

# CURRENT FED DC-DC SWITCHED INVERTER BASED HYBRID POWER GENERATION FOR ADVANCE POWER QUALITY IN MICRO-GRID APPLICATION

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**Abstract:** In the distribution system, hybrid renewable energy is used as a source for high power generation and also in micro-grid application. The hybrid source such as the photovoltaic, wind and fuel power supply has pollution free energy generating source. The proposed current fed DC-DC converter has combined the property of both Z-Source Inverter (ZSI) and Simple Boost Inverter (SBI). The ZSI produces high voltage gain and the advantage of SBI is that it uses a low passive device. The Maximum Power Point Tracking (MPPT) aids to produce the switching pulse in the present current fed inverter. The MPPT has produced high power and also controls the DC link voltage. The P&O and Fuzzy logic based MPPT is applied in hybrid renewable energy based Current Fed Switched Inverter (CFSI). The suggested hybrid power generation based current Fed switched inverter is used in both linear and nonlinear loads. This paper can be used to enhance the power qualities, reduce the harmonic content and minimize the power losses in the power generation for AC micro-grid application. It can be carried out by the power factor correction analysis in Matlab/Simulink platform, and corresponding simulation results are presented using control scheme based on output three phase voltage and a current signal.

**Keywords:** Current Fed Switched Inverter (CFSI), Maximum Power Point Tracking (MPPT), Perturb & Observe (P & O), Fuzzy Logic Control (FLC), Induction Motor (IM), AC Micro-grid, Power Factor Correction (PFC).

## 1. Introduction

The hybrid energy systems such as photovoltaic, fuel cell and wind energy are used together to generate high power and to increase the system efficiency. Mostly, three different renewable energy resources are integrated and connected with a

common AC bus link and the performances of the system under varying loads are designed for power quality analysis. The fuel cell can achieve maximum power generation, leading current control in the transformer less Current Source Inverter (CSI) and high boost capability of three phase inverter. Here, the combination of ZSI and CSI based switched inverter is developed for recovering the shoot through a problem and boost-buck capability and also to improve Electro Magnetic Interference (EMI) noise immunity in CFSI.

The Switched Boost Inverter (SBI) has reached as ZSI because both have similar attributes, but the filter count is less compared with ZSI, and in addition, its gain is not as much as ZSI. The topology of Z-source inverter is perceived as the relationship of LC with alteration and standard pulse width modulated (PWM) signal with adjustments. This setup is most appropriate for low and wide fluctuating input voltage, for example, fuel cell, PV array, and wind power generation.

There is varied control strategy developed for the different operating conditions in three phase micro-grid application. The hybrid structure that claim a couple of converters will be described, during which the first elevator coordinates with a matching chopper voltage of the photovoltaic source, whereas the other inverter is utilized for changing those DC into AC. Here, in order to implement the energy management studies with distribution electrical system for power generation.

The reduction of harmonic content in micro-grid connected inverter topology is obtained with LCL filter attenuating the higher order harmonics

using a novel control technique. The better performance of the system is found out under the output waveform of Fast Fourier Transform (FFT) and Total Harmonic Distortion (THD).

A novel fuzzy logic technique drawn on MPPT insisting on the hybrid power system, is allowed to acquire the most extreme power in order to improve steady and dynamic state behaviors. Therefore, the generation system achieves a steady and stable state of power for both AC loads and utility grid. The model of multilevel inverter depends primarily on the levels and H-bridge modules for attaining the high electricity capability, confederate with low commutation losses and lower output harmonics.

The THD estimation, in which the values of the output voltage waves were evaluated with outstanding makes it easy to improve the range of output levels. In this, a lesser amount of switches and gate driver circuits are utilized and some switches are employed for a particular interval of time. Besides, the cost including the complexity of the circuit is reduced particularly for higher output levels under the achievement of higher DC link voltages, and also leads to a reduction in Harmonic Distortion (HD) and EMI.

### 1.1. Work Flow

Hybrid renewable sources turn out the excessive power together with less distortion by utilizing the present current fed switched inverter. The control of the proposed converter uses the distributed MPPT such as P&O and fuzzy-based control to regulate and ensure continuous supply in the inverter. The different types of loads are used in the proposed method and this paper reveals the hybrid current fed DC-DC conversion which depends on renewable energy source based power generation for improving power quality in the micro-grid connected system.

The fuzzy based distributed MPPT techniques provide the maximum power generation while compared to P&O based distributed MPPT scheme. The better performance of the present system is achieved in the multilevel inverter which is compared with the conventional VSI using the simulation results of PFC waveforms.

The main advantages of Distributed Maximum Power Point Tracking (DMPPT) are used to provide the maximum power tracking and the intrinsic capability to weaken an effect on the voltages of the PV module disturbances coming from

the grid are depicted by means of simulation results verified with designed analog circuit based formulation.

The less number of switches based multilevel inverter gives better performance while compared to conventional VSI. Here, the cascade type of multilevel inverter including with four DC source and six switches is investigated via hybrid PWM technique of alternative phase opposition and phase disposition with variable frequency method.

### 1.2. Literature Review

This paper describes the use of current fed switched inverter which has functioned as both ZSI and SBI. The ZSI produces a discontinuous supply of current but our proposed inverter has generated an intermittent supply of current [1-2]. The analysis about the inverter has achieved a high step up capability, increased current control and high power factor. The inverter uses one LC filter and minimum switches are required for high power production [3].

The ZSI has performed in both buck and boost modes of operation and using the diode it can reduce the stress across the diode of the inverter. The power factor of the device depends on the value of inductance used [4]. In micro grid, the inverter performs in both islanded and grid connected condition. The power flow is controlled by a drooping coefficient [5].

The hybrid power source generates high power and supply to the storage device. This system produces the constant power at the load side of the inverter [6]. The hybrid power production such as fuel cell, micro-hydel, and PV based inverter has decentralized the generating power from the inverter side [7]. The micro hydro is designed with stable input power to run the motor. The hybrid sources are incorporated across the AC bus and contribute to the linear, non-linear load and induction motor. The compensator gadget is utilized to amend the load voltage and current and reduce the harmonics [8].

The proposed system uses the feed forward control to improve the power quality of the system. In order to achieve the optimal output voltage and current of hybrid DMPPT system, this consists of series and parallel circuit configuration. Also, the overall system efficiency of the present configuration is improved [9]. To make improvements, the fuzzy logic control produces most excessive power and facilitate to accomplish a steady and conscientious power together with AC loads and the utility grid by the generation system [10].

This paper analyzes the various MPPT such as distributed, and hybrid MPPT. The hybrid based distributed MPPT produces more power and is fed into the various load applications [11-12]. The fuzzy logic control is absolutely based MPPT, succeeded promptly in control design regarding DC-DC new buck converter for the micro-grid application. It can help deliver a more viable solution for the nonlinear systems due to the greater flexibility of supply [13].

The proposed nine level based inverter uses the minimum number of switched and gate circuits while compared with the seven-level inverter. This inverter produces the distortion less power at the output and increases the stability of the system [14]. This paper has multi-input for high power requirement in grid application and renewable source has produced stable output and reduced the voltage ripple [15]. The current fed inverter produces the continuous input supply and reduces the high frequency as well as ripple component at the output of the proposed inverter [16].

## 2. Micro-Grid Topology Description

The present micro-grid configuration comprises of distributed energy resources like wind power generation, fuel cell, Solar photovoltaic (PV) panels, Power electronics devices, and DC link voltage for various load conditions such as linear, non-linear, unbalanced and AC motor. The loads are fed through a voltage sources inverter (VSI) as well as a Multilevel Inverter (MLI) and a hybrid power system is connected to a suitable grid connected system for power quality analysis. The overall system description of micro-grid topology is shown below in figure 1.

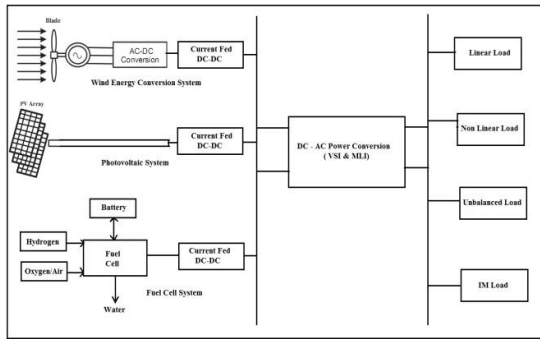


Fig. 1. Block Diagram of Micro-Grid Topology

Normally, the micro-grid is connected to AC load through three phase inverters and injects high-quality power into the grid. In AC load based

inverter, a capacitor is generally used as an interface between the inverter and distributed generation. The LC filter is used; high switching frequency is concerned to ensure that no extreme harmonics are produced by pulse width modulation (PWM). The hybrid DC-DC power converter of the above-mentioned diagram is indicated here as a current fed switched boost inverter. The circuit arrangement of this topology is shown in below figure 2.

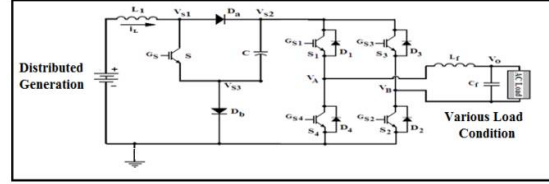


Fig. 2. Current Fed Switched Boost DC-DC Converter Topology

The formation of an above converter is described as the combination of the low passive component count of SBI and high-gain qualities of ZSI. The dynamic evaluation of the three phase inverter is commenced to set up the connection to DC input or the AC output for quite a number of AC load applications. The modulation index of current fed DC-DC switched boost inverter can be expressed as,

$$M_{CFSBI} = \frac{V_{out}}{V_{freq}} = \frac{1}{1 - 2D} \quad (1)$$

The CFSBI topology presents the shoot through methodology. Moreover, this kind of inverter can be able to varying the input voltage to a preferred output voltage. This method integrates to improve EMI immunity and additionally, step up gain with respect to the inverter is found owing to complementation of shoot-through interval.

The proposed CFSB converter diminishes the bother related with interrupted input current of ZSI by worthy inductor coupled with the input. It is apt for a distributed hybrid renewable energy suit without need of using an input filter.

## 3. Dynamic Model of Power Generation System

The mathematical model of distributed generation is an efficient in power system. It is now used all over the world for small scale power generation for household applications such as an off-grid or grid connected system. This type of system is

settled near at the Point of Common Coupling (PCC) use.

The power generation components in hybrid distributed energy technologies, for example, small wind, small hydro, solar photovoltaic, biomass, micro turbine, gas turbines and fuel cells, and so on. The Hybrid Distributed Renewable Energy (HDRE) system is defined as a combination of more than two renewable energy sources, that when incorporated, defeat the limitations underlying in either.

### 3.1 Wind Generation Model

The dynamic behavior of an electric system has high wind power generation and the detailed model is used as high extent. Moreover, the complete models could not function admirably because of high state variables and little time constants. Subsequently, the rearranged models are used for speaking to wind generations in power system dynamics simulations that assist in analysis and have an effect on a high number of wind generations on the conduct of a large power system. The wind-turbine model related equation is given below,

$$C_{power}(\lambda, \beta) = c_1 \left( \frac{c_2}{\lambda_i} - c_3 \beta - c_4 \right) e^{-c_5/\lambda_i} + c_6 \lambda_i \quad (2)$$

$$C_{power}(\lambda) = 0.5176 \left( \frac{116}{\lambda} - (116 \times 0.035) - 5 \right) e^{\left( -\frac{21}{\lambda} - 21 \times 0.035 \right)} + 0.0068 \lambda \quad (3)$$

The  $C_p$  curve characteristic of the wind turbine is shown in figure 3. Here, the tip speed ratio indicates peripheral velocity and based on this speed rotor blade position could be changed with the same wind speed. The wind speed changes the power coefficient and so the tip speed ratio will be varied.

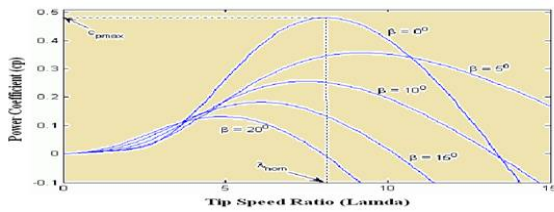


Fig. 3. Wind Turbine Characteristic of  $C_p$  Curve

The torque and power characteristics of wind turbine can be comprised by equations given below,

$$T_m = \frac{P_m}{W_{rotor\ speed}} \quad (4)$$

$$P_m = C_{power}(\lambda, \beta) 0.5 \rho A V^3 \quad (5)$$

The model is used for generating power from a wind based Permanent Magnet Synchronous Generator (PMSG). The most advantage of a wind turbine model is that it does not require reactive magnetizing current, which permits an operation of high power and high efficiency.

### 3.2 Two Diode Photovoltaic Array Model

The dynamic performance of the double diode configuration allows the photovoltaic array power Vs voltage and current Vs voltage characteristics curves by changing the cell temperature, ideality issue, sunlight and total resistance value. The arithmetical equation of photovoltaic is enormous under limited shading/module conditional circumstances. The configuration of double diode photovoltaic (PV) array model and P-V/I-V characteristic curves are shown in figure 4.

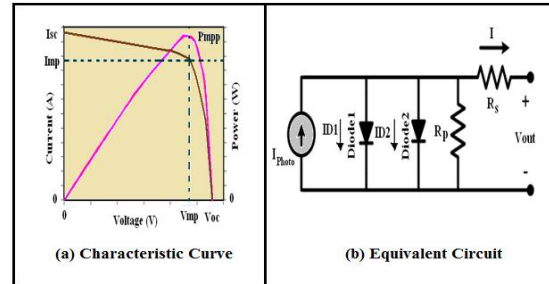


Fig. 4. Two Diode Photovoltaic Cell Configuration

Based on double diode models, the non-ideal photovoltaic array output current can be expressed as,

$$I_{output} = I_{Photo} - I_{Diode1} - I_{Diode2} - I_{Shunt} \quad (6)$$

The photovoltaic array can be designed with DC current source which is parallel with double diode. The current is acquired by methods for dispersion and recombination of charge mechanisms. The output current equation comprises of photo current, shunt current and diode action and so on. The mathematical equation for the p-n junctions current is given below,

$$I_{Photo} = I_{ShrtCrt} + K_I (T_{Cell} - T_{reference}) G \quad (7)$$

$$I_{output} = N_P I_{photo}$$

$$- N_P I_{01} \left[ \exp \left( \frac{V + IR_S \left( \frac{N_S}{N_P} \right)}{N_S \alpha_1 V_T} \right) - 1 \right] \\ - N_P I_{02} \left[ \exp \left( \frac{V + IR_S \left( \frac{N_S}{N_P} \right)}{N_S \alpha_2 V_T} \right) - 1 \right] \\ - \left( \frac{V + IR_S \left( \frac{N_S}{N_P} \right)}{R_P \left( \frac{N_S}{N_P} \right)} \right) \quad (8)$$

### 3.3 Fuel Cell Generation Model

The power generation of Proton Exchange Membrane (PEM) type fuel cells has the combination of  $H_2$  and  $O_2$  against a platinum catalyst accelerator to develop a photovoltaic model is called as the product of electrochemical energy and water. The schematic diagram of PEM fuel cell is shown below in figure 5.

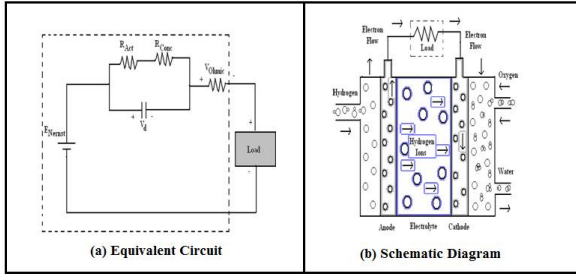


Fig. 5. Schematic Representation of Fuel Cell Configuration

When current abruptly changes with respect to operating voltage to reach its final equilibrium state. The Output of fuel cell voltage is written as,

$$V_{OutputFuelCell} = E_{Nernst} - V_{Act} - V_{ohmic} - V_{Conc} \quad (9)$$

$$E_{Nernst} = 1.229 - 8.5 \times 10^{-4}(T - 298.15) + 4.318 \\ \times 10^{-5} T \left[ \ln(P_{H_2}) + \frac{1}{2} \ln P_{O_2} \right] \quad (10)$$

$$V_{Act} = K_1 + K_2 T + K_3 T \ln(CO_2) + K_4 T \ln(I) \quad (11)$$

$$V_{ohmic} = I \left( \frac{r_m l}{A} \right) \quad (12)$$

$$V_{Conc} = K_5 e^{K_6 I} \quad (13)$$

Here,  $T$  denotes the stack temperature (K) and  $I$  ( $mA/cm^2$ ) represents the operating current density and also  $CO_2$  is defined as a concentration of  $O_2$  at catalyst accelerator interface ( $mol/cm^3$ ). The present simulation model uses parametric coefficient values whose are given below,

$$K_1 = -0.9514, \\ K_2 = 0.00312, \\ K_3 = 7.4 \times 10^{-5}, \\ K_4 = -1.87 \times 10^{-4}, \\ K_5 = 1.1 \times 10^{-4} - 1.2 \times 10^{-6}(T^\circ - 273), \\ K_6 = 8 \times 10^3 \quad (14)$$

$V_{cell}$  makes use of current density, temperature cell and reactant pressure, and membrane hydration. On the off chance that every one of the cells are associated with a series arrangement, stack output is ascertained by the outcome of cell voltage and a number of cells in the stack ( $N$ ).

### 4. Proposed control method

The hybrid renewable energy is connected to a micro-grid system through the current fed switched inverter. The proposed system produces high power by using MPPT in power converter and regulates the inverter power. The comparison results provided the maximum power generation in proposed system while compared to MPPT P&O and MPPT Fuzzy. The three phase multilevel inverter can be controlled by using voltage and current regulation in output side.

#### 4.1 Distributed MPPT

Generally, there are various MPPT methods which involve various implementations depending on hybrid power generation topology. A DMPPT can be implemented in each DC/DC converter based on renewable energy. Here, it can allow the improvement of hybrid system power efficiency.

The fuzzy based MPPT algorithm provides better performance and maximum power generation while compared to Perturb & Observe based algorithm. The Block diagram of distributed MPPT architecture is shown in figure 6.



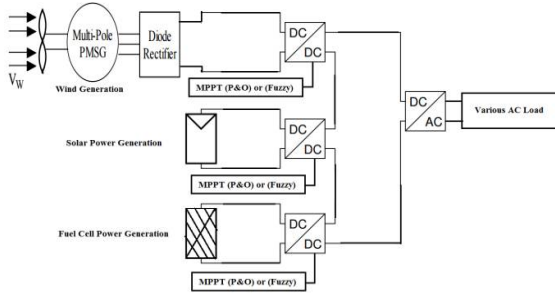


Fig. 6. Block Diagram of Distributed MPPT

Furthermore, the presented paper has diffused Perturb and Observe (P&O) based MPPT algorithms while tracking maximum power response independent on the environmental condition with implementation involves a voltage and current sensor by increasing the cost and complexity.

Similarly, the Fuzzy logic algorithm is the most powerful control methods for power generation system and it has a multi-rules-based solution and multivariable consideration. The Simulink model of proposed Fuzzy and P & O based MPPT is shown in Figure 7. The fuzzy logic control has two input and one output sources.

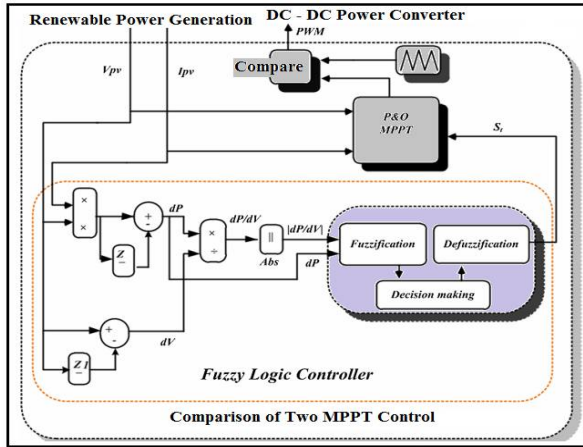


Fig. 7. Simulink model of proposed MPPT Controller

In order to using the Fuzzy Logic Tool Box in Matlab, membership functions and rules are developed in Fig.8(a), 8(b) and 8(c) and speak for the input and output of fuzzy system.

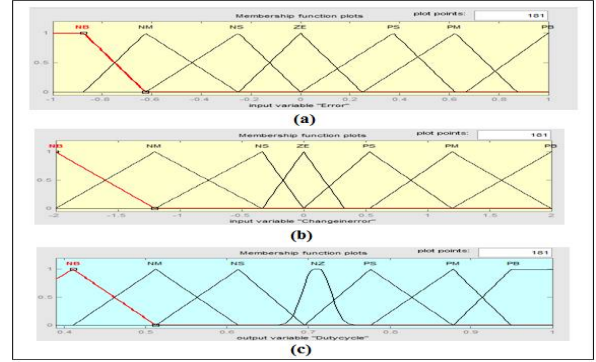


Fig. 8. Membership Function of Graphical View (a) Error (b) Change in error (c) Duty cycle

The output response of fuzzy logic rule base view and surface view are depicted, in figure 9 (a & b).

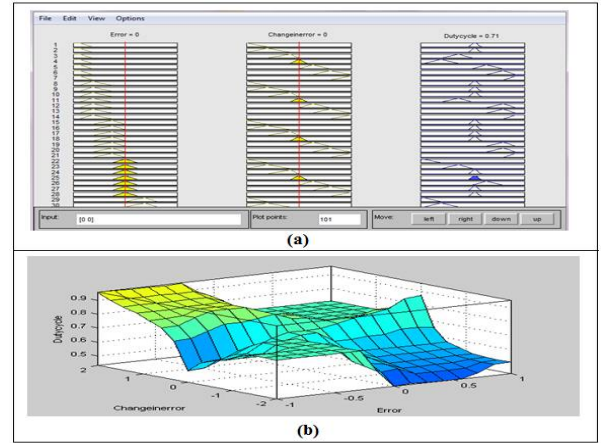


Fig. 9. Fuzzy Graph (a) Rule View (b) Surface View

The presented paper uses the fuzzy case; seven subsets based on forty-nine rules techniques were used for increasing function. The tuning of above techniques are used to get better accuracy and an active response while compared to P&O and MPPT.

#### 4.2 Voltage and Current Control Based VSI

The output of VSI is associated with DC link of proposed hybrid power generation system. The conversion unit which carry out the interface purposes between the DC bus and three phase various AC load followed by the LC filter that pass on and distributes the power to the end user as well as the load.

The voltage/current controller gives a steady output and keeps up the voltage at the point of common coupling stage. The block diagram representation of VSI control scheme is shown in figure 10.

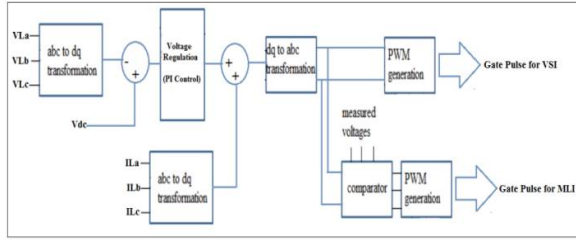


Fig. 10. Block Diagram of control strategy for three phase inverter

The VSI creates a stable power and is fed into the AC load application. The inverter output voltage and current control are supported to the LC filter is quantified and transformed into a synchronous rotating reference frame (abc transformed into dq frame). Then it is matched up with the reference value of DC link voltage. This comparison denotes an error value that is fed to the voltage regulator to incite the reference current for the inverter.

Again the dq is altered into abc frame to deliver the current references, and after that it is utilized to bring about the gate pulse signal for VSI. Similarly, the quantified three phase voltage errors are extended along a gain and the enhanced signal is contrasted with the stable frequency of triangular carrier wave of unity amplitude to trigger the step level gating signals for multilevel inverter.

## 5. Simulation Study

This paper presents the power quality improvement of a hybrid DC-DC power generation based micro-grid system. Better performance of the control scheme, comparison between the proposed MPPT fuzzy method and classical MPPT, P&O with voltage control method were presented for verification.

The power quality analysis of this present system is achieved by using PFC on load side inverter for both VSI and nine level three phase inverter. From the proposed overall structure, it can be observed that the fuzzy MPPT generates maximum power than P&O. The overall proposed Simulink topology is shown in figure 11 and the corresponding simulation results are depicted in Figures 12 to 22.

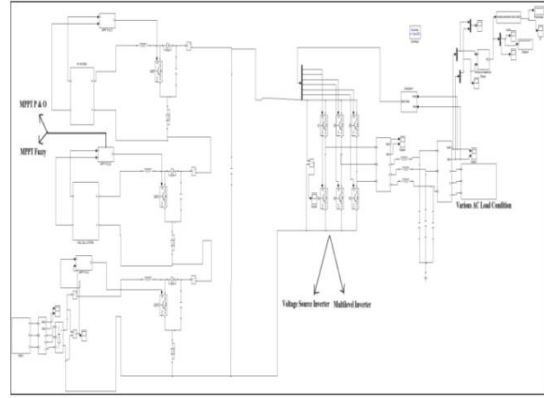


Fig. 11. Overall Simulation Circuit of Proposed System

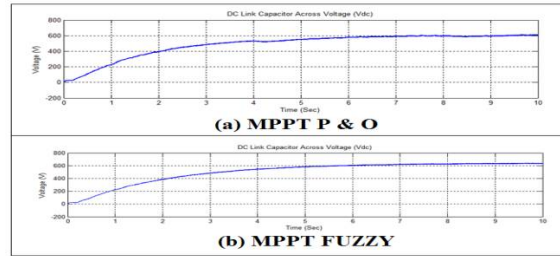


Fig. 12. Capacitor across DC Link Voltage Waveforms

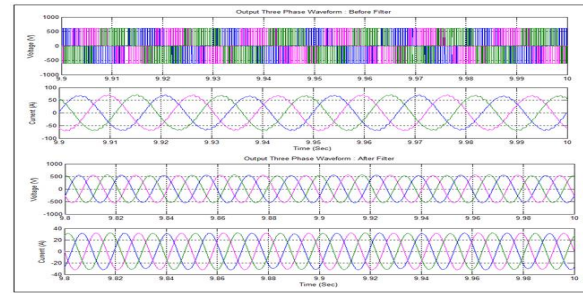


Fig. 13. MPPT P&O based output waveforms with and without filter for linear load

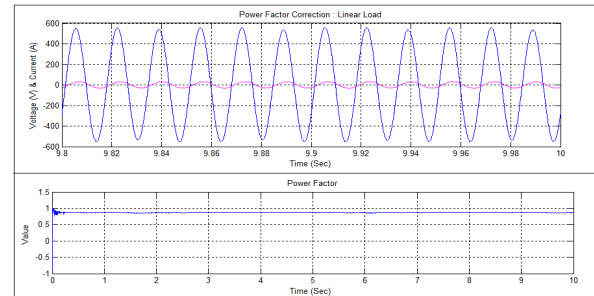


Fig. 14. Power factor correction for linear load condition

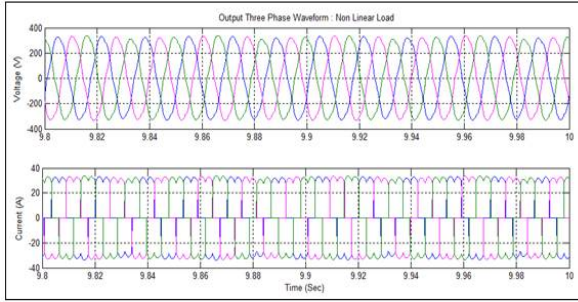


Fig. 15. Output three phase waveform for non linear load

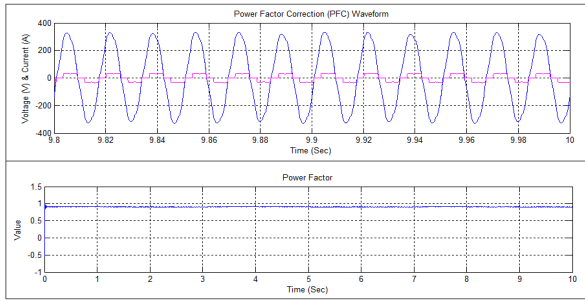


Fig. 16. Power factor correction for non linear load condition

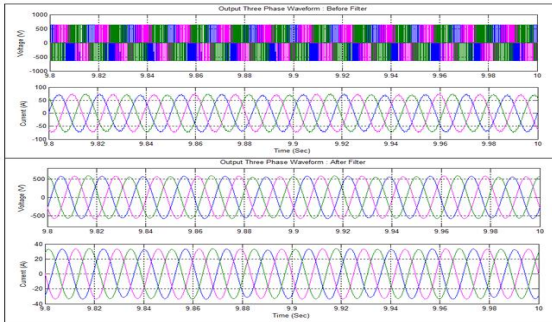


Fig. 17. MPPT Fuzzy Based output waveforms with and without filter for linear load

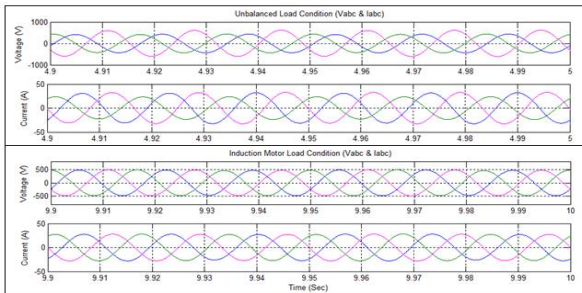


Fig. 18. Output waveforms for various load condition

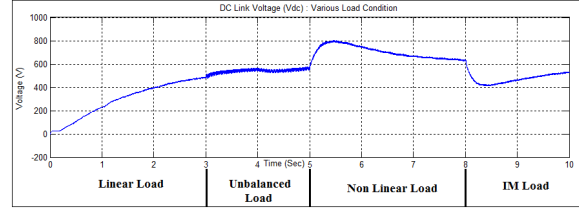


Fig. 19. DC link voltage waveform for various load condition

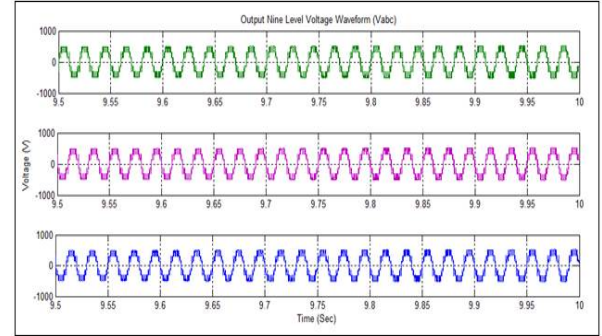


Fig. 20. Nine level output voltage waveform

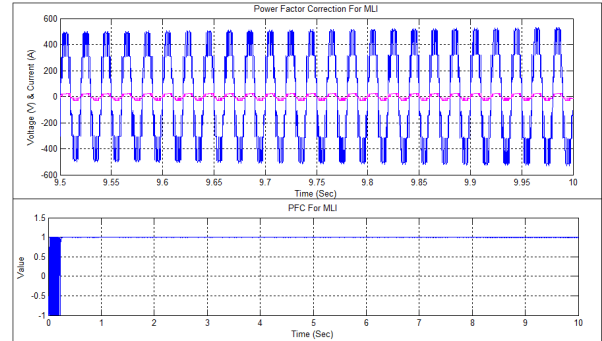


Fig. 21. Power factor correction for multilevel inverter (9 levels)

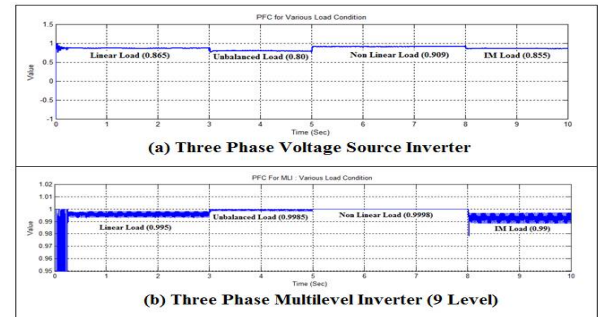


Fig. 22. Comparative results of PFC for various load condition



The simulation parameters of the proposed overall system with load conditions are mentioned in Table 1. From the above simulation, results are shown as a comparative analysis of MPPT based P&O and Fuzzy logic controller and PFC for both voltage source inverter/multilevel inverter are verified using Matlab Simulink environment.

Table 1. Simulation Parameter Specification for proposed system

Parameters Specification	Values
Output voltage (V)	600 - 700
DC link capacitor value [ $\mu$ F]	2300
Carrier Frequency (HZ)	1080
Filter Inductor (L) [mH]	20
Filter Capacitor (C) [ $\mu$ F]	500
Unbalanced Load ( $\Omega$ )	R = 5, 10, 15
Linear Load ( $\Omega$ )	R = 10
Non Linear Load ( $\Omega$ & mH)	R = 10, L = 1
Induction Motor Load Power (VA), Voltage (V) Frequency (Hz), Pole pairs	0.37e3, 230 50, 2

## 6. Conclusion

The proposed hybrid energy based current fed switched inverter improves the power factor for micro-grid application. The current fed switched inverter generates maximum power by using distributed MPPT. The hybrid renewable energy uses various loads such as linear, nonlinear, unbalanced and induction motors. Moreover, distributed MPPT controller such as P&O and fuzzy has been simulated in the proposed hybrid system. The comparison of MPPT P&O and MPPT fuzzy based power production for various load conditions. The fuzzy produces high power with less oscillation and also has less overshoot with fast tracking time compared to MPPT P&O algorithm. The voltage source inverter and multi level inverter based hybrid system are compared. The proposed multilevel inverter has a minimum switching device, less THD, and high efficiency.

## 7. Future Work

The proposed hybrid renewable energy system uses fuzzy based distributed MPPT that generates require power. In future, the MPPT control strategy would be modified and furthermore, the multilevel inverter for high power generations would be changed and additionally, the power factor in hybrid based inverters for AC applications would be enhanced.

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