Power Quality Analysis of Hybrid Cuk Converter Based on Micro Grid Distributed Power Generation System

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Abstract-Distributed energy source based electricity generation is an essential factor for the economic growth and development of a country. There are various sources of renewable energy and their efficient usage of micro gird connected system presented in this paper. A micro grid system represents the distributed generation, energy storage, control system and loads are proficient operating in grid tied mode or islanded mode of operation. The DC-DC CUK converter based on both buck and boost mode of operation is proposed for micro grid distributed system. Here, the main advantages of hybrid boost mode operation of cuk converter, step up configuration is used which will result in improve conversion voltage ratio and better damping of oscillations. In this paper presents the three phase PID controller based voltage source inverter (VSI) in active power conditioner to improve power quality in micro grids based on distributed renewable energy. Micro grid energy resources are connected with the distributed linear, unbalance as well as nonlinear loads through power electronics converter to allow for an efficient, more reliable and quality of power improvement to the distributed load condition. The better power factor correction can be achieved by using seven level inverter configurations while compared to the voltage source inverter based power generation system. Here, this seven level inverter topology is build using a capacitor selection circuit with full bridge power converter, and also connected in cascade for improving system efficiency and reducing the switching power losses. The analysis of power quality in system consists of unbalanced load, linear and non linear load condition has been proposed and verified with results of THD and power factor correction using MATLAB/Simulink environment.

Keywords: Cuk DC-DC Converter, Distributed Energy Resources, Micro grid, Power Factor Correction , Power Quality, Seven Level Inverter, Total Harmonic Distortion

I. INTRODUCTION

In recent times electricity power production methods are changed based on distributed generators powered from any renewable energy resource, in future era electric generation schemes using distributed generation will deliver significant amount of power to loads which are based on renewable energy resources like wind turbine, photovoltaic energy, fuel cells, bio mass [1]-[3]. In general micro grid is a system which consists of one or more power source based on distributed generator along with grid power and various type of loads with single controller. In a given micro grid the integrated energy systems interfaced with grid can either operate in parallel with grid or can be isolated from the grid. An appropriate control scheme is required for micro grid is order to enhance the quality of power delivered to loads and appropriate source allocation methods with load sharing technique is applied to both islanded that is distributed energy system alone supplies load in the absence of grid, here dg's must be designed which can able to withstand local loads including nonlinear loads and grid connected mode. The DGs can compensate the effects of power unbalance and non-linearity occurs in the line due to local loads. During normal operating conditions in any micro grid the power grid supplies different type of loads including non -linear loads [4] - [6].

For any wind based power generation schemes permanent magnet-synchronous generator (PMSG) is applicable which has several advantages compared to induction generator topologies. PMSG employs a voltage source converter which makes it a variable speed application hence power obtained using this scheme is fully controllable [7]. The control strategy of a PMSG is quite simple it does not require reactive power for compensating during magnetization and for a given weight of motor can deliver higher power that is ratio between power and weight is high. Energy storage devices are essential components of micro grid where excess power from generators has to be stored using devices like battery, super capacitor and fuel cells. One of the main advantage of a super capacitor is it can be charged and discharged within very short duration of time and can deliver high power from its storage capacity

within the stipulated discharge time. Battery cannot supply high demand loads whereas this condition can be handled by the use of fuel cell which delivers high energy [8]–[10].

Sophisticated power electronics provide the opportunities for the renewable sources to be exploited in different schemes. The power electronics applications grant the permission of sustainable renewable sources to be coupled with specially designed generator. The generated output is turn up either renewable or grid connected with extensive storage system of its control parameters and load in a micro-grid. The control of a grid connected hybrid (wind-Solar) establishment with MI Cuk converter in which the variation of energy is being considered [11]-[13].The proposed distribution generation system consists of a dc/dc power converter to boost generated voltage and three phase seven level inverter (7 levels). Multilevel inverters designed for a higher voltage level has advantages like improvement in the power quality, power conversion efficiency; reduced harmonics level and electromagnetic interference (EMI) [14].

A direct-driven permanent magnet-synchronous generator (PMSG) is founded on wind turbine model. The primary intention is that to enhance the performance of PMSG to connect with the variable- speed wind turbine and keep up its reliability. PMSG based DG system not only generates electricity for local load but also injects excess power from renewable energy source into the utility grid [15]-[17]. Generally the output voltage of a multilevel inverter is a stepped waveform with different level of voltages in symmetry which gives lower THD compared to a two level pure sine wave inverter. [18],[19] Among various multilevel inverters topologies, the cascaded multilevel converter constitutes an alternative topology design, providing a modular design that can be extend to allow a transformer less interface for grid connection.

In this paper, proposed micro grid system based on renewable energy source is designed for improved power quality. In general a micro-grid is not tolerable to disturbances it is a weak system where power quality enhancement devices like active filters are required to improve power quality of the grid. The proposed control scheme can inject voltage at point of common coupling which can compensate for other frequency harmonics and it can also account for power factor correction. The multilevel inverter used for interfacing the micro and main grid is for improving the quality of power delivered from grid. The simulation results validate the merits of modern and innovative control scheme verified through simulation experiment using Simpower System from Simulink/Matlab.

II. Architecture Of Micro Grid

Micro-grid is a network which comprises of micro-power, load and energy storage system and control contraptions. It can likewise deliver the output has capability to self-control, protection, and management for grid-connected operation or islanded operation. The micro-grid is very imperative in present day power system based applications. In spite of the fact that there are more parts in micro-grids, small-hydro is much developed than other energy resources. Control and protection are big challenges in micro grid, which is generally treated as a hierarchical control. The block diagram of overall system representation of micro grid architecture is show in figure 1.

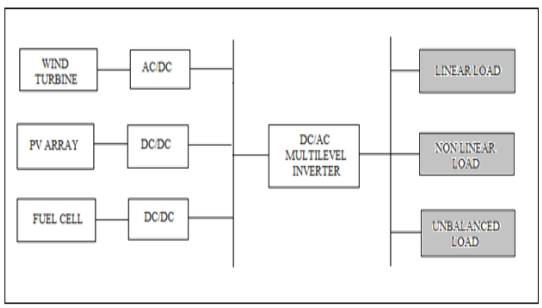

Fig. 1.Block Diagram of Micro grid Architecture

Generally, the energy storage system involves organization for determining which storage should be used in case of a hybrid energy storage system and also for resolving the charge-discharge cycles of preferred storage. The voltages across the DC-link can be sustained the stable value for balanced power flow using hybrid renewable energy and loads, in a micro grid. By changing DC-link voltage would cause the interrupt in normal operation of system.

III. Hybrid Renewable Power Generation

A hybrid renewable power system such as solar, wind and fuel source is combined to generate high power and fed into the inverter based micro-grid system connected to the local load. The inverter has high power production but it has costly. Wind turbine can't run properly in high or low wind speeds and Fuel cell plant unable to working at low temperature. The constant power supply is connected with rechargeable battery bank and then fed to the load. Here, the inverter uses to exchange the Direct Current (DC) supply from the battery to the AC against the AC load.

A. Wind energy

Wind energy produces the alternating current based on wind fed PMSG drives. The conversion of AC- DC power generation using wind turbine fed PMSG is shown in figure 2.

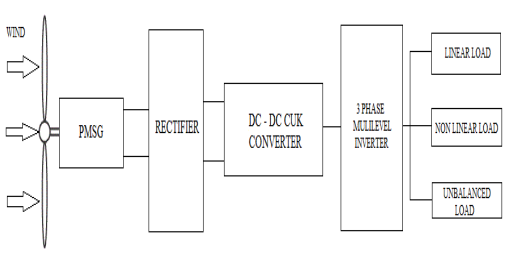

Fig. 2.Block Representation of Wind Energy Conversion System

Wind energy states that the process is used to generate electricity. Wind turbine which is utilized to generate electricity. Wind turbine machine is used for altering the kinetic energy in the wind into mechanical energy. Mechanical energy is changed to electricity by the machine is called a wind generator. Wind generator or turbine has spinning propeller-like blades around a rotor. The rotor is directly rotating the drive shaft, which turn an electric generator. In this paper presents the maximum power generation from WT fed PMSG for Micro grid based various load condition. This characteristic of wind power generation is based on the variation of corresponding variable discussed given below.

Three key elements impact the amount of energy in turbine can be harness from the wind. It comprises of wind speed, air density, and swept area.

$$P = \frac{1}{2}\,\rho \text{Area} V^3 \qquad (1)$$

B. Solar Energy

Photovoltaic cells convert the electricity from sunlight using semiconductor material that exhibit the photovoltaic effect. A photovoltaic system playing role an electricity generation in distributed generation. PV system consists of number of solar cells these are connected in series for generating electrical power with high potential. First the photoelectric effect created by an electrochemical process where crystal atom, ion in a series, generate an electric current. PV Installations may be top of the building, rooftop mounted or wall mounted. Solar PV does not create any pollution. PV directly converts the electricity from sunlight without any rotational parts. The term of photovoltaic is defined as unbiased operating method in which current through the device entirely due to the physical light energy.

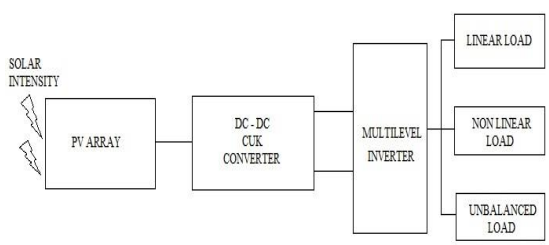

Fig. 3.Solar Based Power Generation in Microgrid System

Solar cell can be used as a photo detector light or other electromagnetic radiation near the visible range and calculating light intensity. Solar cell can produce direct current from sun light which can be used to power converter and also to recharge the battery devices. The real time application of photovoltaic system has used in orbiting satellites and other spacecraft, but today the most PV system are used for grid connected power utility. In this system an inverter is required to convert the electricity AC from DC.

1) Photovoltaic Array

The photoelectric device has electrical characteristic such as current, voltage or resistance, varying. The electrical characteristics depend on exposed sun light. Solar cells are formed to produce module, otherwise known as solar panels. The basic equivalent circuit diagram of solar array is shown in figure 4.

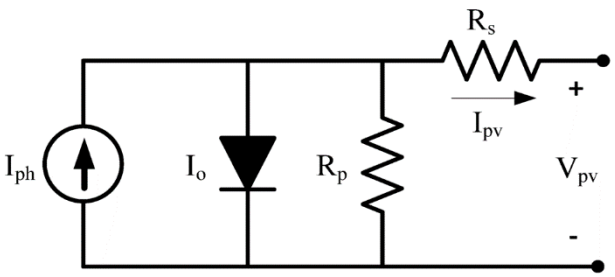

Fig. 4.Schematic Equivalent Circuit Diagram of PV Cell

$$I_{pv} = I_{ph} - I_0 - I_{RP} \qquad (2)$$

C. Fuel Cell Energy

Fuel cell consists of electrochemical cell, which clearly change over from chemical energy of a fuel along with its oxidant to electrical energy by a procedure called electrolyte strategy. The general moralities of a fuel cell are considered as those of the electrochemical batteries. The chemical energy in a fuel cell module is utilized as a fuel and an oxidant put away outside the cell by which the chemical reaction happen. The schematic drawing of fuel cell module is shown in figure 5.

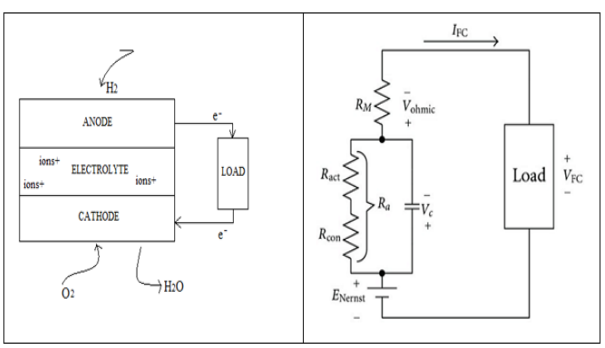

Fig. 5.Schematic Equivalent Circuit Diagram of Fuel Cell

The dynamic fuel is received and got oxidized by means of a source, example a case of hydrogen carried out from the hydrocarbon split. The fuel is rectified by utilizing reformer situated inside or remotely. Additionally, it is known as reformer fuel cell and chemical energy of the fuel utilized for both thermal energy conversion and mechanical energy transformation.

In this electrical energy conversion is indicate as direct energy conversion compared with conventional indirect

method when this conversion is carried out by bacteria, enzymes and algae. Also, this can be known as biochemical fuel cell in sulfur containing mixes are biodegraded to form H2S. Here, the oxygen containing biodegraded squanders which are then utilized as a part of energy components. Remembering to encourage as an objective of the regenerative operation with its energy units, the loss during power production is utilized over and over through regeneration, which can cause by an external department.

IV. CONFIGURATION OF THREE PHASE MULTI LEVEL INVERTER

The multi- level inverter has produce high gain output and also distortion less at the inverter output. It consists of capacitor selection circuit and bridge converters are connected in cascade connection. In positive cycle of multi- level inverter is used application. It can operate in four modes. The seven level inverter circuit configurations are shown in figure 6.

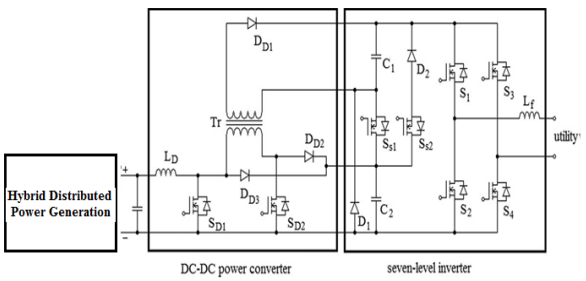

Fig. 6.Proposed Seven Level Inverter Circuit Configuration

In power electronic device the voltages across the capacitor are constant and equal to the $V_{dc}/3$ and $2V_{dc}/3$, respectively. The PV voltages are controlled by the MPPT controller and voltages are in phase with utility voltage. The current control method based PWM is used to generate the pulse and fed into inverter. The pulse width representation of seven level output waveform is shown in figure 7.

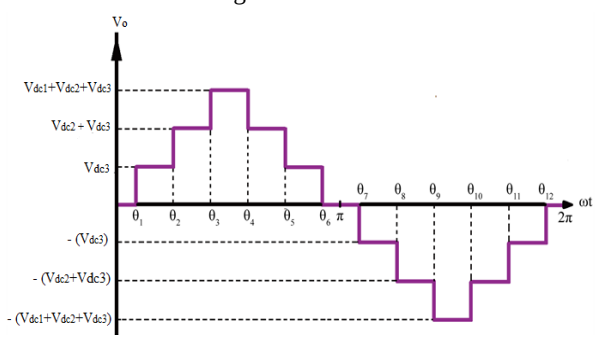

Fig.7.Seven Level Stepped Waveform

To begin with the first stage of the output voltage is higher than the utility voltage used to enhance the inductor current. By this way, the output current of seven-level inverter is controlled by the hint of the reference current. As indicated by the output voltage of the multilevel level inverter must be changed with the utility voltage.

V. PROPOSED CONTROL STRATEGY

The two control methods are used to analysis the power quality in present circuit configuration, which consists of PID based active power control (APC) for voltage source inverter and simplified new control based technique for seven level inverter. The discussion of proposed control scheme is given below with detailed explanation.

A.PID Based Active Power Control

In industrial application the PID controller is used to attain the desired set value for reduce the error by varying a control variable such as changing the position of control valve, a damper and the power supply to a heating element with a new value found by a weight sum. The block diagram of PID based APC is shown in figure 8.

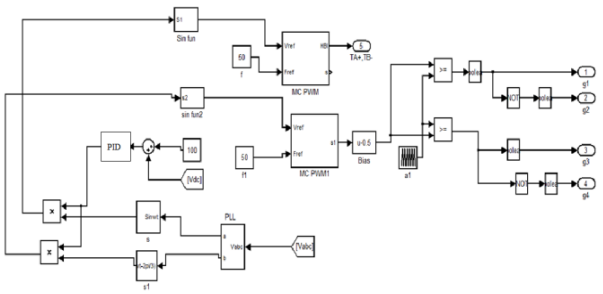

Fig. 8.Simulink Block diagram of PID Based APC

The above mentioned control topology can be applied to three phase voltage source inverter for various load condition including linear load, unbalanced load and non linear load. In order to achieve the better performance analysis and improve the power quality of system are used from the waveform of power factor correction.

B. Current Regulation Based Control

The proposed inverter is controlled by picking an appropriate capacitor and a full-bridge power converter. Both of the above parameters established as cascade connection through three phase power electronic gadgets. Since the power electronic switch is modified with high frequency, in order to produce the seven level voltages as a low switching power loss and in addition to the power efficiency is high. The proposed control scheme of seven level inverter is appeared in figure 9.

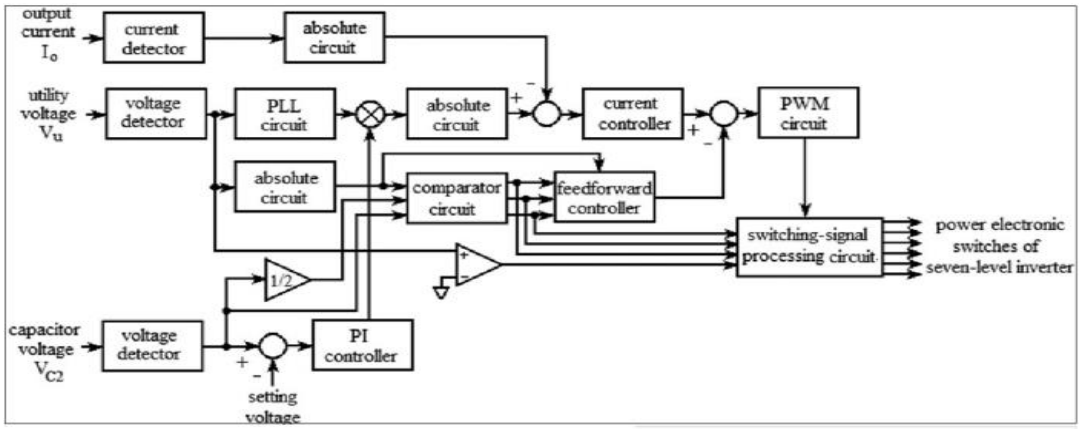

Fig. 9.Seven Level Inverter Control Strategy

Control strategy of the seven-level inverter has sinusoidal output current and which is in phase with the utility voltage. The voltage detector is used and the corresponding sine waveform is fed to the phase locked loop with high amplitude. The PI controller is used to compare the capacitor voltage and setting voltage. The output of the controller and PLL has multiplied to generate a reference signal. The current is detected from the reference signal using current detector. In subtractor the detected voltage and reference is fed and elated to the current controller. The switching state of seven level inverter is presented in given table 1.

TABLE I

Switching Pattern of Seven Level Inverter

	S_{S1}	S_{S2}	S_1	S_2	S_3	S_4
Positive Half Cycle						
$\|V_U\| < V_{dc}/3$	Off	Off	PWM	Off	Off	On
$2V_{dc}/3 > \|V_U\| > V_{dc}/3$	Off	PWM	On	Off	Off	On
$\|V_U\| > 2V_{dc}/3$	PWM	On	On	Off	Off	On
Negative Half Cycle						
$\|V_U\| < V_{dc}/3$	Off	Off	Off	On	PWM	Off
$2V_{dc}/3 > \|V_U\| > V_{dc}/3$	Off	PWM	Off	On	On	Off
$\|V_U\| > 2V_{dc}/3$	PWM	On	Off	On	On	Off

The feed forward controller produces a forward signal by applying the difference of utility grid and absolute voltage. In PWM circuit produce a pulse signal for control of three phase inverter circuit. In order to control it will reduce the pulsating voltage and current at the inverter output. The current controller produces a high gain for reducing the steady state error and improves the response of the inverter based hybrid system. The gain is identified by the bandwidth of the power converter is assigned the value of switching frequency.

VI. SIMULATION RESULTS

To verify the proposed control strategy, more simulations have been analyzed in various load condition using MATLAB simulink platform. This paper proposes the hybrid DC-DC CUK converter based power generation for power quality analysis in micro grid system. The proposed converter use both buck as well as boost modes of operation. The improvement of power quality in micro grid connected system is verified with simulation results of THD and power factor correction. It can be applied on both three phase VSI and multilevel inverter for analyzing and comparing the better performance of proposed system. The simulation results are carried out from the various load condition includes such as linear load, non- linear load and unbalanced load. The simulink overall circuit configuration is shown in figure 10.

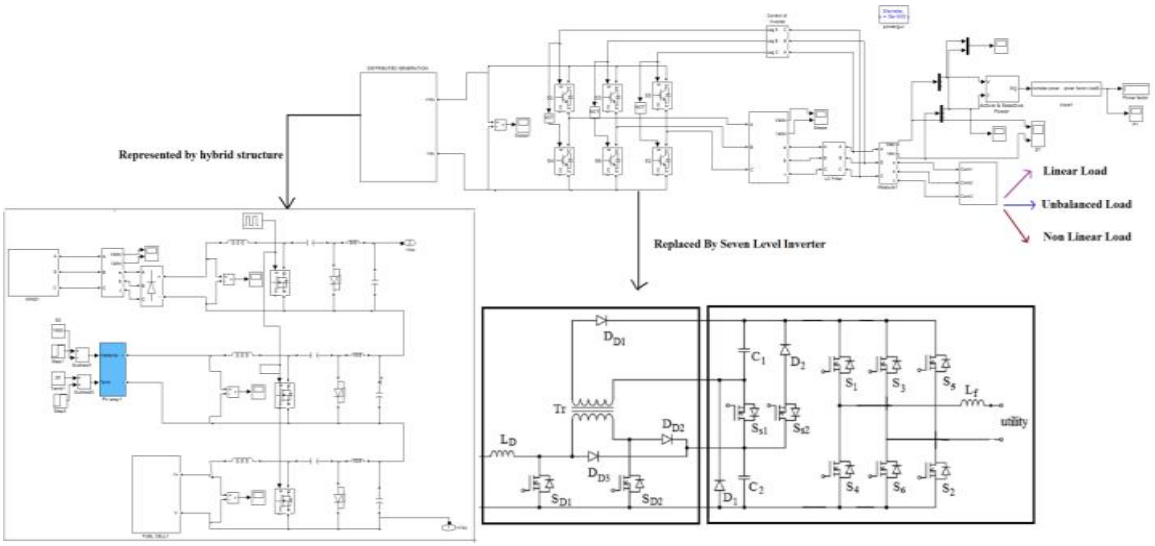

Fig.10. Proposed Simulink Overall Circuit Configuration

The voltage varying modes of operation has been analyzed for various load condition and corresponding dc link across the voltage waveform is shown figure 11 (a&b). The specification of overall simulation parameters is mentioned in below table 2. The output three phase voltage and current waveform of proposed system for linear load condition is depicted in figure 12. The corresponding power quality analysis of voltage source inverter (VSI) based on simulation results from total harmonic distortion (THD) waveform and power factor correction (PFC) waveform are shown in figure 13 (a & b).

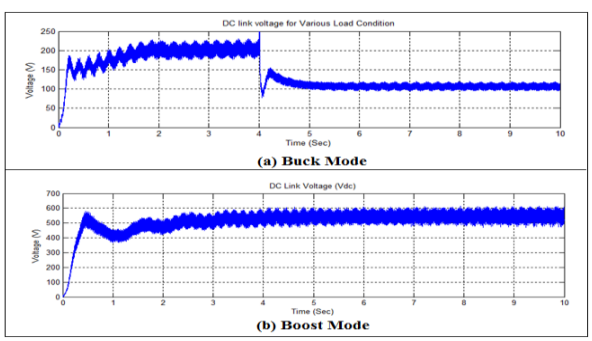

Fig.11. DC Link Capacitor Across Voltage Waveform

TABLE II

Specification of Simulation Parameter

Specification	Values
Output Voltage (V)	500
Switching Frequency (HZ)	50
Filter Capacitor (µF)	1200
Filter Inductor (mH)	20
DC link Capacitor (µF)	1500
Linear Load (Ω & mH)	R=100 , L= 10
Unbalance Load (Ω)	R= 200, 400, 600
Non Linear Load (Ω & mH)	R=100, L=10

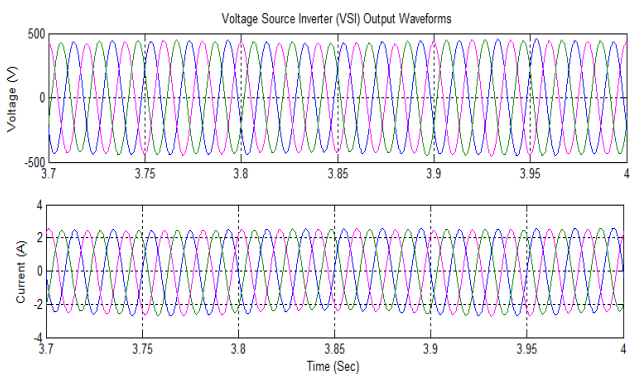

Fig. 12. Output Three Phase Voltage and Current Waveform for Linear Load

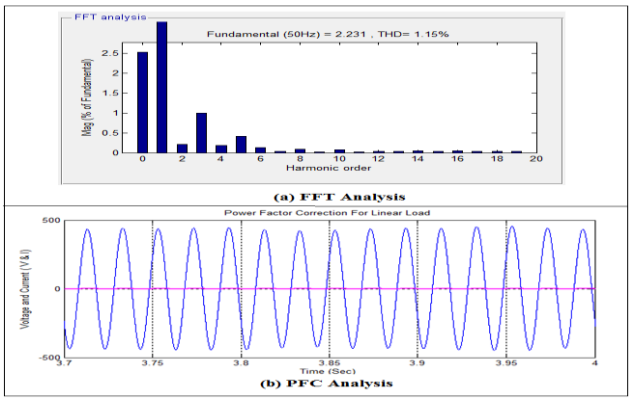

Fig. 13(a & b)Power Quality Analysis for Linear Load

The THD value of the output voltage inverter is a measurement of the harmonic distortion, which is required to be as small as possible in many applications of multilevel converters. The present three phase seven level inverter is involved for the hybrid power supply system, in which the THD of the output voltage as a very important voltage quality measurement. The different load can be applied on both VSI and multilevel inverter, which achieves better performance from the seven level inverter related simulation results are depicted in figures 14 to 17.

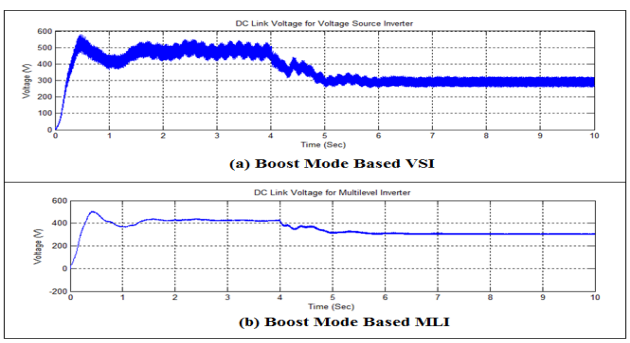

Fig. 14.Comparison Results of DC Link Voltage Waveform

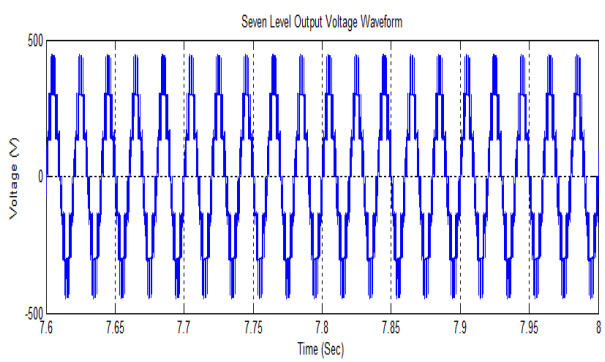

Fig. 15.Output Seven Level Voltage Waveform

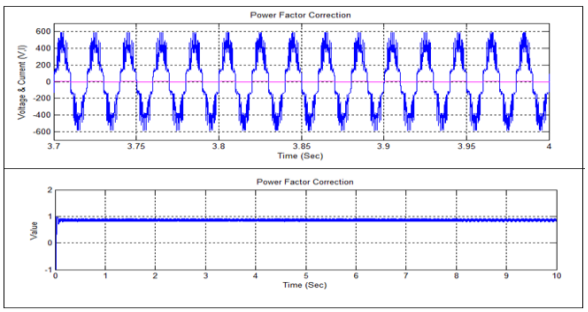

Fig. 16.Power Factor Correction for MLI

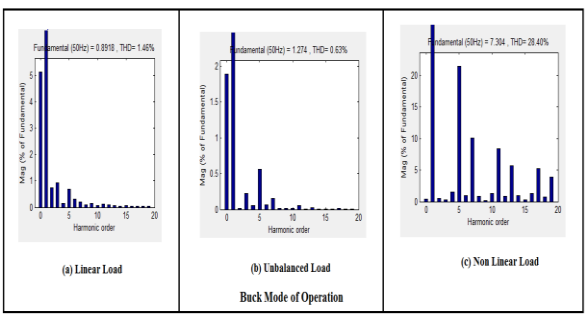

Fig. 17.Total Harmonic Distortion Waveform for Various Loads

VII. CONCLUSION

In this paper proposes the hybrid renewable energy resource DC-DC conversion based power generation for increasing the quality of power in the proposed system. Here, the two mode of operation such as buck and boost has been analyzed for maximum power extract from supply system. To improve the power quality analysis, this system used to replace by PID based active power control in voltage source inverter under linear, unbalanced and non-linear load condition. The renewable energy source is connected in cascaded connection based DC link capacitor for maintaining the voltage. The proposed system has based on dc-dc converter and six level based inverter systems has six power electronic devices are used. The seven level inverter produce the seven level voltages at the output and produce high power factor correction than the conventional multilevel inverter system.

REFERENCES

[1] Y.V.P. Kumar, and R. Bhimasingu, "Performance analysis of green micro grid architectures by comparing power quality indices," in IEEE *Proc. Eighteenth National Power Systems Conference*, pp. 18-20, 2014.

[2] C.Udhaya priyadharshini and P.Aravindan, "Power Quality Improvement Using Various Energy Sources and Energy Storage System in Microgrid," *International Research Journal of Engineering and Technology*, Vol. 02, No. 9, pp. 450-457, Dec. 2015.

[3] T. Zhou and B. Francois, "Energy Management and Power Control of a Hybrid Active Wind Generator for

Distributed Power Generation and Grid Integration," *IEEE Transactions on Industrial Electronics*, Vol. 58, No. 1, pp. 95-104, Mar. 2010.

[4] I. Vechiu, G. Gurguiatu,and E. Rosu, " Advanced Active Power Conditioner to improve power quality in micro-grids," in 2010 *Conference Proc. IPEC, pp.* 27-29, 2011.

[5] U.N. Khan, "Distributed generation and power quality," in IEEE Proc. *International Conference on Environment and Electrical Engineering*, pp. 10-13, 2009.

[6] S.Ibrahim, S Prakash and A.K Bhardwaj, "Power Quality Improvement Performance Using Hybrid (Solar Wind) Energy for Distributed Power Generation," *International Journal of Advanced Research in Computer and Communication Engineering*, Vol. 2,No. 10, pp. 4124-4131, Oct. 2013.

[7] N.R. Nair, and M. Ebenezer, "Operation and control of grid connected wind-PV hybrid system," in IEEE *Proc. 2014 International Conference on Advances in Green Energy,* pp. 17-18, 2015.

[8] N. Meng, P. Wang, H. Wu, W. Wang, and W. Xu, "Optimal sizing of distributed generations in a connected DC micro-grid with hybrid energy storage system," *in* IEEE *Proc. Energy Conversion Congress and Exposition (ECCE),* pp. 3179-3183, 2015.

[9] M.B Ferrera, S.P Litran, E Duran Aranda and J.M Andujar Marquez, "A Converter for Bipolar DC Link Based on SEPIC-Cuk Combination," *IEEE Transactions on Power Electronics*, Vol. 30, No. 12, pp. 6483-6487, Dec. 2015.

[10] H. G. Cabral *et al*, "A PV module-integrated inverter using a Ćuk converter in DCM with island detection scheme," in IEEE *Proc. 13th Brazilian Power Electronics Conference and 1st Southern Power Electronics Conference,* pp. 1-6, 2015.

[11] R. Sarath, and P. Kanakasabapathy, "Hybrid converter based on Cuk topology to supply both AC and DC loads," in IEEE *Proc. Advancements in Power and Energy (TAP Energy), International Conference,* pp. 24-2, 2015.

[12] W.M. Amutha, V. Renugadevi, and V. Rajini, "Investigation of efficiency of dual input dc/dc converter," in IEEE *Proc. IET Chennai Fourth International Conference on Sustainable Energy and Intelligent Systems,* pp. 12-14, *2013*.

[13] R. Sankarganesh, and S. Thangavel, "Maximum power point tracking in PV system using intelligence based P&O technique and hybrid cuk converter," in IEEE *Proc. International Conference on Emerging Trends in Science, Engineering and Technology,* pp. 13-14, 2013.

[14] J.C Wu and C.W Chou, "A Solar Power Generation System with a Seven-Level Inverter," *IEEE Transactions on Power Electronics*, Vol. 29, No. 7, pp. 3454-3462, Dec. 2015.

[15] B. Raj Kiran, M. Jayaraman, and V.T. Sreedevi, " Power quality analysis of a PV fed seven level cascaded H-bridge multilevel inverter," in IEEE *Proc. International Conference of Advanced Communication Control and Computing Technologies,* pp. 8-10, 2015.

[16] P.S Kumar, and M. Satyanarayana, " Comparative analysis of modulation strategies applied to seven-level diode clamped multi-level inverter fed induction motor drive," in IEEE *Proc. Conference on Power, Control, Communication and Computational Technologies for Sustainable Growth,* pp. 11-12, 2015.

[17] O. Farrok, M.R.I. Sheikh, and M.R. Islam, "An advanced controller to improve the power quality of micro-grid connected converter," in IEEE *Proc. International Conference on Electrical & Electronic Engineering,* pp. 4-6, 2016.

[18] J.C Wu, K.D Wu, H.L Jou and S.K Chang, "Seven-level active power conditioner for a renewable power generation system," *IET Renewable Power Generation*, Vol. 8, No. 7, pp. 807-816, Mar. 2014.

[19] F Cardoso Melo, R Ruiz Spaduto, L.C Gomes de Freitas, C Eduardo Tavares, J.R Rubens Macedo Jr and H.O Rezende, "Harmonic Distortion Analysis in a Low Voltage Grid-Connected Photovoltaic System," *IEEE Latin America Transactions*, Vol. 13, No. 1, pp. 136-142, Jan. 2015.