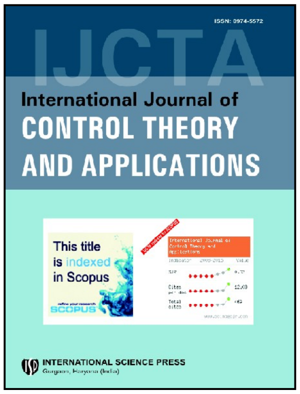

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Power Quality Improvement in Renewable Energy Resources Based Microgrid System Using Active Power Conditioner

Hemanand T.[1] and N. P. Subramaniam[2]

[1] *Sathyabama University, Chennai, India, E-mail: hemanand.miteee@gmail.com*
[2] *Pondicherry Engineering College, Puducherry, India*

Abstract: The micro-grid for medium level power generation involves aseveral alternative power sources of small in size with or without utilitygrid.Solar cells, micro-turbines (natural gas), wind turbines,fuel cells andbatteries are the major small power renewable alternative sources and they are usually connected to the distribution network of low voltage level through power electronic based converters. This paper proposesa three-phase Active PowerConditioner to enhance micro grid power quality based on renewable energy. Active Power Conditioner (APC) works as an interface between the microgrid AC busand renewable energy sources. Also, it can be provedessential alternative to compensate voltage and current disturbances in distribution power systems. The novel control strategy presented in this paper offersthepossibility of injecting electrical energy from the different renewable sources and improves the power quality of the microgrid. The multilevel inverter is connected in between the micro grid and utility grid for power quality analysis such as harmonic compensation, power factor correction, THD (total harmonic distortion), voltage balancing. The proposed topology can be implemented and results show by using MATLAB/SIMULINK.

Keywords: Micro grid, DC – DC converter, Renewable energy, Active power conditioner, Multi level inverter and power quality enhancement.

1. INTRODUCTION

Recently,the installations of more DG's in power distribution networks are encouraging the power generation and energy storage at the distribution level. The concept of Microgridundertakes a clump of loads and microsources working as a singlecontrollable system that gives both heat and power to its local area. Harmonic current compensation in micro grid will be effective by providing the intelligent coordination methods ofmultipleDRs using fuzzy based multipleobjectivetype optimizationmodel. Also, the real and reactive power allocation (RPA) strategy was intended to discharge power flow under wide variations for regulation of power flow[1] – [3].

The active power conditioner method is used for power quality improvement in micro grid system [4]. It makes possible to drive energy, correct the power factor and compensate the current harmonics in the microgrid. For harmonic and reactive power compensation ofthe non-linear load, the both PI controllers based and fuzzy logic controller VSI based shuntactive power filter are implemented [5]-[6]. A Novel predictive methodof controlalgorithm is used for faster computational time by optimizing the transient control and thesteady-stateproblems separately. The simulation results are verified and it handles a PQ issues in wide range, thus increasing the reliability of the micro grid. The hybrid system based BESS integration is regulatedto balance the power between utility grid and PV generation under varying dc load conditionsand solar isolation. Similarly, the adaptive MPPT algorithm based wind/solar hybrid system of front-end rectifier stage for extract the maximum power generation [7]-[9].

The active power component theory (APCT) has beenproposed for controlling harmonics, reactive power and nonlinear load compensation by shunt active power filter. [10]-[12]. All the power quality issues are compensated for fixed speed induction generator by using unified power quality conditioner [13].

In this paper, the micro grid system based renewable energy for power quality improvement is proposed. The Active Power Conditioner (APC) is used to improve the powerquality in a microgrid. The control strategy can be inserting energy into the microgrid, correcting the power factor,compensating the current harmonics, and maintaining the balanced supply voltage at the PCC (Point of Common Coupling). The multilevel inverter connected between the micro grid and utility grid for power quality improvement. The Simulation results show the validity of the innovative control strategy proposed through simulation tests using SimPowerSystems from SIMULINK/MATLAB.

2. MICRO GRID STRUCTURE

TheMicro Gridconcepts are doing an important role in the portfolio of nation energy. It can be used to encounter peaking power, baseload power, backup power, power quality,remote power,heating and cooling needs.The electricity generation, transmission, and distribution are supported and strengthen by MG resources.The two important power quality aspects considered are usually namely harmonic distortion andtransient voltagevariations of the network voltage. The micro grid component consists of wind energy, solar PV panel and fuel cell. The micro grid system is shown below in fig 1.

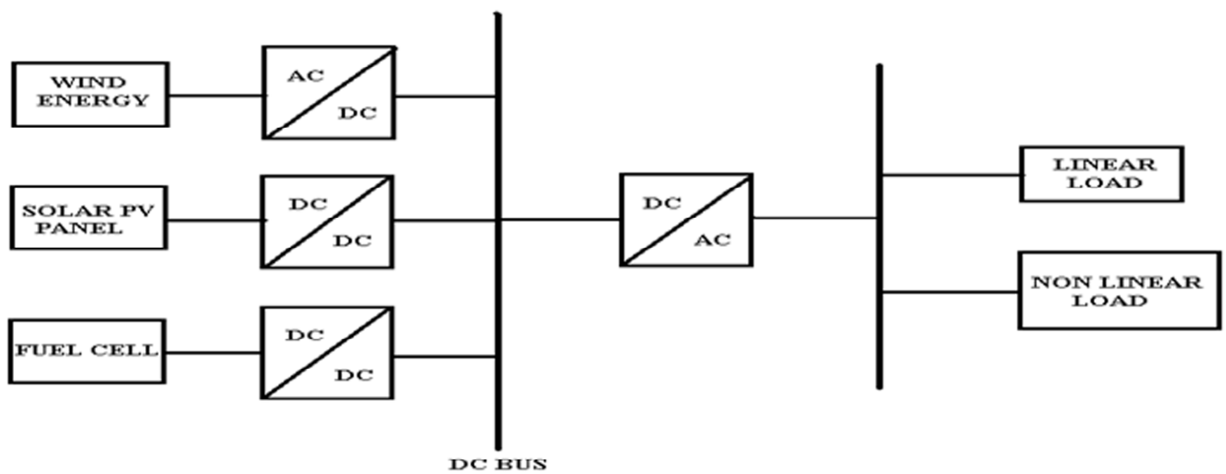

Figure 1: Micro grid system

Each source model can be completedindependently and connected in a micro-gridconfiguration.During disturbances, without harming the integrity of transmission system, the static switch is able to act independently to separate the subsystem and the distribution system in order to isolate the microgrid. But in microgrids it is also possible that all generationunits are connected with synchronized power electronic inverters [9].

3. MULTIPLE DISTRIBUTED RESOURCE SYSTEM

The main goal of microgridoperationisused tosupplyelectricpower with high reliabilitytothe loads regardless ofabnormal operating conditionsin the multiple distributed resource system. The distributed resources such as wind energy, solar PV panel and fuel cell connected via DC-DC converter are used for micro grid applications. Thebasicconceptof this paper is to use the multi level inverterinterfacedDRs in order tocounterpoise power factor correction and multiple harmonic components.

3.1. Wind Turbine with Pmsg System

Due to the quick development of power electronic field and the growing interest in wind turbine, manufacturers could be able to find the low cost and most suitable technologies to put in recent applications. The extraction of kinetic energy from the wind which is passing through its rotor will operate the wind turbine.The development of power by a wind turbine is given by,

$$P = 1/2 C_P v V_w{}^3 A \tag{1}$$

Permanent magnet synchronous generator are more popular, because of the high reliabilityincreased power to volume ratio,increased efficiency, decreasing cost of magnets, and no need of external excitation, easyto control and smaller in size. The PMSG with wind turbines circuit is shown below in fig. 2.

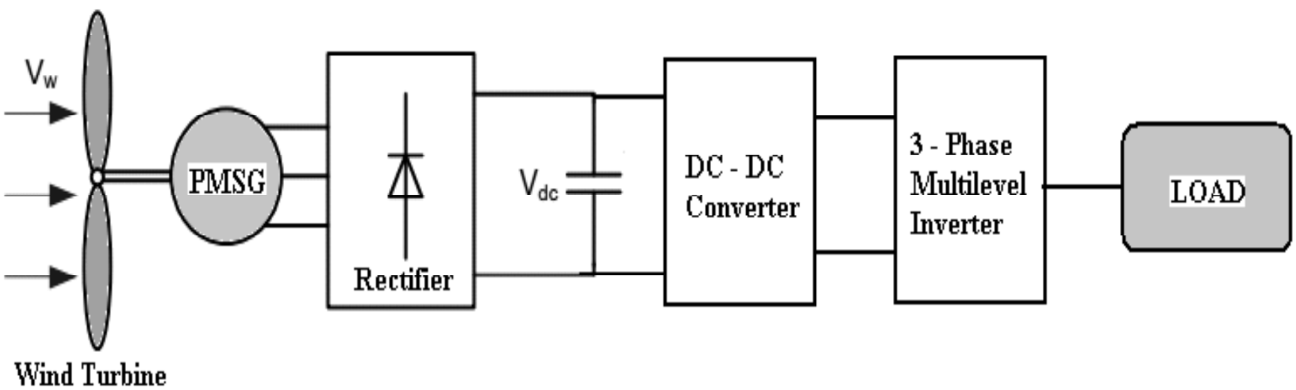

Figure 2: WT + PMSG configuration

The dynamic equation for interaction between turbine-PMSG is written by equation of torque is given by,

$$T_w - T_{em} = J_w \frac{d\Omega_w}{dt} + f_w \Omega_w \tag{2}$$

Where, T_w and T_{em} are respectively the wind turbine mechanical torque (2) and PMSG electromagnetic torque. J_w and f_w being the total wind turbine inertia and viscous friction coefficient.In order of optimization the PMSG for wind turbine system integrated with wind speed profile, wind turbine and diode rectifier.

3.2. Solar Photovoltaic System (PV)

The simplest PV model can be considered as a diode. When exposed to light, the electrons and holes are separated when the photos energy is higher than the band gap energy. Under the influence of the electric field of the p-n junction diode, the electrons and holes flow through an external circuit. Finally, the light energy can be converted into the electrical energy. The equivalent circuit diagram of PV cell system is shown below in fig. 3.

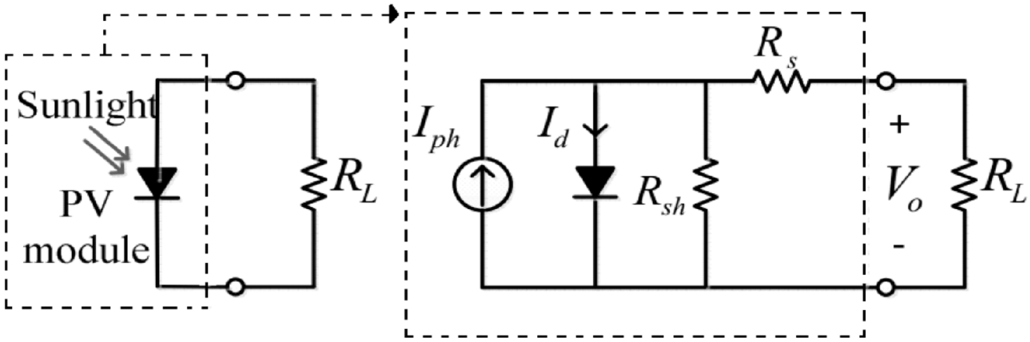

Figure 3: Equivalent circuit diagram of PV system

The basic model includes a photocurrent source, a single diode junction and a series resistance and a shunt resistance.The equations which describes the characteristics of PV cell are presented below.Current I is described as,

$$I = I_L - I_{D^e}\left(\frac{V + I'R_S}{nV_{th}} - 1\right)\frac{V + \dot{I}R_S}{R_{Sh}} \quad (3)$$

Where, I_L is the photo current, I_D is the reverse saturation current of the equivalent diode, R_S and R_{Sh} are the series and shunt resistances of the PV cell and n is the diode quality factor. The schematic diagram of PV with inverter is shown in fig. 4.

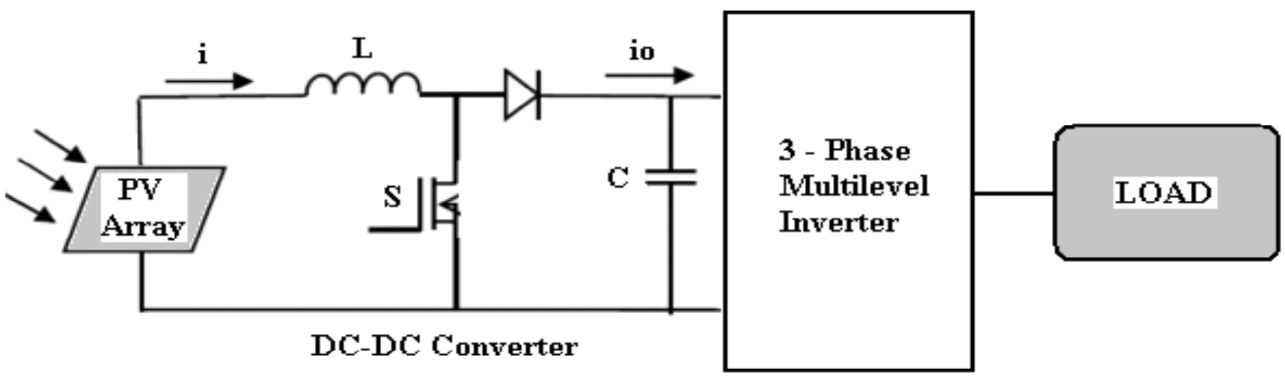

Figure 4: Schematic diagram of PV with inverter

The level of radiation from the solar energy determines DC power generated in the PV system. Fig. 4 shows theDC power from PV system which is convertedtoacpowerforthe purpose of injecting AC power intothegridvia adc -dcboostconverterandadc- acpowerinverter. In this paper, the controller of the DC-DC converter is achieved by using PWM pulse generation method.

3.3. Fuel Cell System

An electrochemical device that converts chemical energy form into thermal and electrical energies form is known as In this paper, a suitable SB- PWM (simple boost pulse width modulation) is implemented and generation potential of PEMFC (Proton Exchange Membrane Fuel Cell) developed. The schematic and equivalent circuit of fuel cell is shown in figure 5.

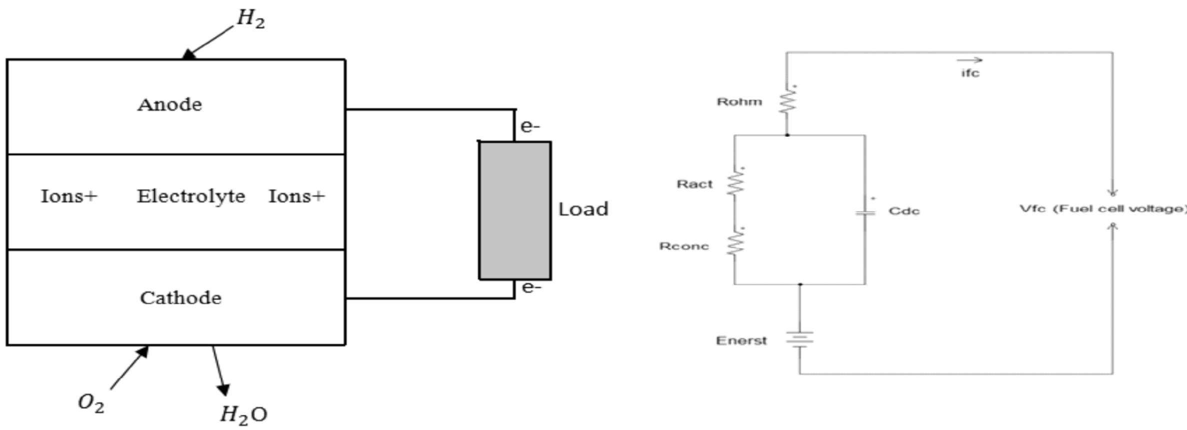

Figure 5: Schematic and equivalent circuit of fuel cell

The voltage of the cell is given in Equation,

$$V_{cell} = E_{thermo} - V_{act} - V_{ohmic} - V_{cone} \tag{4}$$

V_{act} is an activation losses which are irreversible and are unavoidable,concentration polarization voltage drop is represented by V_{conc} andohmic polarization by V_{ohmic}. The fuel cell with inverter topology is shown in figure 6.

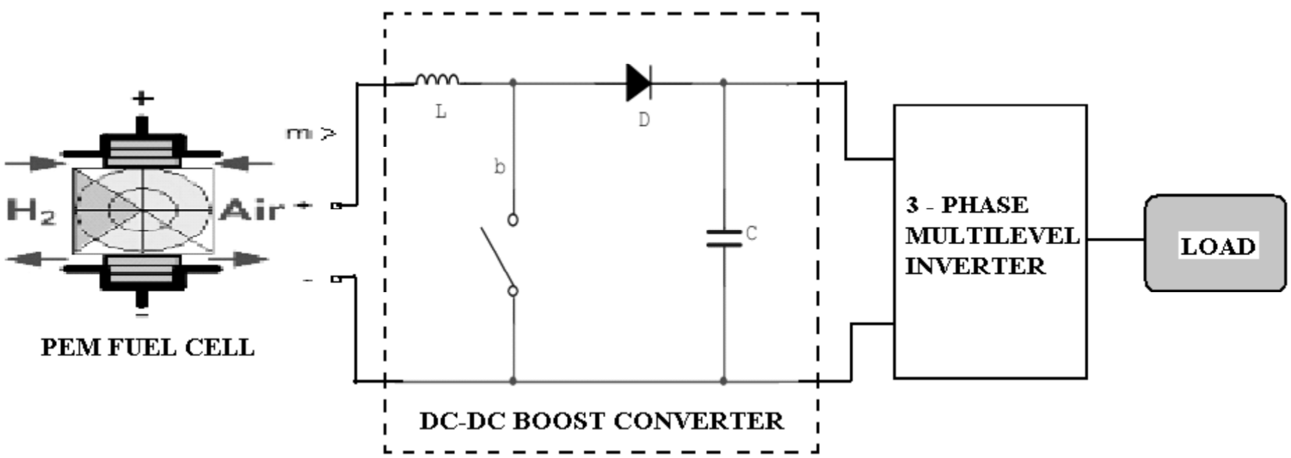

Figure 6: Fuel cell with inverter topology

The PEM fuel cell with DC-DC power converter structure allows to avoiding nonminimum phase property and output voltage is controlled directly, that simplifies the controller design.

3.4. Three Phase Multilevel Inverter System

The standard inverter drives are used for medium voltage industrial applications whereas the multilevel voltage-source inverters are exclusively studied for high-power applications.Multilevel inverter have the capability to produce waveforms with a better harmonic spectrum and to reduce theinsulation stress of the motorwinding.In this paper, the harmonic analysis of normal three phase inverter and five level three phase inverter is presented. Tocompensateharmoniccurrent,thethreephasemultilevel powerinverterscan utilize the voltage regulated pulse widthmodulation by using Active power conditioner control scheme. The three phase multilevel inverter diagram is shown in figure 7.

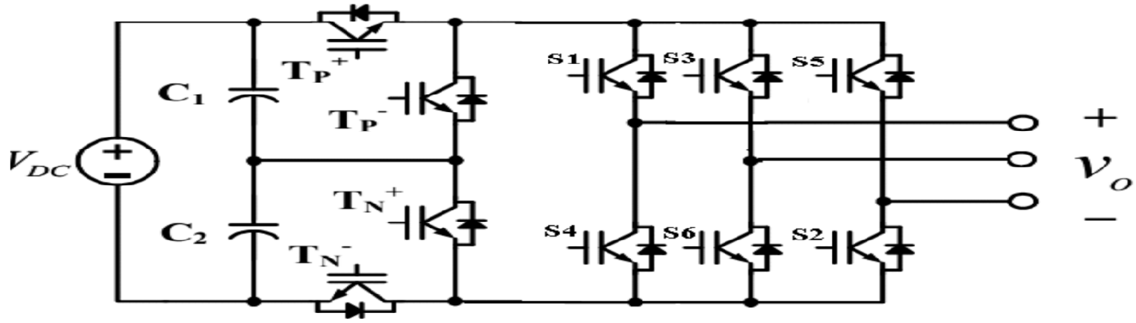

Figure 7: Three phase multi level inverter topology

The main concept of multilevel voltage inverters is to have aimproved sinusoidal current and voltage by using switches in series [10]. The switching angles of multilevel inverters are very important as many switches are put in series. The reason is stated that all of the switches should be operated insuch a way that the very low harmonic distortion will be presented in the output current and voltage waveform.The sum of the voltage generated by each cell will give the total output voltage. Theswitching angles are chosen accordingly in order to minimize the harmonic distortion.The switching state of multilevel output voltage is tabulated 1 in below.

Table 1
Output voltage according to switching states

Output Voltage (V_0)	*Switching condition* T_P^+	T_P^-	T_N^+	T_N^-	S_1, S_6, S_2	S_3, S_5, S_4
V_{DC}	ON	OFF	OFF	ON	ON	OFF
$V_{DC}/2$	OFF	ON	OFF	ON	ON	OFF
	ON	OFF	ON	OFF	ON	OFF
	OFF	ON	ON	OFF	ON	OFF
0	OFF	ON	ON	OFF	OFF	ON
$-V_{DC}/2$	OFF	ON	OFF	ON	OFF	ON
	ON	OFF	ON	OFF	OFF	ON
$-V_{DC}$	ON	OFF	OFF	ON	OFF	ON

4. PROPOSED CONTROL TOPOLOGY

The non-linear load and switching power converters affects the power quality in the micro grid. One of the possible solution to tackle the power quality issues is to utilize the APC as a power interface system between the AC bus of themicrogrids and renewable energy sources as shown in Fig. 1. Additionally, it can be proved to be an essential alternative to mitigatevoltage and current disturbances in distribution systems. This proposed topology has showed good controllability than the converter having three-leg four-wire. The drawback of five level multilevel inverter used in this paper is shown that it contains more number of power semiconductor devices [11] – [13]. Normally, it is possible to suppress disturtions like Total Harmonic Distortion, voltage unbalance and others. The Simulink diagram of control scheme is shown below in figure 8.

The APC controller is used to provide improved power quality ina microgrid even when the supply voltage itself would be unbalanced and/or distorted. The APC can compensate non linear load current by compelling the current in the micro grid side to become balanced and sinusoidal with the help of proposed control algorithm.

The operation of active filters depends on the harmonic injection required by the load.A current having equal and opposite in polarity is generated by active filtersand injecting it to the point of coupling andcompels

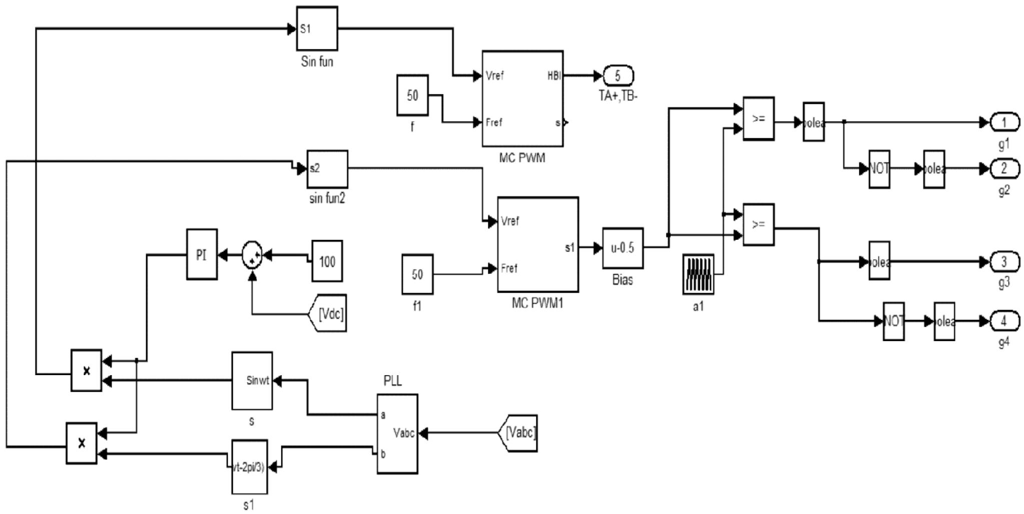

Figure 8: APC control structure

the sourcevoltage to be near sinusoidal. As a consequence, the filtering algorithm employed provides the harmonic compensation characteristics for theloadvoltage harmonics calculations.The active conditioner converter type can be either VSI or CSI bridge structure. The proposed method can be series, shunt, or a combination of both. In this paper, the series connection of active power conditioner used for VSI based harmonic compensation is proposed.

5. SIMULATION RESULTS AND DISCUSSION

The micro grid system including various renewable energy sources, DC-DC converters, Active power conditioner (APC) based multilevel inverter and different load conditions has been developed in SIMULINK/MATLAB. The renewable source such as consider wind energy, PV system and PEM fuel cell for power quality analysis. The control scheme of APC is used to improve the power quality in a microgrid. The simulation results has verified and presented according to the following power quality indicators: harmonic compensation, THD (Total Harmonic Distortion) and power factor correction. The overall circuit configuration of simulation block is shown below in fig. 9.

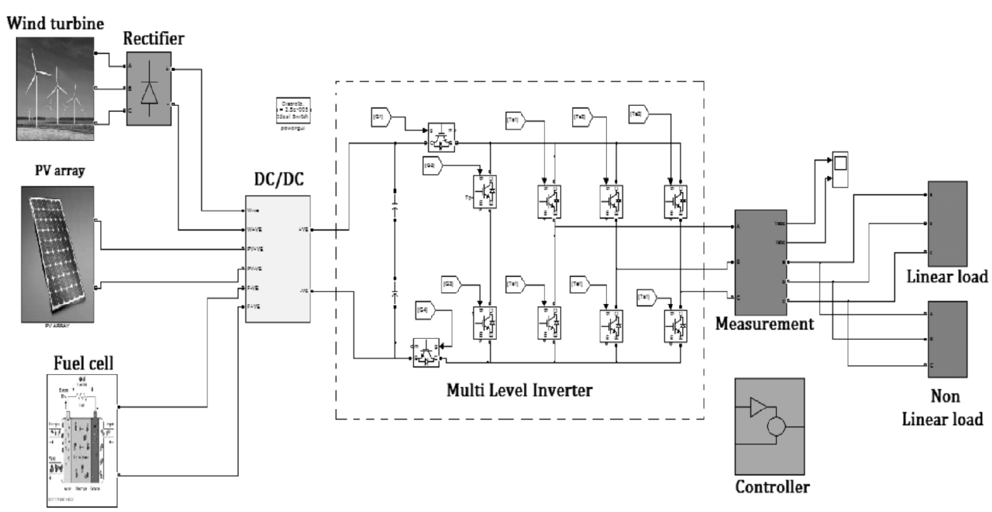

Figure 9: Overall simulation circuit configuration

The investigated active power conditioner has been simulated with six IGBTs controlled by the system parameters is tabulated 2 in given below.

Table 2
Simulation parameter for overall circuit

Parameters	*Values*
Output voltage (V)	400
DC link capacitor value [mF]	500
Filter Inductor (L) [mH]	
Filter Capacitor (C) [µF]	1200
Switching Frequency (HZ)	50
Linear Load (&!&mH)	R =10L =0.001
Non Linear Load (&!&mH)	R =10L =1

Theharmonic components analysis in the proposed multilevel inverter can beperformed.The benefits of proposed multilevel inverter shows that it contains a less number of power elements, smaller in filter size, less circuit complexity and high in efficiency. The overall DC link capacitor across the voltage is shown below in fig. 10.

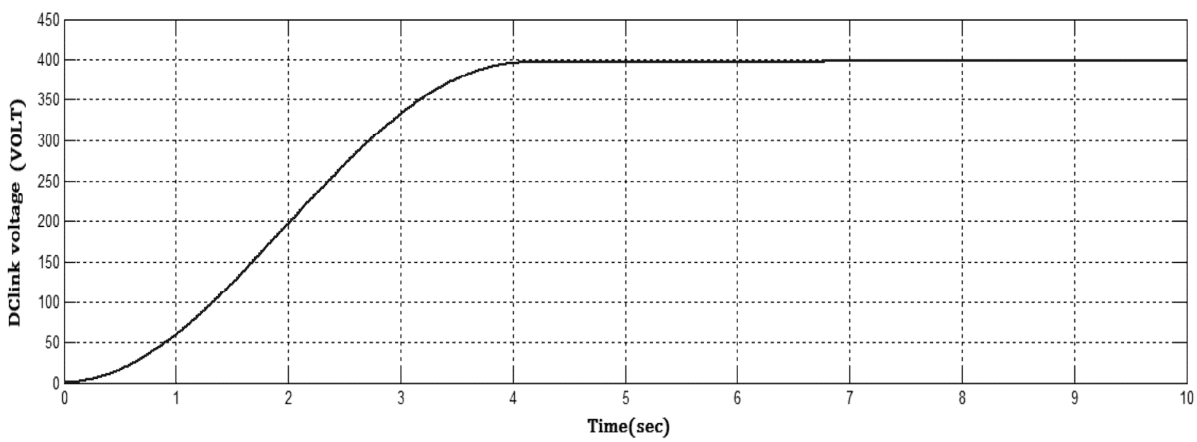

Figure 10: DC link capacitor across voltage

The circuit configuration is analyzed in both VSI based three phase inverter and five level three phase inverter for power quality improvement. The power factorcorrection can be achieved by using DC-AC connection. Because, in distorted conditions the results are power and also the capacitor life is shorter. So maintenance cost also high. The various load condition is verified in simulation such as linear load and non linear load condition. The output voltage and current waveform for linear load is shown below in fig. 11.

The VSI based inverter of linear load with filter for power factor correction (0.90) can be achieved waveform is shown below in fig. 12.

The harmonic compensation of linear load VSI based inverter can be obtained total harmonic distortion (1.08%) is shown below in fig. 13.

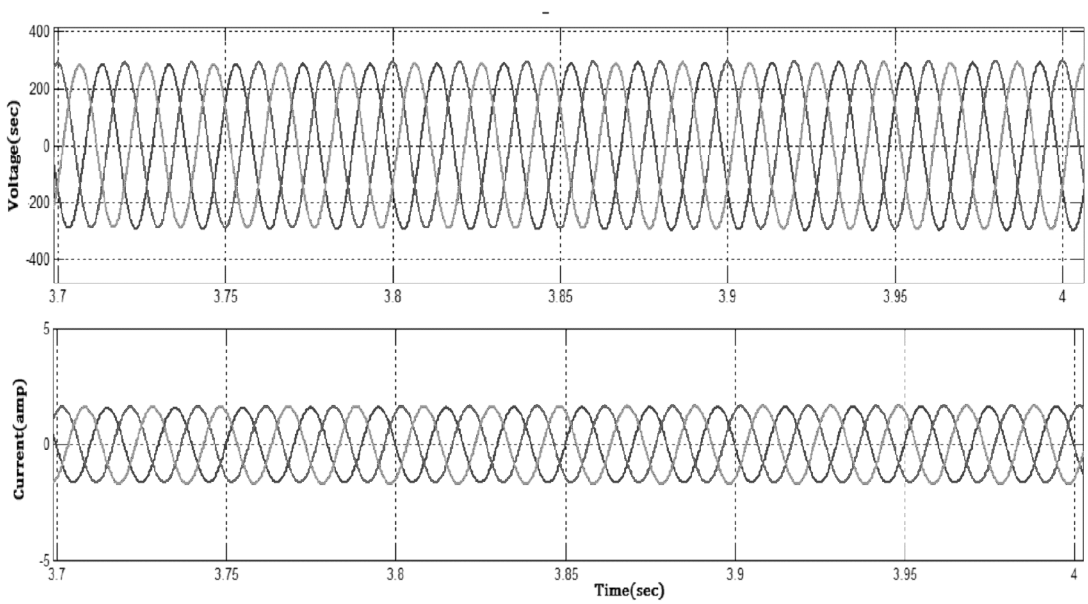

Figure 11: Output voltage and current waveform for linear load

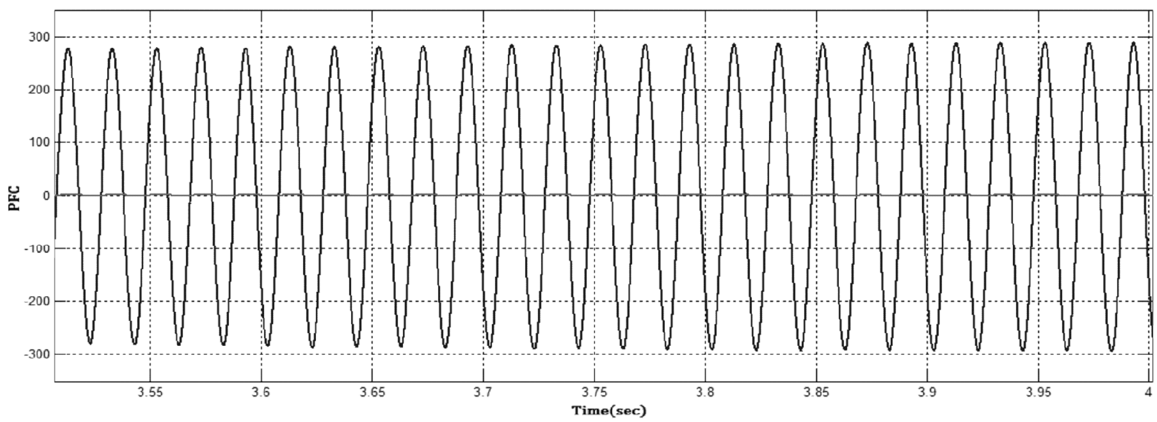

Figure 12: Power factor correction for linear load

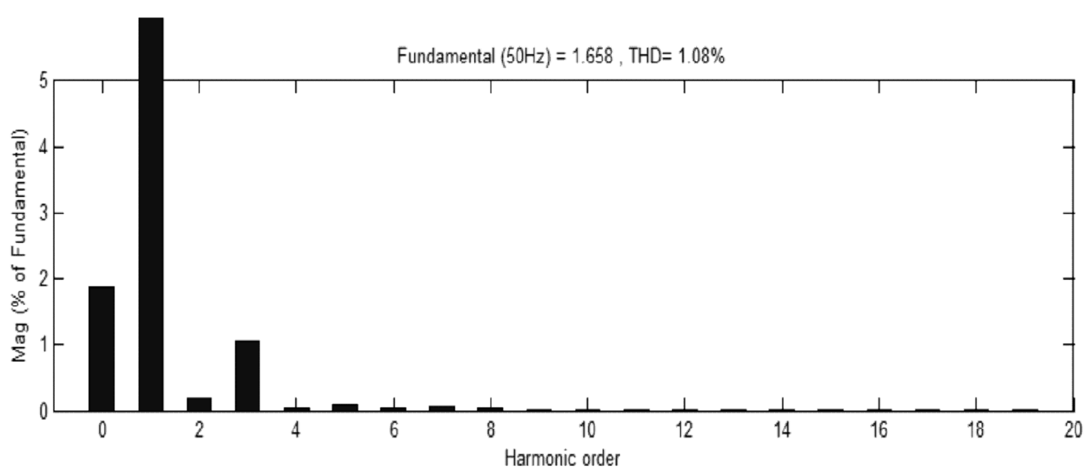

Figure 13: Total harmonic distortion for linear load

Similarly, the non linear load condition can be verified the same above mentioned condition for power quality improvement. The output voltage and current waveform of inverter with non linear load conditions, THD is shown below in figures 14 and 15. The power factor correction (PFC) can be achieved 0.86 and total harmonic distortion (THD) is obtained 20.17% for VSI based inverter with non linear load conditions.

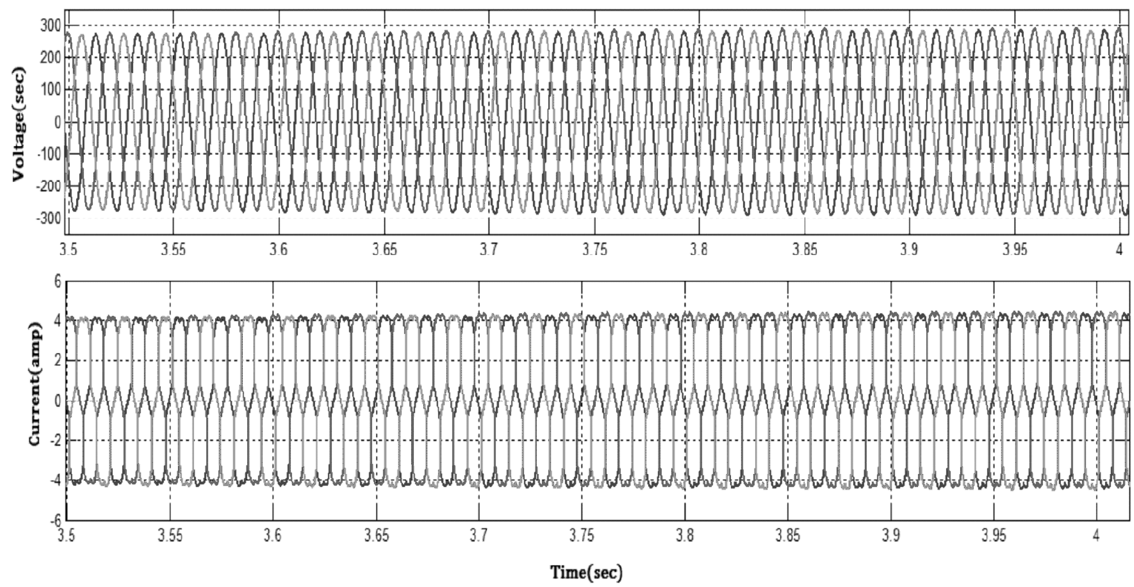

Figure 14: Output voltage and current waveform for non linear load

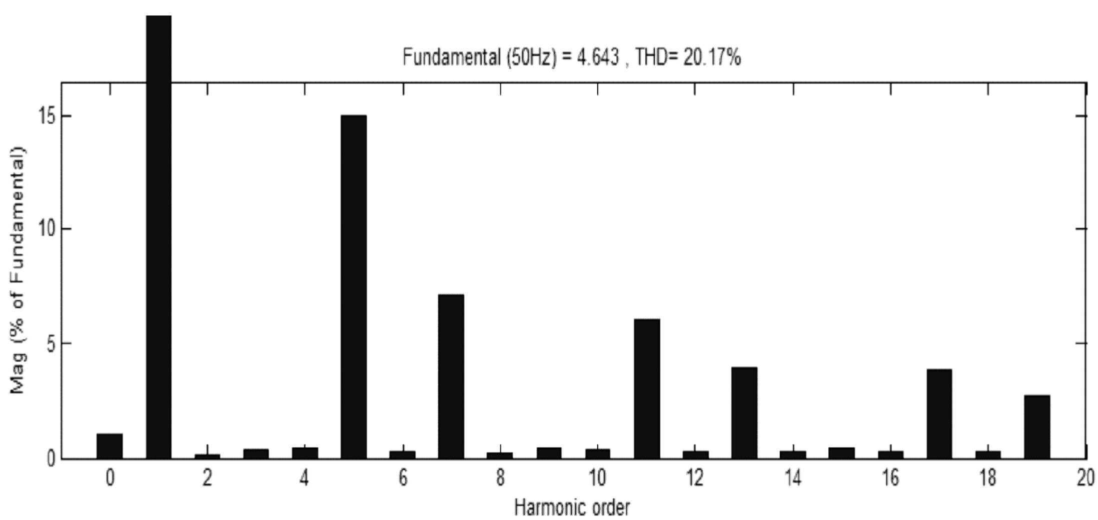

Figure 15: Total harmonic distortion for non linear load

In the proposedcontrol topology, the APC can be able to implementa unity power factor between the supply voltage and the microgrid side currents. The phase of the micro grid side currents is inverted accordingly to the supply voltage phases at the PCC because the APC power injection valve is greater than the power required by the load side. The VSI based inverter without filter of output voltage is shown below in figure 16.

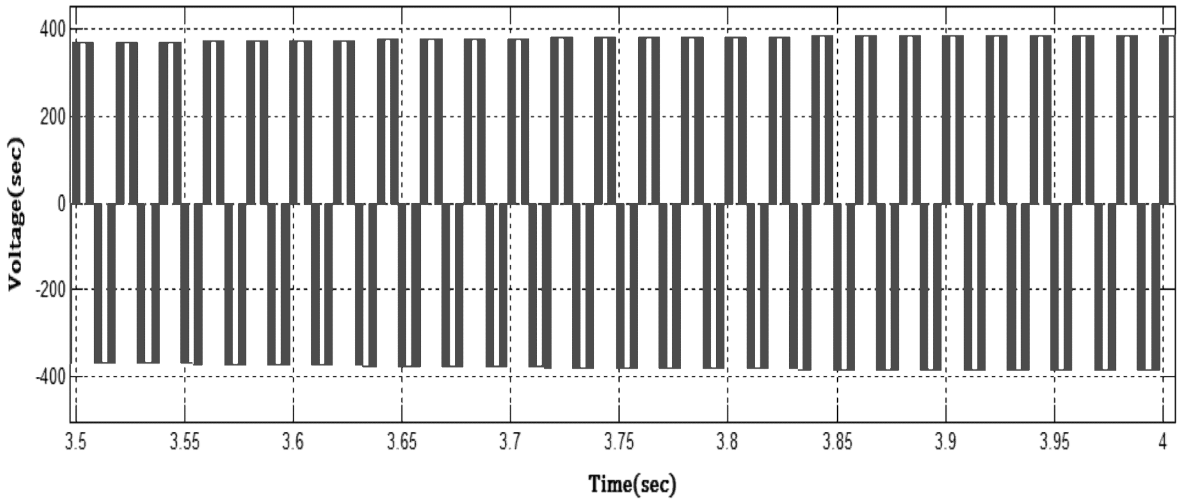

Figure 16: Output voltage without filter for linear load

In order to overcome the problem and using filter components cost instead of applying multilevel inverter for above mentioned process. Here, five levels based three phase inverter using without filter for compensation of harmonic and power factor. The output three phase voltage of multilevel inverter is shown below in fig. 17. The total harmonics distortion can be reduced and PFC can be achieved (0.96) by using this five level inverter.

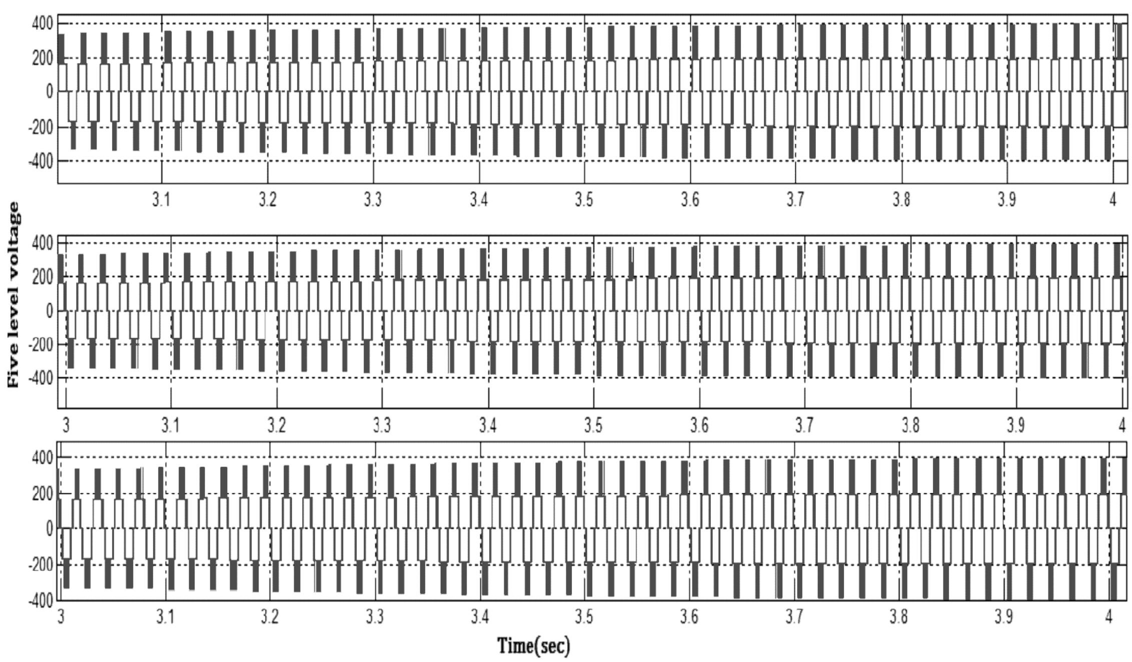

Figure 17: Five level three phase voltage waveform

The system operates at unity power factor, since both the output voltage and the output current are in phase and hence inject active power to the grid. Simulation results proves that the proposed multilevel inverter has the grid connection capability when compared with VSI based conventional type inverter.Micro grid based DG systems are important to future main grids for the high-quality, efficient and reliable delivery of electricity supply.

6. CONCLUSION

The Active power conditioner can be simultaneously mitigating voltage harmonics, voltage unbalance and improve the power factor.This APC can be used in a micro grid interconnection between renewable sources and grid. The phase of micro grid sidevoltage inverted to the phase of supply voltage, because of power injected by theAPC exceeds the power required by the load. So remaining energy is injected in to the micro grid and compensates the voltage harmonics. The various load feed by the micro grid is not affected in voltage level. The five levels based three phase multilevel inverter proposed for better performance of harmonic compensation and power factor correction. The voltage and current balancing can be obtained by linear and non linear load conditions.

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