boil one litter of water in the jug. This test showed that regardless of the voltage applied the energy required for the application was approximately 390 kilojoules. In monetary terms boiling an electric jug costs no more or less regardless of the voltage. The table below in Figure 2 shows the average calculated energy use for the electric jug over a wide range of voltages. This table shows that a higher voltage does result in a slightly lower energy use. This change is too small to be significant. When this test was repeated many times at 240 volts the variation between tests was approximately +/- 2 kilojoules. Other factors include heat loss and energy transfer rates but as measured are minimal. Inductive appliances: This product range contains the electric motors and has an output which is work based. The devices tested included a refrigerator, freezer, vacuum cleaner, washing machine, pedestal fan and an induction motor used in a power tool. In this group of appliances the most significant with respect to a household power bills are the refrigerator and freezer. These appliances typically make up 10% of domestic energy usage. From measurements of active power consumption in the refrigerator an increase of 10% of voltage resulted in a power increase of only 5% The freezer tested was significantly older and large and showed a variation of 10% in active power. This compares to the total power increase of 17% for the refrigerator and 26% for the freezer respectively. The electronic devices: The so called entertainment appliances are many and varied but consume very little of the overall power in a domestic installation. Tests were performed on a V.C.R. and Television, Computer and Microwave. The microwave oven although providing heating still falls into the electronic category, as the microwave power supply is generated by semiconductor switching. By far the most interesting of these devices was the personal computer. Its switched mode power supply ensures that its energy use is almost impervious to supply voltage changes. A reasonably current Pentium II computer was subjected to a wide variation of voltages between 200 to 270 volts. The table below shows that the computer power varied only 3% over the entire 70 volt range. In the case of the microwave, television and video cassette recorder the change in power usage was approximately half that of the voltage variation. These devices can make up to 20% of a domestic power bill however changes in power consumption are less than half that that of the voltage variation. Because these devices tend to run on a time cycle rather than a work cycle they have the potential to cost more to run with higher voltage. Domestic lighting: Home lighting accounts for approximately 10% of the average electricity bill. This is one area in which voltage variation does affect power use and energy costs. In this section 4 types of lamp were chosen to represent the majority of domestic lighting appliances. These were the incandescent lamp, fluorescent (uncorrected), compact fluorescent and Halogen.

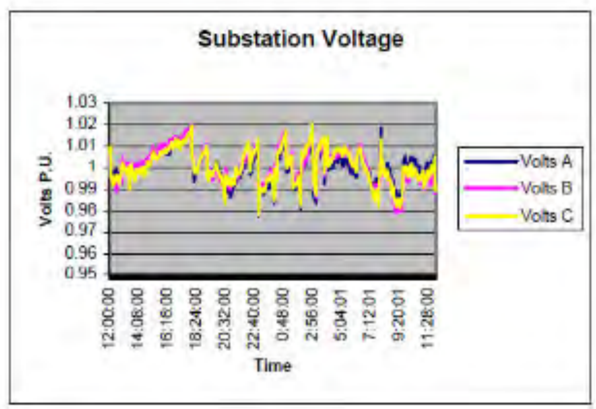


Figure 2: *Substation voltage over 24 hours.*

The incandescent lamp is basically a resistive device which is sensitive to voltage variation and its temperature changes significantly. This tends to work toward protection of the lamp as tests show that a 5% variation produces only 8% power variation but a 10% voltage change produces a change in power of approximately 16%. As lamps tend to be switched on continuously the cost is unlikely to vary from the expected deviations due to any householder intervention. Therefore voltage changes are mirrored in energy costs. The significant change in temperature and light output of the incandescent lamp makes it the most affected domestic appliance of voltage variations. The halogen lamp tests results were similar to that of the incandescent but slightly worse. The halogen lamp recorded a 17% increase in power for a 10% increase in voltage. The Fluorescent lamp was tested both uncorrected and corrected however as the majority of fluorescent lamps in homes are uncorrected only those results are included in the summary. The fluorescent lamp fared worse than the incandescent in its power changes with a rise of 22% in active power for a 10% rise in voltage. The total power measured showed and increase in 38% for the same voltage rise. Fluorescent lights have the same problem as the inductive devices i.e. the increase in reactive power with over voltage. As the voltage is increased the fluorescent lamps power factor decreases. The 21 watt compact fluorescent lamp tested could be placed into the category of electronic appliances. With a +/-20% variation the power change was directly proportional to the voltage i.e the current did not change and remained fairly constant regardless of the voltage.

2.2 Factors affecting supply voltage quality

Supply voltage quality in the point of common coupling (PCC) of an industrial company is affected by the following factors.

- Customers load characteristics (active and reactive loads, fluctuations of loads, harmonic currents, load unbalance in the three phases).
- Characteristics of the supply network (transformer impedance, voltage level in the MV network).
- Load characteristics of other consumers in the same LV or MV network.
- Random effects like faults in the network or natural phenomena. Generally, power consumption and power losses in the LV consumers' power system are affected by several characteristics.

One of the most critical parameters for a consumer is the voltage magnitude (level) in the power system. The main problem of customers is often supposed to be too low voltage in the feeder. As network impedance is constant most of the time, the voltage deviation is mainly caused by load current variations. It is customary, that in industrial substations, the voltage on the transformer secondary side is stepped up in order to ensure the voltage level close to rated voltage during peak loads. This is also done to handle the voltage drops during the start of powerful induction motors. The situation with relatively high voltage levels is quite usual in Estonia. This situation brings along additional power consumption and extra power losses, which will also contribute as extra costs.

2.3 Results of supply voltage

The supply voltage of several industrial companies has been investigated in the years 2000 to 2010. The total number of measurement sites was about 70. The measurement point was the PCC or the LV bus bars of the MV/LV transformer. In the following some examples of supply voltage measurement results are shown. The first Figure shows the phase voltages 10 min mean values throughout one week period and the second Figure the probability density of measured values, the corresponding normal distribution of measured values and the optimum distribution and distribution according to standard EN50160. The probability density functions calculated from measurement results have different expected values and dispersion. Most probably the voltage is higher during low loads and lower during high loads. In general, the following cases of density distributionfunctions could be described:

- Narrow distribution, optimum expected value;
- Narrow distribution, but shifted either towards higher or lower voltages from optimum.
- Expanded distribution, optimum expected value;
- Expanded distribution, but shifted either towards higher or lower voltages from optimum.

The idea of voltage level optimization is based upon statistical analyses of measurement results. Calculating the actual voltage distribution density, reshaping it to normal distribution and comparing it to the optimum distribution density curve enables to draw conclusions about adjustments of transformer steps if necessary or reinforcing the the supply circuit (transformer and lines) or improving reactive power compensation.

2.4 Voltage fluctuations

Voltage fluctuations can be described as repetitive or random variations of the voltage envelope due to sudden changes in the real and reactive power drawn by a load. The characteristics of voltage fluctuations depend on the load type and size and the power system capacity. Figure 2.4 illustrates an example of a fluctuating voltage waveform. The voltage waveform exhibits variations in magnitude due to the fluctuating nature or intermittent operation of connected loads. The frequency of the voltage envelope is often referred to as the flicker frequency. Thus there are two important parameters to voltage fluctuations, the frequency of fluctuation and the magnitude

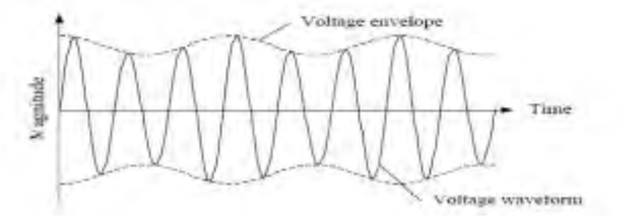


Figure 3: *Terminal voltage waveform of fluctuating load.*

of fluctuation. Both of these components are significant in the adverse effects of voltage fluctuations.

In Figure 3 the voltage changes are illustrated as being modulated in a sinusoidal manner. However, the changes in voltage may also be rectangular or irregular in shape. The profile of the voltage changes will depend on the current drawn by the offending fluctuating load. Typically, voltage changes caused by an offending load will not be isolated to a single customer and will propagate in an attenuated form both upstream and downstream from the offending load throughout the distribution system, possibly affecting many customers.

2.5 Effects of voltage fluctuations

The foremost effect of voltage fluctuations is lamp flicker. Lamp flicker occurs when the intensity of the light from a lamp varies due to changes in the magnitude of the supply voltage. This changing intensity can create annoyance to the human eye. Susceptibility to irritation from lamp flicker will be different for each individual. However, tests have shown that generally the human eye is most sensitive to voltage waveform modulation around a frequency of 6-8Hz. The perceptibility of flicker is quantified using a measure called the short-term flicker index, Pst, which is normalized to 1.0 to represent the conventional threshold of irritability. The perceptibility of flicker, a measure of the potential for annoyance, can be plotted on a curve of the change in relative voltage magnitude versus the frequency of the voltage changes. Figure 2 illustrates the approximate human eye perceptibility with regard to rectangular modulated flicker noting that around the 6-8Hz region fluctuations as small as 0.3% are regarded as perceptible as changes of larger magnitudes at much lower frequencies. Figure 4 is often referred to as the flicker curve and represents a Pst value of 1.0 for various frequencies of rectangular voltage fluctuations. Although regular rectangular voltage variations are uncommon in practice they provide the basis for the flicker curve, defining the threshold of irritability for the average observer. It is worth noting that the flicker curve is based on measurements completed using a 60W incandescent light bulb. This is used as a benchmark measurement, however the perceptibility of lamp flicker will vary depending on the size and type of lamp used.

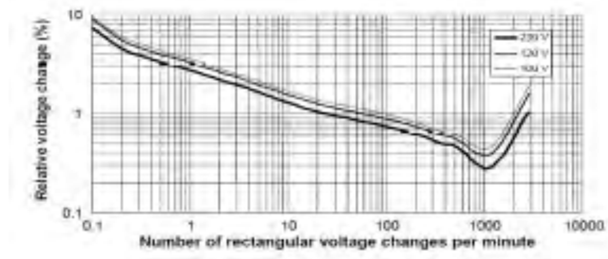


Figure 4: *Flicker curve for rectangular modulation frequencies.*

Voltage fluctuations on the public low voltage power system are required to be within accepted tolerances specified in the standards. In general the acceptable region of voltage fluctuations falls below the flicker curve illustrated in Figur4. Voltage fluctuations may also cause spurious tripping of relays; interfere with communication equipment; and trip out electronic equipment. Severe fluctuations in some cases may not allow other loads to be started due to the reduction in the supply voltage. Additionally, induction motors that operate at maximum torque may stall if voltage fluctuations are of significant magnitude.

2.6 Causes of voltage fluctuations

Voltage fluctuations are caused when loads draw currents having significant sudden or periodic variations. The fluctuating current that is drawn from the supply causes additional voltage drops in the power system leading to fluctuations in the supply voltage. Loads that exhibit continuous rapid variations are thus the most likely cause of voltage fluctuations. Examples of loads that may produce voltage fluctuations in the supply include

- Arc furnaces
- Arc welders

Installations with frequent motor starts (air conditioner units, fans) Motor drives with cyclic operation (mine hoists, rolling mills) Equipment with excessive motor speed changes (wood chippers, car shredders) Often rapid fluctuations in load currents are attributed to motor starting operations where the motor current is usually between 3-5 times the rated current for a short period of time. If a number of motors are starting at similar times, or the same motor repeatedly starts and stops, the frequency of the voltage changes may produce flicker in lighting installations that is perceivable by the human eye. Consider the simple model representing a fluctuating load drawing real power P, and reactive power Q, connected to a power system with an impedance of resistance R, and reactance X, as illustrated in Figure 2.6. The voltage VR seen by the customer can usually be regulated by operating the system voltage VS at a slightly higher value to ensure VR remains at the required value, e.g. 230V for a single-phase system. During steady state operation this can be achieved through the use of automatic tap changers on transformers, line drop compensators and voltage regulators. For more rapid changes in load current the operation of such devices is not fast enough in response to effectively regulate the voltage to stay at the required value. The resultant voltage due to the current drawn by the load is illustrated in the phasor diagram of figure 5 where VS is the supply voltage and VR is the resultant voltage seen by the load at the point of common connection (PCC).

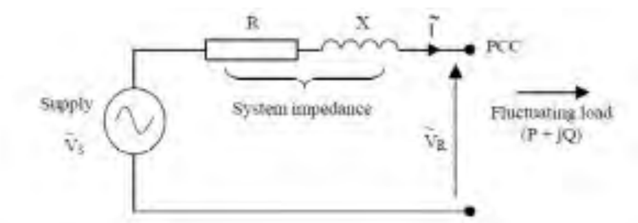


Figure 5: *Simple model of power system*

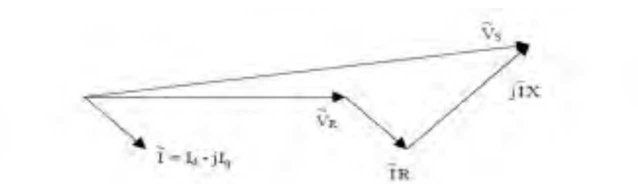


Figure 6: *Phasor diagram of supply voltage.*

3 SEPARATE ENERGY STORAGE DEVICE

As with any technology trying to find its widespread acceptance and commercialization, the new technology either has to represent a breakthrough in its functionality and capabilities irrespective to cost, or has to match the performance of a conventional technology at a lower cost. SESD seems to fall in the first category. In order to distinguish its benefits and capabilities from other energy storage technologies, four selected energy storage devices (Pumped hydro, compressed air, batteries and flywheels) are briefly described below. Pumped Hydro storage energy is potential energy represented by a body of water at is illatively high elevation. The water is elevated with a motor/pump during periods of low electric power demand. Dropping the elevation to allow water flow through hydro turbines at a lower elevation produces the electrical energy. The round trip efficiency is greater than %60. Due to its massive mechanical assemblies, it responds slowly, typically minutes. It requires two reservoirs at different elevations, which makes it difficult to find suitable sites. Compressed Air is stored by a compressor that is supplied by energy generated during periods of low electric power demand. When electric power demand nears peak, the compressed air is released to turn a combustion turbine. Since it also consumes fuel, the efficiency of the device cannot be given directly. But compared to gas turbines, its efficiency is approximately 70%. It operates either full ON or full OFF. Its response to demand is typically in seconds. Finding sites and storing air without significant leakage limit the potential use of these devices. Batteries store energy in electrochemical form. A series of low-voltage/power battery modules connected in parallel and series to achieve desired electrical characteristic forms the battery system. Battery energy storage is one of the most cost effective energy storage. Batteries require an ac/dc power conversion unit. Modular type small batteries with advanced power electronics technologies can provide four-quadrant operation along with rapid response. The round trip efficiency of batteries is approximately 80%. Due to chemical kinetics involved, they cannot handle high power for long periods. Rapid deep discharges may eventually lead to replacement of the battery, since this kind of operation reduces battery lifetime. There also exist environmental concerns related to battery storage because it generates toxic gas during charging and utilize hazardous materials presenting potential disposal problems. Flywheels store kinetic energy within a rotating mass driven by a motor/generator. A PCS is used to drive the motor/generator. Like batteries, flywheel systems are also modular and low cost. Like SMES, they have high efficiency, have the ability to absorb and supply both reactive and active power, and responds rapidly to power demand. However, charging and discharging at very high power require large torque to be generated, which may result in increased complexity and cost. Since they involve parts that rotate at very high speed, low reliability and high maintenance are the concerns of this technology. Without any doubt, the cost of SESD is currently high, compared to the above described storage technologies. However, SESD systems have overcome that above storage devices limitations.

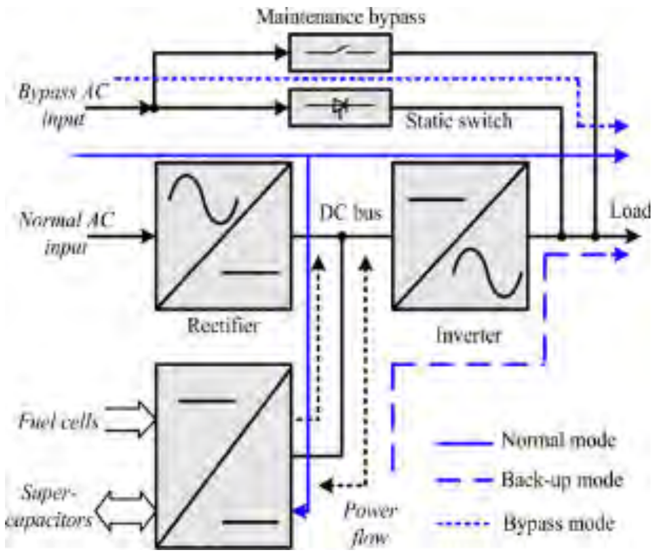


Figure 7: *Block diagram of a dual-conversion UPS system based on FC and SC.*

3.1 Bidirectional isolated dc–dc converter for hybrid system

The hybrid system based on fuel cells (FCs) and super capacitors (SCs) as an environmentally renewable energy system has been applied in many fields, such as hybrid electric vehicle, uninterruptible power supply (UPS), and so on. As an example, a block diagram of extended-run time battery less double-conversion UPS system powered by FCs and SCs is illustrated in figure 7. Compared to diesel generators and batteries, FCs are electrochemical devices that convert the chemical potential of the hydrogen into electric power directly with consequent high conversion efficiency, so it has the possibility to obtain the extended runtime range with the combustible feed from the outside. But one of the main weak points of the FC is its slow dynamics because of the limited speed of hydrogen delivery system and the chemical reaction in the membranes with a slow time constant. Hence, during the warming-up stage or load transient, SCs are utilized as the auxiliary power source for smoothing the output power. In addition, the fuel-cell output voltage is varied widely, almost 2:1, depending on the load condition, and the terminal voltage of the SC bank is also variable during charging and discharging periods. Thus, it is very important for the conversion system to be capable of harvesting power from these two different power sources efficiently in widely input voltage range and load conditions. In recent years, many configurations of a hybrid dc power conversion system relating to FCs and SCs have been proposed. Connecting FCs and SCs by two individual dc–dc converters separately to a mutual dc voltage bus is the most common configuration, which offers many advantages, especially, faster and more stable system response. However, it increases the system cost and power losses. Multiple dc voltage bus, which connects FCs and SCs to different cascaded voltage buses through converters, is also a widely used configuration, but the disadvantages are high power losses and low reliability. Moreover, FCs and the SCs cannot keep the bus voltage constant except if they are oversized. The simplest configuration is to parallel FCs and SCs directly as one power source but the output currents cannot be controlled independently. In addition, a multiport configuration was introduced.

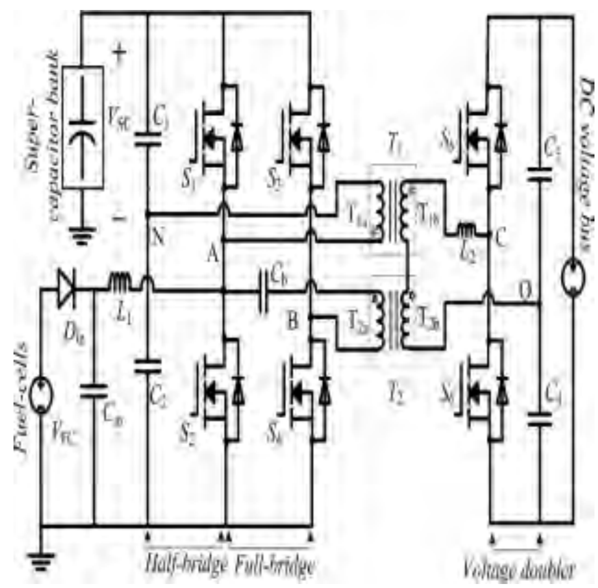


Figure 8: *Proposed hybrid bidirectional dc–dc converter topology.*

For the application where the galvanic isolation is required, an isolated multiport converter family was investigated. The boost-type input port can limit the current ripple and this characteristic is helpful to increase the lifetime of FCs, but the diode connected in series with each MOSFETs makes reversible power flow impossible. To overcome this drawback, two current-fed dual-input bidirectional converters were proposed and investigated.

3.2 Operation principle

As shown in figure 8 BHB structure locates on the primary side of the transformer T1 and it associates with the switches S1 and S2 that are operated at 50% duty cycle. The SC bank as an auxiliary energy source is connected to the variable low voltage (LV) dc bus across the dividing capacitors, C1 and C2. Bidirectional operation can be realized between the SC bank and the high-voltage (HV) dc bus. Switches S3 and S4 are controlled by the duty cycle to reduce the current stress and ac RMS value when input voltage VFC or VSC are variable over a wide range. The transformers T1 and T2 with independent primary windings as well as series-connected secondary windings are employed to realize galvanic isolation and boost a low input voltage to the HV dc bus. A dc blocking capacitor Cb is added in series with the primary winding of T2 to avoid transformer saturation caused by asymmetrical operation in full-bridge circuit. The voltage doubler circuit utilized on the secondary side is to increase voltage conversion ratio further. The inductor L2 on the secondary side is utilized as a power delivering interface element between the LV side and the HV side. According to the direction of power flow, the proposed converter has three operation modes that can be defined as boost mode, SC power mode, and SC recharge mode. In the boost mode, the power is delivered from the FCs and SCs to the dc voltage bus. In the SC power mode, only the SCs are connected to provide the required load power. When the dc bus charges the SCs, the power flow direction is reversed which means the energy is transferred from the HV side to the LV side, and thereby the converter is operated under the SC recharge mode.

3.3 Storage size determination

The need to reduce greenhouse gas emissions due to fossil fuels and the liberalization of the electricity market have led to large scale development of renewable energy generators in electric grids. Among renewable energy technologies such as hydroelectric, photovoltaic (PV), wind, geothermal, biomass, and tidal systems, grid-connected solar PV continued to be the fastest growing power generation technology, with a 70% increase in existing capacity to 13GW in 2008. However, solar energy generation tends to be variable due to the diurnal cycle of the solar geometry and clouds. Storage devices (such as batteries, ultra capacitors, compressed air, and pumped hydro storage can be used to i) smooth out the fluctuation of the PV output fed into electric grids ("capacity firming") discharge and augment the PV output during times of peak energy usage ("peak shaving") store energy for nighttime use, for example in zero-energy buildings and residential homes. Depending on the specific application (whether it is off grid or grid-connected), battery storage size is determined based on the battery specifications such as the battery storage capacity (and the minimum battery charging/discharging time).

For off-grid applications, batteries have to fulfill the following requirements: (i) the discharging rate has to be larger than or equal to the peak load capacity; (ii) the battery storage capacity has to be large enough to supply the largest night time energy use and to be able to sup-

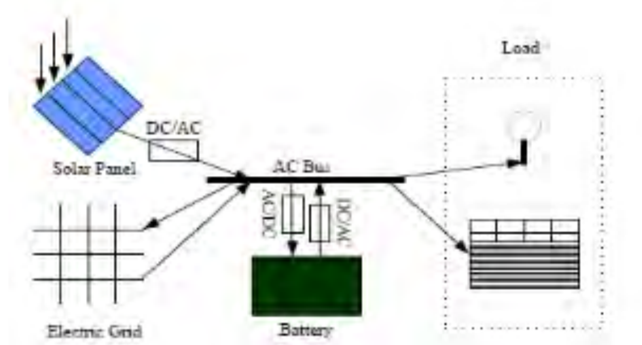


Figure 9: *Grid-connected PV system with battery storage and loads.*

ply energy during the longest cloudy period (autonomy). The IEEE standard provides sizing recommendations for lead-acid batteries in stand-alone PV systems. The solar panel size and the battery size have been selected via simulations to optimize the operation of a stand-alone PV system, which considers reliability measures in terms of loss of load hours, the energy loss and the total cost. In contrast, if the PV system is grid-connected, autonomy is a secondary goal; instead, batteries can reduce the fluctuation of PV output or provide economic benefits such as demand charge reduction, and arbitrage. The work in analyzes the relation between available battery capacity and output smoothing, and estimates the required battery capacity using simulations. In addition, the battery sizing problem has been studied for wind power applications and hybrid wind/solar power applications. Design of a battery energy storage system is examined for the purpose of attenuating the effects of unsteady input power from wind farms, and solution to the problem via a computational procedure results in the determination of the battery energy storage system's capacity. Similarly, based on the statistics of long-term wind speed data captured at the farm, a dispatch strategy is proposed which allows the battery capacity to be determined so as to maximize a defined service lifetime/unit cost index of the energy storage system; then a numerical approach is used due to the lack of an explicit mathematical expression to describe the lifetime as a function of the battery capacity. Sizing and control methodologies for a zinc-bromine flow battery-based energy storage system are proposed to minimize the cost of the energy storage system. However, the sizing of the battery is significantly impacted by specific control strategies. Methodology for calculating the optimum size of a battery bank and the PV array for a stand-alone hybrid wind/PV system is developed, and a simulation model is used to examine different combinations of the number of PV modules and the number of batteries. An approach is proposed to help designers determine the optimal design of a hybrid wind-solar power system; the proposed analysis employs linear programming techniques to minimize the average production cost of electricity while meeting the load requirements in a reliable manner. Genetic algorithms are used to optimally size the hybrid system components, i.e., to select the optimal wind turbine and PV rated power, battery energy storage system nominal capacity and inverter rating. The primary optimization objective is the minimization of the levelized energy cost of the island system over the entire lifetime of the project. In this paper, we study the problem of determining the battery size for grid-connected PV systems. The targeted applications are primarily electricity customers with PV arrays "behind the meter," such as residential and commercial buildings with rooftop PVs. In such applications, the objective is to reduce the energy cost and the loss of investment on storage devices due to aging effects while satisfying the loads and reducing peak electricity purchase from the grid (instead of smoothing out the fluctuation of the PV output fed into electric grids). Our setting1 is shown in figure 9. Electricity is generated from PV panels, and is used to supply different types of loads. Battery storage is used to either store excess electricity generated from PV systems for later use when PV generation is insufficient to serve the load, or purchase electricity from the grid when the time-of-use pricing is lower and sell back to the grid when the time-of-use pricing is higher. Without a battery, if the load was too large to be supplied by PV generated electricity, electricity would have to be purchased from the grid to meet the demand. Naturally, given the high cost of battery storage, the size of the battery storage should be chosen such that the cost of electricity purchase from the grid and the loss of investment on batteries are minimized. Intuitively, if the battery is too large, the electricity purchase cost could be the same as the case with a relatively smaller battery. In this paper, we show that there is a unique critical value (denoted as Cc ref, refer to Problem 1) of the battery capacity such that the cost of electricity purchase and the loss of investments on batteries remains the same if the battery size is larger than or equal to Cc ref and the cost is strictly larger if the battery size is smaller than Cc ref. We obtain a criterion for evaluating the economic value of batteries compared to purchasing electricity from the grid, propose lower and upper bounds on Cc ref given the PV generation, loads, and the time period for minimizing the costs, and introduce an efficient algorithm for calculating the critical battery capacity based on the bounds; these results are validated via simulations. The contributions of this work are the following: i) to the best of our knowledge, this is the first attempt on determining the battery size for grid-connected PV systems based on a theoretical analysis on the lower and upper bounds of the battery size; in contrast, most previous work are based on simulations, e.g., the work in a criterion for evaluating the economic value of batteries compared to purchasing electricity from the grid is derived (refer to Proposition 4 and Assumption 2), which can be easily calculated and could be potentially used for choosing appropriate battery technologies for practical applications; and iii) lower and upper bounds on the battery size are proposed, and an efficient algorithm is introduced to calculate its value for the given PV generation and dynamic loads; these results are then validated using simulations. Simulation results illustrate the benefits of employing batteries in grid-connected PV systems via peak shaving and cost reductions compared with the case without batteries (this is discussed in Section V.B). The paper is organized as follows. In the next section, we lay out our setting, and formulate the storage size determination problem. Lower and upper bounds on Cc ref are proposed in Section III. Algorithms are introduced in Section IV to calculate the value of the critical battery capacity. In Section V, we validate the results via simulations. Finally, conclusions and future directions are given in Section VI.

3.4 Dynamic voltage restorer

Among the power quality problems (sags, swells, harmonics…) voltage sags are the most severe disturbances. In order to overcome these problems the concept of custom power devices is introduced recently. One of those devices is the DVR, which is the most efficient and effective modern custom power device used in power distribution networks. DVR is a recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR can also added other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations and the location of DVR is shown in figure 10.

3.5 Principle of DVR operation

A DVR is a solid state power electronic switching device consisting of either GTO or IGBT, a capacitor bank as an energy storage device and injection transformer. It is linked in series between a distribution system and a load that shown in figure 11.

The basic idea of the DVR is to inject a controlled voltage generated by a forced commuted converter in a series to the bus voltage by means of an injecting trans-

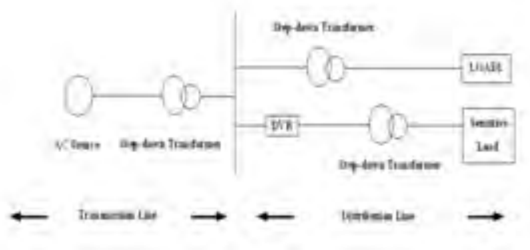


Figure 10: *Location of DVR*

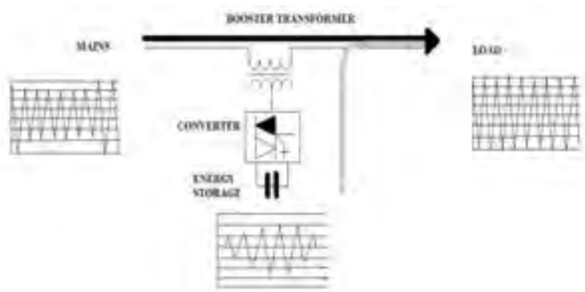


Figure 11: *Principle of DVR test system*

former. A DC to AC inverter regulates this voltage by sinusoidal PWM technique. All through normal operating condition. The DVR injects only a small voltage to compensate for the voltage drop of the injection transformer and device losses. However, when voltage sag occurs in the distribution system. The DVR control system calculates and synthesizes the voltage required to preserve output to the load by injecting a controlled voltage with a certain magnitude and phase angle into the distribution system to the critical load. Note that the DVR capable of generating or absorbing reactive power but the active power injecting of the device must be provided by an external energy source or energy storage system. The response time of DVR is very short and is limited by the power electronic devices and the voltage sag detection time. The prediction response time is about 25millisecond, and which is much less than some of the traditional methods of voltage correction such as tap-changing transformer.

3.6 Integration of SESD with DVR

The basic structure of a DVR based on SESD is shown in figure 12. It consists of SESD, capacitor bank, voltage source inverter (VSI),low pass filter and a voltage injection transformer.

In order to mitigate the simulated voltage sag in practical application, a discrete PWM-Based control scheme is implemented, with reference to DVR as shown in figure 3.9. The aim of the control scheme is to maintain a constant voltage magnitude at the sensitive load point,

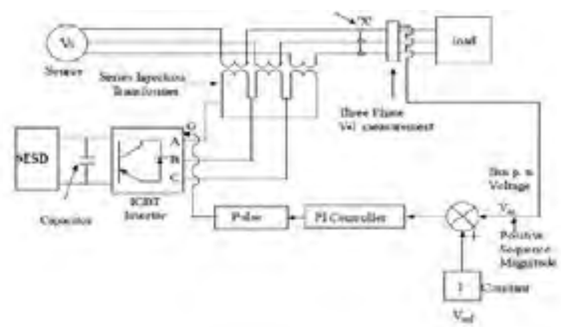


Figure 12: *DVR (SESD based)*

under the system disturbance. The control system only measures the rms voltage at load point; The DVR control system exerts a voltage angle control as follows: Voltage sag is created at load terminals by a three phase fault as shown in figure 3.12 load voltage is converted into per unit quantity and is passed through sequence analyzer. The magnitude is then compared with reference voltage (Vref) through which error signal is fed to PI controller. This voltage is then fed to triggering circuit. Pulse width modulated (PWM) control technique is applied for inverter switching so as to produce a three phase 50 Hz sinusoidal voltage at the load terminals. Chopping frequency is in the range of a few KHz. The IGBT inverter is controlled with PI controller in order to maintain 1 p.u. voltage at the load terminals i.e. considered as base voltage =1p.u.

4 PROPOSED SYSTEM

Simulation in general terms can be defined as the representation of a system in its realistic form. When a computer program is used to create a model to mimic a real world system, then the term 'computer simulation' comes into action such models are called computer simulated models. MATLAB is a software package for high performance numerical computation and visualization. It provides an interactive environment with hundreds of built in function for technical computation, graphics, and animation. Best of all, it also provides easy extensibility with its own high-level programming language. Typical uses include math and computation, algorithm development, data acquisition, modeling, simulation, and prototyping, data analysis, exploration and visualization, scientific and engineering graphics, application development, including graphics user interface building. A simulation model is developed in MATLAB using Simulink and Sim Power System set toolboxes. The simulation is carried out on MATLAB version 8 with ode3 solver. The electrical system is simulated using Sim Power System.

4.1 Simulation Model of without SESD based DVR

Figure 13 shows the without SESD based DVR and a three phase to ground fault is applied to the system at point with fault resistance of 0.35ω for time duration of 50 micro second which result voltage variations.

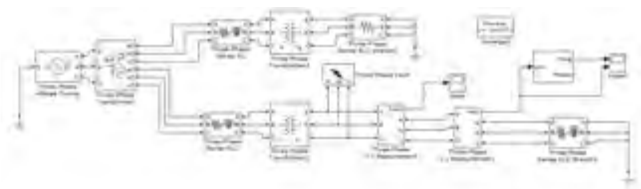


Figure 13: *Simulation diagram of without SESD based DVR*

4.2 Simulation Model of with SESD based DVR

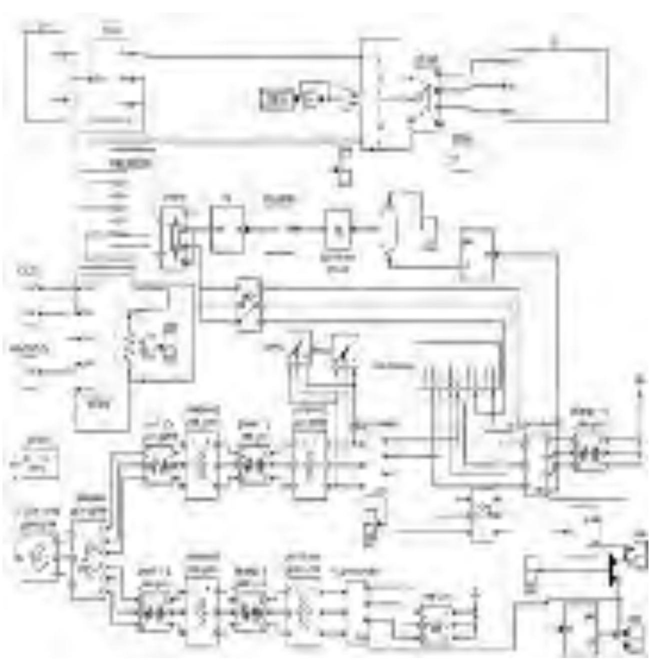


Figure 14: *DVR with SMSD*

Single line diagram of the test system for DVR Based on SMES is composed by a 13 kV, 50 Hz generation system, feeding two transmission lines through a 3-winding transformer connected in Y/δ/δ, 13/115/115 kV. Such transmission lines feed two distribution networks through two transformers connected in δ/Y, 115/.5 kV. We verify the working of DVR for voltage compensation at 0.35 ohms fault resistances for fixed time duration of 50µs. The DVR performance in presence of Superconducting magnetic energy storage unit (SMES) is analyzed for symmetrical three phase to ground fault. While we take SESD with 588KA current flowing through it, for analysis of system performance i.e. voltage sag compensation. This proposed system is shown in figure 14.

5 RESULT

The behavior of the complete proposed system of distribution system to compensate voltage variation by DVR based on separate energy storage devices. For the proposed test system, the output waveforms for SESD based DVR in three phase distribution systems, Compensation of long and short term voltage variations are represented below. Figure 15 shows the rms voltage at load point when the system operates with no DVR and a three phase fault is applied to the system. When the DVR is in operation the voltage interruption is compensated almost completely and the rms voltage at the sensitive load point is maintained at normal condition.

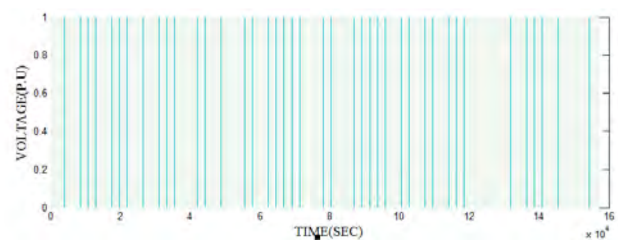


Figure 15: *Firing pulse generated by discrete PWM generator.*

The simulation is carried out SESD based DVR is introduced to compensate the voltage variations occurred due to the three phase to ground fault which is as shown in figure 16.

Figure 17 shows the Simulation output for fault clearing only short term voltage variation.

Figure 18 shows Simulation output for fault clearing both long and short term voltage variation (GRID).

Figure 19 shows Simulation output for fault clearing both long and short term voltage variation (PV).

Figure 20 shows Simulation output for fault clearing both long and short term voltage variation (BATTERY).

6 CONCLUSION

The power quality problems such as short and long term voltage variations are discussed in this project and Compensation techniques using custom power electronic devices are presented. Dynamic Voltage Restorer (DVR) comprises of PWM based PI controller which is are emerging device used in general for power quality improvement. Hence in this work, a compensation techniques is arrived by mainly use of DVR and SESD. A

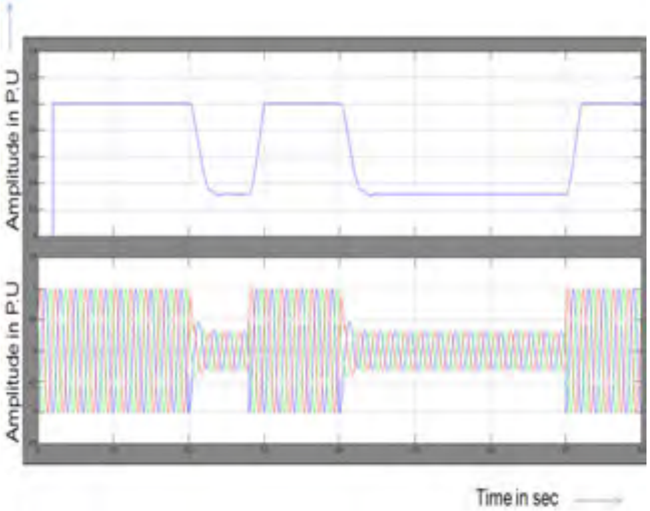


Figure 16: *Simulation output for without SESD based DVR*

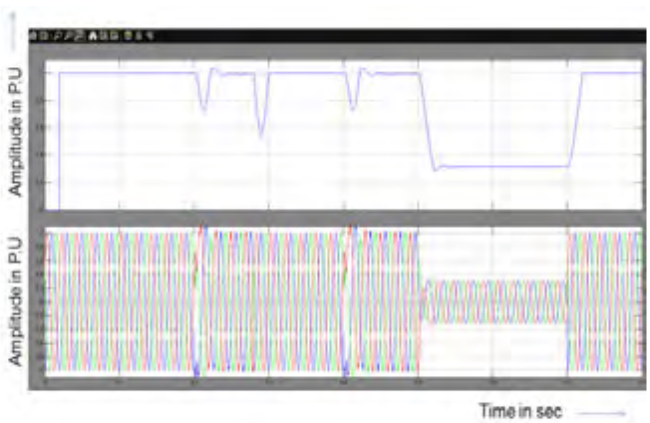


Figure 17: *Simulation output for fault clearing only short term voltage variation.*

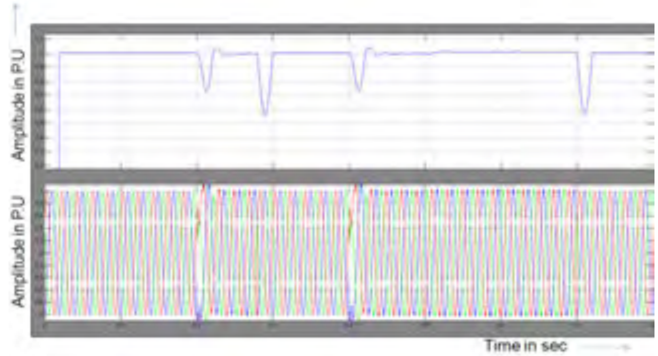


Figure 18: *Simulation output for fault clearing both long and short term voltage variation (GRID)*

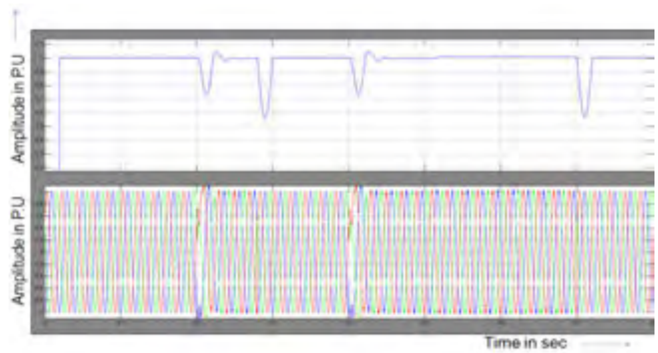


Figure 19: *Simulation output for fault clearing both long and short term voltage variation (PV).*

new design which incorporates a SESD module as a DC voltage source to mitigation voltage variations and enhances power quality of a distribution system based on DVR is used in this work. Simulations are carried out by using MATLAB SIMULINK. The Simulation results prove that the SESD can be a useful DC source for the DVR.

References

[1] M. Sownthara, M. Siva Ramkumar, "Wireless Communication Module To Replace Resolver Cable In Welding Robot" in International Journal of Advanced Information Science and Technology on 23(23) pp 230-235,2014.

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2)

[3] M. Sivaram Krishnan, M. Siva Ramkumar, "Power Management of a Hybrid Solar-Wind Energy System, International Journal of Engineering Research & Technology, 2 (1) pp 1988-1992.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, "Power Quality Analysis In Hybrid Energy Generation System" in 'International Journal of Advance Research in Computer Science and Management Studies 2 (1) pp 188-193

[5] S. Sriragavi, M. Sivaram Krishnan, M. Siva Ramkumar "Static Compensator In Power Quality Improvement For Lvts" in International Journal of Scientific Research and Review, 6(11) ,pp 51-60

[6] D. Kavitha, C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineer-

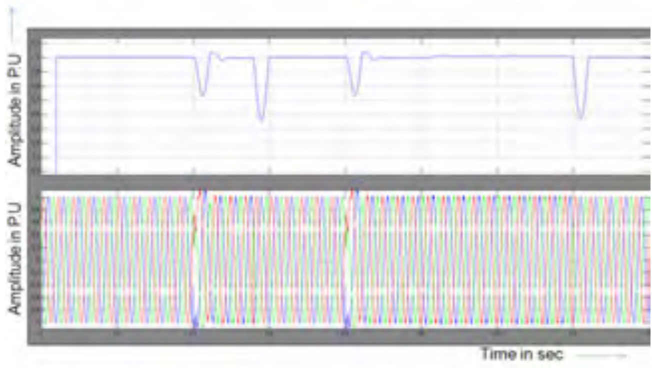


Figure 20: *Simulation output for fault clearing both long and short term voltage variation (BATTERY).*

ing Research, ISSN 0973-4562 Vol. 10 No.20 (2015), pg. 17749-17754.

[7] A. Amudha. “Enhancement of Available Transfer Capability using FACTS controller” in International journal of Applied Mechanics and Materials, Vol. 573, pp 340-345

[8] A. Amudha. “Optimal placement of Unified Power Flow Controller in the transmission line using SLF algorithm” in International journal of Applied Mechanics and Materials, Vol. 573 (2014) pp 352-355

[9] V .J .Vijayalakshmi, C. S. Ravichandran, A. Amudha. “Predetermination of Higher Order Harmonics by Dual Phase Analysis” in International journal of Applied Mechanics and Materials Vol. 573 (2014) pp 13-18.

[10] Amudha, Christopher Asir Rajan, “Generator scheduling under competitive environment using Memory Management Algorithm” in Alexandria Engineering Journal, Elsevier Volume 52, Issue 3, September 2013, Pages 337–346

[11] K. Balachander, “Design and Hardware Implementation of Speed Control of Induction Motor using Z - Source Inverter”, International Journal of Electronics Engineering Research, Vol. 9(6), pp. 931-937.

[12] K. Balachander, A. Amudha,” Design and Hardware Implementation of Interleaved Boost Converter Using Sliding Mode Approach”, International Journal of Electronics Engineering Research, Volume 9, Number 5 (2017) pp. 745-750

[13] R. Sri Sangeetha, K. Balachander,’ Unbalanced and over Current Fault Protection in Low Voltage DC Bus Micro Grid Systems’, Middle East Journal of Scientific Research, Volume – 24, No. 2(2016), pp. 465-474.

[14] K. Balachander, P. Vijayakumar, “Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)” International Journal of Applied Environmental Sciences”, Volume - 08, No.16 (2013), pp.2035-2042.

[15] K. Balachander, P. Vijayakumar, “Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ”, American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, P. Vijayakumar, “Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India”, Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[17] K. Balachander, P. Vijayakumar, “Renewable Energy System Optimization of Two Different Locations” CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659& Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, V. Ponnusamy, ‘Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System’ International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[19] K. Balachander, V. Ponnusamy, ‘Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER’ International Journal of Applied Engineering Research’, Volume 7, Number 3 (2012), pp. 247-256. .

[20] K. Balachander, S. Kuppusamy, V. Ponnusamy, ‘Modeling and Simulation of VSDFIG and PMSG Wind Turbine System’, International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[21] K. Balachander, ‘A Review of Modeling and Simulation of PV Module’, Elixir, Electrical Engineering, 42 (2012) pp. 6798-6802.

[22] S. Kuppusamy, K. Balachander, ‘Embedded based capacitance fuel level sensor’, Elixir, ElectricalEngineering, 43 (2012) pp. 6751-6754

[23] K. Balachander, S. Kuppusamy, V. Ponnusamy, ‘" Comparative Study of Hybrid Photovoltaic-Fuel Cell System / Hybrid Wind-Fuel Cell System

for Smart Grid Distributed Generation System" Proceedings of IEEE International Conference on Emerging Trends in Science, Engineering and Technology at JJ College of Engineering, Trichy on 13 th and 14 th December 2012. DOI: 10.1109/ INCOSET. 2012.6513950, pp.462-466

IMPLEMENTATION OF HARMONIC MITIGATION OF GRID CONNECTED MODIFIED MLI FOR VARIABLE-SPEED WIND ENERGY CONVERSION SYSTEM

D. Sivakumar, A. Amudha, K. Balachander, M. Siva Ramkumar

Abstract: This paper proposes a single-phase nine-level (9L) inverter topology suitable for control strategy and design of an AC/DC/AC IGBT-PMW power converter for PMSG-based variable-speed wind energy conversion systems (VSWECS) operation in grid/load-connected mode are presented. VSWECS consists of a PMSG connected to a AC-DC IGBT-based PWM rectifier and a DC/AC IGBT-based PWM inverter with LCL filter. The proposed inverter is realized using a T-type neutral point-clamped inverter connected in cascade to a floating capacitor (FC) H-bridge. Additionally, two low-frequency switches are added across the dc-link enabling the inverter to generate a 9L waveform. A sensor less voltage control based on redundant switching state is developed and embedded with PWM controller, which is responsible for regulating the FC voltage at one quarter of the dc source voltage. The proposed PWM technique employs the generation of 9L waveform without using any voltage sensor, thereby reducing the complexity of the overall control scheme. This, in turn, will make the overall system appealing for various industrial applications. In comparison to conventional and recent topologies, generation of the 9L waveform using a lower number of components is the notable contribution. Another important feature of the proposed inverter is that if FC H-bridge fails, it can be bypassed, and the inverter can still operate as a 5L inverter at its nominal power rating. Furthermore, a comprehensive comparison study is included which confirms the merits of the proposed inverter against those of other state-of-the art topologies. Finally, simulation and hardware results are included for validating the feasibility of the proposed system.

Keywords: Wind Power, H-bridge inverter, floating capacitor, sensor less voltage control.

1 Introduction

Installation of wind energy conversion systems and rate of benefiting from the wind energy has greatly increased in last two decades. Especially in recent years, due to both a significant decrease in costs of wind power production and the technological developments in wind tribune production,contribution of wind energy in the electricity power production systems has increased rapidly.Variable- speed wind turbines have many advantages overfixed-speed generation such as increased energy capture,operation at maximum power point, improved efficiency,and power quality. In wind energy conversion systems, there are two operating modes of wind turbine generators (WTG)system: fixed speed and variable-speed operating modes.Multilevel Inverters provide smoother output waveforms when the levels are increased simultaneously the Total Harmonic distortion is also Reduced. The number of levels is inversely proportional to Total Harmonic Distortion such that at infinity levels the THD becomes zero.[1] On the contrary, a larger number of levels increases the part counts, resulting in a larger installation area and increased cost of implementation. These notions have recently captured the attention of researchers, who have been trying to create economically and technically justified structures. Hence, considerable efforts are being dedicated to reduce the switches and part counts while maintaining the technical superiority of these devices [2,3]. There are four main categories of multilevel inverters, which are as follows:

- Neutral point clamped (NPC) or diode-clamped structure
- Flying capacitor (FC) configuration
- Cascaded H-Bridge (CHB) arrangement
- New designs of multilevel inverters

The NPC multilevel inverter, also called the diode-clamped inverter, is considered the first generation multilevel inverter. Based on a series connection of capacitor banks, this structure provides multiple levels in the output voltage waveform.The main impediments regarding this type of inverter are unbalanced capacitor voltages that necessitate multiple clamping diodes, and higher number of power. A detailed survey of applicable 9L inverters for distributed generation (DG) is presented in [4]. Also, a new topology with a cascade connection of

5L active neutral-point-clamped (ANPC) and 3L floating capacitor (FC) H-bridge is proposed. A combination of CHB with FC H-bridge presented in [5] consists of one dc source and eight switches only. However, regulation of FC voltage at $\frac{1}{3V_{dc}}$ requires additional circuit, while mere experimental results are presented. A configuration which includes 5L double flying capacitor multi cell (DFCM) converters cascaded with FC H-bridge is recommended in [6] to overcome the increased diversity factor in a DFCM converter. A 9L cross-connected intermediate level unit integrated with ANPC is introduced in [7]. Most of these topologies are hybrid combinations of one or more converter families (NPC, FC, and CHB). Many such hybridizations resulting in 9L RPC inverter are reported in literature [8-10]. Although for identical voltage levels, the topologies mentioned require a lesser number of components, the drawbacks associated are high-frequency switching of power devices, a lot of feedback sensors, increased voltage diversity factor and higher control complexity. From the industrial point of view, use of a high number of part counts in conventional multilevel inverters increases both the intricacy of the circuitry as well as the complexity of the control scheme involved. This eventually leads to higher cost implications and reduced reliability. Therefore, this letter presents a novel hybrid 9L inverter on the basis of reduced part count and using sensorless PWM technique. A detailed comparison is carried out and is presented to illustrate the distinctive characteristics and benefits of the proposed inverter. Firstly, a single-phase grid-connected system comprising the proposed topology is simulated, and then its loss evaluation is manifested through the simulation results. Further, a laboratory scale prototype of the proposed inverter is built. Simulation waveforms and experimental measurements are elucidated both for steady-state and transient operating conditions to validate the proposed hybrid inverter.

2 PROPOSED SYSTEM

Fig. 1 shows the power circuit topology of the proposed 9L inverter. It comprises mainly three units; a 3L TNPC cascaded with 3L FC H-bridge unit and two low-frequency switches (LFS) across the dc-link. With V dc being the total input voltage, the voltages across the dc-link capacitors and FC are equal to $\frac{V_{dc}}{2}$ and $\frac{V_{dc}}{4}$ respectively. The idea of cascading TNPC with FC yields in the following advantage of fewer number of power devices, power diodes, and capacitors, and more importantly it is modular in comparison with other inverters generating same number of levels. The resulting topology is adaptable for a higher number of voltage levels by appending more FC H-bridges as per the level requirement. Ideally, the inverter is capable of generating nine levels of output voltage: $\pm V_{dc}$, $\pm\frac{3V_{dc}}{4}$, $\pm\frac{V_{dc}}{2}$,$\pm\frac{V_{dc}}{4}$, 0. At a first glance, the cascade configuration of TNPC and FC with two LFS might seem inconspicuous. In the absence of a LFS unit, with the dc-link midpoint being the return path for the output current, the cascade combination of TNPC and FC can only generate five levels: $\pm\frac{V_{dc}}{2}$, $\pm\frac{V_{dc}}{4}$, 0. Also, in this case, the peak values of the output voltages are only half of the dc-link voltage, i.e.,$\pm\frac{V_{dc}}{2}$. However, with inclusion of two LFS units across the dc-link, it is possible to obtain full value of the dc-link voltage, i.e., $\pm V_{dc}$ for both positive and negative half cycles of the output voltage. As a result, it can synthesize output voltage with additional levels $\pm V_{dc}$ and $\pm\frac{3V_{dc}}{4}$ .For this, power switches are to be gated appropriately in a sequence. Table I summarizes all the possible switching combinations and their effect on the FC voltage. Assuming the devices to be ideal, FC is large enough and load as pure resistive, the active current path over a positive half cycle of the output voltage for each level is obtained as follows:

1. Maximum positive output (V_{dc}) : This voltage is designated as L_{4+} Switches S1, S3, and S4 are ON, connecting the terminal a to V_{dc} and $\bar{S}_5$ ON, connecting the terminal b to ground. Thus the voltage across the load is $V_0 = V_{dc} + 0 = V_{dc}$.

2. Three-fourth positive output ($\frac{3V_{dc}}{4}$): Two switching combinations are available. For L_{31+} , switches $\bar{S}_1$, $\bar{S}_2$ $\bar{S}_3$ and S_4 are ON, connecting the terminal a to $\frac{V_{dc}}{4}$, and $\bar{S}_5$ is ON, connecting the terminal b to ground. Thus the voltage across the load is $V_0 = V_{dc} - v_{dc} = \frac{3V_{dc}}{4}$. For L_{32+} , switches S_1 $\bar{S}_2$ S_3 and $\bar{S}_4$ are ON, connecting the terminal a to $\frac{-V_{dc}}{4}$ and $\bar{S}_5$ is ON, connecting the terminal b to ground.Thus the voltage across the load is $V_0 = V_{dc} - \frac{V_{dc}}{4} = \frac{3V_{dc}}{4}$.

3. Half-level positive output $\frac{V_{dc}}{2}$: This voltage is designated as L_{2+} . Switches $\bar{S}_1$, $\bar{S}_2$, S_3 and S_4 are ON, connecting the terminal a to $\frac{V_{dc}}{2}$, $\bar{S}_5$ and is ON, connecting the terminal b to ground. Thus the voltage across the load is $V_0 = \frac{V_{dc}}{2} + 0 = \frac{V_{dc}}{2}$.

4. One-fourth positive output ($\frac{V_{dc}}{4}$): Two switching combinations are available. For L_{11+} , switches S_2 , $\bar{S}_3$ and S_4 are ON, connecting the terminal a to ($\frac{V_{dc}}{4}$) , and is $\bar{S}_5$ ON, connecting the terminal b to ground. Thus the voltage across the load is $V_0 = 0 + \frac{V_{dc}}{4} = \frac{V_{dc}}{4}$. For L_{12+} , switches S_1 , $\bar{S}_2$, S_3 , and $\bar{S}_4$ are ON, connecting the terminal a to $\frac{+V_{dc}}{4}$ and $\bar{S}_5$ is ON, connecting the terminal b to ground. Thus the voltage across the load is $V_0 = \frac{V_{dc}}{2} - \frac{V_{dc}}{4} = \frac{V_{dc}}{4}$.

5. Zero output: Two switching combinations are available. For L_{0+} switches S_2 , S_3 , and S_4 are ON, con-

necting the terminal a to ground, and $\bar{S_5}$ is ON, connecting the terminal b to ground. For L_{0-} ,switches S_1 , S_3 and S_4 are ON, connecting the terminal a to V_{dc} and S_5 is ON, connecting the terminal b to V_{dc} . In both cases, the terminal ab is short circuited, and the voltage across the load is zero.

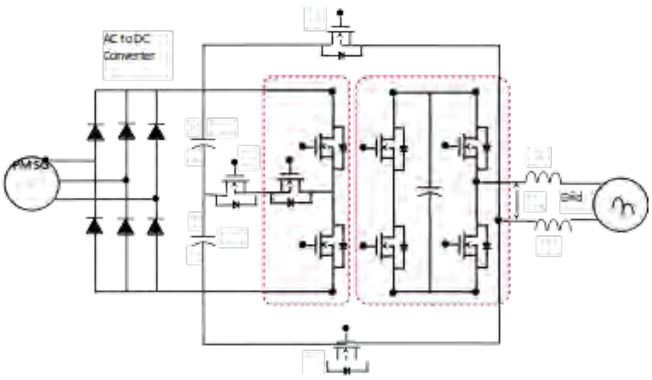


Figure 1: *The power circuit topology of the proposed 9L inverter.*

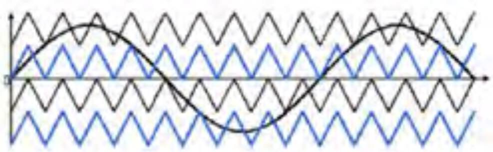


Figure 2: *9-level PWM schema using triangular carriers disposed to carry out PWM .*

The number of power switches conducting the circuit current plays a crucial role in determining the efficiency of the inverter. In the proposed inverter, this figure ranges from four switches to five switches, with one of the switches operating at low frequency (50 Hz). Consequently, the number of active power switches in the circuit current path is lower in comparison to [11-12] and hence, this topology has a better efficiency.

3 SENSORLESS V OLTAGE B ALANCING OF FC

One of the key targets of the proposed inverter control is to regulate FC voltage to one-quarter of the dc source voltage. It is clear from Table I that 14 switching states can provide different paths for load current among which ten states are beneficial in producing five levels, comprising $\frac{-3V_{dc}}{4}$, $\frac{-V_{dc}}{4}$, 0, $\frac{V_{dc}}{4}$ and $\frac{3V_{dc}}{4}$. This implies that there are a few switching states that provide a different path for the current through the system while maintaining the same output voltage level. This redundancy in switching states can be effectively utilized for

Table 1: Switching states and their impact on FC voltage of the Proposed inverter

States	**S1**	**S2**	**S3**	**S4**	**S5**	**Output voltage**	**FC voltage**
L_{4+}	1	0	1	1	0	Vdc	No effect
L_{31+}	0	0	0	1	0	3Vdc/4	Discharging
L_{32+}	1	0	1	0	0	3Vdc/4	Charging
L_{2+}	0	0	1	1	0	Vdc/2	No effect
L_{11+}	0	1	0	1	0	Vdc/4	Discharging
L_{12+}	0	0	1	0	0	Vdc/4	Charging
L_{0+}	0	1	1	1	0	0	No effect
L_{0-}	1	0	1	1	1	0	No effect
L_{11-}	1	0	1	0	1	-Vdc/4	Discharging
L_{12-}	0	0	0	1	1	-Vdc/4	Charging
L_{2-}	0	0	1	1	1	-Vdc/2	No effect
L_{31-}	0	0	1	0	1	-3Vdc/4	Discharging
L_{32-}	0	1	0	1	1	-3Vdc/4	Charging
L_{4-}	0	1	1	1	1	-Vdc	No effect

charging and discharging the FC voltage, thereby allowing it to balance around its requisite value. In order to arrive at an efficient design for the PWM controller, the effect of each possible and valid switching state on FC voltage is studied and reported in Table I. It is worth mentioning here that all the switching states do not result in deviation of the FC voltage. At each level of output voltage (except $\pm\frac{V_{dc}}{2}$ and $\pm V_{dc}$), switching state redundancies exist. Contrary to the general philosophy of voltage balancing using voltage sensor for sensing the FC voltage, a sensorless approach as proposed by [13] is slightly adapted and used in this proposed topology. This makes the proposed System more cost effective.

In order to stabilize and regulate the FC voltage, it is decided to charge FC during the positive half cycles of the fundamental voltage (viz, switching states L_{12+} and L_{32+}) and discharge during the negative half cycles (viz, switching states L_{11+} and L_{32+}) respectively. The charging and discharging time period of the FC is kept similar to one complete cycle of the fundamental output voltage, which leads to equalization of energy into and from the FC in every cycle of the output voltage and consequently, the voltage across the FC is maintained at the desired level in all conditions. Regarding the sizing of FC, the parameters to be considered for its design are; voltage ripple ΔV_c , switching frequency f_{sw} and the maximum value of load current (i_{pk}) . Thus, its value is calculated using the following formula:

$$C = \frac{I_{pk}}{\Delta V_c f_{sw}} \tag{1}$$

Selection of a higher switching frequency leads to shorter charging/discharging time thereby enhancing the balancing performance. While the voltage balancing concept is dependent on symmetric charging/discharging times, other factors like grid voltage distortion in the case of grid-connected renewable systems and the non idealities present in the real power devices/components do not affect its performance significantly [14-17].

4 MULTILEVEL PWM WITH INTEGRATED VOLTAGE BALANCING CONTROL

There are different control techniques available for a H- bridge MLI. Among all those techniques, PWM control technique which produces less total harmonic distortion (THD) values is most preferable. In PWM technique, modulated signal can be of pure sinusoidal, third harmonic injected signals and dead band signals. The carrier signal is a triangular wave. For generating triggering pulses of MLI, pure sinusoidal wave as modulating signal and multi carrier signal which is of triangular in shape have been considered [14], For a m-level MLI, m-1 carrier signals are required. For generation of triggering pulses to the cascaded MLI, carrier signals are constructed for different modulation indices using APOD, POD, PD, PS and Hybrid control techniques. In the present work, in the carrier-based implementation the phase disposition PWM scheme is used. There in, the a-phase modulation signal is compared with two (n-1 in general) triangle waveforms. The rules for the in phase disposition method, when the number of level N = 3, are

- The N −1 = 3-1=2 carrier waveforms are arranged so that every carrier is in phase.
- The converter is switched to −V dc /2 when the reference is greater than both carrier waveforms.
- The converter is switched to zero when the reference is greater than the lower carrier waveform but less than the upper carrier waveform.
- The converter is switched to −V dc /2 when the reference is less than both carrier waveforms.

In the carrier-based implementation, at every instant of time the modulation signals are compared with the carrier and depending on which is greater, the switching pulses are generated [18-20]. As seen from Figure 2, the figure illustrates the switching pattern produced by the carrier-based PWM scheme. In the PWM scheme there are two triangles, the upper triangle ranges from 1 to 0 and the lower triangle ranges from 0 to −1.In the similar way for an N−1 level inverter, the $(N-1)$ triangles are used and each has a peak-to-peak value of $\frac{2}{N-1}$.

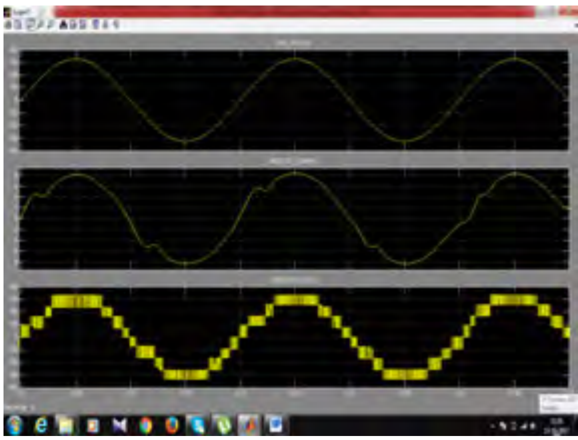
Hence the upper most triangle magnitude varies from 1 to $(1-\frac{2}{(N-1)})$, second carrier waveform from $(1-\frac{4}{(N-1)}$, and the bottom most triangle varies from $(2-\frac{2}{(N-1)})$ to −1 It is clear from the figure that during the positive cycle of the modulation signal, when the modulation is greater than Triangle 1 and Triangle 2, then S_{1ap} and S_{2ap} are turned on and also during the positive cycle $S2ap$ is completely turned on. When $S1ap$ and $S2ap$ are turned on, the converter switches to the $\frac{+V_{dc}}{2}$. When S_{1ap} and S_{2ap} are on, the converter switches to zero and hence during the positive cycle S_{2ap} is completely turned on and S_{1ap} and S_{1an} will be turning on and off and hence the converter switches from $+V_{dc}$ to 0. During the negative half cycle of the modulation signal the converter switches from 0 to $\frac{-V_{dc}}{2}$. The phase voltage equations for star-connected, balanced three-phase loads expressed in terms of the existence functions and input nodal voltage $V30=\frac{V_{dc}}{2}$, $V20=0$, $V10=\frac{-V_{dc}}{2}$.

5 SIMULATED PERFORMANCE OF PROPOSED SYSTEM

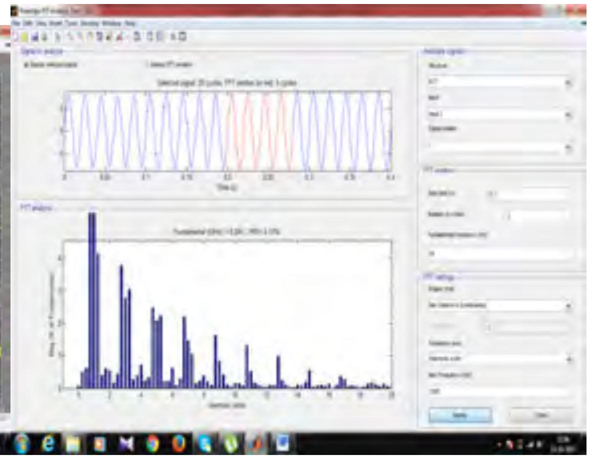
A single-phase grid connected setup shown in Fig. 1 is simulated using MATLAB/Simulink to verify the performance of the proposed inverter with its sensor less control. The results in Fig. 3(a) shows the grid voltage, grid current and inverter voltage of existing system. Fig. 3(b) shows the grid current THD over the percentage rated output power. Fig (c) shows a step change in reference grid current is applied. it is apparent from the resulting waveform that the actual results inverter current tracks the new reference value, as commanded within a cycle time, exhibiting high dynamic performance [21-23].The inverter is controlled to inject grid current at non unity power factor, while exchanging reactive power with the grid, thereby proving its stable operation as shown in the Fig 3 (d).Meanwhile, the FC voltage is observed to be well within its set value at all times. Further, analytical estimation of the switching losses, conduction losses and total losses for the proposed inverter is carried out. Fig. 3(e) shows the the grid current THD over the percentage rated output power. From the plots, it can be inferred that the proposed inverter exhibits an improved efficiency over the RPC topology. The 9L output voltage THD is about 2.62% without any additional filters, as depicted in Fig. 3(e). The above mentioned simulations results confirm the applicability of the proposed inverter for all possible real-time operating conditions.

6 Experimental Results

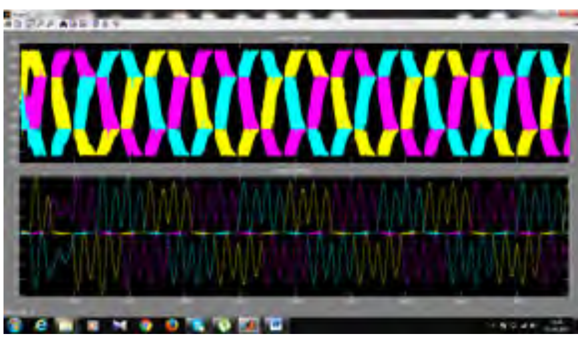
A down-scaled prototype of the proposed inverter is built to validate its performance. Discrete IRFP840



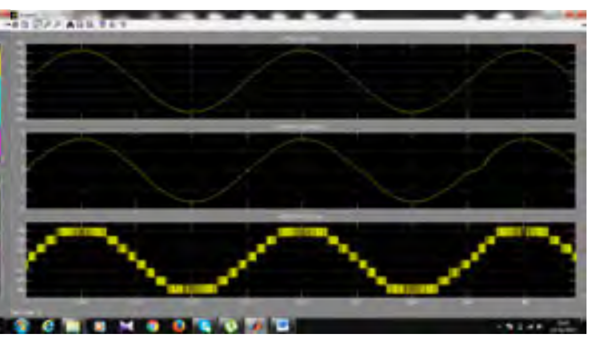
(a) Grid voltage, grid current,Inverter voltage of existing system.



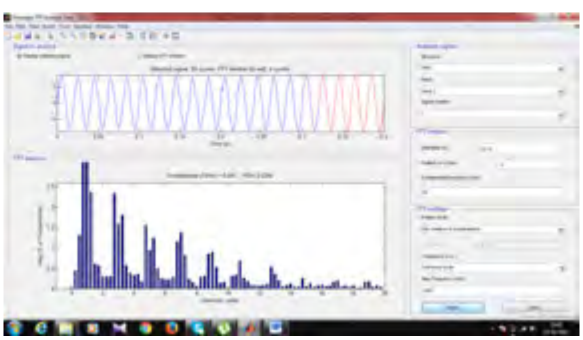
(b) grid current THD for existing system



(c) Wind voltage and wind current



(d) Grid voltage, grid current. Inverter voltage of proposed



(e) grid current THD for proposed system

Figure 3: Simulation results

MOSFETs are used as switching devices gated with 7667 drivers. DSPIC 30f4011 is used as a core controller to implement the proposed control algorithm in real-time. A capacitance value of 1.1 mF is used for all the capacitors in the experiment. The dc-link voltage Vdc is set to 48 V and a resistive-inductive load of 500 ohm connected at the output. To appraise the performance of the proposed topology and its control, experimental results are elucidated. Fig. 4(a)-(d) shows the steady state voltage across switching pulse FC, inverter output voltage and load current. It is evident from Fig. 4(e) that the FC voltage remains stabilized at its requisite value (12 V) against variations in the modulation indices. The voltage across the dc-link capacitors depicting the natural balancing property of the proposed inverter is shown in Fig. 4(c).

The above mentioned experimental results confirm the applicability of the proposed inverter for all possible real-time operating conditions.

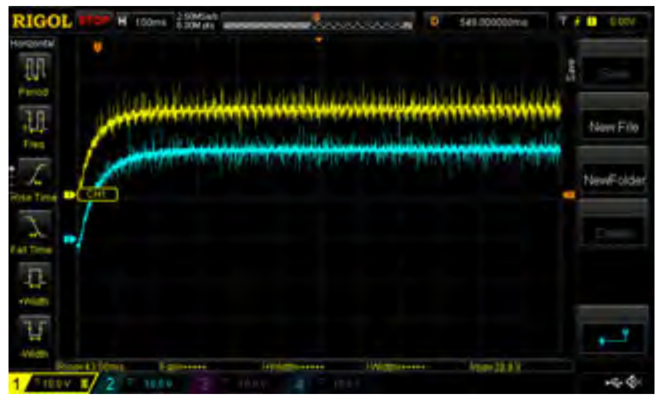
7 CONCLUSION

Multilevel inverters are being developed and extensively exploited for generating high quality output voltages for numerous medium-voltage application fields. Applications urging a higher number of voltage levels escalate the number of components required. But use of high number of part counts in conventional multilevel inverters increases both the circuit intricacies as well as the control scheme involved, thereby resulting in higher cost implications and reduced reliability. Therefore, to subdue these disadvantages, this letter proposes a novel hybrid 9L inverter topology formed by cascading a TNPC and FC with two LFS connected across the dc link. This is achieved using only ten power switches (among which two are operated at line frequency). Only one FC is incorporated in the circuit for generating the 9L output voltage. Further, it is confirmed that the proposed inverter structure has improved reliability and by cascading additional FCs, it can be effortlessly extended to obtain even higher number of voltage levels. In addition, a sensorless PWM technique based on the principle of energy balance for regulating the voltage of FC is suggested. An exhaustive review of recently proposed multilevel inverter topologies with RPC applicable for grid integration of renewable sources is carried out and the ensuing comparison certifies the merits of the proposed topology over conventional inverters.

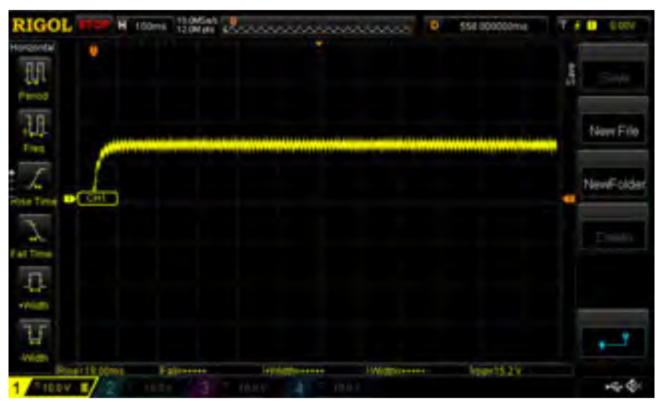
References

[1] R.Rajkumar, K.Ramanathan, M.Venkatesh Kumar,"Review On Various Multilevel Inverter Topologies For Renewable Energy Sources" International

(a) Gate Pulse Of Switch S1, S2 ,S3 & S4



(b) DC link Capacitor Cdc1 and Cdc2 Voltage.



(c) FC Capacitor voltage,

(d) Nine Level Inverter Output Voltage.

Figure 4: Hardware results

Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.4 (2015) PP. 3762-3765.

[2] A. Amudha, , M. Siva Ramkumar , M. Sivaram Krishnan “Perturb and Observe Based Photovoltaic Power Generation System For Off-Grid Using Sepic Converter” International Journal of Pure and Applied Mathematics , 114(7), pp. 619-628 , 2017 .

[3] M. Siva Ramkumar, M. Sivaram Krishnan, A. Amudha, “Resonant Power Converter Using GA For PV Applications” International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[4] M. Siva Ramkumar, M. Sivaram Krishnan, A. Amudha, “Impedance Source Inverter and Permanent Magnet Synchronous Generator For Variable Speed Wind Turbine ” International Journal of Computer & Mathematical Sciences, 6 (9) pp 98-105, 2017.

[5] M. Siva Ramkumar “Unmanned Automated Railway Level Crossing System Using Zigbee” in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017.

[6] M.Subramanian, M. Siva Ramkumar, A. Amudha, , K.Balachander and D.Kavitha “Power Quality Improvement In Low Voltage Transmission System Using Static Compensator” in International Journal of Control Theory and Applications (IJCTA) 10 (38) pp 247-261, 2017.

[7] M. R. Latha, S. Kuppusamy, A. Amudha, K. Balachander, M. Siva Ramkumar “ An Efficient Single Stage Converter Based Pv-Dvr For Improving Voltage Quality” in International Journal of Control Theory and Applications, 10 (38) pp 177-193, 2017.

[8] M. Sivaram Krishnan, M. Siva Ramkumar, “Power Management of a Hybrid Solar-Wind Energy System, International Journal of Engineering Research & Technology, 2 (1) pp 1988-1992.

[9] Emayavaramban. G, Amudha. A, ‘sEMG Based Classification of Hand Gestures using Artificial Neural Networks’, Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[10] Emayavaramban. G, Amudha. A, ‘Recognition of sEMG for Prosthetic Control using Static and Dynamic Neural Networks’, International Journal of Control Theory and Applications,Vol.2 (6), pp.155-165, September 2016.

[11] Emayavaramban. G, Amudha.A, ‘Identifying Hand Gestures using sEMG for Human Machine Interaction’, ARPN Journal of Engineering and Applied Sciences, Vol.11 (21), pp.12777-12785, November 2016.

[12] Ramkumar. S, Elakkiya. A, Emayavaramban. G, ‘Kind Data Transfer Model - Tracking and Identification of Data Files Using Clustering Algorithms’, International Journal of Latest Technology in Engineering, Vol.3 (8), pp.13-21, August 2014.

[13] D. Manoharan, A. Amudha. “Condition Monitoring And Life Extension Of EHV Transformer” International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)

[14] D. Manoharan, A. Amudha. A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6233-6240.

[15] K. Balachander, “Design and Hardware Implementation of Speed Control of Induction Motor using Z - Source Inverter”, International Journal of Electronics Engineering Research, Vol. 9(6), pp. 931-937.

[16] K. Balachander, A. Amudha,” Design and Hardware Implementation of Interleaved Boost Converter Using Sliding Mode Approach”, International Journal of Electronics Engineering Research, Volume 9, Number 5 (2017) pp. 745-750

[17] K. Balachander, P. Vijayakumar, “Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ”, American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[18] K. Balachander, P. Vijayakumar, “Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India”, Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[19] K. Balachander, V. Ponnusamy, ‘Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System’ International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[20] K. Balachander, S. Kuppusamy, V. Ponnusamy, ‘Modeling and Simulation of VSDFIG and PMSG Wind Turbine System’, International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[21] K. Balachander, S. Kuppusamy, V. Ponnusamy, ‘" Comparative Study of Hybrid Photovoltaic-Fuel Cell System / Hybrid Wind-Fuel Cell System

for Smart Grid Distributed Generation System" Proceedings of IEEE International Conference on Emerging Trends in Science, Engineering and Technology at JJ College of Engineering, Trichy on 13 th and 14 th December 2012. DOI: 10.1109/ INCOSET. 2012.6513950, pp.462-466

[22] Shanthi and S.P. Natarajan "Comparative Study on Uni polar Multi carrier PWM Strategies for Five Level Flying Capacitor Inverter", International conference on control automation communication and energy conservation-2009.4th- 6th June 2009.

POWER GRID CONNECTED SEMI-Z SOURCE INVERTER SUPPLIED BY PHOTOVOLTAIC AND WIND SYSTEM WITH A NEW MODULATION STRATEGY

D. Babu, A. Amudha, K. Balachander, G. Emayavaramban, M. Siva Ramkumar

Abstract: In recent years, due to energy crisis, renewable energy distributed power generators, such as wind turbine, photovoltaic (PV) cell, fuel cell, and thermoelectric generation modules, are becoming more and more popular in industrial and residential applications. Many renewable energy such as PV cell, fuel cell and thermoelectric generation can only output dc voltage. So an inverter interface has to be utilized for grid-connected applications. So many inverter topologies have been proposed and reviewed recently like as Z-source proposed inverter. In this proposed semi-Z-source inverters for a single-phase photovoltaic (PV) system. With low cost and doubly grounded features.These semi-Z-source inverters only two active switches. To achieve the same output voltage as the traditional voltage-fed full-bridge z-source inverter. The input dc source and the output ac voltage of the semi-Z-source inverter share the same ground. Thus lead into less leakage ground current advantages over other non-doubly grounded inverters.

Keywords: Photovoltaic system (PV), Z-Source Inverter, Modulation strategy.

1 Introduction

How can we increase the amount of photovoltaic (PV) generation? From this viewpoint, we are over viewing electric facilities from power plants to electric appliances in demand sites. PV modules generate DC electric power. The power should be converted to AC that is synchronized with commercial grids to be transmitted and distributed to demand sites. To reduce energy dissipation through the transmission, the power is sent near the demand site after being raised the electric voltage to 66 kV or higher. The power is transformed to 100 V and provided to residential outlets after multi-processed reduction in voltage at substations and pole-mounted transformers. Therefore, we should consider how we can establish efficient transmission and distribution systems for PV generation in addition to cost, efficiency and lifetime for generation facilities, if we utilize the power source as infrastructure [1-6]. Transmission facilities for PV generation often stay idle as well as generation facilities themselves, because they do not yield electricity during night and poor weather. If contribution from solar power were much smaller than transfer capability, existing facilities could take care of it. To understand this problem easily, we assume a huge PV farm comparable to a nuclear power plant with a giga wattage class output. PV generation, which has poor yield for its footprint, needs vast ground to generate such a big power. Consequently, the generation facilities must be set up in sites far from consuming regions. Transmission facilities must have enough large capacity for maximum current which can be generated under the best weather condition. They do not work during off-generating time such as at night and under poor sunshine. If PV plants supplied constant huge power as dam type hydraulic or nuclear plants, we would make choice of a far-reaching transmission system that connects distant sources and a consuming centre [7-13]. Electric power storage devices, such as batteries, can absorb fluctuation of PV generation and equalize power transmission. However, this scheme reduces capacity of transmission facilities and requires rather huge additional cost for the huge accumulators. Therefore, until drastically reduced cost is available for storage devices, we cannot adopt this method. Then, put gas turbines together, with which we are able to adjust output power rather rapidly. The combined plant can absorb the fluctuation of PV generation, and consequently, improve the operation ratio for transmissions. However, it requires a parallel established thermal power plant comparable to the PV, which is a roundabout way for our initial goal, the introduction of a large amount of PV. As mentioned above, large scale PV plants in remote sites have a serious problem on economic efficiency. We need a new power system that enables the introduction of a massive amount of distributed PV units in demand sites. This article proposes DC micro grid systems as an option for such a purpose [14-21]. THE Z-source inverter (ZSI) was proposed in 2002 as an alternative to the traditional dc-ac converter. The ZSI fulfills the buck-boost function in a single-stage converter by utilizing a Z-source network, consisting of two identical inductors, two identical capacitors, and a diode. By employing an extra switching state, called shoot-through state, the ZSI can boost the input dc voltage to the desired dc link voltage. In comparison with the traditional two-stage inverter (consisting of a dc-dc boost converter and a voltage source inverter), the ZSI has a better efficiency, simpler design, and reduced cost. The Z-source inverter (ZSI) was presented as an improved version of the classical ZSI. It has many additional advantages such as continuous input current and joint earthing of the dc source and the dc-link bus. Moreover, the voltage of one of the quasi-Z-source network capacitors is significantly reduced resulting in a smaller passive components size. Taking into account the aforementioned characteristics, the ZSI can be considered as an attractive candidate for several power electronics applications, including photovoltaic applications [22-25].

2 PHOTOVOLTAIC SYSTEM AND WECS

Converting solar energy into electrical energy by PV installations is the most recognized way to use solar energy. Since solar photovoltaic cells are semiconductor devices, they have a lot in common with processing and production techniques of other semiconductor devices such as computers and memory chips. As it is well known, the requirements for purity and quality control of semiconductor devices are quite large. With today's production, which reached a large scale, the whole industry production of solar cells has been developed and, due to low production cost, it is mostly located in the Far East. Photovoltaic cells produced by the majority of today's most large producers are mainly made of crystalline silicon as semiconductor material.. Solar photovoltaic modules, which are a result of combination of photovoltaic cells to increase their power, are highly reliable, durable and low noise devices to produce electricity. The fuel for the photovoltaic cell is free. The sun is the only resource that is required for the operation of PV systems, and its energy is almost inexhaustible. A typical photovoltaic cell efficiency is about 15%, which means it can convert 1/6 of solar energy into electricity. Photovoltaic systems produce no noise, there are no moving parts and they do not emit pollutants into the environment. Taking into account the energy consumed in the production of photovoltaic cells, they produce several tens of times less carbon dioxide per unit in relation to the energy produced from fossil fuel technologies. Photovoltaic cell has a lifetime of more than thirty years and is one of the most reliable semiconductor products. Most solar cells are produced from silicon, which is non-toxic and is found in abundance in the earth's crust. Figure 1 shows the photovoltaic cell. Photovoltaic systems (cell, module, network) require minimal maintenance. At the end of the life cycle, photovoltaic modules can almost be completely recycled. Photovoltaic modules bring electricity to rural areas where there is no electric power grid, and thus increase the life value of these areas. Photovoltaic systems will continue the future development in a direction to become a key factor in the production of electricity for households and buildings in general. The systems are installed on existing roofs and/or are integrated into the facade. These systems contribute to reducing energy consumption in buildings. A series of legislative acts of the European Union in the field of renewable energy and energy efficiency have been developed, particularly promoting photovoltaic technology for achieving the objectives of energy savings and CO2 reduction in public, private and commercial buildings. Also, photovoltaic technology, as a renewable energy source, contributes to power systems through diversification of energy sources and security of electricity supply. By the introduction of incentives for the energy produced by renewable sources in all developed countries, photovoltaic systems have become very affordable, and timely return of investment in photovoltaic systems has become short and constantly decreasing. In recent years, this industry is growing at a rate of 40% per year and the photovoltaic technology creates thousands of jobs at the local level.

Figure 1: *Photovoltaic cell.*

2.1 Functioning of the PV cells

The word photovoltaic consists of two words: photo, a greek word for light, and voltaic, which defines the measurement value by which the activity of the electric field is expressed, i.e. the difference of potentials. Photovoltaic systems use cells to convert sunlight into electricity. Converting solar energy into electricity in a photovoltaic installation is the most known way of using solar energy. The light has a dual character according to quantum physics. Light is a particle and it is a wave. The particles of light are called photons. Photons are massless particles, moving at light speed. In metals and in the matter generally, electrons can exist as valence or as free. Valence electrons are associated with the atom, while the free electrons can move freely. In order for the valence electron to become free, he must get the energy that is greater than or equal to the energy of binding. Binding energy is the energy by which an electron is bound to an atom in one of the atomic bonds. In the case of photoelectric effect, the electron acquires the required energy by the collision with a photon. Part of the photon energy is consumed for the electron getting free from the influence of the atom which it is attached to, and the remaining energy is converted into kinetic energy of a now free electron. Free electrons obtained by the photoelectric effect are also called photoelectrons. The energy required to release a valence electron from the impact of an atom is called a work out Wi, and it depends on the type of material in which the photoelectric effect has occurred.

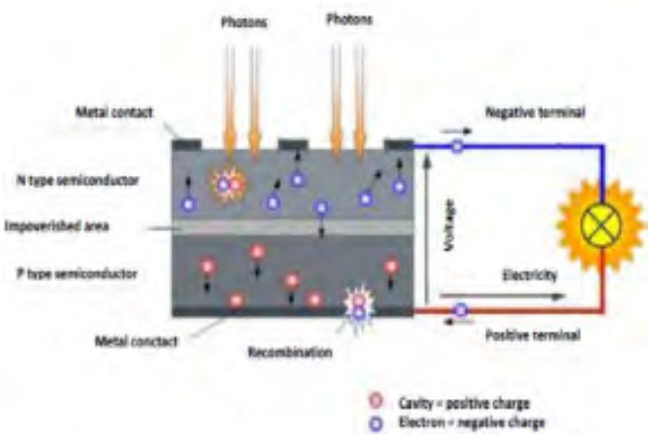


Figure 2: *Functioning of PV cell.*

The previous equation shows that the electron will be released if the photon energy is less than the work output. The photoelectric conversion in the PV junction. PV junction (diode) is a boundary between two differently doped semiconductor layers; one is a P-type layer (excess holes), and the second one is an N-type (excess electrons). At the boundary between the P and the N area, there is a spontaneous electric field, which affects the generated electrons and holes and determines the direction of the current. To obtain the energy by the photoelectric effect, there shall be a directed motion of photoelectrons, i.e. electricity. All charged particles, photoelectrons also, move in a directed motion under the influence of electric field. The electric field in the material itself is located in semiconductors, precisely in the impoverished area of PV junction (diode). It was pointed out for the semiconductors that, along with the free electrons in them, there are cavities as charge carriers, which are a sort of a byproduct in the emergence of free electrons. Cavities occurs whenever the valence electron turns into a free electron, and this process is called the generation, while the reverse process, when the free electron fills the empty spaces - a cavity, is called recombination. If the electron-cavity pairs occur away from the impoverished areas it is possible to recombine before they are separated by the electric field. Photoelectrons and cavities in semiconductors are accumulated at opposite ends, thereby creating an electromotive force. If a consuming device is connected to such a system, the current will flow and we will get electricity. In this way, solar cells produce a voltage around 0,5-0,7 V, with a current density of about several tens of mA/cm2 depending on the solar radiation power as well as on the radiation spectrum. The usefulness of a photovoltaic solar cell is defined as the ratio of electric power provided by the PV solar cells and the solar radiation power. The usefulness of PV solar cells ranges from a few percent to forty percent. The remaining energy that is not converted into electrical energy is mainly converted into heat energy and thus warms the cell. Generally, the increase in solar cell temperature reduces the usefulness of PV cells. Standard calculations for the energy efficiency of solar photovoltaic cells are explained below. Energy conversion efficiency of a solar photovoltaic cell (η "ETA") is the percentage of energy from the incident light that actually ends up as electricity. This is calculated at the point of maximum power, Pm, divided by the input light irradiation (E, in W/m2), all under standard test conditions (STC) and the surface of photovoltaic solar cells (AC in m2). STC - standard test conditions, according to which the reference solar radiation is 1.000 W/m2, spectral distribution is 1.5 and cell temperature 250C.

2.2 Types of solar PV cells

Electricity is produced in solar cells which, as noted, consist of more layers of semiconductive material. When the sun's rays shine down upon the solar cells, the electromotive force between these layers is being created, which causes the flow of electricity. The higher the solar radiation intensity, the greater the flow of electricity. The most common material for the production of solar cells is silicon. Silicon is obtained from sand and is one of the most common elements in the earth's crust, so there is no limit to the availability of raw materials. Solar cell manufacturing technologies are:

- Monocrystalline
- Polycrystalline
- Bar-crystalline silicon
- Thin-film technology

Cells made from crystal silicon (Si), are made of a thinly sliced piece (wafer), a crystal of silicon (monocrystalline) or a whole block of silicon crystals (multicrystalline); their efficiency ranges between 12% and 19%. Monocrystalline Si cells: conversion efficiency for this type of cells ranges from 13% to 17%, and can generally be said to be in wide commercial use. In good light conditions it is the most efficient photovoltaic cell. This type of cell can convert solar radiation of 1.000 W/m2 to 140 W of electricity with the cell surface of 1m2. The production of monocrystalline Si cells requires an absolutely pure semiconducting material. Monocrystalline rods are extracted from the molten silicon and sliced into thin chips (wafer). Such type of production enables a relatively high degree of usability. Expected lifespan of these cells is typically 25-30 years and, of course, as well as for all photovoltaic cells, the output degrades somewhat over the years. It is shown in figure 3. Multicrystalline Si cells: this type of cell can convert solar radiation of 1.000 W/m2 to 130W of electricity with the cell surface of 1m2. The production of these cells is economically more efficient compared to monocrystalline. Liquid silicon is poured into blocks, which are then cut into slabs. During the solidification of materials crystal structures of various sizes are being created, at whose borders some defects may emerge, making the solar cell to have a somewhat lower efficiency, which ranges from 10% to 14%. The lifespan is expected to be between 20 and 25 years.

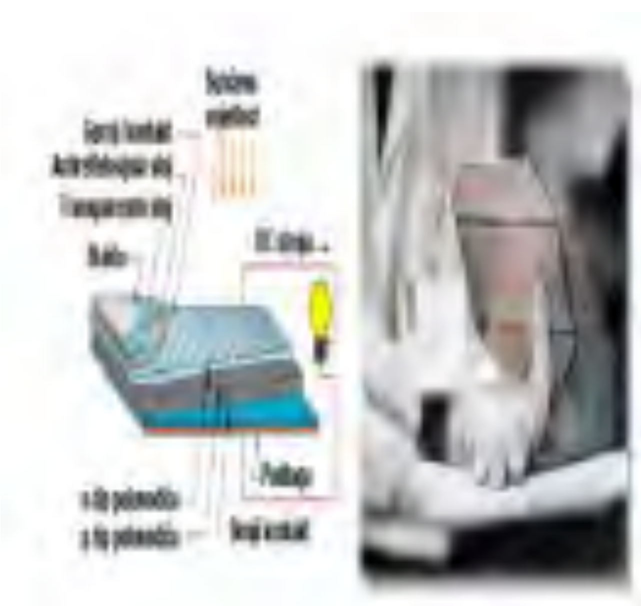


Figure 3: *Typical monocrystalline cells.*

Ribbon silicon has the advantage in its production process in not needing a wafer cutting (which results in loss of up to 50% of the material in the process of cutting). However, the quality and the possibility of production of this technology will not make it a leader in the near future. The efficiency of these cells is around 11%. In the thin-film technology the modules are manufactured by piling extremely thin layers of photosensitive materials on a cheap substrate such as glass, stainless steel or plastic. The process of generating modules in thin-film technology has resulted in reduced production costs compared to crystalline silicon technology, which is somewhat more intense. Today's price advantage in the production of a thin-film is balanced with the crystalline silicon due to lower efficiency of the thin-film, which ranges from 5% to 13%. The share of thin-film technology on the market is 15% and constantly increasing, it is also expected an increase in years to come and thus reduce the adverse market ratio in relation to the photovoltaic module of crystalline silicon. Lifespan is around 15-20 years. There are four types of thin-film modules (depending on the active material) that are now in commercial use:

- Amorphous silicon (a-Si)
- Cadmium Tellurium (CdTe)
- Copper indium gallium selenide (CIS, CIGS)
- Thermo sensitive solar cells and other organ cells (DSC)

The development of these organic cells is yet to come, since it is still testing and it is not increasingly commercialized. Cell efficiency is around 10%. The tests are going in the direction of using the facade integrated systems, which has proven to be high-quality solutions in all light radiation and all temperature conditions. Also, a great potential of this technology is in low cost compared to silicon cells. There are other types of photovoltaic technologies that are still developing, while others are to be commercialized. Regardless of the lifespan, the warranty period of today's most common commercial photovoltaic modules is 10 years at 90% power output, and 25 years at 80% power output.

2.3 Energy depreciation of PV cells

The period of energy depreciation of photovoltaic cells is the time period that must pass using a photovoltaic system to return the energy that has been invested in the construction of all parts of the system, as well as the energy required for the breakdown after the lifetime of a PV system. Of course, the energy depreciation time is different for different locations at which the system is located, thus it is a lot shorter on locations with a large amount of irradiated solar energy, up to 10 or more times shorter than its lifetime. South Istria has approximately 1.700 kWh/m2 annual radiation, while the northern part of Istria has somewhere around 1.500 kWh/m2.

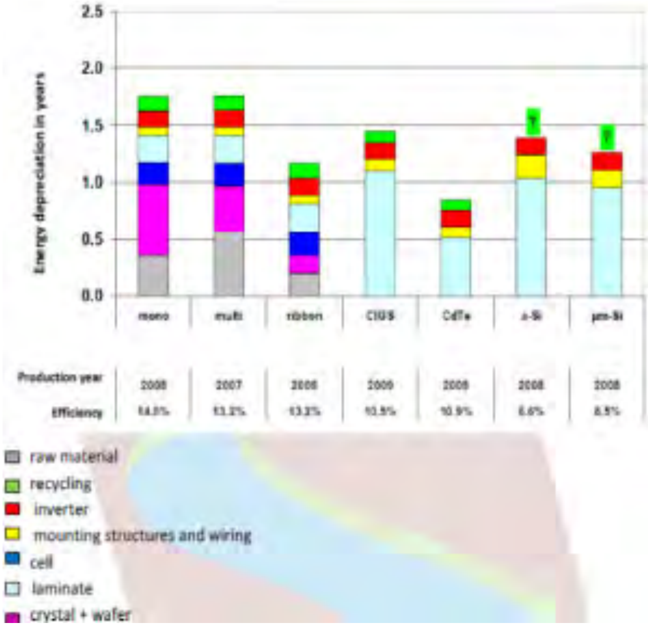


Figure 4: *Availability of energy.*

The figure 4 shows the available data on the energy depreciation for the various technologies of photovoltaic cells, with their respective efficiencies in given years of production. In relation to the south of Istria, which is shown in Figure 2.7, the energy depreciation in the city of Zagreb is, for example, about 20% longer, in southern Dalmatia is 10 to 15% shorter than in Istria, which corresponds to solar radiation intensity-insolation map.

2.4 WECS

Figure 5 represents the complete wind energy conversion systems (WECS), which converts the energy present in the moving air (wind) to electric energy. The wind passing through the blades of the wind turbine generates a force that turns the turbine shaft. The rotational shaft turns the rotor of an electric generator, which converts mechanical power into electric power. The major components of a typical wind energy conversion system include the wind turbine, generator, interconnection apparatus and control systems. The power developed by the wind turbine mainly depends on the wind speed, swept area of the turbine blade, density of the air, rotational speed of the turbine and the type of connected electric machine.

As shown in figure 5, there are primarily two ways to control the WECS. The first is the Aerodynamic power control at either the Wind Turbine blade or nacelle, and the second is the electric power control at an interconnected apparatus, e.g., the power electronics converters. The flexibility achieved by these two control options facilitates extracting maximum power from the wind during low wind speeds and reducing the mechanical stress on the wind turbine during high wind speeds.

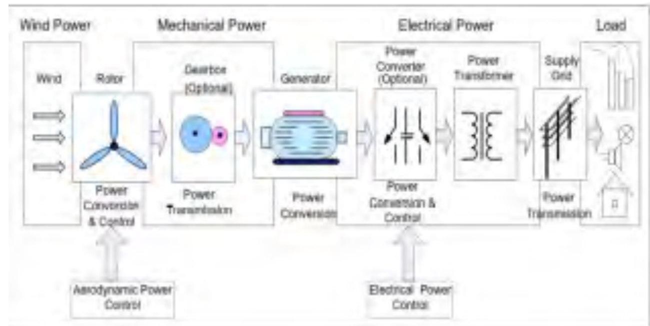


Figure 5: *Wind Energy Conversion System.*

3 Z-SOURCE INVERTER

The objective of this chapter is to describe theoretical, mathematical analysis and the merits of Impedance Source (Z - Source) Inverter and to compare with the conventional source inverters. Bridge rectifier is commonly used in high power applications. The impedance network is a two port network. A two port network has two input terminals and two output terminals. This network is also called as lattice network. This lattice network consists of split inductors (L1 and L2) and capacitors (C1 and C2) in X -shape. Three Phase AC supply is given to the rectifier unit; rectification is a process of converting alternating current or voltage into a direct current or voltage. The Impedance Source (Z - Source) Inverter consists of voltage source from rectifier supply, impedance network, three phase inverter and with AC motor load. This impedance network is coupled with inverter main circuit and source. This impedance network is a second order filter. This network is energy storage or filtering element for the Impedance Source Inverter. DC to AC converters is known as inverter. The function of an inverter is to change a DC input voltage to AC output voltage of desired magnitude and frequency. Three phase inverters are normally used for high power applications. We choose 120' conduction for proper and reliable operation of inverter. MOSFET have chosen for three-phase inverter. There are three modes of operation of one half cycle for Y-connected load. This Impedance Source (Z - Source) Inverter is used to overcome the problems in the conventional source inverters. This Impedance (2 - Source) Source Inverter employs a unique impedance network coupled with the inverter main circuit to the power source. This inverter has unique features compared with the conventional sources.

3.1 Block diagram of z-source inverter system

Three phase A.C. supply is fed to the rectifier, which will convert threephase A.C. supply to D.C. The rectified D.C. supply is now given to an inverterthrough an impedance network. The impedance inverter output is now fed tothe AC load as input. The process is explained in the flow diagramshown in figure 6.

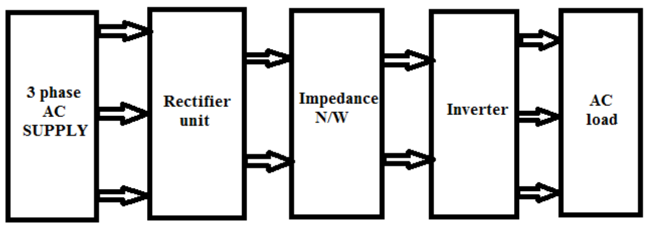


Figure 6: *Block diagram of the Z-source system.*

3.2 Theoretical analysis

Impedance network is a two port network. A two port network is simply a network inside a box and the network has only two pairs of accessible terminals. Usually one pair represents the input and the other represents output. This network is also called as lattice network. Lattice network is one of the common four terminals two port network. The lattice network is used in filter sections and is also used as attenuators. Lattice networks are sometimes used in ladder structure in some special applications. In this lattice network, L1 and L2 series arm inductances, C1 and C2 are diagonal capacitances. This network is coupled with the main circuit and the source, to describe the operating principle of inverter.

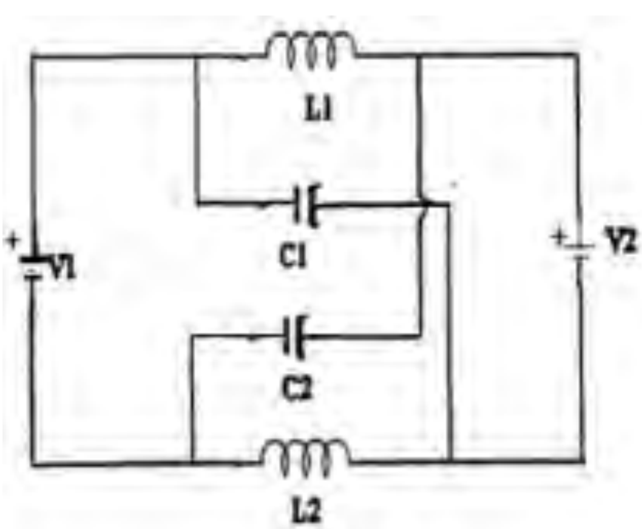


Figure 7: *Equivalent circuit of Z-source inverter.*

The Impedance Source Inverter (Z - Source) bridge has one extra zero state. When the load terminals are shorted through both upper and lower devices of any one phase leg or all three phase legs this shoot through zero state is forbidden in Voltage Source Inverter (VSI), because it would cause a Shoot-Through. This network makes the Shoot Through zero state possible. This state provides unique buck-boost feature to the inverter. The equivalent circuit of the Impedance Source Inverter (2 - Source) is shown figure 6. The inverter bridge is equivalent to a short circuit when the inverter bridge is in the Shoot-Through zero state. The equivalent switching frequency from the impedance source network is six times the switching frequency of the main inverter, which greatly reduces the required inductance of the impedance source network.

3.3 Description of z- source network

The impedance Source Network is a combination of two inductors and two capacitors. This combined circuit, the impedance Source Network is the energy storage or filtering element for the Impedance Source Inverter (Z-Source). This impedance source network provides a second order filter. This is more effective to suppress voltage and current ripples. The inductor and capacitor requirement should be smaller compared to that of conventional inverters. When the two inductors and L2) are small and approach zero, the Impedance source network reduces to two capacitors (C1 and C2) in parallel and becomes conventional voltage source inverter. Therefore, a conventional voltage inverter's capacitor requirements and physical size is the worst case requirement for the Impedance Source Inverter (Z - Source). Considering additional filtering and energy storage provided by the inductors, the Impedance Source Network should require less capacitance and smaller size compared with the conventional Voltage Source Inverter (VSI).

3.4 Impedance source inverter

To overcome the above problems of the conventional Voltage Source and Current Source inverters, this work presents an impedance - source (or impedance-fed) power converter (abbreviated as Z - source converter) and its control method for implementing DC - to - AC, AC - to - DC, AC - to - AC, and DC - to - DC power conversion. Figure 3.3 shows the general Impedance Source Inverter (Z - Source) structure. In figure 8, a two-port network that consists of a split-inductor and capacitors connected in X shape is employed to provide an impedance source (Z-source) which connects the converter (or inverter) to the DC source or another converter. The DC source load can be either a voltage or a current source load. Therefore, the DC source can be a battery, diode rectifier, thyristor converter, fuel cell, an inductor, a capacitor, or a combination of all these. Switches used in the converter can be a combination of switching devices and diodes such as the anti-parallel combination and the series combination as shown in figure 7. The inductance can be provided through a split inductor or two separate inductors.

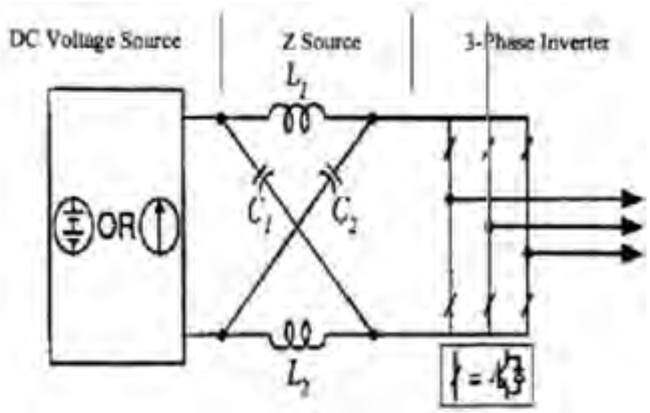


Figure 8: *Z-source inverter structure using antiparallel combination of switching device and diode.*

The Z - source employs a unique impedance network (or circuit) to couple the converter main circuit to the power source, load, or another converter, for providing unique features that cannot be observed in the traditional V and I source converters where a capacitor and inductor are used, respectively. The Z-source converter overcomes the above-mentioned conceptual and theoretical barriers and limitations of the traditional Voltage Source Inverter and Current Source Inverter and provides a novel power conversion concept. The Z-source concept can be applied to all DC-to-AC, AC-to-DC, AC-to-AC, and DC-to-DC power conversion. This work focuses on application of the Z-Source inverter fed Induction Motor Drive: a Z-Source inverter for DC to AC power conversion needed for Induction Motor.

3.5 Operation and control

Impedance Source (Z - Source) Inverter is thought to be a one - stage boost - buck inverter and one - stage topology which is somewhat considered as having higher efficiency over its counterpart of two-stage shown in figure 9. Impedance Source (Z - Source) Inverter has a special impedance network between the bridge and the input voltage source.

This special circuit structure makes Impedance Source (Z - Source) Inverter which has an additional Shoot-Through (ST) switching state in which the upper DC rail and lower rail are shorted together. In Shoot-Through

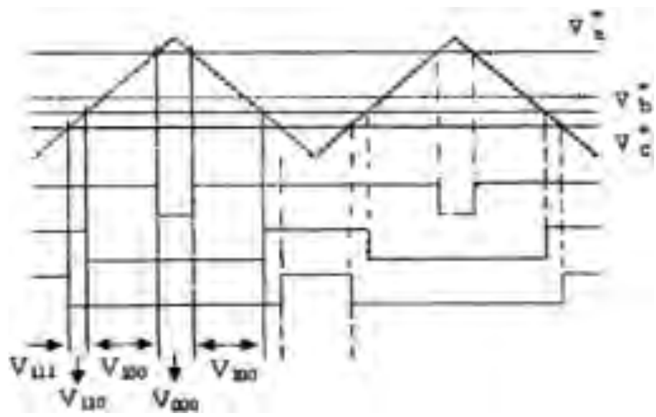


Figure 9: *PWM strategies of ZSI.*

state the two inductors are being charged by the capacitors and in Non-shoot-Through (NST) states the inductors and input DC source transfers energy to the capacitors and load. This process is similar to the boost converter. Seen from the AC side the Shoot-Through states are the same with null states, so by replacing the null states with Shoot-Through states, the boost function of Impedance Source (2 - Source) Inverter is achieved.

There are typically two categories of Pulse Width Modulation strategies for Impedance Source (Z - Source) Inverter according to the different Shoot-Through state insertion methods. The principle of this method is that the Shoot-Through states are inserted at every transition by overlapping the upper and lower driver signals.

The upper and lower driver signals can be derived by properly level shifting the modulation signals of Voltage Source Inverter (VSI) as shown in figure 8. The shifting values are set properly so as to ensure the occupied duration of the two null states to be the same. The feature of this modulation strategy is that the transition time in one switching cycle is the same with Voltage Source Inverter (VSI), the Shoot-Through ST state is divided into six parts and the equivalent switching frequency of impedance network is six times of switching frequency. Therefore the volume of inductors could be reduced drastically.

4 PROPOSED SYSTEM

Figure 10 shows the block diagram of the power grid connected semi-z-source inverter which is supplied by photovoltaic system. The semi-z-source inverter is controlled by PWM controller with new modulation strategy. The semi-z-source inverter comprises of DC-DC boost converter and DC-AC inverter. Figure 11 shows multiple DC sources with z-source converter which is connected in power grid.

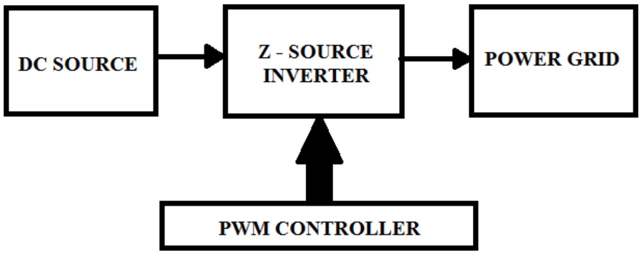


Figure 10: *Block diagram of proposed system.*

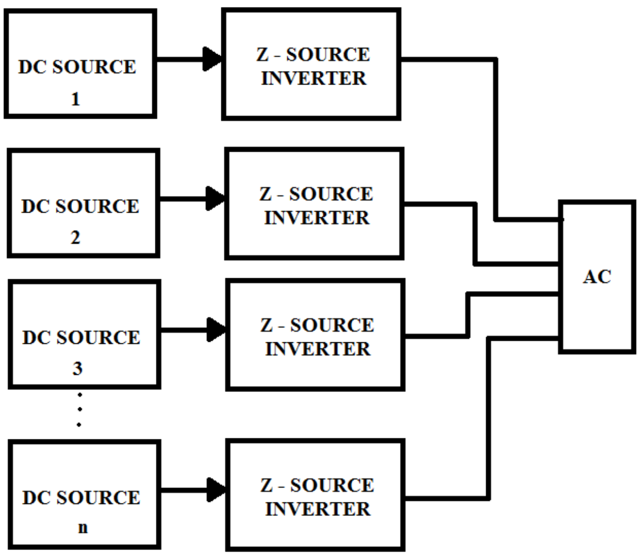


Figure 11: *Semi-z-source inverter with multiple DC sources.*

4.1 PV supplied semi-z-source inverter

As of late, because of vitality emergency, sustainable power source dispersed power generators, for example, wind turbine, photovoltaic (PV) cell, energy component, and thermoelectric era modules, are ending up increasingly well known in mechanical and private applications. Numerous sustainable power source, for example, PV cell, energy unit, thermoelectric era can just yield dc voltage. So an inverter interface must be used for matrix associated applications. Such huge numbers of inverter topologies have been proposed and looked into as of late like as Z-source proposed inverter. In this proposed semi-Z-source inverters for a solitary stage photovoltaic (PV)system. With minimal effort and doubly grounded highlights.These semi-Z-source inverters just two dynamic switches. To accomplish a similar yield voltage as the conventional voltage-nourished full-connect z-source inverter. The info dc source and the yield air conditioning voltage of the semi-Z-source inverter share a similar ground. Consequently prompting less spillage ground current focal points over other non-doubly grounded inverters.

4.2 PV array

A PV Array consists of a number of individual PV modules or panels that have been wired together in a series and/or parallel to deliver the voltage and amperage a particular system requires. An array can be as small as a single pair of modules, or large enough to cover acres.The performance of PV modules and arrays are generally rated according to their maximum DC power output (watts) under Standard Test Conditions (STC). Standard Test Conditions are defined by a module (cell) operating temperature of 24oC (77 F), and incident solar irradiant level of 1000 W/m2 and under Air Mass 1.4 spectral distribution. Since these conditions are not always typical of how PV modules and arrays operate in the field, actual performance is usually 84 to 90 percent of the STC rating. The simulation of solar panel is shown in figure 12 and the overall PV system is shown in figure 13.

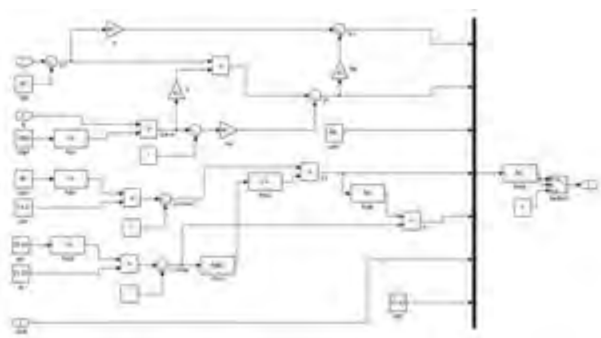


Figure 12: *Semi-z-source inverter with multiple DC sources.*

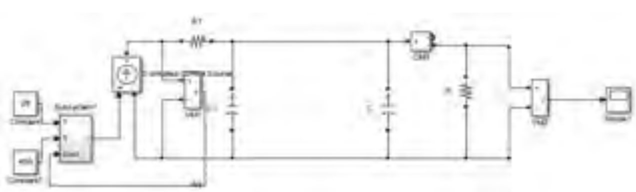


Figure 13: *Semi-z-source inverter with multiple DC sources.*

4.3 Semi-z-source inverter

The Impedance Source (Z - Source) Inverter comprises of voltage source from rectifier supply, impedance organize, three stage inverter and with AC engine stack. This impedance organize is combined with inverter fundamental circuit and source. This impedance arrange is a moment arrange channel. This system is vitality stockpiling or separating component for the Impedance Source Inverter. DC to AC converters is known as inverter. The capacity of an inverter is to change a DC input voltage to AC yield voltage of wanted extent and recurrence. Three stage inverters are ordinarily utilized for high power applications. We pick 120' conduction for legitimate and solid operation of inverter. MOSFET have decided for three-stage inverter. Figure 14 shows the simulation diagram of the z-source inverter. There are three methods of operation of one half cycle for Y-associated stack. This Impedance Source (Z - Source) Inverter is utilized to beat the issues in the ordinary source inverters. This Impedance (2 - Source) Source Inverter utilizes an interesting impedance organize combined with the inverter primary circuit to the power source. This inverter has extraordinary elements contrasted and the ordinary sources.

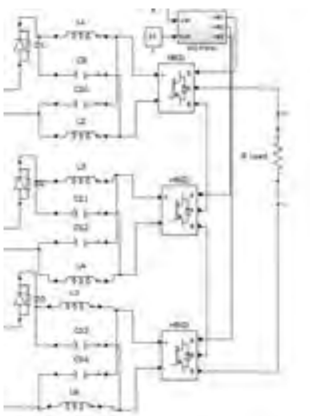


Figure 14: *Semi-z-source inverter.*

The overall simulation diagram of the proposed PV supplied semi-z-source inverter which is connected in power grid is shown in figure 15.

5 Results

The behavior of the complete proposed system that is high efficient semi-z-source inverter which is supplied by photovoltaic system when connected with power grid is discussed in this chapter. There are two PV system is used in proposed work. The simulation result of both the photovoltaic system is shown in figure 16 and figure 17 as output voltage waveform.

The pulses from the new modulation strategy which controls the power semiconductror switches in the semi-z-source inverter is shown in figure 18.

The output pulses of the power semiconductor switches which are in semi-z-source inverter circuit is shown in figure 19.

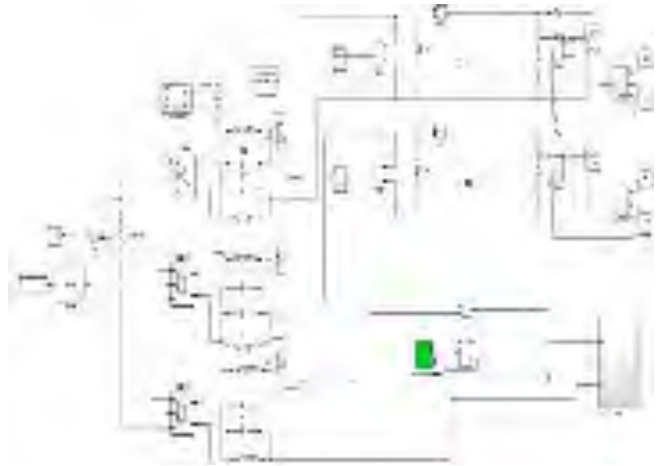


Figure 15: *Overall system.*

Figure 16: *PV1 output voltage.*

The sinusoidal that is AC voltage output from the semi-z-source inverter is shown figure 20.

The Figure 21 Shows that SIMULINK model of PMSG model. It will generate DC output.

The power output from the PMSG is shown figure 22.

The DC voltage output from PMSG is shown figure 23.

6 Conclusion

This paper has presented an impedance-source (semi-z-source) power converter for connecting DC energy source with power grid. To control the semi-z-source inverter new modulation strategy is proposed. The semi-Z-source converter employs a unique impedance network (or circuit) to couple the converter main circuit to the power source, thus providing unique features that cannot be observed in the traditional voltage-source and current-source converters where a capacitor and inductor are used, respectively. The Z-source converter overcomes the conceptual and theoretical barriers and limitations of the traditional voltage-source converter and current-source converter and provides a novel power conversion concept. The Z-source concept can be applied to almost all dc-to-ac, ac to-dc, ac-to-ac, and dc-to-dc power conversion. It should be noted again that the Z-source concept can be applied to the entire spectrum of power conversion. Based on the concept, it is apparent that many Z-source conversion circuits can be derived.

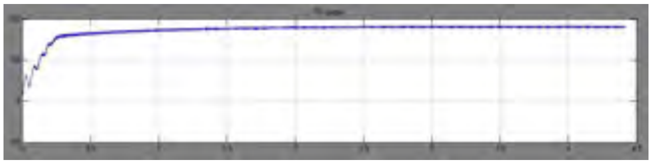


Figure 17: *PV2 output voltage.*

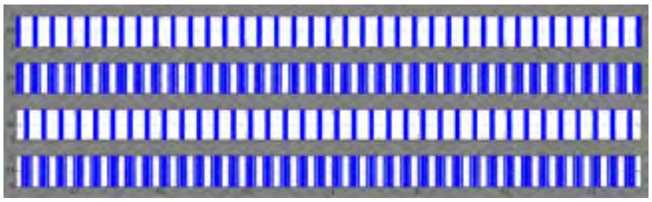


Figure 18: *Output pulses of modulation strategy.*

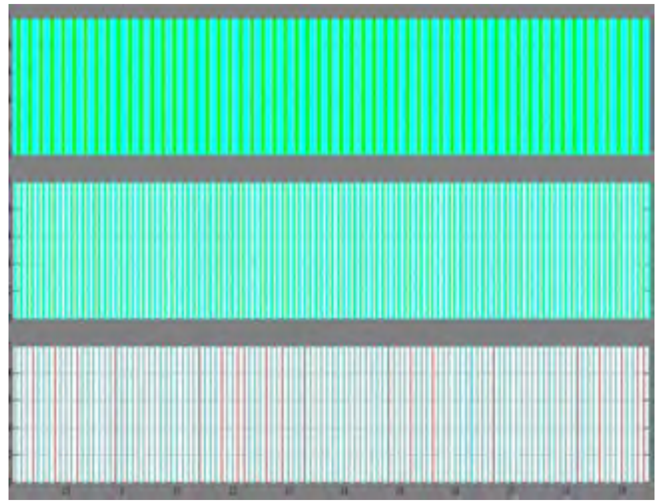


Figure 19: *Output pulses of inverter.*

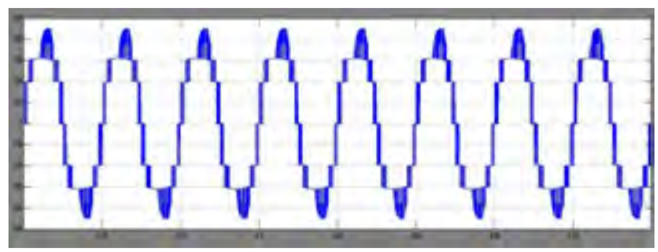


Figure 20: *Output pulses of inverter.*

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] K. Govindaraju, V. Bhavithira, D. Kavitha, S. Kuppusamy, and K. Balachander, "Improvement of Voltage Profile and Loss Minimization in IEEE 14 Bus System using FACTS Devices" in International Journal of Control Theory and Applications, ISSN: 0974-5572 Vol. 10 No.38 (2017), pg. 213-224.

[3] E.Koutroulis, F.Blaabjerg, "Methodology for the optimal design of transformerless grid-connected PV inverters, " Power Electron., lET , vol.5, no. 8, pp.1491,1499, September 2012.

[4] H. Tao, J. L. Duarte, andM. AM. Hendrix, "Line-interactive UPS using a fuel cell as the primary source," IEEE Trans. lnd. Electron., vol. 55, no. 8, pp. 3012-3021, Aug. 2008.

[5] A. Amudha, ,M. SivaRamkumar , M. Sivaram Krishnan "Perturb and Observe Based Photovoltaic Power Generation System For Off-Grid Using Sepic Converter" International Journal of Pure and Applied Mathematics , 114(7), pp. 619-628 , 2017 .

[6] M. SivaRamkumar, M. Sivaram Krishnan, A. Amudha, "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[8] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017.

[9] M.Subramanian, M. Siva Ramkumar, A. Amudha, , K.Balachander and D.Kavitha"Power Quality Improvement In Low Voltage Transmission System Using Static Compensator" in International Journal of Control Theory and Applications (IJCTA) 10 (38) pp 247-261, 2017.

[10] V.Chandra Prabha , A. Amudha, , K.Balachander, M. Siva Ramkumar " MPPTAlgorithm For Grid Integration of Variable Speed Wind Energy Conversion System" in International Journal of Control Theory and Applications, 10 (38) pp 237-246, 2017.

[11] R. Yuvaraj, K. Balachander, A. Amudha, S. Kuppuamy, M. Siva Ramkumar " Modified Interleaved Digital Power Factor Correction Based On The Sliding Mode Approach" in International Journal of Control Theory and Applications, 10 (38) pp 225-235, 2017.

[12] R. Ravichandran, K. Balachander, A. Amudha, M. Siva Ramkumar, S.Kuppusamy" Estimation Of Electrical Parameter Using Fuzzy Logic Controller Based Induction Motor" in International Journal of Control Theory and Applications, 10 (38) pp 205-212 , 2017.

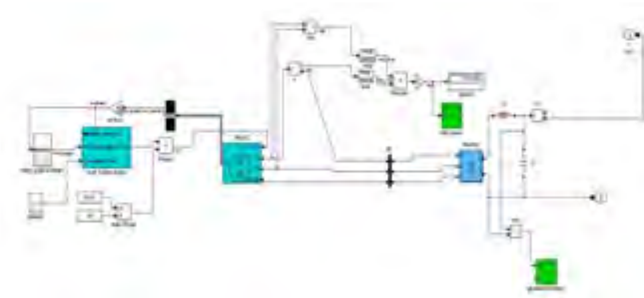


Figure 21: *Simulation model of PMSG.*

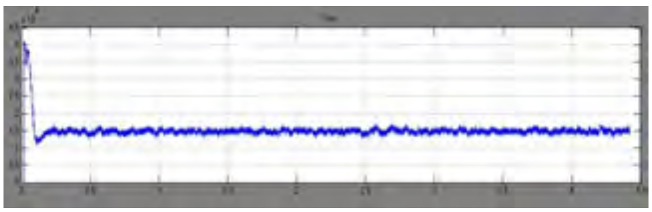


Figure 22: *Simulation power Output of PMSG.*

[13] K. R. Jeyakrishna, A. Amudha. ,K. Balachander, M. SivaRamkumar " Electric Vehicle Battery Charging Station Using Dual Converter Control" in International Journal of Control Theory and Applications, 10 (38) pp 195-203, 2017.

[14] M. R. Latha, S. Kuppusamy, A. Amudha, K. Balachander, M. SivaRamkumar " An Efficient Single Stage Converter Based Pv-Dvr For Improving Voltage Quality" in International Journal of Control Theory and Applications, 10 (38) pp 177-193, 2017.

[15] R. Sudhakar, M. Siva Ramkumar, "Boosting With SEPIC" in 'International Journal of Engineering and Science' 3 (4) pp 14-19,2014.

[16] M. Sownthara, M. Siva Ramkumar, "Wireless Communication Module To Replace Resolver Cable In Welding Robot" in International Journal of Advanced Information Science and Technology on 23(23) pp 230-235,2014.

[17] M. Sivaram Krishnan, M. Siva Ramkumar, "Power Quality Analysis In Hybrid Energy Generation System" in 'International Journal of Advance Research in Computer Science and Management Studies 2 (1) pp 188-193

[18] Ramkumar. S, Elakkiya. A, Emayavaramban. G, 'Kind Data Transfer Model - Tracking and Identification of Data Files Using Clustering Algorithms', International Journal of Latest Technology in Engineering, Vol.3 (8), pp.13-21, August 2014.

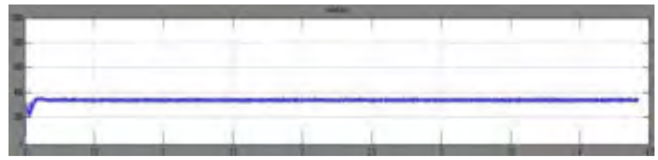


Figure 23: *Simulation voltage Output of PMSG.*

[19] D. Kavitha, C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.20 (2015), pg. 17749-17754.

[20] Amudha, Christopher AsirRajan, "GENCO'S Strategies for Selling Power and Reserve using Hybrid Algorithms of LR, GD and ANN". WULFENIA Journal. Vol. 19, No. 9, pp. 99-118, 2012.

[21] K. Balachander, P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659& Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[22] K. Balachander, S. Kuppusamy, Dr.VijayakumarPonnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[23] K. Balachander, S. Kuppusamy, Dr.VijayakumarPonnusamy, '" Comparative Study of Hybrid Photovoltaic-Fuel Cell System / Hybrid Wind-Fuel Cell System for Smart Grid Distributed Generation System" Proceedings of IEEE International Conference on Emerging Trends in Science, Engineering and Technology at JJ College of Engineering, Trichy on 13 th and 14 th December 2012. DOI: 10.1109/ INCOSET. 2012.6513950, pp.462-466

[24] Dr K Balachander, Dr A Amudha, "PLC Based Control of Fuel Oil Pump Houses in Thermal Power Station", International Journal of Scientific Research and Review, Vol. 6 (11), pp. 6-14.

[25] S.Motapon, L.Dessaint, K.AI-Haddad, "A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, " IEEE Trans. Ind. Electron. , vo1.61, no.3, pp.1320,1334, March 2014.

A HIGH GAIN INPUT-PARALLEL OUTPUT-SERIES DC/DC CONVERTER WITH DUALCOUPLED-INDUCTORS

Kalimuthu, M. Siva Ramkumar, A. Amudha, K. Balachander, M. Sivaram Krishnan

Abstract: This paper presents a very distinctive boost device with twin coupled-inductors and a voltage variety module. On the one hand, the primary windings of two coupled-inductors unit of measurement connected in parallel to share the input current and deflate this ripple at the input. On the other hand, the projected device inherits the deserves of interleaved series-connected output capacitors for prime voltage gain, low output voltage ripple and low switch voltage stress. Moreover, the secondary sides of two coupled-inductors unit of measurement connected asynchronous to a regenerative device by a diode for extending the voltage gain and leveling the primary-parallel currents. In addition, the active switches unit of measurement turned on at zero-current and conjointly the reverse recovery disadvantage of diodes is relieved by low cost leak inductances of the coupled inductors. Besides, the energy of leak inductances is recycled.

Keywords: High gain, dc-dc converter, input-parallel output-series, and dual coupled-inductors.

1 Introduction

A DC-to-DC converter is an electronic circuit or electromechanical device that converts supply of direct current (DC) from one voltage level to another. It is a type of electrical power converter. [1-5]Power levels vary from terribly low (small batteries) to terribly high (high-voltage power transmission). DC to DC converters square measure utilized in moveable electronic devices like cellular phones and portable computer computers, that square measure provided with power from batteries primarily. Such electronic devices typically contain many sub-circuits, every with its own voltage level demand completely different from that provided by the battery or associate degree external offer (sometimes higher or less than the availability voltage), to boot, the battery voltage declines as its keep energy is drained. Switched DC to DC converters provide a way to extend voltage from a part lowered battery voltage thereby saving area rather than victimization multiple batteries to accomplish an equivalent factor. Most DC to DC convertor circuits additionally regulate the output voltage. Some exceptions embrace high-efficiency crystal rectifier power sources, that square measure a sort of DC to DC convertor that regulates the present through the LEDs, and straightforward charge pumps that double or triple the output voltage. [6-12]DC to DC converters developed to maximize the energy harvest for photovoltaic systems and for wind turbines are called power optimizers. Practical electronic converters use switching techniques. Switched-mode DC-to-DC converters convert one DC voltage level to a different, which may be higher or lower, by storing the input energy briefly so emotional that energy to the output at a distinct voltage. The storage could also be in either flux storage parts (inductors, transformers) or field of force storage parts (capacitors). This conversion technique will increase or decrease voltage. switch conversion is a lot of power economical (often seventy fifth to 98%) than linear voltage regulation, that dissipates unwanted power as heat. quick semiconductor rise and fall times square measure needed for efficiency; but, these quick transitions mix with layout parasitic effects to create circuit style difficult. the upper potency of a switched-mode convertor reduces the warmth sinking required, and will increase battery endurance of moveable instrumentality. potency has improved since the late Nineteen Eighties because of the utilization of power FETs, that square measure able to switch a lot of with efficiency with lower switch losses at higher frequencies than power bipolar transistors, and use less advanced drive electronic equipment. Another necessary improvement in DC-DC converters is commutation the regulator diode by synchronous rectification employing a power field-effect transistor, whose "on resistance" is far lower, reducing switch losses. Before the wide convenience of power semiconductors, low-power DC-to-DC synchronous converters consisted of associate degree electro-mechanical vibrator followed by a voltage transformer feeding a thermionic valve or semiconductor rectifier, or synchronous rectifier contacts on the vibrator. during this paper, the DC-DC convertor is victimization twin coupled inductors are often connected in input parallel output series of lay to rest effort thought for accelerate the gain of the circuit.[13-18] twin coupling suggests that 2 conductors square measure named as inductively coupled or magnetically coupled [1] once they square measure organized specified a amendment in current through one wire induces a voltage across the ends of the opposite wire through magnetism induction. The number of inductive coupling between 2 conductors is measured by their coefficient.

2 Existing System

A basic boost convertor will give infinite voltage gain with extraordinarily high duty quantitative relation. In apply, the voltage gain is restricted by the parasitic components of the facility devices, inductance and condenser. Moreover, the extraordinarily high duty cycle operation could induce serious reverse-recovery drawback of the rectifier diode and huge current ripples that increase the conductivity losses. On the opposite hand, the input current is sometimes massive in high output voltage and high power conversion, however low-voltage-rated power devices with tiny on-resistances might not be chosen since the voltage stress of the most switch and diode is severally appreciate the output voltage within the standard boost convertor. Associate in nursing interleaved fly-back convertor supported three-state switch cell for prime intensify and high power conversion is projected. Though the convertor will eliminate the most limitations of the quality fly-back, this circuit may be a very little complicated and therefore the input current ripples are massive from the experimental results.[10-16]

3 Proposed System

This paper proposes Associate in Nursing input-parallel output-series boost convertor with twin coupled inductors for prime intensify and high power applications. This configuration inherits the deserves of high voltage gain, low output voltage ripple and low-tension stress across the facility switches. Moreover, the conferred convertor is ready to show on the active switches at zero-current and alleviate the reverse recovery drawback of diodes by cheap outpouring inductances of the coupled inductor.

4 Circuit and Operation

1) First stage [t0-t1]: At t = t0, the facility switch S1 is turned on with zero current switch (ZCS) owing to the outflow inductance Lk1, whereas S2 remains turned on, as shown in Fig. 4. Diodes D1, D2 and Dr square measure turned off and solely output diode D3 is conducting. The present falling rate through the output diode D3 is controlled by the leak-age inductances Lk1 and Lk2 that alleviates the diodes' reverse recovery drawback. This stage ends once the present through the diode D3 decreases to zero.[15-20]

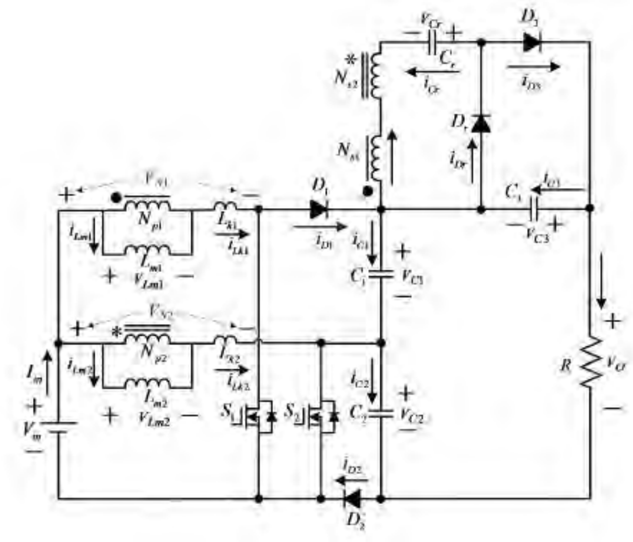


Figure 1: *circuit diagram.*

2) Second stage [t1-t2]: throughout this interval, each the facility switches S1 and S2 square measure maintained turned on, as shown in Fig.5 All of the diodes square measure reversed-biased. The magnetizing inductances Lm1 and Lm2 moreover as outflow inductances Lk1 and Lk2 square measure linearly charged by the input voltage supply Vin. This era ends at the moment t2, once the switch S2 is turned off.

3) Third stage [t2-t3]: At t = t2, the switch S2 is turned off, that makes the diodes D2 and Dr turned on. The energy that magnetizing inductance Lm2 has hold on is transferred to the secondary facet charging the electrical device Cr by the diode Dr, and therefore the current through the diode Dr and therefore the electrical device Cr is set by the outflow inductances Lk1 and Lk2. The input voltage supply, magnetizing inductance Lm2 and outflow inductance Lk2 unleash energy to the electrical device C2 via diode D2.

4) Fourth stage [t3-t4]: At t = t3, diode D2 mechanically switches off as a result of the overall energy of outflow inductance Lk2 has been utterly discharged to the electrical device C2. There's no reverse recovery drawback for the diode D2. Magnetizing inductance Lm2 still transfer's energy to the secondary facet charging the electrical device Cr via diode Dr. the present of the switch S1 is capable the summation of the currents of the magnetizing Inductances Lm1 and Lm2.

5) Fifth stage [t4-t5]: At t = t4, the switch S2 is turned on with ZCS soft-switching condition Due to the leakage inductance Lk2, and the switch S1 remains in on state. The current falling rate through the diode Dr is controlled by the leakage inductances Lk1 and Lk2, which alleviates the diode reverse recovery prob-

lem. This stage ends when the current through the diode Dr decreases to zero at t = t5.

6) Sixth stage [t5-t6]: The operating states of stages 6 and 2 are similar. During this interval, all diodes are turned off. The magnetizing inductances Lm1, Lm2, and the leakage inductances Lk1, Lk2 are charged linearly by the input voltage. The voltage stress of D1 is the voltage on C1, and the voltage stress of D2 is the voltage on C2. The voltage stress of Dr is equivalent to the voltage on Cr, and the voltage stress of D3 is the output voltage minus the voltages on C1 and C2 and Cr.

7) Seventh stage [t6-t7]: The power switch S1 is turned off at t = t6, which turns on D1 and D3, and the switch S2 remains in conducting state. The input voltage source Vin, magnetizing inductance Lm1 and leakage inductance Lk1 release their energy to the capacitor C1 via the switch S2. Simultaneously, the energy stored in magnetizing inductor Lm1 is transferred to the secondary side. The current through the secondary sides in series flows to the capacitor C3 and load through the diodeD3.

8) Eighth stage [t7-t0]: At t = t7, since the total energy of leakage inductance Lk1 has been completely released to the capacitor C1, diode D1 automatically switches off. The current of the magnetizing inductance Lm1 is directly transferred to the output through the secondary side of coupled inductor and D4.

5 Coupled Inductor Design

Usually, the duty cycle should be less than 0.8 to reduce conduction loss of the switches. If the voltage gain and switch duty cycle are selected, the turns ratio of the coupled inductor can be calculated by

$$N = \frac{M_{CCM}(1-D)}{2} - 1 \tag{1}$$

According to higher than analysis, the run inductance of the coupled inductors has some effects on the voltage gain. Luckily, the run inductance will be accustomed limit the diode current falling rate and alleviate the diode reverse recovery drawback. Therefore, a compromise ought to be created to optimize the performance of the device. Moreover, considering the input current ripples and current sharing performance, the run inductance of the coupled inductors ought [1-6] to be designed as symmetrical as potential. The connection of the run inductance, the diode current falling rate, and also the turn's quantitative relation is expressed by equation,

$$L_{k1} = L_{k2} = \frac{kV_0}{2N(N+1)}\frac{diD_r}{dt} = \frac{kV_0}{2N(N+1)}\frac{diD_3}{dt} \tag{2}$$

6 Experimental Waveform Diagram and Verification

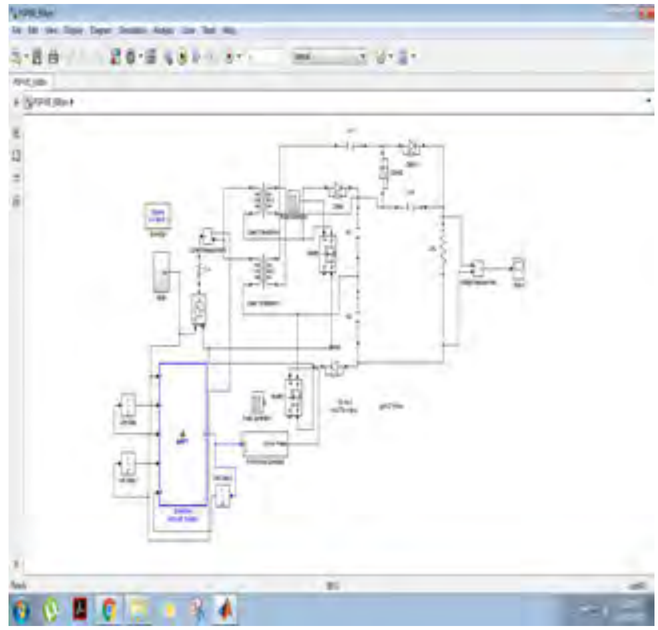


Figure 2: *simulation diagram.*

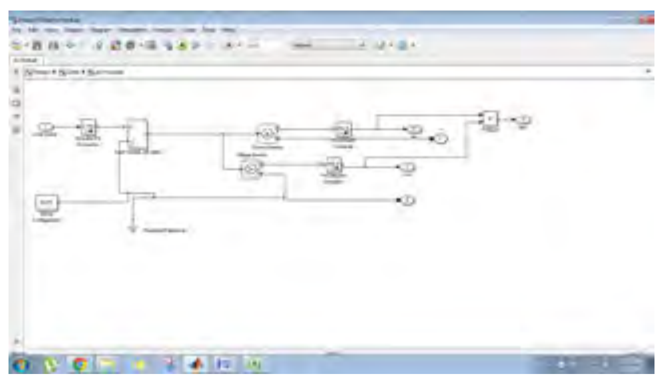


Figure 3: *solar module.*

7 Steady State Performance of device

To change the circuit performance analysis of the planned device in CCM, and also the following conditions square measure assumed.[7-15]

1) All of the facility devices square measure ideal. That's to mention, the on-state resistance RDS (ON) and every one parasitic capacitor of the most switches square measure neglected, and also the forward drop of the diodes is unnoticed. 2) The coupling-coefficient k of every coupled-inductor is outlined as Lm/ (Lm+Lk).

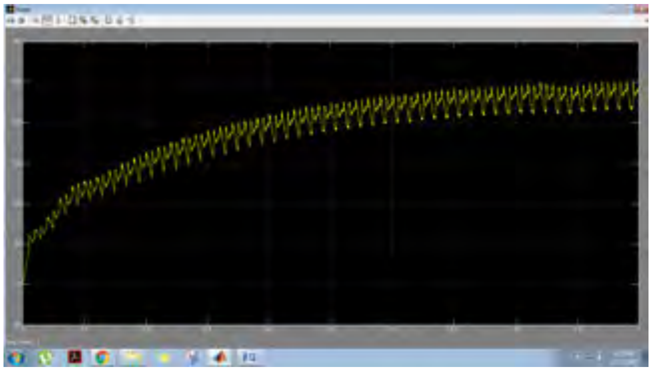


Figure 4: *output waveform.*

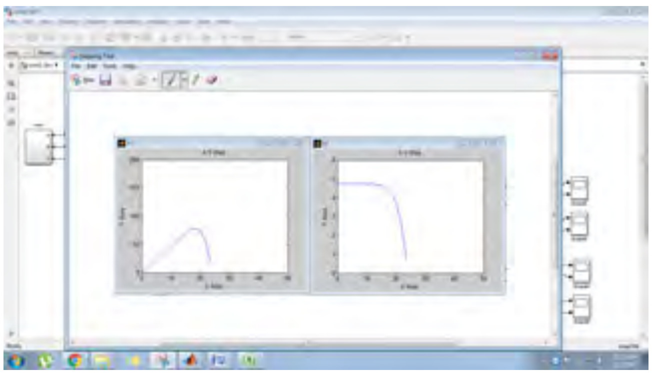


Figure 5: *solar pv,iv graph.*

Components	Parameters
Input voltage V_{in}	18-36V
Output voltage V_O	200V
Maximum output power P	500W
Switching frequency f_s	40kHz
Turns ratio N_s/N_p	19/18
Magnetizing inductor L_m	120uH
Leakage inductor L_{k1},L_{k2}	2.1 uH
Power switches S_1,S_2	FIRFP150N
Diodes D_1 ,D_3 and D_r	DSSK20-015A
Diode D_2	DSSK28-01AS
Capacitors C_1 and C_2	220uF/100 V
Capacitor C_r	47uF/100 V
Capacitor C_3	470uF/ 200V

Table 1

The flip quantitative relation N of every coupled-inductor is adequate NS /NP; 3) The parameters of 2 coupled-inductors square measure thought of to be an equivalent, particularly lumen1 = Lm2 = Lm, Lk1 = Lk2 = Lk, NS1/NP1= NS2 /NP2=N, k 1= Lm1/ (Lm1+Lk1) = k 2= Lm2/ (Lm2+Lk2) = k 4) Capacitors C1, C2, C3 and metal square measure massive enough. Thus, the voltages across these capacitors square measure thought of as constant in one shift amount.[22]

8 Conclusion

For low input-voltage and high improve power conversion, this paper has with success developed a high voltage gain some necessary characteristics of the projected convertor are:

1) It can do a way higher voltage gain and avoid operative at extreme duty cycle and diverse flip ratios; 2) the voltage stresses of the most switches square measure terribly low, that square measure one fourth of the output voltage beneath N=1; 3) The input current may be mechanically shared by every part and low ripple currents square measure obtained at input; 4) the most switches may be turned on at ZCS in order that the most switch losses square measure reduced; 5) this falling rates of the diodes square measure controlled by the run inductance in order that the diode reverse-recovery drawback is eased. At an equivalent time, there's a main disadvantage that the duty cycle of every switch shall be not but five hundredth beneath the interleaved management with 180˚phase shift.

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] M. Siva Ramkumar, M. Sivaram Krishnan, "Power Management of a Hybrid Solar- Wind Energy System" International Journal of Engineering Research & Technology, vol. 3(2) pp.1988-1992, 2014.

[3] M. Siva Ramkumar, M. Sivaram Krishnan, A. Amudha, "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid

Renewable Energy System Using Fc-Uc " in International Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[5] M Siva RamKumar, A. Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016. .

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763-769,2014.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2),2014

[9] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[10] D. Kavitha, C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.20 (2015), pg. 17749-17754.

[11] D. Manoharan, A. Amudha. "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, A. Amudha. A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6233-6240.

[13] M. Sivaram Krishnan, A. Amudha, , M. Siva Ramkumar, 'Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms', International journal of Pure and Applied Mathimatics,118 (11), pp 609-617,2018 DOI:10.12732/ijpam.v118i11.79

[14] A. Amudha. "Optimal placement of Unified Power Flow Controller in the transmission line using SLF algorithm" in International journal of Applied Mechanics and Materials, Vol. 573 (2014) pp 352-355

[15] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035-2042.

[16] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[17] K. Balachander, P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[18] K. Balachander, P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[19] K. Balachander, V. Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[20] K. Balachander, V. Ponnusamy, 'Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research', Volume 7, Number 3 (2012), pp. 247-256. .

[21] K. Balachander, S. Kuppusamy, V. Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[22] S. Motapon, L. Dessaint, K.AI-Haddad, "A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, " IEEE Trans. Ind. Electron. , vo1.61, no.3, pp.1320,1334, March 2014.

A DC - DC CONVERTER IN HYBRID SYMMETRICAL VOLTAGE MULTIPLIER CONCEPT

S. Tamil Selvan, M. Siva Ramkumar, A. Amudha, K. Balachander, D.Kavitha

ABSTRACT: Voltage multiplier factor circuits area unit wide employed in several high-voltage/low-current applications this paper proposes a hybrid SVM (HSVM) for dc high-voltage applications. The multiplier factor is made by cascading a diode-bridge rectifier associated an (symmetrical voltage multiplier factor) SVM with diode-bridge rectifier because the initial stage of multiplier. The planned topology saves 2 high-voltage capacitors and needs just one secondary of HVT. Besides, it's lesser free fall and quicker transient response at start-up, compared with typical SVM.

Keywords: Hybrid Symmetrical Voltage Multiplier, Diode Rectifier, Voltage Drop, And Transient Response.

1 Introduction

A high-voltage, electrical energy (HVDC) electrical power transmission (also known as an influence super road or associate degree electrical super highway) uses electrical energy for the majority transmission of electric power, in distinction with the a lot of common electrical energy (AC) systems.[5] For long-distance transmission, HVDC systems could also be more cost-effective and suffer lower electrical losses. For underwater power cables, HVDC avoids the serious currents needed to charge and discharge the cable capacitance every cycle. For shorter distances, the upper price of DC conversion instrumentation compared to associate degree AC system should still be even, attributable to different edges of electrical energy links. HVDC permits power transmission between unsynchronised AC transmission systems. Since the facility flow through associate degree HVDC link is controlled severally of the point between supply and cargo, it will stabilize a network against disturbances attributable to fast changes in power. HVDC additionally permits transfer of power between grid systems running at completely different frequencies, like fifty cps and sixty cps. This improves the steadiness and economy of every grid, by permitting exchange of power between incompatible networks. [1-10]

The Voltage number, however, may be a special style of diode rectifier circuit which might doubtless turn out associate degree output voltage over and over bigger than of the applied input voltage. though it's usual in electronic circuits to use a voltage electrical device to extend a voltage, generally an acceptable step-up electrical device—transformer or a specially insulated transformer needed for prime voltage applications might not invariably be on the market. One different approach is to use a diode voltage number circuit that will increase or "steps-up" the voltage while not the utilization of a electrical device. Voltage multipliers square measure similar in many ways to rectifiers therein they convert AC-to-DC voltages to be used in several electrical and electronic circuit applications like in microwave ovens, sturdy field of force coils for cathode-ray tubes, static and high voltage equipment, etc, wherever it's necessary to possess a really high DC voltage generated from a comparatively low AC provide. Generally, the DC output voltage (Vdc) of a rectifier circuit is proscribed by the height [13-16] price of its curved input voltage. however by mistreatment mixtures of rectifier diodes and capacitors along we will effectively multiply this input peak voltage to administer a DC output adequate some odd or perhaps multiple of the height voltage price of the AC input voltage.[11-16]

2 Existing System

A conventional symmetrical voltage multiplier factor (SVM) has far better performance, compared with its half-wave counterpart. However, it needs a high-voltage electrical device (HVT) with center-tapped secondary to perform its push–pull reasonably operation. For this type of operation, 2 ac sources, out of section by 180o, were needed. Therefore, Associate in Nursing HVT with center-tapped secondary was wont to operate SVM in push– pull manner, However, the employment of HVT with center-tapped secondary windings has 2 drawbacks. First, it will increase the complexness of electrical device winding, and second, any imbalance between the output voltages (driving voltages) of the 2 secondary windings might produce to generation of elementary and better order odd harmonics within the dc output of SVM. Such harmonics area unit reciprocally proportional to load current, and it's tough to eliminate.[17-22]

3 Projected System

An HSVM has been projected for dc-high-voltage applications. The projected topology has been found to possess smaller fall, quicker dynamic response, lesser element count, and lesser complexness, compared with the traditional SVM

4 Projected HSVM technique

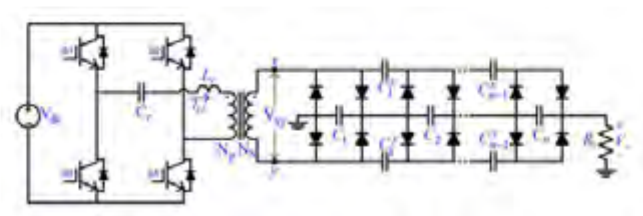


Figure 1: *circuit diagram.*

The first stage of the projected topology may be a diode-bridge rectifier and also the remaining stages kind Associate in Nursing SVM. the primary stage of the projected topology doesn't have coupling capacitors; so, it saves 2 high-voltage capacitors. because the projected topology may be a combination of diode-bridge rectifier and SVM, it's named as Associate in Nursing HSVM. The secondary coil of HVT is connected in parallel to diode bridge rectifier and SVM. Thus, each the diode-bridge rectifier and SVM area unit driven in parallel by the input provide voltage Vxy (t). However, their output terminals area unit connected in series; so, the full output voltage of the projected topology is adequate the add of the output voltages of the diode-bridge rectifier and SVM. In steady-state operation, the capacitors of the smoothing column can discharge through the load and recharge to peak worth doubly each cycle of the input voltage. Thus, there exist 2 charging modes (modes one and 3) and 2 discharging modes (2 and 4) in one complete cycle of operation. throughout modes one and three, the capacitors of the smoothing column area unit charged in parallel by the currents (i1, i2, . . . , in) and (I1, I2, . . . , In), severally, whereas throughout modes a pair of and four, the capacitors of the smoothing column area unit discharged nonparallel through the load.[27-35]

As the 1st stage of the planned HSVM is directly connected (without coupling capacitors) to the input ac supply, its smoothing electrical device charges to peak price among the primary [*fr1] cycle of the input voltage. On the opposite hand, in typical SVM, the smoothing electrical device of 1st stage takes 2 to 3 cycles to charge to peak price thanks to the restricted rate of charge transfer from the coupling capacitors of this stage. Consequently, the planned HSVM has slightly quicker transient response at start-up, when put next with typical SVM.[5-10]

5 Analysis of planned management

Ideally, if I0 = 0, then every electrical device of the smoothing column can excite to VS (max). Thus, the no-load output voltage of the planned HSVM is V0 = nVxy (max), that is adequate that of the traditional SVM. However, if I0 = 0, then the output voltage would be but V0 = nVS (max) thanks to the presence of voltage ripple and dip. Therefore, to estimate the on-load output voltage, it's necessary to search out the output dip (δVo) and voltage ripple (δVo). To alter the analysis, it's assumed that every one the capacitors area unit of an equivalent size (i.e., the capacitance of every electrical device is adequate C).

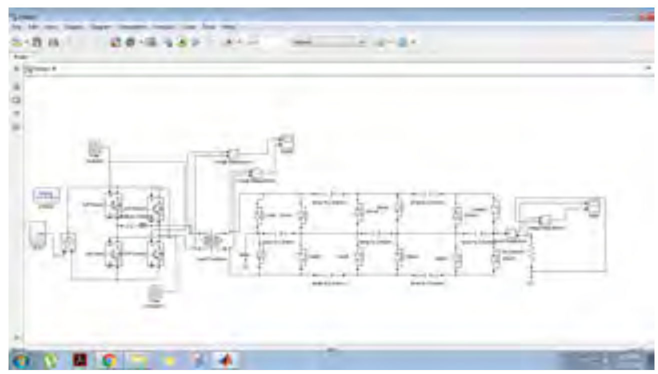


Figure 2: *simulation diagram.*

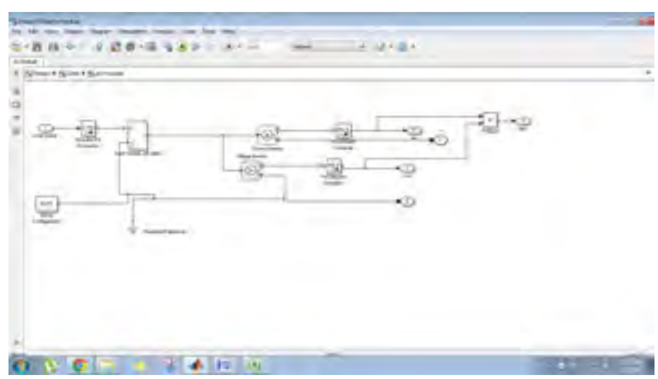


Figure 3: *solar module.*

5.1 Output Voltage Ripple

The output voltage ripple (δVo) is created thanks to periodic charging and discharging of the smoothing columns capacitors. allow us to suppose that charge Q is transferred to load in time T = 1/f by electrical device

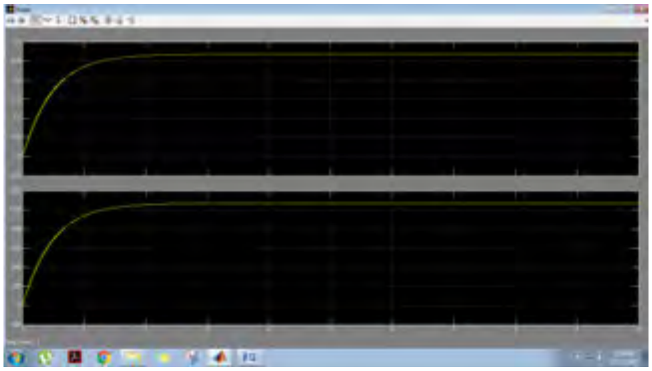


Figure 4: *output waveform.*

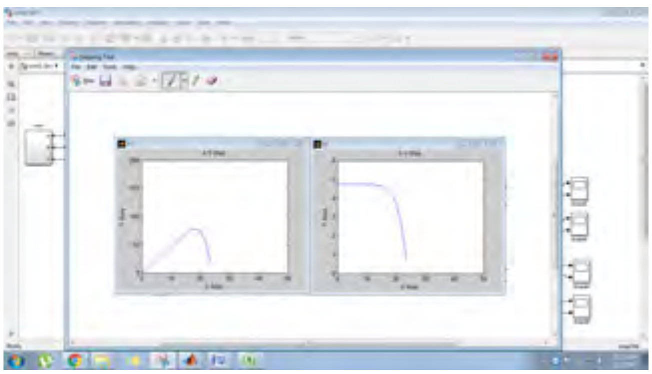


Figure 5: *solar pv, iv graph.*

C1 of the smoothing column. Thus, cyber web charge transferred to load by C1 in time T/2 is Q/2, and therefore the peak–peak rippleproduced across C1 is δV1 = Q/2C1. at the same time, all different capacitors of the smoothing column (C2, C3, . . . , Cn) transfer charge Q/2 to the load and knowledge similar peak–peak voltage ripple. the overall output voltage ripple is obtained by summing the individual voltage ripple of every electrical device as[41-45]

$$\delta V = \frac{Q}{2}\left(\frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_n}\right) = \frac{nI_0}{2fC} \quad (1)$$

Here, $Q = I/f$, wherever $f = 1/T$ is that the operational frequency and I_0 is that the load current.

5.2 Output dip

The dip is that the distinction between the output voltage with and while not load. the overall output dip is determined by finding the total of the individual voltage drops at the capacitors of the smoothing column as follows. The dip δV1 at electrical device C1 is

$$\Delta V1 = 0 \quad (2)$$

The dip at electrical device C1 is zero as a result of the absence of coupling capacitors of the primary stage. The dip δV2 at electrical device C2 is

$$\Delta V2 = \frac{Q}{C}\left(\left[\frac{n}{2} - \frac{1}{2}\right]\right) \quad (3)$$

Similarly, the voltage drops δV3 at capacitors C3 is

$$\Delta V3 = \frac{Q}{C}\left(\left[\frac{n}{2} - \frac{1}{2}\right] + \left[\frac{n}{2} - \frac{2}{2}\right]\right) \quad (4)$$

Summing the individual voltage drops (δV1, δV2, δV3, δVn), simplifying, and victimization letter of the alphabet = Io/f, we get,

$$\Delta V = \frac{I_0}{fC}\left[\frac{n^3}{6} - \frac{n^2}{4} + \frac{n}{12}\right] \quad (5)$$

Using (1) and (5), the common output voltage is,

$$V_0(av) = nV_s(max) - \Delta V - \frac{\delta V}{2} = nV_s(max) - \frac{I_0}{fC}\left[\frac{n^3}{6} - \frac{n^2}{4} + \frac{n}{3}\right] \quad (6)$$

Now, on examination existing with planned , we will observe that then planned HSVM has higher output voltage regulation (i.e., less load-dependent voltage drop) than standard SVM. this can be attributable to the rationale that the primary stage of the planned topology doesn't have coupling capacitors; thus, this stage doesn't expertise any voltage loss. On the opposite hand, in standard SVM, the primary stage experiences largest voltage loss attributable to voltage drops across its coupling capacitors[10-22].

6 Conclusion

An HSVM has been planned for dc-high-voltage applications. it had been fashioned by cascading a diode-bridge rectifier And an SVM. The circuit topology, operation, and steady-state analysis are represented well. The planned topology has been found to possess smaller dip, quicker dynamic response, lesser part count, and lesser complexness, when put next with the standard SVM. The practicability of the planned HSVM has been valid each by simulation and experimental results of a laboratory scaled-down model. each the simulation and experimental results confirmed the superior performance of the planned topology. Thus, the planned topology could also be thought of as a more robust different to the standard SVM.

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Power Management of a Hybrid Solar- Wind Energy System" International Journal of Engineering Research & Technology vol. 3(2) pp.1988-1992, 2014.

[3] M. Siva Ramkumar, M. Sivaram Krishnan, A. Amudha, "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha. "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc" in International Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[5] M Siva RamKumar, A. Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016. .

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763-769,2014.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2),2014

[9] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[10] D. Kavitha, C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.20 (2015), pg. 17749-17754.

[11] D. Manoharan, A. Amudha. "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, A. Amudha. A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6233-6240.

[13] A. Amudha. "Enhancement of Available Transfer Capability using FACTS controller" in International journal of Applied Mechanics and Materials, Vol. 573, pp 340-345

[14] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035-2042.

[15] K. Balachander, P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[17] K. Balachander, P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 − 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, Vijayakumar Ponnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[19] K. Balachander, Vijayakumar Ponnusamy, 'Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research', Volume 7, Number 3 (2012), pp. 247-256. .

[20] K. Balachander, S. Kuppusamy, Vijayakumar Ponnusamy, 'Modeling and Simulation of VSDFIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[21] M. Sivaram Krishnan, A. Amudha, , M. Siva Ramkumar, 'Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms', International journal of Pure and Applied Mathimatics,118 (11), pp 609-617,2018 DOI:10.12732/ijpam.v118i11.79

[22] S. Motapon, L. Dessaint, K.AI-Haddad, "A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, " IEEE Trans. Ind. Electron. , vo1.61, no.3, pp.1320,1334, March 2014.

HIGH STEP-UP DC-DC CONVERTER BASED ON THREE-WINDING COUPLED INDUCTOR

P. Chitra, M. Siva Ramkumar, A. Amudha, K. Balachander, G.Emayavaramban

Abstract: during this paper a completely unique topology for top increase DCDC convertor is introduced. The convertor makes use of coupled electrical device and voltage multiplier factor cell to achieve the specified high increase voltage gain. the most benefits of the projected convertor square measure easy topology, high increase voltage gain, continuous input current, exercise the energy of the run inductance of the coupled electrical device, and utilizing only 1 active switch with reduced voltage stress. Reduced switch voltage stress leads to choice of switch with low on-resistance that improves the potency. Operational principles of the convertor in steady state square measure studied Associate in Nursingd an analytical approach is employed to realize voltage gain and switch voltage stress.

Keywords: DC-DC boost converter; high step-up; coupled inductor; high voltage conversion ratio..

1 Introduction

In natural philosophy engineering, a DC to DC convertor may be a circuit that converts a supply of electricity from one voltage to a different. it's a category of power convertor. DC to DC converters square measure vital in transportableelectronic devices like cellular phones and portable computer computers, that square measure furnished power from batteries. Such electronic devices typically contain many sub-circuits with every sub-circuit requiring a novel voltage level totally different than that equipped by the battery (sometimes higher or under the battery voltage, and presumably even negative voltage). in addition, the battery voltage declines as its keep power is drained. DC to DC converters provide a technique of generating multiple controlled voltages from one variable battery voltage, thereby saving area rather thanvictimization multiple batteries to produce totally different components of the device. Many ways exist to attain DC-DC voltage conversion.Each of those ways has its specific advantages and drawbacks, counting on variety of in operation conditions and specifications. samples of such specifications ar the voltage conversion magnitude relation vary, the maximal output power, power conversion potency, range of elements, power density, galvanic separation of in- and output, etc. onceplanning fully-integrated DC-DC converters these specifications typically stay relevant, even so a number of them cangain weight, as additional restrictions emerge. for example the used IC technology, the IC technology choices and also the on the market chip space are going to be dominant for the assembly value, limiting the worth and quality issue of the passive elements. [1-6] .These restricted values can in-turn have a significant impact upon the selection of the conversion technique. Recently the utilization of change of magnitude DC-DC converters with high voltage magnitude relation has been augmented.

2 Existing System

In the typical systems they're mistreatment voltage multiplier factor to attain the voltage boost. By increasing the voltage multiplier factor cells boost gain worth is accrued to some worth. however the increase magnitude relation during this technique isn't reached desired worth. to induce desired worth got to add additional range of multiple cells, however this creates additional price and losses within the system and additionally creates quality within the circuit.

3 projected System

It is supported coupled electrical device and diode-capacitor voltage multiplier factor cells. Simplicity of management and implementation as a result of utilizing just one active switch is one among the benefits of the projected topology. usage the energy of the discharge inductance of the coupled electrical device results in associate improved potency. in the meantime the voltage of the active switch is clamped to an occasional voltage condenser that prevents the ability switch from high voltage spikes. Reduction of voltage stress for active switch leads to use of switch with low on- resistance that results in more increase within the overall potency. The projected device will be generalized for achieving additional increase voltage gain mistreatment low voltage diodes and capacitors.[6-10]

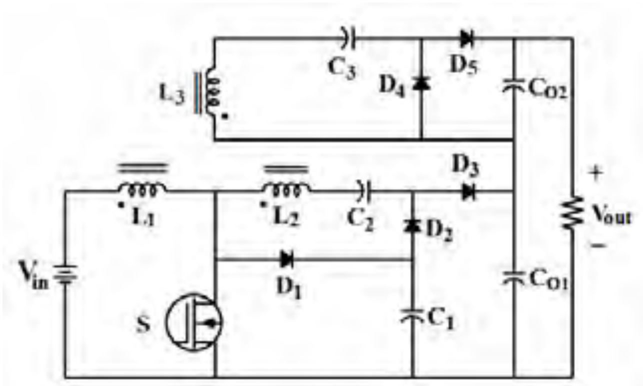


Figure 1: *circuit diagram.*

4 PROJECTED DEVICE TOPOLOGY

The coupled electrical device will be shapely by a perfect electrical device with primary coil N" 2 secondary windings i.e. N2 and N3, a magnetizing inductance lumen and a leak inductance h. Operation of the device is split into four intervals and is mentioned hereafter.

4.1 Interval one trtd:

This interval begins with turning the switch S on. The voltage across the magnetizing and leak inductances equals V/n' so this in lumen is increasing linearly. This interval is reverse recovery mode of the 2 diodes D3 and D5 and lasts till their currents reaches zero and that they stop conducting. during this interval each of the output capacitors pass and carbonic acid gas area unit discharging their energy to the load. This mode is finished at I=I.[11-15]

4.2 Interval a pair of tJ-tzl:

This interval begins once reverse recovery method of diodes D3 and D5 is finished. in contrast to the previous interval this interval is that the main physical phenomenon interval once S is on. attributable to physical phenomenon of the switch S energy of the input voltage supply V/n is provided to magnetizing inductance leading to linear increase of the lumen current. Diodes D2 and D4 area unit conducting from the start of this interval.so the energy hold on in condenser C, that is that the energy of the leak inductance of the coupled electrical device, recycles into the circuit. The load is isolated from input supply and also the output capacitors area unit activity the load. This interval lasts till the switch S is turned off at 1=12. [16-20]

4.3 Interval three trt:

This interval begins by turning switch S off. Input current, that is capable leak inductance current, charges the parasitic condenser of the switch and builds up its voltage. so diode D conducts and also the energy of the leak inductance is hold on in condenser C to avoid incidence of high voltage spikes on power switch. Voltage of the magnetizing electrical device is negative and its current is reducing. Output capacitors CO and carbonic acid gas area unit charging from input supply. This interval lasts until CI absorbs the energy of the leak inductance. subsequently the input current equals the secondary current i2 and DI is reverse biased and turned off in zero current. This mode finish at 1=/j.

4.4 Interval four trt4/:

during this interval the switch S continues to be turned off. Magnetizing electrical device current is reducing. Diodes Dj and D5 area unit still conducting and feeding load and output capacitors. The input current is capable secondary current i2• The input supply, primary and secondary windings of the coupled electrical device (N and N2) and condenser C2 area unit connected series to charge the output condenser through diode Dj• Finally once the switch S is turned on this interval is finished and Interval one of ensuing shift cycle begins.

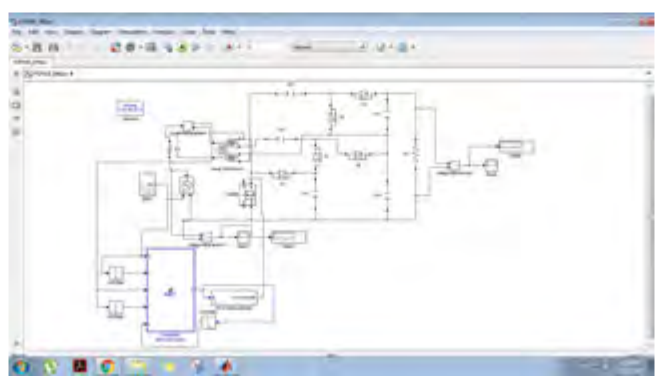


Figure 2: *simulation diagram.*

5 Steady state Analysis

The voltage gain of the projected boost device is calculated. For the simplicity of the analysis, outflow inductance of the coupled inductance is neglected. conjointly all capacitors ar giant enough. Therefore, their voltages ar thought of constant. because it will be seen from Fig. one the output voltage of the device is that the add of

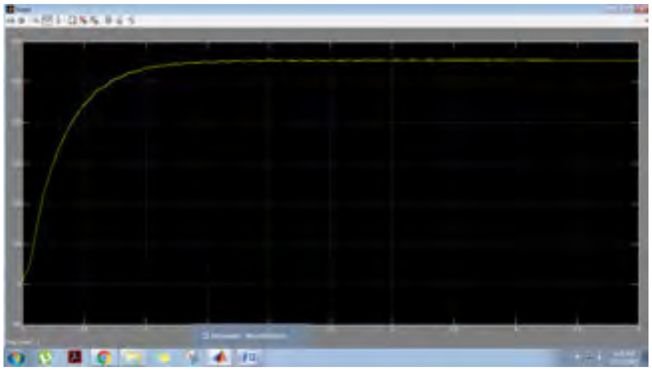


Figure 3: *output waveform.*

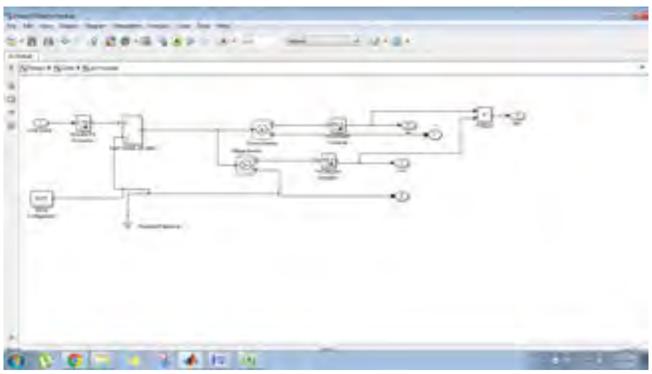


Figure 4: *solar module.*

the voltages across output capacitors gap and carbon dioxide, that is denoted in (1) as follows:

$$V_{out} = V_{CO1} + V_{CO2} \tag{1}$$

In order to get the gain of the device the voltage of every output capacitance ought to be derived as a operate of the input voltage Vim coupled inductance flip ratios n2 and nj, and switch duty cycle (D). because the opening move one ought to calculate the voltage across CO, The voltage across magnetizing inductance lumen in switch conductivity interval DT" will be declared as:[21,22]

$$V_{Lm}^{DT_s} = \frac{V_{in} + V_{C2} - V_{C1}}{1 + n_{21}} \tag{2}$$

Similarly throughout interval D'Ts during which the facility MOSFET is in off-state, the voltage of the magnetizing inductance lumen is as follows:

$$V_{Lm}^{D'T_s} = \frac{V_{in} + V_{CO1} - V_{C2}}{1 + n_{21}} \tag{3}$$

Using Krichoffs law,

$$V_{C1} = \frac{V_{CO1} - V_{in} - V_{C2}}{1 + n_{21}} + V_{in} \tag{4}$$

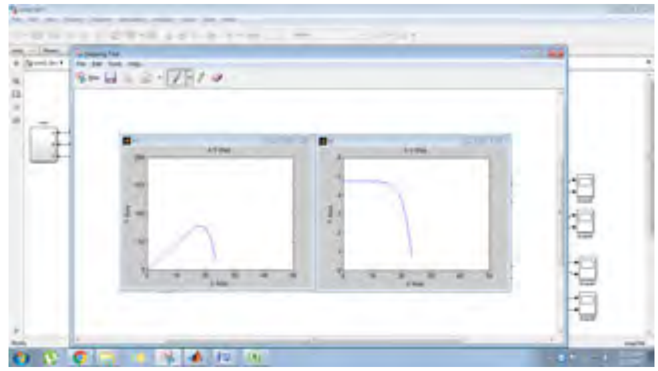


Figure 5: *solar pv,iv graph.*

$$V_{C2} = V_{C1} + n_{21} V_{in} \tag{5}$$

Finally the over all voltage gain will be exprssed as

$$M_{CCM} = \frac{V - out}{V_{in}} = \frac{n_{31} + n_{21} + 2}{1 - D} \tag{6}$$

Parameter	Value/Part num.
Coupled inductor core	ETD-59
Coupled inductor turn ratio	1: 2.7: 2.7
Switch *S*	IRFP2907
C_1	22uF
C_2	10uF
C_3	47uF
C_{O1} , C_{O2}	2*22uF
D_1	STPS30100
D_2 - D_5	BYV27-200

Figure 6: *Table 1 Values of parameters.*

6 Conclusion

In this paper a unique topology for top change of magnitude DC-DC converters is given. it's supported coupled electrical device and diode- capacitor voltage multiplier factor cells. Principles and steady state analysis of the planned convertor in CCM is mentioned. Voltage gain of the convertor is compared with similar. Simplicity of management and implementation as a result of utilizing just one active switch is one amongst the benefits of the planned topologymeantime the voltage of the active switch is clamped to an occasional voltage electrical condenser that prevents the facility switch from high voltage spikes. Reduction of voltage stress for active switch leads to use of switch with low on-resistance that results in additional increase within the overall potency.

The planned convertor is generalized for achieving additional change of magnitude voltage gain victimisation low voltage diodes and capacitors. Extended circuit and its analysis also are given. Simulation results proven the validity of theoretical analysis of the essential planned convertor.

References

[1] X.Hu, C.Gong, "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled Inductors," IEEE Trans. Power Electron., vo1.30, no.3, pp.1306, 1317, March 2015.

[2] M. Siva Ramkumar, M. Sivaram Krishnan "Power Management of a Hybrid Solar- Wind Energy System" International Journal of Engineering Research & Technology vol. 3(2) pp.1988-1992, 2014.

[3] M.Siva Ramkumar, M.Sivaram Krishnan, Dr.A. Amudha "Resonant Power Converter Using GA For PV Applications" International Journal Of Electronics, Electrical And Computational System,6 (9) pp 239-245 , 2017.

[4] M. Sivaram Krishnan, M. Siva Ramkumar, A. Amudha "Frequency Deviation Control In Hybrid Renewable Energy System Using Fc-Uc" in International Journal of Control Theory and Applications, 10 (2) pp 333-344, 2017.

[5] M Siva RamKumar, Dr. A Amudha, R. Rajeev "Optimization For A Novel Single Switch Resonant Power Converter Using Ga To Improve Mppt Efficiency Of Pv Applications" in International Journal of Applied Engineering Research, 11(9) pp 6485-6488, 2016. .

[6] M. Sivaram Krishnan. M. Siva Ramkumar, M. Sownthara "Power Management Of Hybrid Renewable Energy System By Frequency Deviation Control" in 'International Journal of Innovative Research in Science, Engineering and Technology' on 3 (3) pp 763-769,2014.

[7] M. Siva Ramkumar "Unmanned Automated Railway Level Crossing System Using Zigbee" in International Journal of Electronics Engineering Research, 9 (9) pp 1361-1371, 2017

[8] M. Siva Ramkumar, M. Sivaram Krishnan "Hybrid Solar-Wind Energy System" in 'International Journal of Advance Research in Computer Science and Management Studies' 2(2),2014

[9] Emayavaramban. G, Amudha. A, 'sEMG Based Classification of Hand Gestures using Artificial Neural Networks', Indian Journal of Science and Technology, Vol.9 (35), pp.1-10, September 2016.

[10] D. Kavitha, Dr. C. Vivekanandan, "An Adjustable Speed PFC Buck- boost Converter Fed Sensorless-BLDC Motor" in International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.20 (2015), pg. 17749-17754.

[11] D. Manoharan, Dr. A. Amudha "Condition Monitoring And Life Extension Of EHV Transformer" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)

[12] D. Manoharan, Dr. A. Amudha A Novel Optimization of stresses acting and failure rates with power transformer International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6233-6240.

[13] Dr. A. Amudha "Enhancement of Available Transfer Capability using FACTS controller" in International journal of Applied Mechanics and Materials, Vol. 573, pp 340-345

[14] K. Balachander, Dr. P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Energy Systems in Technical, Environmental and Economical aspects (Case Study: Pichanur Village, Coimbatore, India)" International Journal of Applied Environmental Sciences", Volume - 08, No.16 (2013), pp.2035-2042.

[15] K. Balachander, Dr. P. Vijayakumar, "Modeling, Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India ", American Journal of Engineering Research, Volume - 02, Issue-11(2013), pp-174- 184.

[16] K. Balachander, Dr. P. Vijayakumar, "Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load, Case Study: A Textile Showroom in Coimbatore, India", Life Science Journal, (2013), Volume. 10, Issue. 7s, pp. 839-847.

[17] K. Balachander, Dr. P. Vijayakumar, "Renewable Energy System Optimization of Two Different Locations" CiiT International Journal of Automation and Autonomous System [Print: ISSN 0974 – 9659 & Online: ISSN 0974 – 9551(IF: 0.134)] Issue: April 2013, DOI: AA042013001.

[18] K. Balachander, Dr. VijayakumarPonnusamy, 'Economic Analysis, Modeling and Simulation of Photovoltaic Fuel Cell Hybrid Renewable Electric System for Smart Grid Distributed Generation System' International Journal of Mechanical Engineering and Technology, Volume 3, Issue 1, January- April (2012), pp. 179-186.

[19] K. Balachander, Dr. VijayakumarPonnusamy, 'Optimization, Simulation and Modeling of Renewable Electric Energy System with HOMER' International Journal of Applied Engineering Research', Volume 7, Number 3 (2012), pp. 247-256. .

[20] K. Balachander, S. Kuppusamy, Dr. VijayakumarPonnusamy, 'Modeling and Simulation of VSD-FIG and PMSG Wind Turbine System', International Journal of Electrical Engineering, Volume 5, Number 2 (2012), pp. 111-118.

[21] M.Sivaram Krishnan, Dr.A. Amudha, M.Siva Ramkumar, 'Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms', International journal of Pure and Applied Mathimatics,118 (11), pp 609-617,2018 DOI:10.12732/ijpam.v118i11.79

[22] S. Motapon, L. Dessaint, K.AI-Haddad, "A Comparative Study of Energy Management Schemes for a Fuel-Cell Hybrid Emergency Power System of More-Electric Aircraft, " IEEE Trans. Ind. Electron. , vo1.61, no.3, pp.1320,1334, March 2014.