Power Quality Analysis in Hybrid Power Generation For Modified Current Fed Switched DC-DC Converter Using Intelligent Controller

K.VASUDEVAN
Assistant Professor, Department of EEE,
Sriram Engineering College, Chennai, Tamilnadu, India.
vasudevank1978@gmail.com

P.RAMESH
Assistant Professor, Department of EEE,
Anna University, University College of Engineering, Ramanathapuram, Tamilnadu, India.
ramesh2905@gmail.com

Abstract: *Renewable power propagation is desirable for off-grid services and processing remote areas without causing construction of an expensive and elaborated grid substructure. A Microgrid power system involves stability for the sources, it should be controllable too. Since the reliability of the system depends on the stability of energy generating units. This paper provides a detailed analysis and discussion of the different controller based hybrid power generations for a Microgrid application. Here, the altered current fed DC-DC switched converter is designed for achieving both maximum and minimum power generation from distributed energy resources. Propagated power generation systems consider such as a photovoltaic (PV) array, wind turbine, and fuel cell which predict with significant renewable energy technologies. The integration of microgrid with the distributed generation (DG) provides several advantages like high efficiency in power supply, reliability, security, minimum power loss and setting back the enlargement infrastructure. A modified topology of Cuk and boost based power conversion is also developed and controlled by using various kinds of maximum power point tracking (MPPT) schemes. This control is also known as distributed MPPT and consists of process like P&O, Fuzzy Logic Control (FLC), Artificial Neural Network (ANN) and Adaptive Neural Fuzzy Interference System (ANFIS) for attaining maximum energy generation. The output voltage and current regulation of inverter are examined in both the buck and boost methodologies for operation at different power periods with changes in different load conditions including linear, nonlinear, unbalanced, and induction motor. The power factor correction (PFC) is also evaluated using different control methods. Eventually, the simulation results are obtained using comparative analysis in the Matlab/Simulink platform.*

Keywords: *Renewable Energy, DC/DC Power Converter, Power Factor Correction (PFC), Microgrid, Fuel-cell System, Maximum Power Point Tracking (MPPT), Induction Drive*

1. Introduction

Dual voltage source inverter (DVSI) is activated to enhance the power quality and uniformity of the microgrid. The ability of DVSI in which power generated by the microgrid is infused with absolute power by the primary voltage source inverter (VSI) and the reactive, harmonic, and unstable load compensate is performed by ancillary voltage source inverter[1-2]. From DVSI absolute load power is contributing by the two inverters, power losses beyond the semiconductor switches of every inverter are decreased. The basis of inverter is contributing absolute power; the inverter requires tracking the key basic positive sequence of current and bandwidth reduced. An Auxiliary inverter is providing zero sequence of load current and Distributed generation units with smooth the progress control of nearby generations and stock up facilities from a microgrid [3-5].

A microgrid adapt the power from renewable energy sources, for example, fuel cell, photovoltaic cell, wind energy frameworks are attached to main grid and load utilizing a power converter. A grid connected inverter, acts as a major role in trading power from micro grid to main grid network and coupled load [6]. A microgrid work in grid sharing approach as providing power to the load and work in the grid infusing mode if power to the principle grid.

Nowadays a renewable energy grid connected technology has become more useful because it has so many advantages like lower electromagnetic interference, low core loss, small filter size, low acoustic noise, reduced DC grid voltage and less bandwidth. The reduction of DC grid voltage reduced the switching losses [7-9].The renewable energy is variable and volatile one. Therefore, the energy storage gadget is fundamental which keeps up the ability of power balance smoothly at the DC link. Multilevel inverters (MLI) are operated satisfactorily for renewable energy sources with the resultant of low switching frequency and voltage [10].

The sinusoidal PWM (SPWM) approach obviously makes use in multilevel inverters to enhance the switching performance and can attain with trim down switching frequency that causes a reduced switching losses. The MLIs are comprehensively classified into three sorts as its own the number of switches, for example, neutral point clamped, clamped H-bridge (CHB) and flying capacitor. The MLI is of awesome significance in the power electronic industry and reduces the percentage of harmonics level [11-15].

An application FACTS controller, for example, static compensator (STATCOM) and static synchronous arrangement compensator (SSSC) improve power quality which is typically recognized with a capacitor [16-18]. The photovoltaic structure as an uttermost of final power point tracking control is operational with fuzzy logic under varying solar irradiance. A suitably designed wind turbine uses to extract the power for a fuzzy set of DC link voltage error, with its rate of varying progress and error of the inverter. The inverter is positioned in direct axis for reducing the high frequency oscillations. The voltage and current of the photovoltaic panel change in accordance with the atmospheric condition and load changes. The output power of solar panel is maintained at the possible maximum power [19-20]. An individual PV front end can work at its optimized power point and the entire available energy in the PV array is often sent to the grid.

The microgrid is delicate since it can be created by a power converter and load. The battery and super capacitor stockpiling utilized to deal with rapid change in power surges result in quick DC link voltage regulation, successful energy management and diminished current stress on management. The use of the energy storage system is over a wide idea because it can use the variability of smoothly generated power, avoid power quality problems, regulate the voltage and frequency of the microgrid. The DC-DC converter is utilized for connecting all energy sources and storage systems and to stabilize the transmission system [21-24]. Generally, high power application VAR compensations are achieved using a multilevel inverter, which has a number of DC sources with common DC bus. The output of DC bus is connected to the utility. It ensures continuity of power. Grid connected inverter has the ability to synchronize with a utility line.

The hybrid energy storage system using a super capacitor is meant to enhance the battery life expectancy by diverting a transient battery current to super capacitor units. The advance development of a multi-cell based multilevel converter is increased because the harmonic distortion is reduced and the high-quality output voltage results in an enhanced exploitation in industrial application. The registered stepped voltage produces by the multilevel converter, the outputs each of which is formed by a capacitor voltage, voltage source converter, and suitable switching [25-26].

This paper presents a hybrid distributed power generation based modified DC-DC converter with VSI and MLI for power quality analysis using different MPPTs under numerous AC load conditions. The detailed description of the proposed system configuration is verified and analyzed with a comparison of various control technique MPPT including P&O, Fuzzy, ANN and ANFIS based power system.

2. Hybrid Distributed Energy Propagation

Distributed energy storage system uses a renewable energy as it experiences a fast development. The intermittent power source can be overcome by using hybrid energy sources. The Distributed generation system is used for supplying remote location not connected to the main utility or areas interconnected to a weak grid. The Distributed generation is a source of small electric power connected to a distribution network representing a creative and efficient way to generate power. The DG control structure has the capacity to infuse the require power and in addition to acting as a harmonic compensator.

The Hybrid energy system is formed of two storage devices, namely one is high energy system, and the other is high power density. DG is used as a backup source as the source is intermittent in nature. DG has high reliability, low cost and reduced filter size. The dynamic design of PV, wind and fuel cell power propagation is explained in the sections below.

2.1 Circuit Design for PV Model Using Double Diode

An originally conceived double diode model permits us to configure for a PV arrangement produces power-voltage and current-voltage characteristic waveforms by varying solar cell temperature, irradiance from the sunlight, ideality factor and series resistance value. The parallel double diode PV model is also applicable for the purpose of partial model mismatch and shading condition. The electrical equivalent circuit of this model is shown in figure 1.

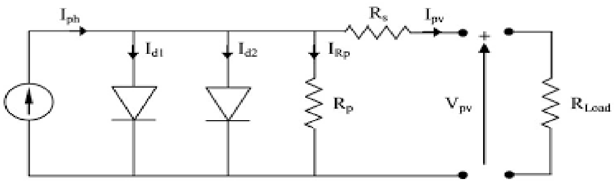


Fig 1. Double diode PV cell equivalent circuit

The non ideal single diode and two diode of PV cell are expressed in below equation,

$$I = I_{Photo} - I_{Series}\left(\frac{\exp(V + R_{Series}I)}{V_t} - 1\right) - \frac{V + R_{Series}I}{R_{Shunt}} \quad (1)$$

$$I = I_{Photo} - I_{Diode1} - I_{Diode2} - I_{Shunt} \quad (2)$$

$$I_{Photo} = I_{shrtCrt} + K_I(T_{Cell} - T_{ref})G \quad (3)$$

$$I_{Diode1} = I_{01}\left[e^{\frac{V+IR_S}{\alpha_1 V_T}} - 1\right] \& \ I_{Diode2} = I_{02}\left[e^{\frac{V+IR_S}{\alpha_2 V_T}} - 1\right] \& \ I_{Shunt} = \frac{V + IR_S}{R_p} \quad (4)$$

PV has a passive capacitive filter which decouples the input voltage and the current from its power level by reducing the current and voltage ripples. It increases the utilization of power electronic devices. For instance, UPS, power converter, an air conditioner, regulator, etc connected to the point of coupling the non-linearity is increased. The non-linearity load shows the way to increase the harmonics present in the system. Harmonics are eliminated by using a shunt active filter connected to inverter. In a solar power system, the photon energy is greater than band gap; the photocurrent is proportional to the solar radiation. The two diode PV cell has characteristic known for accuracy of a high degree under intermittent energy resource. Power electronic converters are utilized to keep up the voltage and current at the load side and it is used for controlling power flow in microgrid power system.

2.2 Design of Wind Turbine - PMSG Model

The windmill is used for generating electricity. A wind turbine converts kinetic energy into mechanical. The wind blades are used for producing energy. The air blown into the blades rotates, providing kinetic energy. Mechanical energy is converted into electricity with the help of generator. Maximum power extraction is essential for a wind energy conversion system (WECS) for increasing efficiency. Fuzzy logics have more advantages when compared to MPPT for intermittent renewable energy sources. Optimum power is extracted from a wind energy conversion system using a fuzzy logic algorithm. The schematic block diagram representation of a wind generator is shown in figure 2.

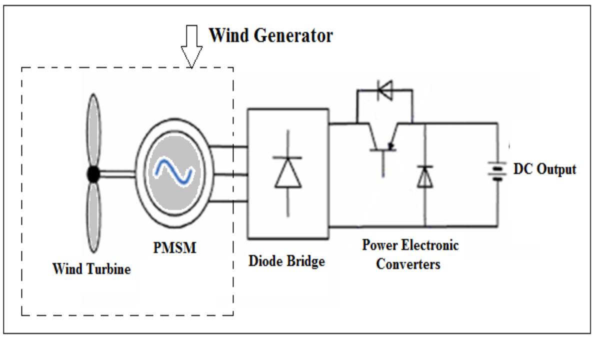


Fig 2. Block Diagram representation of a wind generation

It stabilizes the DC link voltage and avoids a high frequency component. The torque and power generation of wind depend upon the wind blades and air pressure. The mechanical output power of wind energy expressed is given below,

$$P_{output} = Coeff_{power}(\lambda, \beta)\frac{\rho A}{2}V_{wind} \quad (5)$$

There are distinctive perceptions about an intermittent energy resource, in which the wind power technologies play a vital that conveyed in two ways, namely fixed speed and variable speed power production systems. A variable speed power generation extracts maximum power in contrast with the fixed speed power generation. The Permanent magnet synchronous generator (PMSG) has the advantage of less weight, less support and extremely useful in the modern research field. Wind energy converter is meant to change the duty cycle and perform as switch mode rectifier.

The fuzzy logic control extracts maximum power from the wind energy converter system and stabilizes the DC link voltage. The Duty cycle controls the charging and discharging functions of a DC link capacitor. The utilization of PMSG has advantages like high energy yield, smaller mechanical stress, no copper loss on its rotor, high active and reactive power controllability.

2.3 Design of PEM Fuel Cell Model

Fuel cell is a device that produces electricity through a chemical reaction between positively charged hydrogen ion and oxygen. It operates without combustion. So it is a pollution-free energy source. Proton exchange membrane fuel cell recognizes the design and performance of cell and thermal response. The hydrogen consumption of fuel cell is respect with the fuel cell power. The Fuel cell has a low dynamic range and a low transient range, which results in lagging of power by the driver and it has high efficiency because it is potentially more efficient than combustion engine even at a low temperature. In PEM, fuel cell allows only hydrogen ion and prevents the flow of electron. In a fuel cell, the polarization curve is proportional to the operating pressure. The rate of chemical reaction is comparable to the deficient weight of hydrogen and oxygen. The dynamic and static model of PEM fuel cell is depicted in figure 3.

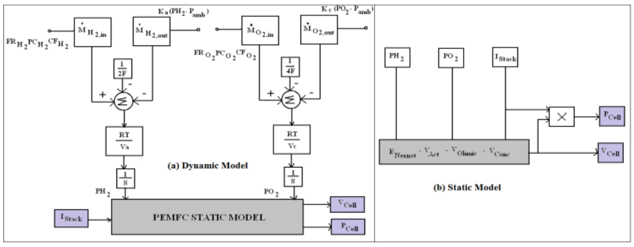


Fig 3. A Schematic Model diagram of PEM fuel cell

$$V_{PEM}FC = E_{Nernst} - V_{Act} - V_{Ohmic} - V_{Conc} \quad (6)$$

$$E_{Nernst} = 1.229 - 8.5 \times 10^{-4}(Temp - 298.15) + 4.318 \times 10^{-5} Temp\left[\ln\left(P_{H_2} + \frac{1}{2}\ln P_{0_2}\right)\right] \quad (7)$$

$$V_{Act} = \delta_1 + \delta_2 Temp + \delta_3 Temp \ln(CO_2) + \delta_4 Temp \ln(I) \quad (8)$$

$$V_{Ohmic} = I\left(\frac{r_m l}{A}\right) \quad (9)$$

The dynamic and static model of a PEM power module is utilized for transient voltage, cell temperature, input/output flow of hydrogen/oxygen rates and temperatures of cathode/anode and pressures under sudden change in load current.

3. System Configuration and Description

In microgrid, power is extracted from variable energy sources that include wind, photovoltaic, fuel cell, battery. The voltage source inverter (VSI) has increased reliability, better utilization of microgrid, less bandwidth and reduced size of the filter. Voltage source inverter supplies real power required for tracking the positive sequence of current. The Multi level converter is used for medium and high power applications and it uses many techniques.

Double flying capacitor based multicell converter is used considering reduction in voltage rating transformer small operation in the even distribution of voltage stress, size and smaller cost. The output voltage is doubled in a multilevel converter and it uses low power switches. An increase in the number of levels reduces harmonics. The modified current fed DC-DC power converter with distributed renewable resources based hybrid topology is shown in figure 4.

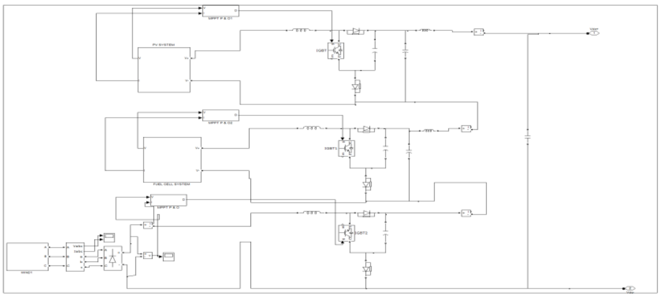


Fig 4. Modified DC-DC Power Converter with Distributed Generation

The multilevel inverter (MLI) fed drive reduces the torque, current ripple and improves the durability of machines. A multilevel converter achieves high power using series semiconductor, switches with less DC voltage source to perform power conversion by synthesizing the stepped DC voltage waveform. Commutation of multiple DC sources produces high output. The voltage of power semiconductor, switches depends upon the voltage of the DC source in a multi-cell based multilevel converter. The harmonics is reduced. The simulation circuit diagram of eleven level single phase inverter structure is implemented using Matlab/Simulink and its simulink arrangement is shown in figure 5.

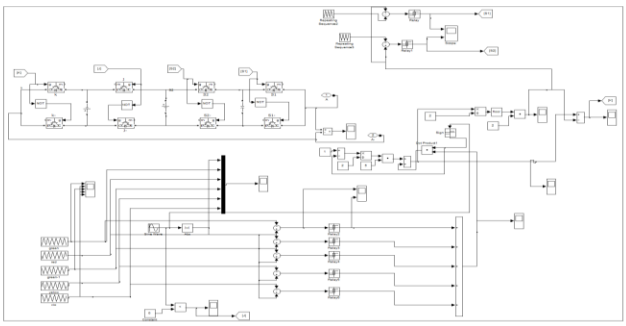


Fig 5. Simulation Circuit of eleven level inverter configurations

The size, cost, complexity, harmonics are reduced in an eleven level inverter since utilizing a smaller number of switches. The minor DC voltage is connected to a significant DC voltage and produces small steps and increases the output voltage. The two levels produce a minor level -1, 0, +1. The major level voltage ranges are considered as -4,-2, 0, +2, +4. Minor and major converter produces eleven levels in all. Current harmonics are infused into the grid while increasing the losses that damage the sensitive loads when the non-linear load is PCC. Shunt active filter acts as a compensator for load harmonics and is connected across the load.

There are different kinds of AC load conditions applied on this proposed overall system consisting of linear, unbalanced load, nonlinear load, and induction motor load. The various load conditions are shown simulation figure 6 below.

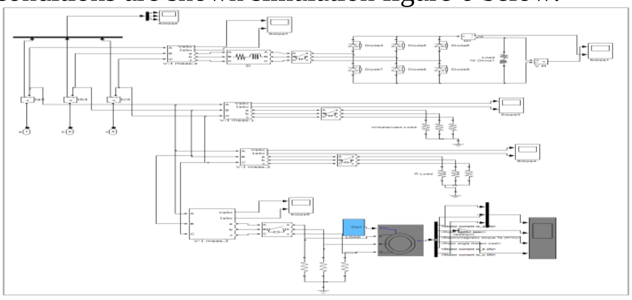


Fig 6. Different Kind of Several AC Load Condition

Voltages are unequal as a result of unbalanced load prompting negative sequences in the supply voltage. Voltage increases the negative sequence as a result of negative sequence and current is injected in the AC side causing a static synchronous compensator to trip. During unbalance load, the voltage is controlled through a reduction in the negative sequence current flow.

4. Proposed MPPT Control Techniques

The use of intermittent energy sources for the power keeps on changing according to the weather and atmospheric temperature. Here, the MPPT is used for improving the efficiency in power production. There are many techniques P&O, Fuzzy, ANN, ANFIS based MPPT considered for a power generation under various applications.

4.1 P & O Based MPPT

The first conventional method is also known as perturb and observe with easy to implement. The output power is increased by adjusting source impedance to equal that of load impedance

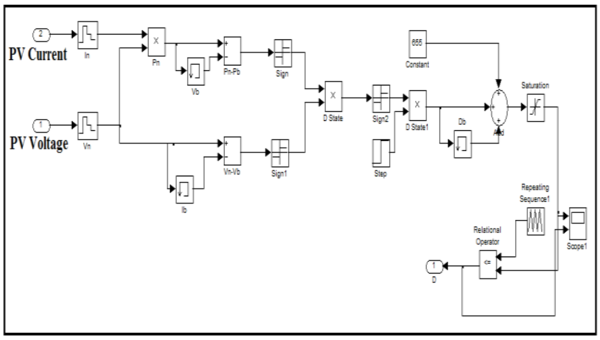


Fig 7(a). Simulink Block of P&O based MPPT

The output power examined by varying the supply voltage in shown figure 7(a). When the voltage increases, power and duty cycle also increase. The output power is compared to the previous perturbation until the maximum power is obtained.

4.2 Fuzzy Logic Control Based MPPT

The second FLC based MPPT generates fuzzy inputs by reading the voltage and the current from an intermittent energy sources. The PV realizes the most prominent output power, which causes for to determining the duty ratio by changing the operating point with the contribution of fuzzy logic. The Simulink block of FLC based MPPT is depicted in figure 7 (b).

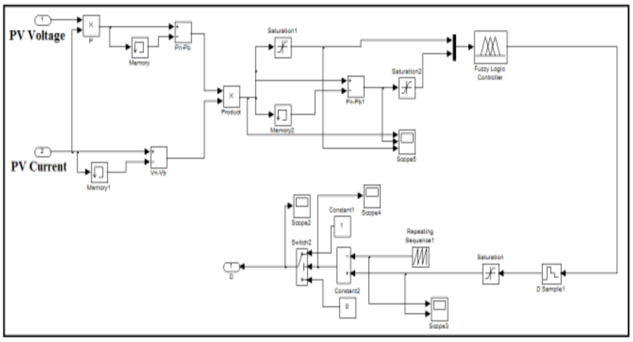


Fig 7(b). A Simulink Block of FLC based MPPT

4.3 Artificial Neural Network Based MPPT

A third method is that MPPT is used for recognizing the most extreme power of PV by utilizing power measurement. ANN consists of an ANN tracker and an optimal power point. The tracker is used for calculating the voltage and current corresponding to the some maximum power renewable resources. The optimal power point is used for adjusting the duty cycle of the power converter for attaining the maximum power which can be transferred to the load, this is indicated in figure 7 (c).

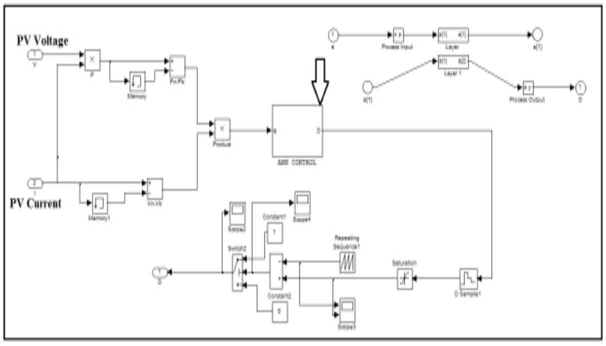


Fig 7(c). Simulink Block of ANN Based MPPT

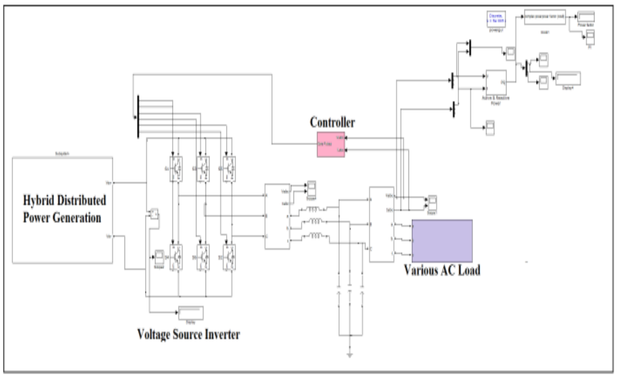


Fig 8. Proposed Overall Simulink Circuit Topology

4.4 Adaptive Neuro Fuzzy Inference System Based MPPT

The fourth method is that ANFIS based MPPT offers quicker dynamic response with accuracy. This is used for MPPT control, the duty cycle of converter and in addition the modulation index of voltage source inverter. It is a combination of fuzzy logic control and artificial neural network based development for extracting maximum power from supply resources. The block representation of proposed ANFIS with MPPT is shown in figure 7(d).

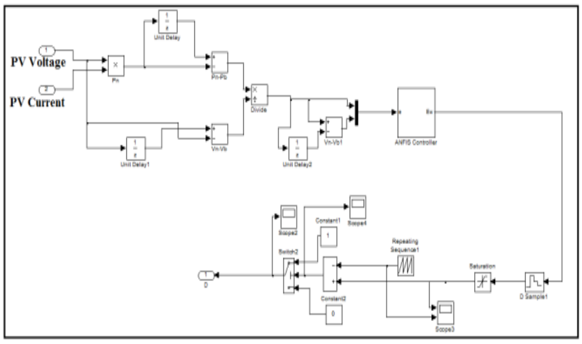


Fig 7(d). Simulink Block of MPPT with ANFIS Controller

5. Results and Discussion under Simulation Study

Improvement in the power quality, hybrid power generation based microgrid application is analyzed and verified by results of different MPPT control techniques under several load conditions. The execution of the proposed structure is accomplished by utilizing comparative audit with the essential verification of control policy. Here, the Matlab-Simulink platform is used for identifying the better results from the power factor correction of VSI and MLI. The ANFIS based MPPT scheme produces better results compared to other control techniques for all the entire three phase inverter structure. The overall simulink proposed circuit diagram is shown in figure 8.

The corresponding conventional simulation results, the proposed MPPT control strategy based voltage source and multilevel inverter configuration are presented in figures 9 to 15.These diagrams consist of four MPPT with different load conditions. Here, the PFC analysis is used for finding out the improvement in power quality in the micro grid system.

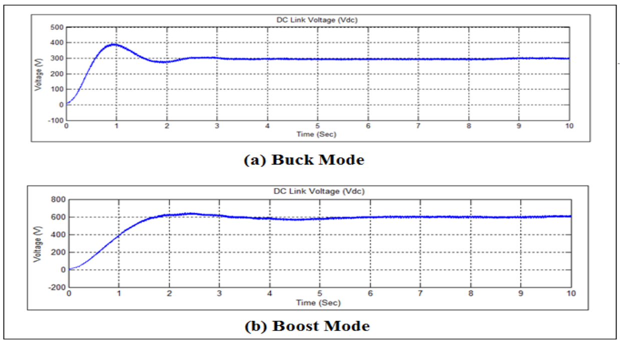


Fig 9(a). DC Link Capacitor across Voltage for Linear Load

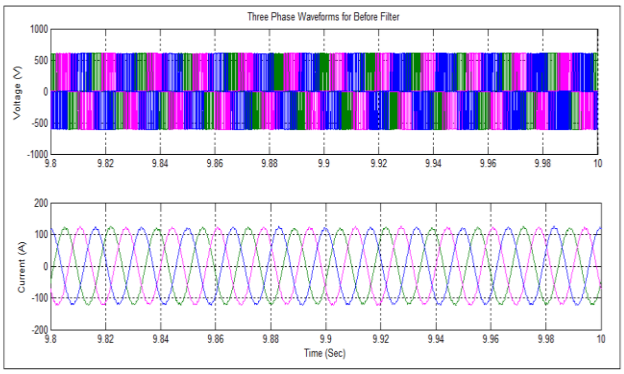


Fig 9(b). Output Three Phase Voltage and Current Waveform for Before Filter

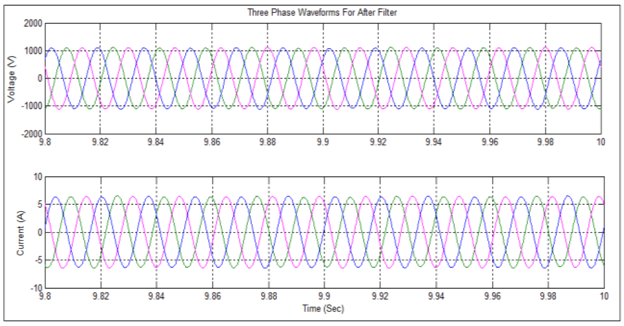


Fig 9(c). Output Voltage and Current Waveform for After Filter

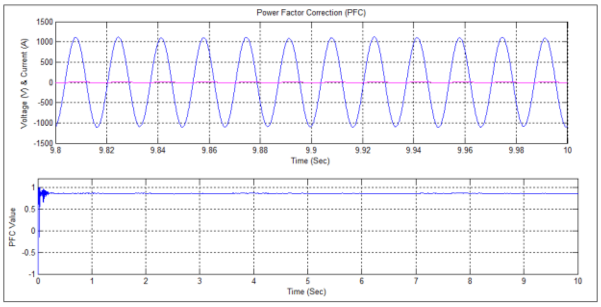


Fig 9(d). Power Factor Correction for Linear Load

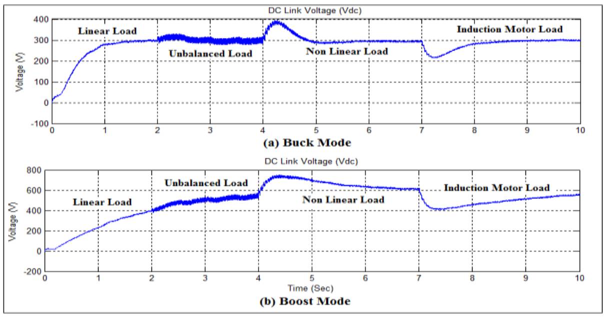


Fig 10(a). DC Link Voltage Waveform under various load condition

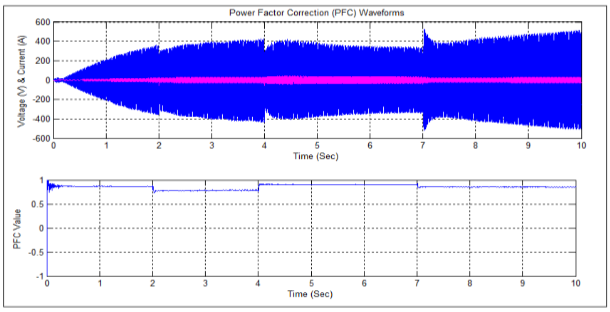


Fig 10(b). PFC for P & O based MPPT in Boost Mode

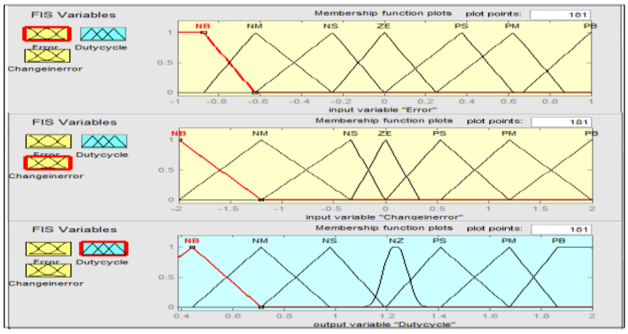


Fig 11(a). Input and Output Membership Function Waveforms

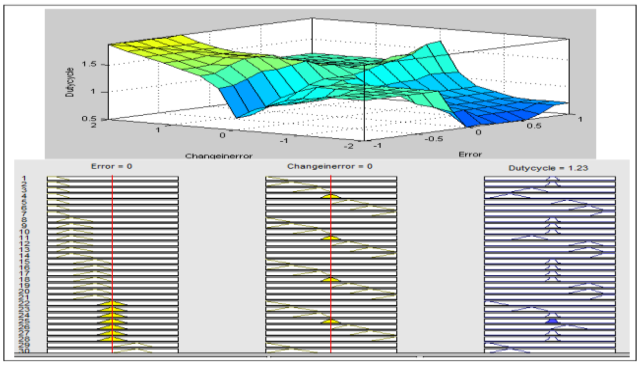


Fig 11(b). Fuzzy Based Graphical View of Surface and Rules Waveforms

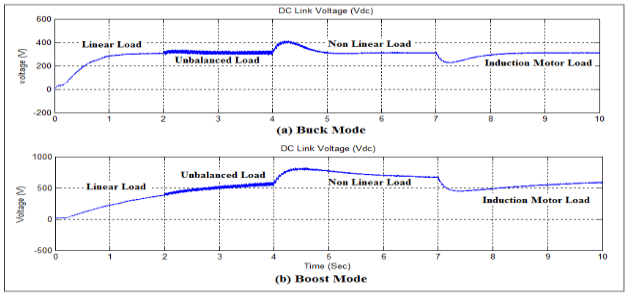


Fig 11 (c). Voltage waveform for Fuzzy Based MPPT

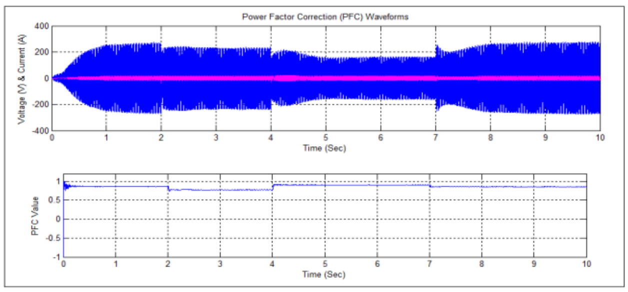


Fig 11(d). PFC Waveform under Buck Mode

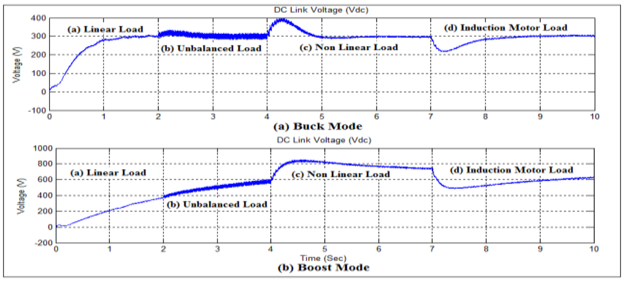


Fig 12(a). Capacitor across DC Link Voltage Waveforms

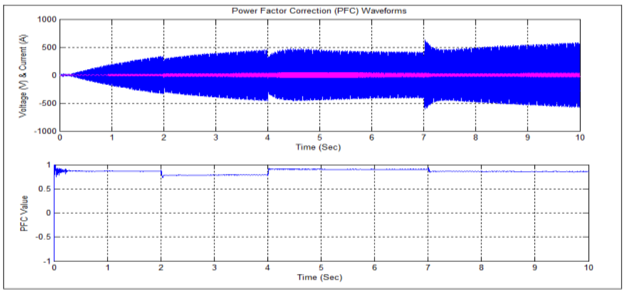


Fig 12(b). PFC Waveform for ANN Based MPPT in Boost Mode

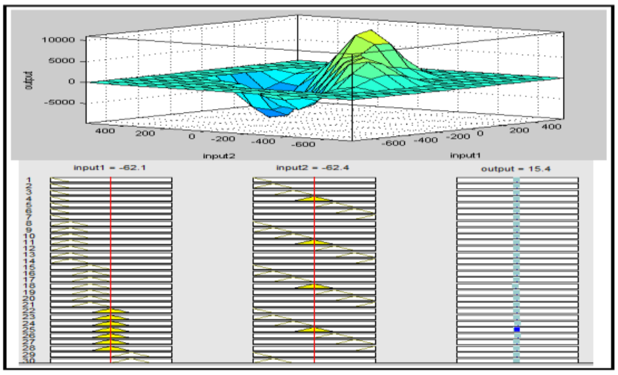


Fig 13(a). ANFIS Based Graphical View of Surface and Rule Waveforms

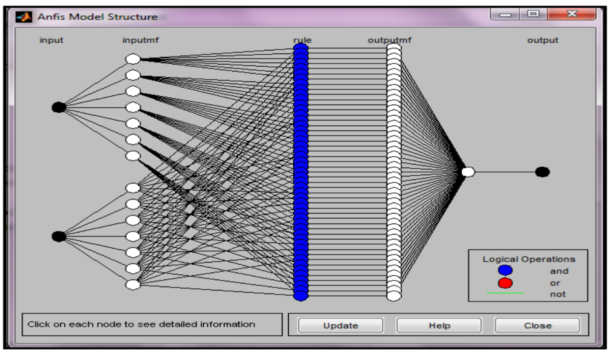


Fig 13(b). Model Structure of ANFIS

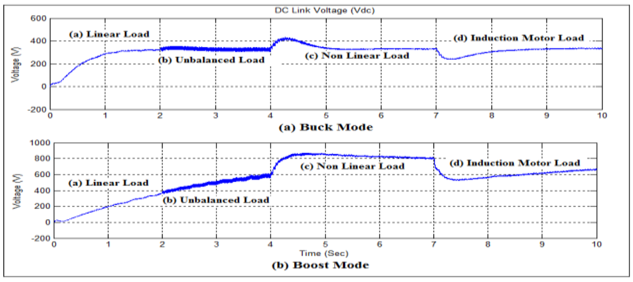


Fig 13(c). DC Link Voltage Waveform under Different Load Condition

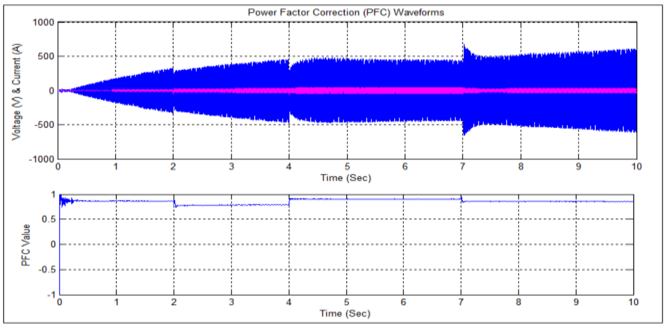


Fig 13(d). PFC Waveform for ANFIS Based MPPT in Boost Mode

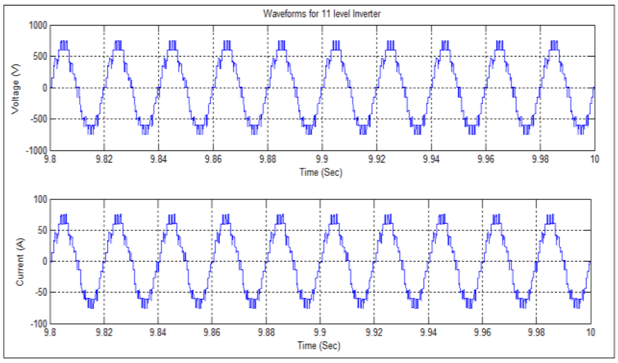


Fig 14(a). Single Phase eleven level Voltage and Current Waveform

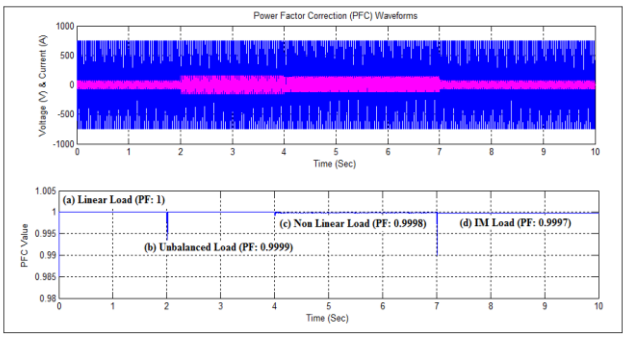


Fig 14(b). PFC Waveform for Multilevel Inverter

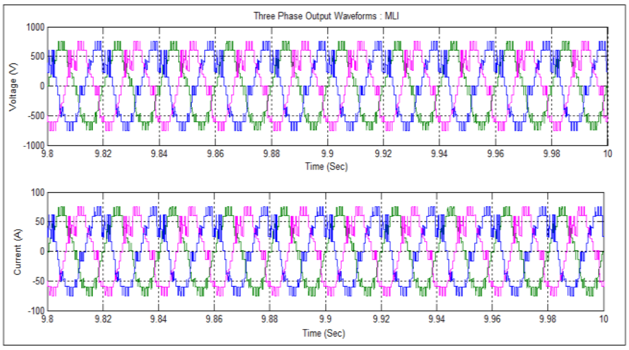
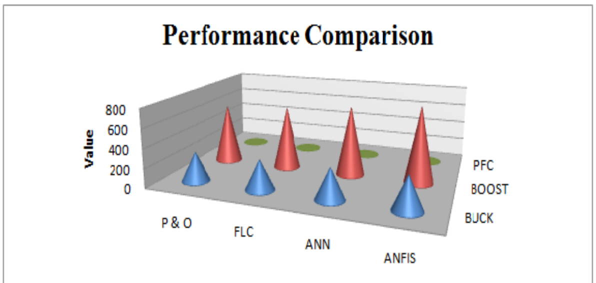


Fig 14(c). Output 11 Level Voltage and Current Waveform



	P & O	FLC	ANN	ANFIS
BUCK	300.1	304.4	314.4	336.8
BOOST	609.1	649.7	714.5	778.1
PFC	0.8615	0.8696	0.8743	0.8802

Fig 15. Comparative Simulation Results for Proposed System

The proposed multilevel inverter is utilized for decreasing the quantity of cells and voltage rating of the flying capacitors. This corresponding simulation comes about while contrasted and traditional VSI results in reduced the cost and sizes of the flying capacitor based power converters and makes it more realistic. The voltage and current waveforms of eleven levels inverter are shown in figure 14(a).

This multilevel inverter is applied on both buck and boost mode operations under various AC load conditions for power quality improvement, in order to achieve the results indicated the analysis of power factor correction. These representing simulation results are indicated in figures 14 (b & c). The overall indicated above the performance of the system with comparison results under various MPPT controllers based representation is shown in figure 15 above.

6. Conclusion

The power quality for the hybrid power source based modified current fed DC-DC converter with a voltage source and multilevel inverter for micro grid application is presented in this paper. Distributed power propagation is developed and consists of a solar cell, wind power and fuel cells in a dynamic system. The amendment to current fed switched DC-DC inverter stick together with Boost and CUK converter is proposed for accomplishing both operations of buck and boost mode under a number of load conditions. This helps accomplishment of a maximum power generation from the renewable energy resources by using distributed maximum power point tracking (DMPPT). There are four kinds of MPPT considered, such as P&O, Fuzzy, ANN and ANFIS based control technique proposed for verification of the improvement in power generation with three phase VSI at eleven level inverter.

Based on a detailed simulation study, the proposed overall configuration provides multiple benefits which include less cost, improved PFC, simple design, the minimum computation complexity and elimination of transformers, buck as well as boost mode operation converters and filter circuit. The novel design of eleven levels based double flying capacitor multi cell converter is used for reducing voltage rating and the volume of stored energy with a reduction in the cost and size of the system performance. The proposed ANFIS based DMPPT is developed with a hybrid system for providing satisfactory results compared to other three control techniques. Moreover, the maximum energy generation and power factor correction have been carried out for the proposed multilevel inverter under various load conditions, including linear, unbalanced, non linear and induction motor drives and a comparative simulation study has also been done in this paper.

References

1. Manoj Kumar M. V, Mishra M.K and Kumar C.: *A Grid-Connected Dual Voltage Source Inverter with Power Quality Improvement Features*. In: IEEE Transactions on Sustainable Energy, VI (2015), No 2, April 2015, p.482-490.
2. Wu F, Li B and Duan J.: *Calculation of switching loss and current total harmonic distortion of cascaded multilevel grid-connected inverter and Europe efficiency enhancement considering variation of DC source power*. In: IET Power Electronics, IX (2016), No 2, Feb. 2016, p.336-343.
3. Gururaj M. V, Vinatha U. and Jayasankar V. N.: *Interconnection of wind-solar hybrid Renewable Energy source to the 3 phase-3 wire distribution system along with power quality improvements at the grid side*. In: International Conference on Power and Advanced Control Engineering ICPACE ’15, 2015, Bangolore, p.168-172.

4. Chitra and Himavathi S.: *Reduced switch multilevel inverter for performance enhancement of induction motor drive with intelligent rotor resistance estimator*. In: IET Power Electronics, VIII (2015), No 12, Dec.2015, p.2444-2453.
5. Bhattacharjee C and Roy B.K,: *Advanced fuzzy power extraction control of wind energy conversion system for power quality improvement in a grid tied hybrid generation system*. In: IET Generation, Transmission & Distribution, X (2016), No 5, April 2016, p.1179-1189.
6. Hosseinzadeh M and Salmasi F.R.: *Power management of an isolated hybrid AC/DC micro-grid with fuzzy control of battery banks*. In: IET Renewable Power Generation, IX (2015), No 5, June 2015, p.484-493.
7. SurendraBabu N.N.V and Fernandes B.G.: *Cascaded Two-Level Inverter-Based Multilevel STATCOM for High-Power Applications*. In: IEEE Transactions on Power Delivery, XXIX (2014), No 3, June 2014, p.993-1001.
8. Varghese and Aathira K.V.: *Current fed switched inverter with improved modulation index*. In: International Conference on Circuits, Power and Computing Technologies ICCPCT '15, 19-20 March 2015, Nagercoil, p.1-4.
9. Etxeberria, Vechiu I, Camblong H,Vinassa J V and Camblong H.: *Hybrid Energy Storage Systems for renewable Energy Sources Integration in microgrids: A review*. In: Conference Proceedings IPEC '10, 27-29 Oct.2010, Singapore, p.532-537.
10. Hua C, Fang Y.H and Chen W.T.: *Hybrid maximum power point tracking method with variable step size for photovoltaic systems*. In: IET Renewable Power Generation, X (2016), No 2, Feb. 2016, p.127-132.
11. Liu L, Li H, Xue Y and Liu W.: *Decoupled Active and Reactive Power Control for Large-Scale Grid-Connected Photovoltaic Systems Using Cascaded Modular Multilevel Converters*. In: IEEE Transactions on Power Electronics, XXX (2015), No 1, Jan. 2015, p.176-187.
12. Kamal T, Hassan S.Z, Hui Li, Mumtaz S and Khan L.: *Energy management and control of grid-connected wind/fuel cell/battery Hybrid Renewable Energy System*. In: International Conference on Intelligent Systems Engineering ICISE '16, 15-17 Jan. 2016, Islamabad, p.161-166.
13. Hassan S.Z, Mumtaz S, Kamal T and Khan L.: *Performance of grid-integrated photovoltaic/fuel cell/ electrolyzer/battery hybrid power system*. In: Power Generation System and Renewable Energy Technologies PGSRET '15, 10-11 June 2016, Islamabad, p.1-8.
14. Sha D, You F and Wang X.: *A High-Efficiency Current-Fed Semi-Dual-Active Bridge DC–DC Converter for Low Input Voltage Applications*. In: IEEE Transactions on Industrial Electronics, LXIII(2016), No 4, April 2016, p.2155-2164.
15. Singaravel M.M.R and Daniel S.A.: *MPPT With Single DC–DC Converter and Inverter for Grid-Connected Hybrid Wind-Driven PMSG–PV System*. In: IEEE Transactions on Industrial Electronics, LXII(2015), No 8, Aug. 2015, p.4849-4857.
16. Dong D, Wen B, Boroyevich D, Mattavelli P and Xue Y.: *Analysis of Phase-Locked Loop Low-Frequency Stability in Three-Phase Grid-Connected Power Converters Considering Impedance Interactions*. In: IEEE Transactions on Industrial Electronics, LXIII(2015), No 1, Jan.2016, p.310-321.
17. Alonso R, Roman E, Sanz A, Martinez Santos V.E and Ibanez P.: *Analysis of Inverter-Voltage Influence on Distributed MPPT Architecture Performance*. In: IEEE Transactions on Industrial Electronics, LIX (2012), No 10, Oct. 2012, p.3900-3907.
18. Mokhberdoran and Ajami A.: *Symmetric and Asymmetric Design and Implementation of New Cascaded Multilevel Inverter Topology*. In: IEEE Transactions on Power Electronics, XXIX (2014), No 12, Jan.2016, p.6712-6724.
19. Khoshkbar-Sadigh, Dargahi V and Corzine K.: *New Flying-Capacitor-Based Multilevel Converter with Optimized Number of Switches and Capacitors for Renewable Energy Integration*. In: IEEE Transactions on Energy Conversion, XXXI (2016), No 3, April 2016, p.846-859.
20. Tummuru N. R, Mishra M.K and Srinivas S.: *Dynamic Energy Management of Renewable Grid Integrated Hybrid Energy Storage System*. In: IEEE Transactions on Industrial Electronics, LXII (2015), No 12, July 2015, p.7728-7737.
21. Vekhande V, Kothari N and Fernandes B.G.: *Switching State Vector Selection Strategies for Paralleled Multilevel Current-Fed Inverter under Unequal DC-Link Currents Condition*. In: IEEE Transactions on Power Electronics, XXXI (2015), No 30, May 2015, p.1998-2009.
22. Afsharikhamaneh M, Abarzadeh M, Ebrahimi J, Sojoudi T and Farhadi P.: *Structure for double flying capacitor multicell converter; progressive double flying capacitor multicell converter*. In: IET Power Electronics, VIII(2015),No 2 Feb. 2015, p.297-308
23. Alexander and Thathan M.: *Modelling and analysis of modular multilevel converter for solar photovoltaic applications to improve power quality*. In: IET Renewable Power Generation, IX (2015), No 1, January 2015, p.78-88.
24. Reznikov, Srndovic, Familiant Y.L, Grandi G and Ruderman A.: *Simple Time Averaging Current Quality Evaluation of a Single-Phase Multilevel PWM Inverter*. In: IEEE Transactions on Industrial Electronics, LXIII (2016), No 6, March 2016, p.3605-3615.

25. Edpuganti and Rathore A. K.: *Optimal Low-Switching Frequency Pulse width Modulation of Medium Voltage Seven-Level Cascade-5/3H Inverter*. In: IEEE Transactions on Power Electronics, XXX (2015), No 1, January 2015, p.496-503.
26. Sadigh K, Dargahi V and Corzine K.A.: *New Multilevel Converter Based on Cascade Connection of Double Flying Capacitor Multi cell Converters and Its Improved Modulation Technique*. In: IEEE Transactions on Power Electronics, XXX (2015), No 12, December 2015, p.6568-6580.