Reducing harmonics in micro grid distribution system using APF with fuzzy logic controller

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Abstract

Renewable generation affects power quality due to its nonlinearity, since solar generation plants and wind power generators must be connected to the grid through high-power static PWM converters. The nonuniform nature of power generation directly affects voltage regulation and creates voltage distortion in power systems. This new scenario in power distribution systems will require more sophisticated compensation techniques. Although active power filters implemented with three-phase four-leg voltage-source inverters (4L-VSI) have already been presented in the project. In distribution systems, the load has been a sudden increase or decreases and it is like as nonlinear loads so the load draw non-sinusoidal currents from the AC mains and causes the load harmonics and reactive power, and excessive neutral currents that give pollution in power systems. Most pollution problems created in power systems are due to the nonlinear characteristics and fast switching of power electronic devices. Shunt active filter based on current controlled PWM converters are seen as a most viable solution. This project presents the harmonics and reactive power compensation from 3P4W micro-grid distribution system by fuzzy controlled shunt active.

INTRODUCTION

The widespread use of non-linear loads is leading to a variety of undesirable phenomena in the operation of power systems. The harmonic components in current and voltage waveforms are the most important among these. Conventionally, passive filters have been used to eliminate line current harmonics. However, they introduce resonance in the power system and tend to be bulky. So, active power line conditioners have become more popular than passive filters as it compensates the harmonics and reactive power simultaneously. The active power filter topology can be connected in series or shunt and combinations of both. Shunt active filter is more popular than series active filter because most of the industrial applications require current harmonic compensation. Different types of active filters have been proposed to increase the electric system quality. The classification is based on following criteria.

❖ Power rating and speed of response required in compensated system.

❖ System parameters to be compensated (e.g. current harmonics, power factor and voltage harmonics)

❖ Technique used for estimating the reference current/voltage.

Current controlled voltage source inverters can be utilized with an appropriate control strategy to perform active filter functionality. The electrical grid will include a very large number of small producers that use renewable energy sources, like solar panels or wind generators.

LITERATURE SURVEY

Johan H. R. Enslin and Peter J. M. Heskes "Harmonic interaction between a large number of distributed power inverters and the distribution network," In this paper discussed the harmonic interaction between a large number of distributed power inverters and the distribution network. This paper is to analyze the observed phenomena of harmonic interference of large populations of these inverters and to compare the network interaction of different inverter topologies and control options.

Uffe Borup, Frede Blaabjerg and Prasad N. Enjeti "Sharing of nonlinear load in parallel-connected three-phase converters," Presented about the sharing of linear and nonlinear loads in three-phase power converters connected in parallel, without communication between the converters. The paper focuses on solving the problem that arises when two converters with harmonic compensation are connected in parallel.

Pichai Jintakosonwit Hideaki Fujita, Hirofumi Akagi and Satoshi Ogasawara "Implementation and performance of cooperative control of shunt active filters for harmonic damping throughout a power distribution system," This paper proposes cooperative control of multiple active filters based on voltage detection for harmonic damping throughout a power distribution system. The arrangement of a real distribution system would be changed according to system operation, and/or fault conditions. In addition, shunt capacitors and loads are individually connected to, or disconnected from, the distribution system.

Pedro Rodríguez, JosepPou, Joan Bergas,J. Ignacio Candela , Rolando P. Burgos and DushanBoroyevich "Decoupled double synchronous reference frame PLL for power converters control," Presented the detection of the fundamental-frequency positive-sequence component of the utility voltage under unbalanced and distorted conditions. Specifically, it proposes a positive-sequence detector based on a new decoupled double synchronous reference frame phase-locked loop (PLL), which completely eliminates the detection errors of conventional synchronous reference frame PLL's. This is achieved by transforming both positive- and negative-sequence components of the utility voltage into the double SRF, from which a decoupling network is developed in order to cleanly extract and separate the positive- and negative-sequence components.

PROPOSED SYSTEM CONFIGURATION

One of the most common problems when connecting small renewable energy systems to the electric grid concerns the interface unit between the power sources and the grid, because it can inject harmonic components that may decorate the power quality. The increasing use in the industry of non-linear loads based on the power electronic elements also introduced serious perturbation problems in the electric power distribution grids. Also, regular increase in the harmonic emissions and current unbalance in addition to high consumption of reactive power can be noticed. The flow of harmonic currents in the electric grids can also cause voltage harmonics and disturbance.

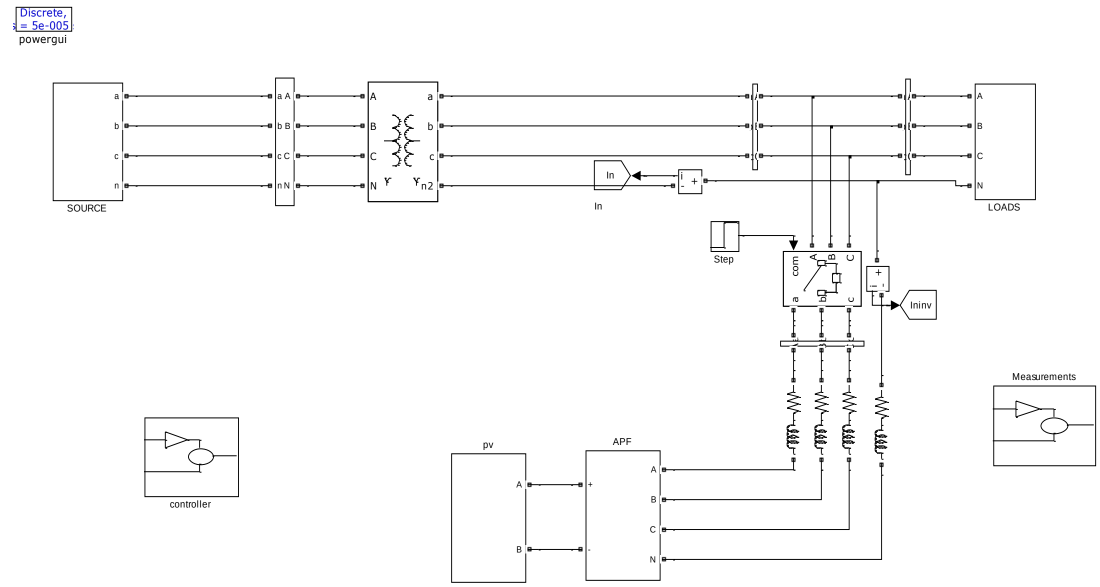
These harmonic currents can interact adversely with a wide range of power system equipment's, control systems, protection circuits and other harmonic sensible loads. The energy distributers like consumers were concerned by imposing some regulation protection against the expansion of harmonic problem. In order to face the problem of harmonics, many solutions have been proposed. These solutions included modifications on the load itself for less harmonic emissions like the case of special structure single phase and three phase rectifier and PWM rectifiers or the connection on the polluted power grids of other traditional or modern compensation systems.

In order to face the problem of harmonics, many researches were encouraged to develop modern, flexible and more efficient solutions for power quality problems including harmonics problem. These modern solutions have been given the name of active compensators or active power filters. The objective of these active power filter abbreviated mostly APF is to compensate harmonic currents and voltages in addition to selective reactive power compensation. Many types of APF have been proposed and used in harmonic compensation. Series APF is used for voltage harmonics compensation. Shunt APF was proposed for current harmonics and reactive power compensation. The Unified Power Quality Filter or Conditioner combines the two types Shunt and Series APF in one device responsible for the simultaneous compensation of voltage, current harmonics and reactive power. Although there are different types of APF, the Shunt APF is still the most famous and used type APF. The main function of Shunt Active Power Filter is to cancel harmonic currents occurring in power grids. The principle of SAPF is to generate harmonic currents equal in magnitude and opposite in phase to those harmonics that circulate in the grid. The non-linear loads absorb non-sinusoidal currents from the grid. Whereas, the SAPF current is generated in a manner that grid current keeps the sinusoidal form. SAPF is controlled to be seen with the non-linear load by the grid either as linear resistive load. There are two main structures for the control of Shunt Active Power Filter; these are the direct control and the indirect control of APF. In the direct control the main idea is to generate filter current references using the appropriate methods. The generated reference currents are then to be compared with the measured APF currents. The error is then used to produce control signals of the filter. The indirect control interests in controlling the grid currents instead of filter currents. It compares the measured grid currents with their generated references. The error is then sent to the control circuit which determines the control signal of the APF.

PROPOSED SIMULATION RESULTS

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. Therefore, the DG systems are required to comply with strict technical and regulatory frameworks to ensure safe, reliable and efficient operation of overall network. With the advancement in power electronics and digital control technology, the DG systems can now be actively controlled to enhance the system operation with improved PQ at PCC. However, the extensive use of power electronics based equipment and non-linear loads at PCC generate harmonic currents, which may deteriorate the quality of power.

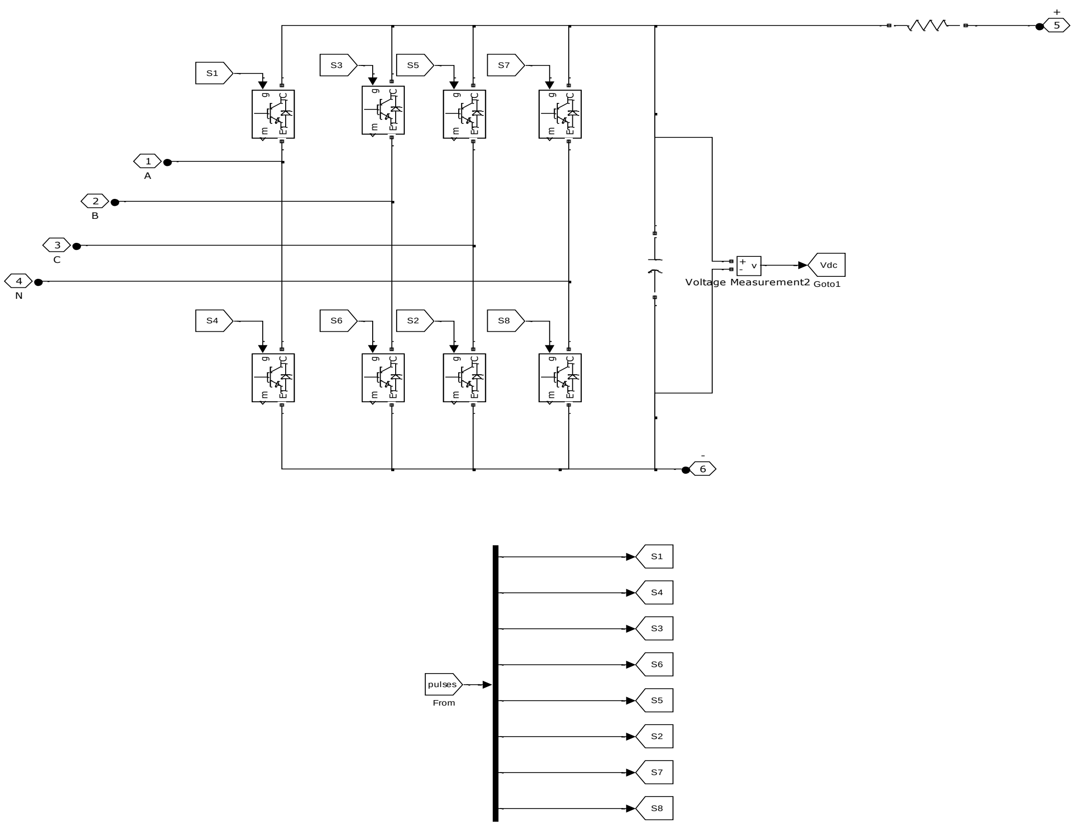
Fig. 1 Main SIMULINK Circuit for the Grid Connected Solar Energy System with Shunt APF



Four Leg Voltage Source Inverter (VSI)

The voltage source inverter is a key element of a DG system as it interfaces the renewable energy source to the grid and delivers the generated power. The fourth leg of inverter is used to compensate the neutral current of load. The main aim of proposed approach is to regulate the power at PCC during: 1) P_RES=0 ; 2) P_RES< total load powe (P_L); and 3) P_RES>P_L. While performing the power management operation, the inverter is actively controlled in such a way that it always draws/ supplies fundamental active power from/ to the grid. If the load connected to the PCC is non-linear or unbalanced or the combination of both, the given control approach also compensates the harmonics, unbalance, and neutral current. The duty ratio of inverter switches are varied in a power cycle such that the combination of load and inverter injected power appears as balance resistive load to the grid.

Fig. 2 Four Leg Inverter



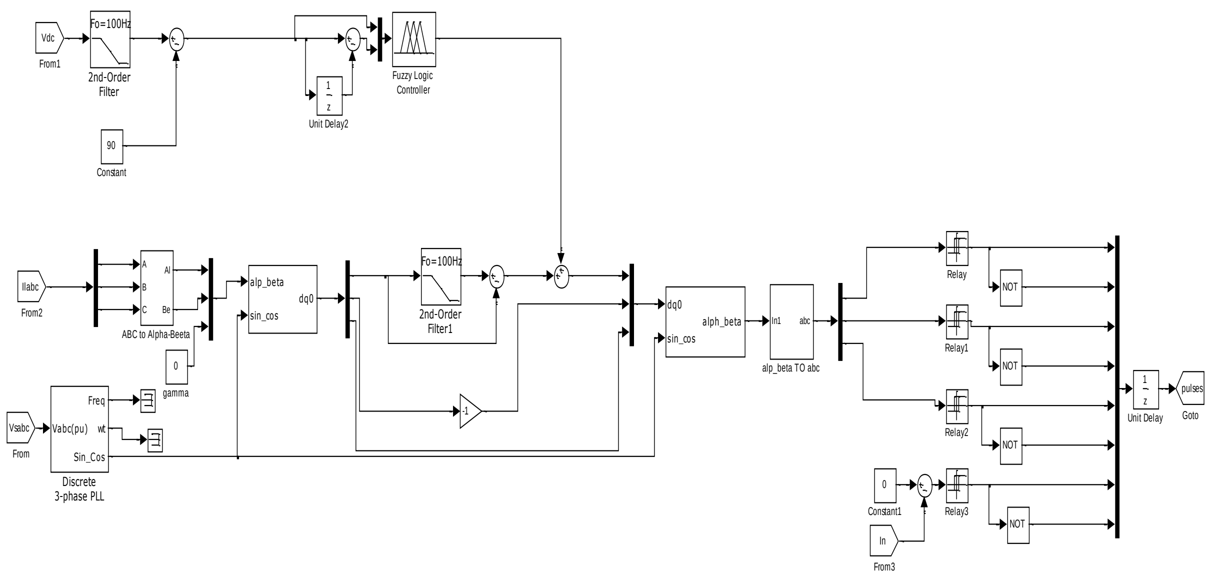
Control Circuit for the Four Leg VSI

A dq-based current reference generator scheme is used to obtain the active power filter current reference signals. The current reference signals are obtained from the corresponding load currents as shown in Fig.3. The dq-based scheme operated in a rotating reference frame. therefore, the measured currents must be multiplied by the sin(wt) and cos(wt) signals. By using dq transformation, the d current component is synchronized with the corresponding phase-to-neutral system voltage and the q current components are phase-shifted by 90°. The sin(wt) and cos(wt) synchronized reference signals are obtained from a Synchronous Reference Frame (SRF) PLL. The SRF-PLL generates a pure sinusoidal waveform even when the system voltage is severely distorted.

A low-pass filter (LPF) extracts the dc component of the phase-currents id to generate the harmonic reference components −i_d^∼ the reactive reference components of the phase currents are obtained by phase-shifting the corresponding AC and dc components of iq by 180◦. In order to keep the dc voltage constant, the amplitude of the converter reference current must be modified by adding an active power reference signal (i_e) with the d component. The resulting signalsi_d, and i_q is transformed back to a three-phase system by applying the inverse Park and Clark transformation

The dc-voltage converter is controlled by a traditional Fuzzy controller. This is an important issue in the evaluation, since the cost function is designed using only current references, in order to avoid the use of weighting factors. Generally, these weighting factors are obtained experimentally, and they are not well defined when different operating conditions are required. The determination of the output control signal is done with an inference engine with a rule base having if-then rules in the form of "IF ε is .... AND Δε is ...., THEN output is ...." With the rule base, the value of the output is changed according to the value of the error signal ε, and the rate-of error Δε.

Fig. 3 Control Circuit for Four Leg Inverter



Simulation Results

A simulation model for the three-phase four-leg PWM converter with the parameters shown in Table 1 has been developed using MATLAB-SIMULINK.

Table 1 Specification parameters

Variable	Description	Value
V_S	Source voltage	55 [V]
f	System frequency	50 [Hz]
v_{dc}	dc-Voltage	162 [V]
C_{dc}	dc capacitor	2200 [μF]
L_f	Filter inductor	5.0 [mH]
R_f	Internal resistance	0.6 [Ω]
T_S	Sampling time	20 [μs]
T_e	Execution time	16 [μs]

The objective is to verify the current harmonic compensation effectiveness of the proposed control scheme under different operating conditions. A six pulse rectifier was used as a non-linear load. In the simulated results shown in Fig. 4, phase to neutral source voltage at t=0 to t=0.8. Fig. 5 shows the source currents at t=0 to t=0.8.

Fig. 4 Phase to Neutral Source Voltage

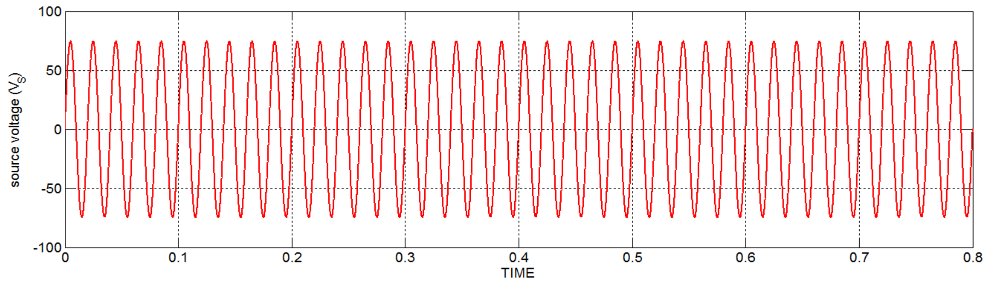
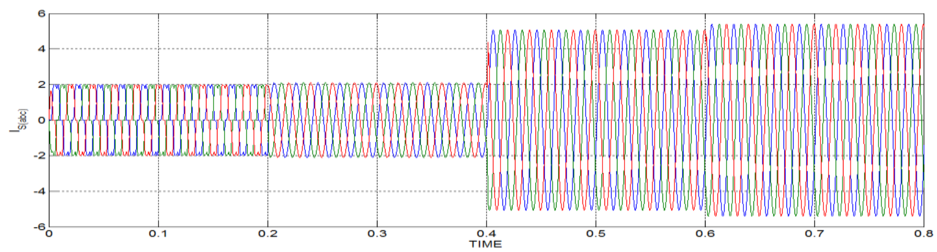


Fig. 5 Source Currents



As the load is non-linear it draws a non-sinusoidal current, without active power filter compensation shown in Fig. 7. And the load current at t=0 to t=0.4 is shown in Fig. 6

Fig. 6 Load Current at 0<t<0.4

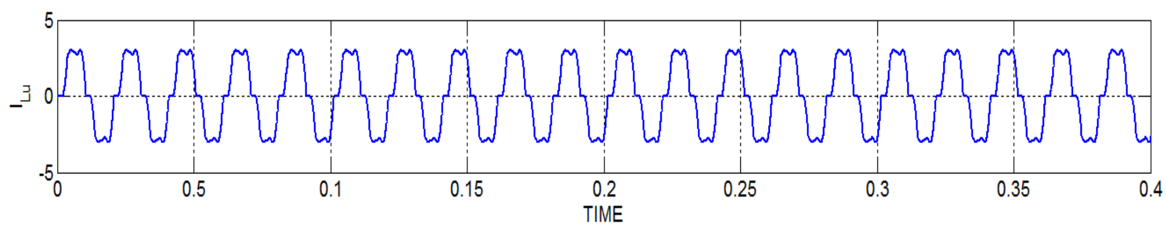
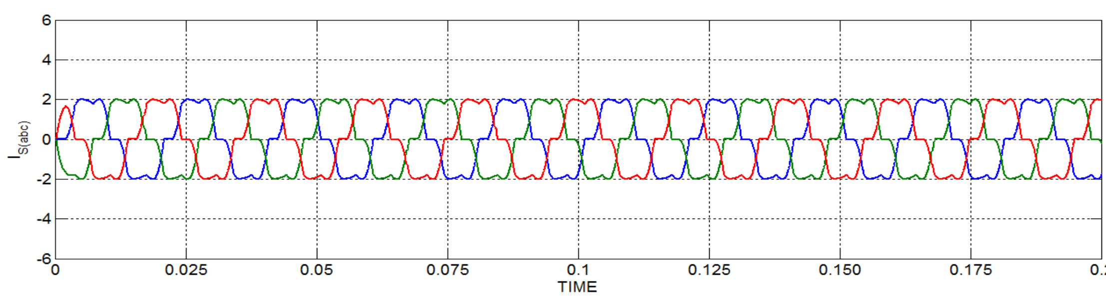
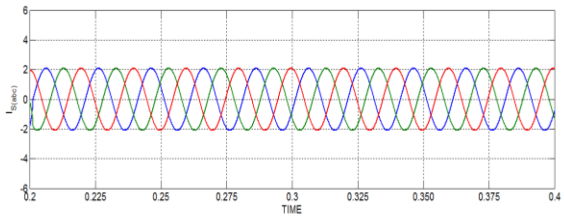


Fig. 7 Source Currents at 0<t<0.2



The active filter starts to compensate at t =0.2. At this time, the active power filter injects an output current iou to compensate current harmonic components, current unbalanced, and neutral current simultaneously. During compensation, the system currents (is) show in Fig. 8 is a sinusoidal waveform, with low total harmonic distortion.

Fig. 8 Source Currents at 0.2<t<0.4



At t =0.4, a three-phase balanced load step change is generated shown in Fig. 9. The compensated system currents, shown in Fig. 10 remain sinusoidal despite the change in the load current magnitude.

Fig. 9 Load Current at 0.4<t<0.6

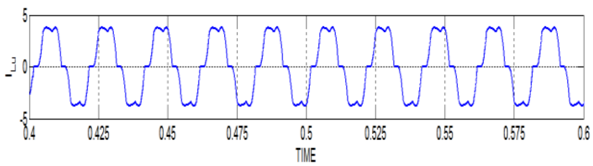
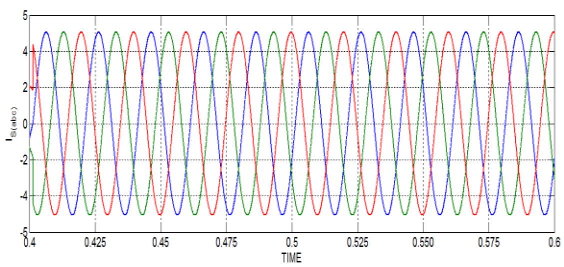


Fig. 10 Source Currents at 0.4<t<0.6



Finally, at t =0.6, a single-phase load step change is introduced in phase u which is equivalent to an 11% current imbalance, shown in Fig.11. As expected on the load side, a neutral current flow through the neutral conductor (iLn), shown in Fig. 12, but on the source side, no neutral current is observed (isn) shown in Fig. 13.

Fig. 11 Load Current

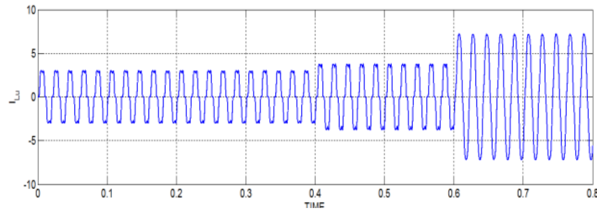


Fig. 12 Load Neutral Current

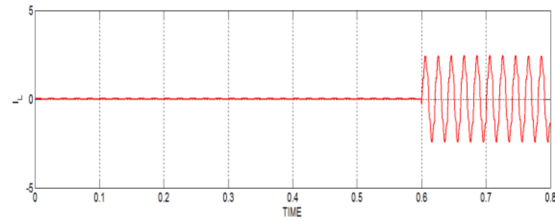
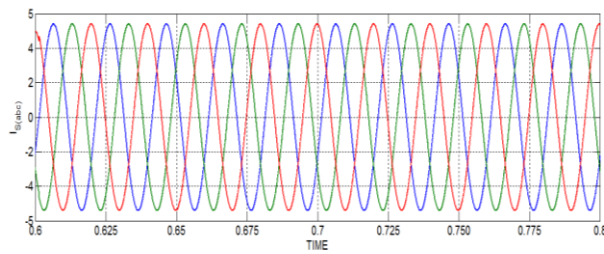


Fig. 13 Source Currents at 0.6<t<0.8



CONCLUSION

Reactive power compensation and voltage regulation are two effective measures to improve the voltage quality. By using new emerging technology the stability and reliability of the system can be maintain very well using FACTS devices. Usually a STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation. VAR compensation is defined as the management of reactive power to improve the performance of ac power systems. In this thesis, a DC-coupled System has been studied, to improve the power quality at point of common coupling with 3-phase 4-wire distributed generation. It has been shown that the grid interfacing inverter can be effectively utilized for power conditioning without affecting its normal operating of real power transfer. The grid-interfacing inverter with the proposed approach can be utilized to:

i) Inject real power generated from RES to the grid,

ii) Operate as a APF This approach thus eliminates the need for additional power conditioning equipment to improve the quality of power at PCC.

The MATLAB/SIMULINK 2009a simulation model of the proposed system with the connection of renewable energy sources is shown and validated. The control circuit is operated with phase lock loop, proportional integral controller and hysteresis controller which is used to generate the gating pulses for the 4-leg inverter and is carried out at load side with non-linear unbalanced load. Thus the current unbalance, current harmonics and load reactive power, due to unbalanced and non-linear load connected to the PCC, are compensated effectively such that the grid side currents are always maintained as balanced and sinusoidal at unity power factor.

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