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Power Quality Improvement of a grid interconnected photovoltaic system by using Shunt Active Power Filter

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Abstract: This paper proposes the improved methodology of power quality in grid interconnected photo voltaic system by using shunt active power filter . With development of new functionalities solar energy based Photovoltaic cells are upcoming energy source with higher efficiency. Solar energy being naturally available in abundance and non- polluting is one of the most promising sources. Excessive use of power electronics devices lead to power quality problems. Harmonics are major problem diminishing the power quality. Active Power filter are powerful tool for mitigation of harmonics. Active filter suppress harmonic current and compensate reactive power simultaneously. This paper presents the performance of Shunt active filter with VSI topology using synchronous reference frame theory. By this methodology harmonic suppression is possible within Renewable energy resources are being increasingly connected in distribution systems utilizing power electronic converters. The inverter is controlled to perform as a multi-function device by incorporating active power filter functionality. The inverter can be utilized as power converter to inject power generated from RES to the grid, and shunt APF to compensate current unbalance, load current harmonics, load reactive power demand and load neutral current. All of these functions may be accomplished either individually or simultaneously.

I. INTRODUCTION

Electric utilities and end users of electric power are becoming increasingly concerned about meeting the growing energy demand. Seventy five percent of total global energy demand is supplied by the burning of fossil fuels. But increasing air pollution, global warming concerns, diminishing fossil fuels and their increasing cost have made it necessary to look towards renewable sources as a future energy solution. Since the past decade, there has been an enormous interest in many countries on renewable energy for power generation. The market liberalization and government's incentives have further accelerated the renewable energy sector growth. Renewable energy source (RES) integrated at distribution level is termed as distributed generation (DG). The utility is concerned due to the high penetration level of intermittent RES in distribution systems as it may pose a threat to network in terms of stability, voltage regulation and power-quality (PQ) issues DES technologies have very different issues compared with traditional centralized power sources. For example, they are applied to the mains or the loads with voltage of 480 volts or less; and require power converters and different strategies of control and dispatch. All of these energy technologies provide a DC output which requires power electronic interfaces with the distribution power networks and its loads. In most cases the conversion is performed by using a voltage source inverter (VSI) with a possibility of pulse width modulation (PWM) that provides fast regulation for voltage magnitude. Power electronic interfaces introduce new control issues, but at the same time, new possibilities.However, without any medium voltage networks adaptation, this fast expansion can affect the quality of supply as well as the public and equipment safety because distribution networks have not been designed to connect a significant amount of generation. Therefore, a new voltage control system to facilitate the connection of distributed generation resources to distribution networks should be developed.

II. DISTRIBUTED GENERATION

Distributed generation, also called on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy generates electricity from many small energy sources. Currently, industrial countries generate most of their electricity in large centralized facilities, such as fossil fuel (coal, gas powered nuclear) or hydro power plants. These plants have excellent economies of scale, but usually transmit electricity long distances and negatively affect the environment. Most plants are built this way due to a number of economic, health& safety, logistical, environmental, geographical and geological factors. For example, coal power plants are built away from cities to prevent their heavy air pollution from affecting the populace. In addition, such plants are often built near collieries to minimize the cost of transporting coal. Hydroelectric plants are by their nature limited to operating at sites with sufficient water flow. Most power plants are often considered to be too far away for their waste heat to be used for heating buildings. Low pollution is a crucial advantage of combined cycle plants that burn natural gas. The low pollution permits the plants to be near enough to a city to be used for district heating and cooling. Distributed generation is another approach. It reduces the amount of energy lost in transmitting electricity because the electricity is generated very near where it is used, perhaps even in the same building. This also reduces the size and number of power lines that must be constructed. Typical distributed power sources in a Feed-in Tariff (FIT) scheme have low maintenance, low pollution and high efficiencies. In the past, these traits required dedicated operating engineers and large complex plants to reduce pollution. However, modern embedded systems can provide these traits with automated operation and renewable, such as sunlight, wind and geothermal. This reduces the size of power plant that can show a profit[7]. The usual problems with distributed generators are their high costs. Distributed cogeneration sources use natural gas-fired micro turbines or reciprocating engines to turn generators. The hot exhaust is then used for space or water heating, or to drive an absorptive chiller for air-conditioning. The clean fuel has only low pollution. Designs currently have uneven reliability, with some makes having excellent maintenance costs, and others being unacceptable. Co generators are also more expensive per watt than central generators. They find favor because most buildings already burn fuels, and the cogeneration can extract more value from the fuel. Recently interest in Distributed Energy Systems (DES) is increasing, particularly onsite generation. This interest is because larger power plants are economically unfeasible in many regions due to increasing system and fuel costs, and more strict environmental regulations. In addition, recent technological advances in small generators, Power Electronics, and energy storage devices have provided a new opportunity for distributed energy resources at the distribution level, and especially, the incentive laws to utilize renewable energies has also encouraged a more decentralized approach to power delivery.

There are many generation sources for DES: conventional technologies (diesel or natural gas engines), emerging technologies (micro turbines or fuel cells or energy storage devices), and renewable technologies (small wind turbines or solar/photovoltaic’s or small hydro turbines). These DES are used for applications to a standalone, a standby, a grid-interconnected, a cogeneration, peak shavings, etc. and have many advantages such as environmental-friendly and modular electric generation, increased reliability, high power quality, uninterruptible service, cost savings, on-site generation, expandability, etc. The research works in the recent papers about DES focus on being utilized directly to a standalone AC system or fed back to the utility mains. That is, when in normal operation or main failures, DES directly supply loads with power), while, when DES have surplus power or need more power, this system operates in parallel mode to the mains.

III. POWER QUALITY

Power quality, or more specifically, a power quality disturbance, is generally defined as any change in power (voltage, current, or frequency) that interferes with the normal operation of electrical equipment. The study of power quality, and ways to control it, is a concern for electric utilities, large industrial companies, businesses, and even home users. The study has intensified as equipment has become increasingly sensitive to even minute changes in the power supply voltage, current, and frequency. Unfortunately, different terminology has been used to describe many of the existing power disturbances, which creates confusion and makes it more difficult to effectively discuss, study, and make changes to today’s power quality problems. The sinusoidal wave shape, voltage changes from a positive value to a negative value, 50 times per second. When this flowing wave shape changes size, shape, symmetry, frequency, or develops notches, impulses, ringing, or drops to zero (however briefly), there is a power disturbance. As stated, there has been some ambiguity throughout the electrical industry and businesses community in the use of terminology to describe various power disturbances. For example, the term “surge” is seen by one sector of the industry to mean a momentary increase in voltage as would be typically caused by a large load being switched off. On the other hand, usage of the term “surge” can also be seen as a transient voltage lasting from microseconds to only a few milliseconds with very high peak values. These latter are usually associated with lightning strikes and switching events creating sparks or arcing between contacts. A communication mistake can have expensive consequences, which includes downtime, or even equipment damage.

Impulsive transients are sudden high peak events that raise the voltage and/or current levels in either a positive or a negative direction. Causes of impulsive transients include lightning, poor grounding, the switching of inductive loads, utility fault clearing, and ESD (Electrostatic Discharge). The results can range from the loss (or corruption) of data, to physical damage of equipment. Of these causes, lightning is probably the most damaging. An oscillatory transient is a sudden change in the steady-state condition of a signal's voltage, current, or both, at both the positive and negative signal limits, oscillating at the natural system frequency. In simple terms, the transient causes the power signal to alternately swell and then shrink, very rapidly. Oscillatory transients usually decay to zero within a cycle (a decaying oscillation). These transients occur when you turn off an inductive or capacitive load, such as a motor or capacitor bank. An oscillatory transient results because the load resists the change. Under voltages are the results of long-term problems that create sags. The term "brownout" has been commonly used to describe this problem, and has been super ceded by the term under voltage. Under-voltages can create overheating in motors, and can lead to the failure of nonlinear loads such as computer power supplies. The solution for sags also applies to under-voltages. More importantly, if an under voltage remains constant, it may be a sign of a serious equipment fault, configuration problem, or that the utility supply needs to be addressed.

IV. HARMONICS

Harmonic distortion is the corruption of the fundamental sine wave at frequencies that are multiples of the fundamental. Symptoms of harmonic problems include overheated transformers, neutral conductors, and other electrical distribution equipment, as well as the tripping of circuit breakers and loss of synchronization on timing circuits that are dependent upon a clean sine wave trigger at the zero crossover point. Harmonic distortion has been a significant problem with IT equipment in the past, due to the nature of switch-mode power supplies (SMPS). These non-linear loads, and many other capacitive designs, instead of drawing current over each full half cycle, "sip" power at each positive and negative peak of the voltage wave. The return current, because it is only short-term, (approximately 1/3 of a cycle) combines on the neutral with all other returns from SMPS using each of the three phases in the typical distribution system. Instead of subtracting, the pulsed neutral currents add together, creating very high neutral currents, at a theoretical maximum of 1.63 times the maximum phase current.

An overloaded neutral can lead to extremely high voltages on the legs of the distribution power, leading to heavy damage to attached equipment. At the same time, the load for these multiple SMPS is drawn at the very peaks of each voltage half-cycle, which has often led to transformer saturation and consequent overheating. Other loads contributing to this problem are variable speed motor drives, lighting ballasts and large legacy UPS systems. Methods used to mitigate this problem have included over-sizing the neutral conductors, installing K-rated transformers, and harmonic filters. Spurred on by the remarkable expansion of the IT industry over the last decade, power supply design for IT equipment has been upgraded via international standards. One major change compensates for electrical infrastructure stresses caused, in the recent past, by large clusters of IT equipment power supplies contributing to excessive harmonic currents within a facility. Many new IT equipment power supplies have been designed with power-factor corrected power supplies operating as linear, non-harmonic loads. These power supplies do not produce the waste current of harmonics

Inter harmonics are a type of waveform distortion that are usually the result of a signal imposed on the supply voltage by electrical equipment such as static frequency converters, induction motors and arcing devices. Cyclo-converters (which control large linear motors used in rolling mill, cement, and mining equipment), create some of the most significant inter harmonic supply power problems. These devices transform the supply voltage into an AC voltage of a frequency lower or higher than that of the supply frequency. The most noticeable effect of inter harmonics is visual flickering of displays and incandescent lights, as well as causing possible heat and communication interference. Solutions to inter harmonics include filters, UPS systems, and line conditioners. Notching is a periodic voltage disturbance caused by electronic devices, such as variable speed drives, light dimmers and arc welders under normal operation.

This problem could be described as a transient impulse problem, but because the notches are periodic over each ½ cycle, notching is considered a waveform distortion problem. The usual consequences of notching are system halts, data loss, and data transmission problems. Noise is unwanted voltage or current superimposed on the power system voltage or current waveform. Noise can be generated by power electronic devices, control circuits, arc welders, switching power supplies, radio transmitters and so on. Poorly grounded sites make the system more susceptible to noise. Noise can cause technical equipment problems such as data errors, equipment malfunction, long term component failure, hard disk failure, and distorted video displays .Since voltage fluctuations are fundamentally different from the rest of the waveform anomalies, they are placed in their own category.

A Voltage fluctuation is a systematic variation of the voltage waveform or a series of random voltage changes, of small dimensions, namely 95 to 105% of nominal at a low frequency, generally below 25 Hz.frequency load exhibiting significant current variations can cause voltage fluctuations. Arc furnaces are the most common cause of voltage fluctuation on the transmission and distribution system. One symptom of this problem is flickering of incandescent lamps. Removing the offending load, relocating the sensitive equipment, or installing power line conditioning or UPS devices, are methods to resolve this problem.

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V. SHUNT ACTIVE POWER FILTER

The shunt-connected active power filter, with a self-controlled dc bus, has a topology similar to that of a Static Compensator (STATCOM) used for reactive power compensation in power transmission systems. Shunt active power filters compensate load current harmonics by injecting equal-but opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase-shifted by 170°.Fig . No. 7.1: shows the basic compensation principle of a shunt active power filter. It is controlled to draw / supply a compensating current i_C from / to the utility, so that it cancels current harmonics on the AC side, and makes the source current in phase with the source voltage. Fig . No. 7.2: shows the different waveforms. Curve A is the load current waveform and curve B is the desired mains current. Curve C shows the compensating current injected by the active filter containing all the harmonics, to make mains current sinusoidal.

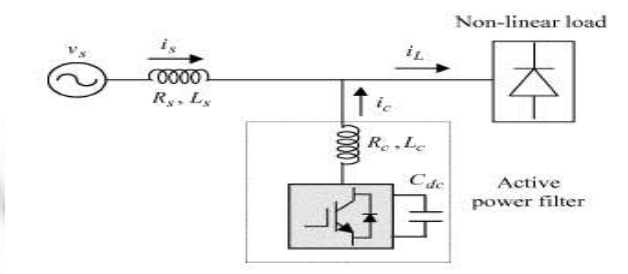

Fig 1: Shunt active power filter Basic compensation principle.

The control scheme approach is based on injecting the currents into the grid using "bang-bang controller." The controller uses a hysteresis current controlled technique. Using such technique, the controller keeps the control system variable between boundaries of hysteresis area and gives correct switching signals for inverter operation. The control system scheme for generating the switching signals to the inverter is shown in Fig.1 The control algorithm needs the measurements of several variables such as three-phase source current, DC voltage, inverter current with the help of sensor. The current control block, receives an input of reference current and actual current are subtracted so as to activate the operation of inverter in current control mode.

V. RESULTS AND DISCUSSIONS

The performance of the proposed structure is assessed by a computer simulation that uses MATLAB Software. The simulation circuit is shown in Fig.2. The performance of the system with proposed control scheme is discussed, for three phase loads and single phase Loads.

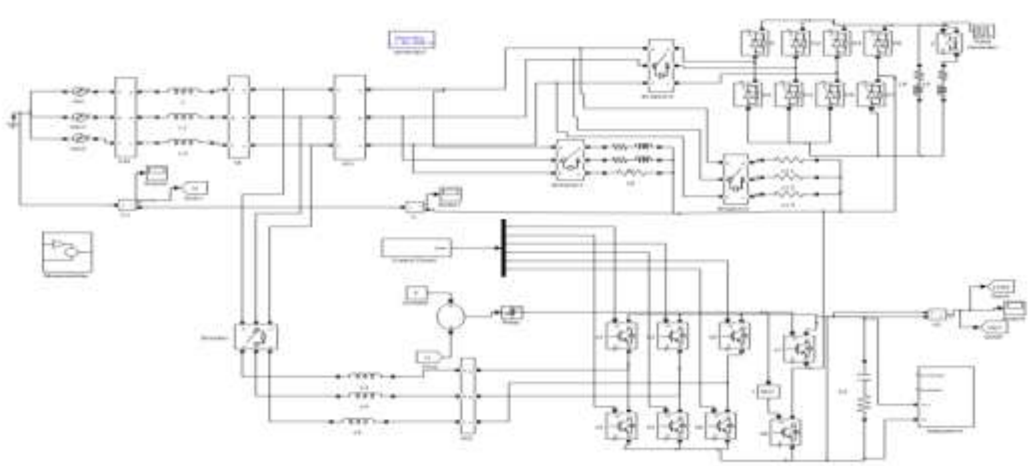

Fig 2: Mat lab /Simulink model of the proposed system.

Matlab is very powerful tool for the simulation. Here three phase AC source is supplied to load. Simulation results and waveforms are shown. Waveforms of Load current and Source current are shown in Fig.3 and Fig4. Fig.5: shows Simulation results of Non- Linear three phase loads

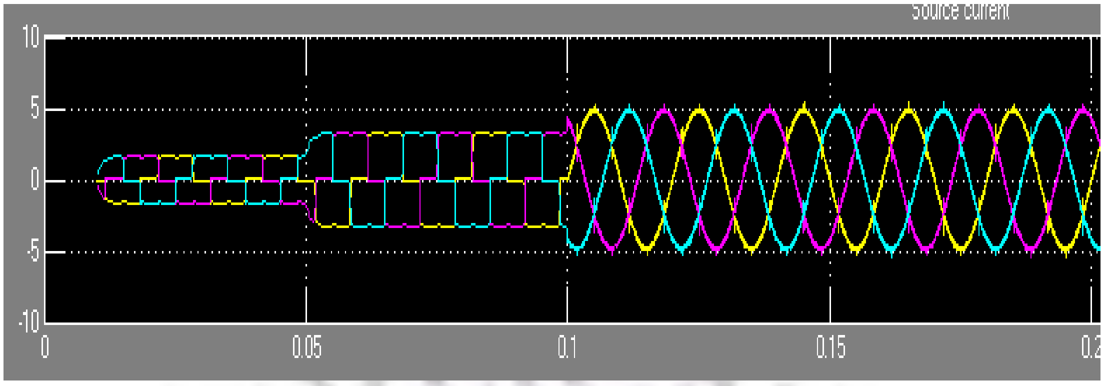

Fig 3: Three phase source current

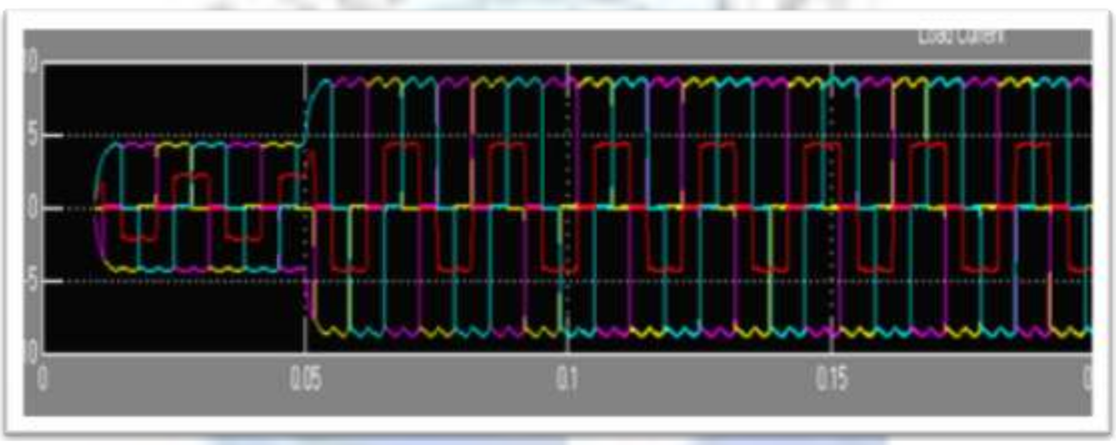

Fig 4: Three phase Load current

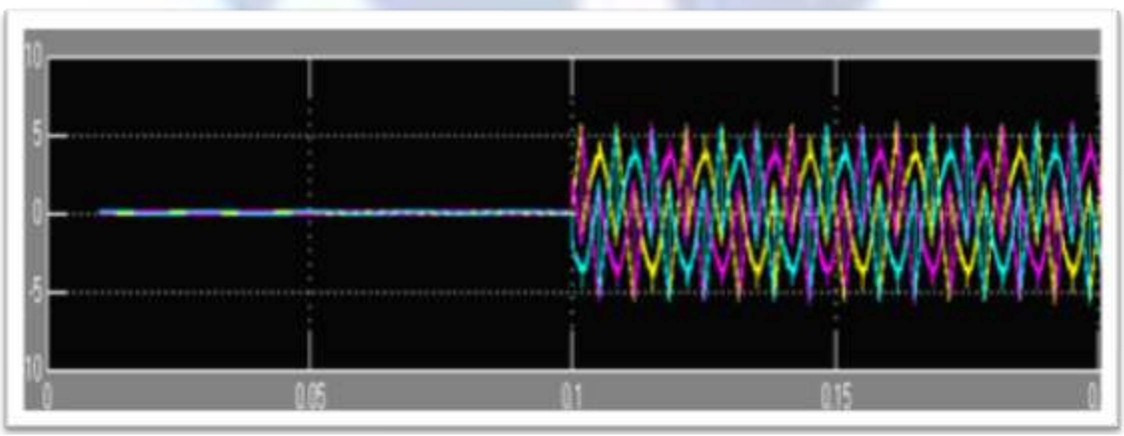

Fig. 5: Simulation results of Non- Linear three phase loads

THD analysis for non linear load:

Fig: 6 shows THD of source current before compensation, Total Harmonic Distortion of Source Current Before Compensation = 30.13%. Fig 7: THD of Source Current After Compensation is shown in Fig 7. Total Harmonic Distortion of Source Current After Compensation = 3.20%. After compensation, THD of the source is reduced from 30.13% to 3.20% which is well below the recommended 5% limit.

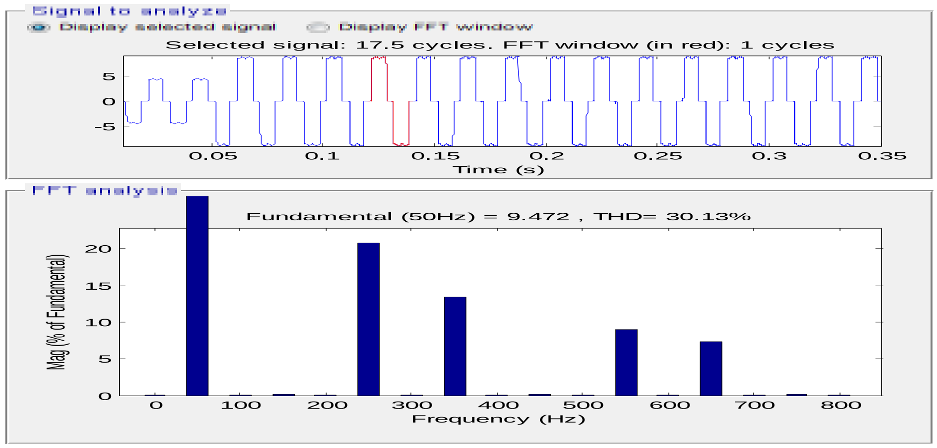

Fig. 6: THD of Source Current Before Compensation

THD of source current after compensation:

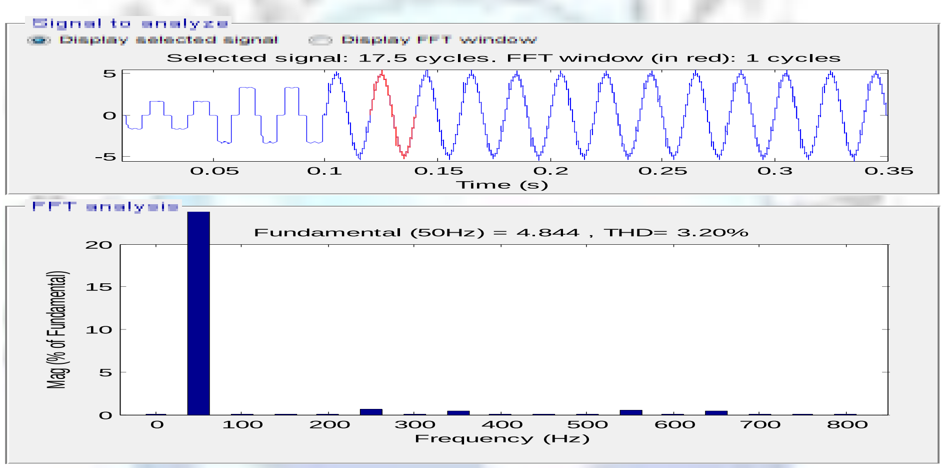

Fig 7: THD of Source Current After Compensation

Fig 8,Fig 9 and Fig 10 shows the source current , load current ,inverter compensating current respectively for a single phase system. The inverter is turned on at o.1 seconds. Fig. 8 it clearly indicates the source current from 0 to 0.1 sec represents the unbalance nature due to the presence of unbalance load. At 0.1 seconds the nature of waveform is sinusoidal this represents the inverter compensated the unbalance wave to balanced sinusoidal wave. The load current waveform is shown in Fig.9 .The inverter supplies the compensating current that is shown in Fig.10

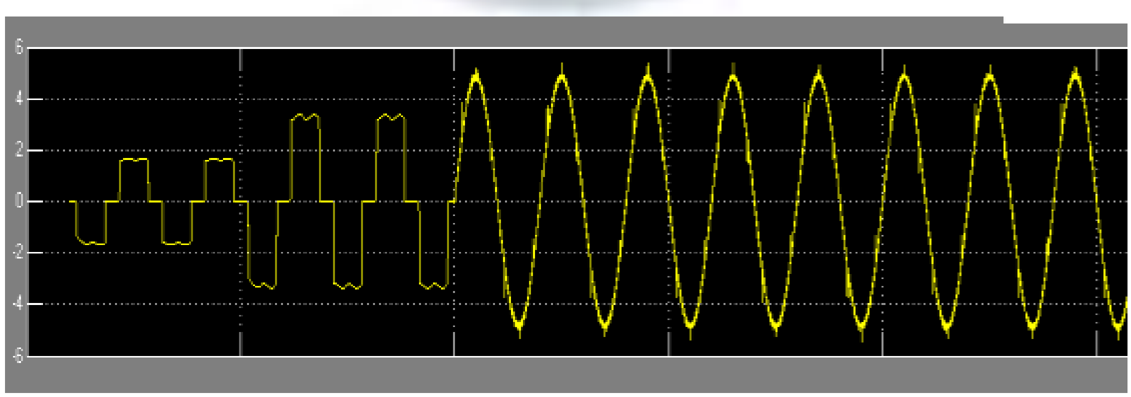

Fig 8: Single phase source current

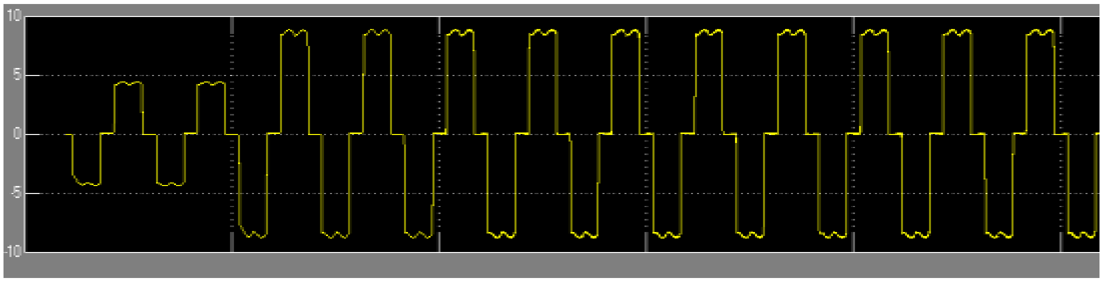

Fig 9: Single phase load current

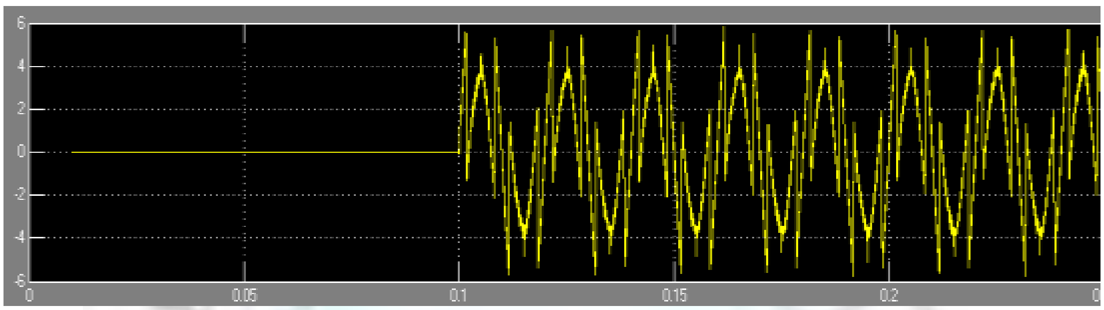

Fig 10 : Simulation results of single phase Load.

VII. CONCLUSIONS

The photovoltaic panel is modeled and connected to three phase four wire distribution system through an inverter. From the results, it can be concluded that the grid interfacing inverter is functioning as a conventional inverter as well as an Active Power Filter. It can also be concluded that the grid interfacing inverter is maintaining sinusoidal source current under various load conditions .It is also reducing THD in the supply currents for various load conditions.

VIII. SCOPE FOR FUTURE WORK:

In this thesis, the inverter is utilized to work as shunt active power filter as well as conventional inverter by using PI control with hysteresis current control technique. This work can be extended by By changing control scheme like fuzzy network, PID control techniques. By using load side control technique like PQ theory.

References

[1]. Mukhtiar Singh, Student Member, IEEE, Vinod Khadkikar, Member, IEEE, Ambrish Chandra, Senior Member, IEEE and Rajiv K. Varma, Senior Member, IEEE "Grid Interconnection of Renewable Energy Sources at the Distribution Level With Power-Quality Improvement Features." IEEE Transactions On Power Delivery, Vol. 26, No. 1, January 2011.

[2]. Y. Jaganmohan Reddy, K. Padma Raju, Y. Venkata Pavan Kumar, "Use of DC Motor-Generator Set for Power Quality Improvement in a Renewable Energy Based Hybrid Power System." International Journal on Recent Trends in Engineering & Technology, Vol. 05, No. 02, Mar 2011.

[3]. Hung-Cheng Chen, Jian-Cong Qiu, and Chia-Hao Liu "Dynamic Modeling and Simulation of Renewable Energy Based Hybrid Power Systems" DRPT 2007, pp. 2703-2709.

[4]. D.M. Brod and D.W. Novotny, "Current Control of VSI PWM Inverters", IEEE Transactions Industrial Application, Vol. IA-21,no.4.pp.562-570,1975.

[5]. M.takeda et al, "Harmonic Current Compensation With Active Filter", in IEEEIIAS Ann. Meeting,1977,pp,707.

[6]. Karuppanan P ,Kamala Kanta Mahapatrab "PLL Synchronization With PID Controller Based on Shunt Active Power Line Conditioner." International Journal of Computer and Electrical Engineering ,Vol.3,No.1,February 2011.

[7]. Aswathy B.Raj , B. Shyam, Robins Anto "Simulation of Distributed Generation Power Inverter as Active Power Filter using MATLAB/Simulink." International Journal on Recent Trends in Engineering and Technology ,Vol.6, No.2,Nov 2011.

[8]. R. C. Dugan, M. F. McGranaghan, S. Santoso, H. W. Beaty, "Electrical Power Systems Quality", Second Edition, McGraw-Hill.

[9]. M. Aiello, A. Catalioti, S. Favuzza, G. Graditi, "Theoretical and Experimental Comparison of Total Harmonic Distortion Factors for the evaluation of Harmonic and Inter harmonic Pollution of Grid-Connected." IEEE Transactions On Power Delivery, Vol. 21, No. 3, July 2006.

[10]. J. M. A. Myrzik, and M. Calais, Member IEEE "String and Module Integrated Inverters for Single-Phase Grid Connected Photovoltaic Systems - A Review". Power Technical Conference Proceedings, 2003 IEEE Bologna.

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