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IMPROVEMENT OF POWER QUALITY USING MULTILEVEL INVERTER BASED SHUNT ACTIVE POWER FILTER

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ABSTRACT

A Multi-Level Inverter (MLI) based Shunt Active Power Filter(APF) is represented in this paper. SingleMLI-APF is used as both Interfacing converters for improvement of Power Quality of the Whole system. Use of MLIs reduces stress on power electronic devices because they can be made to operate at low voltages compared to the conventional two level converters. The output voltage provided by MLIs has small voltage steps, that results in good power quality and low-harmonic components. As Majority of the Renewable systems comprises at least two converters for these tasks, the proposed system may be treated as simple and economical in meeting the same objectives.Peak detection method of control strategy is employed in MLI-APF for power quality improvement. The proposed system is simulated using MATLAB/SIMULINK and tested for power quality improvement.

KEYWORDS: Multi Level Inverter (MLI), Shunt Active Power Filter(SAPF), Peak Detection Method.

INTRODUCTION

Usage of Shunt Active Power Filter (SAPF) is a solution for these problems and is responsible for compensation of harmonics and correction of the power factor of the system. The main control objective of Shunt Active Power Filter consists of generation of reference current wave form for each phase and driving the inverter by generating gating signals to track this reference wave form.Shunt APF operate as controlled current sources injecting current harmonic components to the power distribution system. BhimSingh *et al.* [2] have presented a review on classification of active filters for power quality improvement based on converter type, topology and the number of phases.

By the use of MLIs the switching losses and voltage stress on power electronic devices can be considerably reduced because the power semiconductor devices can be made to operate at low voltages compared to the conventional two level converters. The multilevel Inverters produce a stepped output voltage waveform from several lower dc voltage sources. The output voltage provided by MLIs has small voltage steps, that results in good power quality and low-harmonic components.

RELATED WORK

The main objective of the Shunt Active Power Filter (SAPF) is Generation of reference currents for which many strategiesare available in literature. The Synchronous Reference Frame (SRF) strategy [3] only computes the sinusoidal fundamental components of the load currents; the reactive power compensation and a zero neutral current thus cannot be achieved if the load imbalance at the fundamental frequency occurs. The mostly used instantaneous p-q theory can provide an instantaneous and accuratereference compensating current [4,5] but suffers from the requirement of reference frame transformation from a-b-c axes to d–q axis. A phase-locked loop (PLL) per each phase must be used. W. M. Grady *et al.* [9] have presented a survey of active power line conditioning methodologies with a list of the advantages and limitations of each one. Chang and Shee*et al* [10] have proposed a simple and efficient compensation strategy that is suitable for three-phase shunt active power filters without reference-frame transformation requirement. In addition to these there are several other techniques suchas extraction of load current RMS component[11], indirect current control [12], algorithm based on the real component offundamental load current (I cosF) [15] etc.. Cavallini and Montanari*et al* [18] have proposed the unity power factor strategy known as classic strategy in which conditions the line currents to fit the voltage waveform, provides line current RMS values always lower than those obtained by keeping the instantaneous real power equal to its mean value.

To achieve full compensation of both reactive power and harmonic currents of the load, this paper presents a simple method to determine the SAPF reference compensation currents using dc voltage PI controller, source voltages and source currents. This method does not require any reference frame transformations. Hysteresis band current control PWM strategy is used to drive current controlled voltage source inverter (CC-VSI).

Previous work [1] has addressed the problems of compensating for harmonics and reactive power of the system. To achieve further performance improvement, this paper now explores the use of multilevel converter topologies in a similar context, since such converters are known to achieve an improved harmonic performance.
Simulation results and discussions are given for different test conditions in section IV. Section V concludes this paper.

CONTROL SCHEME OF SHUNT ACTIVE POWER FILTER (SAPF)

General block diagram showing control scheme of a shunt active power filter is shown in Fig. 3.1. The reference currents that are to be tracked by MLAPF to compensate the load current harmonics, reactive power, are generated by peak detection method. Small amount of power required to meet the losses in the inverter circuit are taken into consideration by the dc voltage control unit.

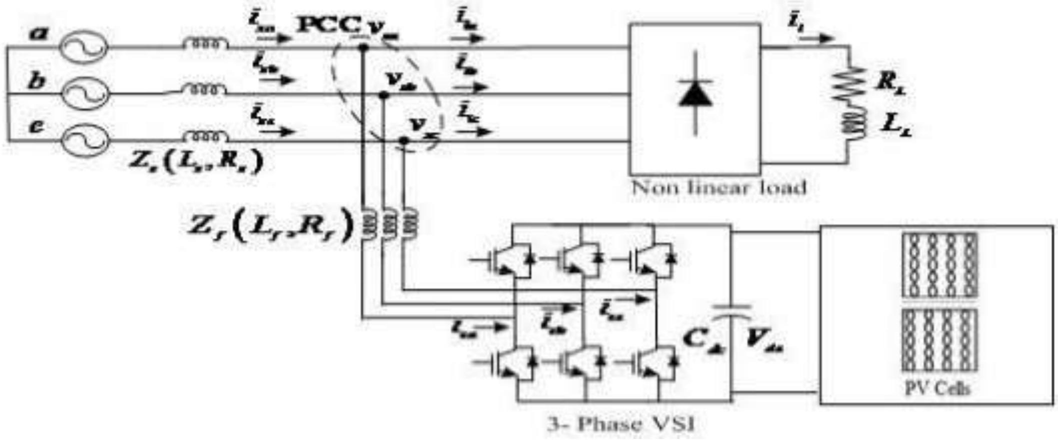


Fig. 2.1. Basic Compensation Principle of Shunt Active Power Filter (SAPF)

Peak detection Method with PI Controller

In this control strategy, the required fundamental component of the distorted load current is extracted by filtering. The band-pass filter is used and tuned at the fundamental frequency (50 Hz), so that the gain attenuation introduced in the filter output signal is zero and the phase-shift angle is 180^0. The output current of the filter is thus equal to the fundamental component of the load current but phase shifted by 180^0. During the operation inverter consumes small amount of real power to meet the switching losses and to keep dc voltage constant. The reference current wave form must also take this component into consideration. Thus the sinusoidal reference current waveform obtained from control strategy has the components corresponding to the fundamental component of the load current, the error signal obtained from the dc voltage control unit.

In order to provide the reactive power required by the load, the current signal obtained from the filter I_{l1} is synchronized with the respective phase to- neutral sourcevoltage so that the inverter ac output current is forced to lead the respective inverter output voltage, thereby transferring the required reactive power. In this way, the current signal allows the inverter to supply the current harmonic components, the reactive power required by the load, and to absorb the small amount of active power necessary to cover the switching losses and to keep the dc voltage constant. Similar scheme is necessary for each phase. The control diagram is shown in fig 2.2

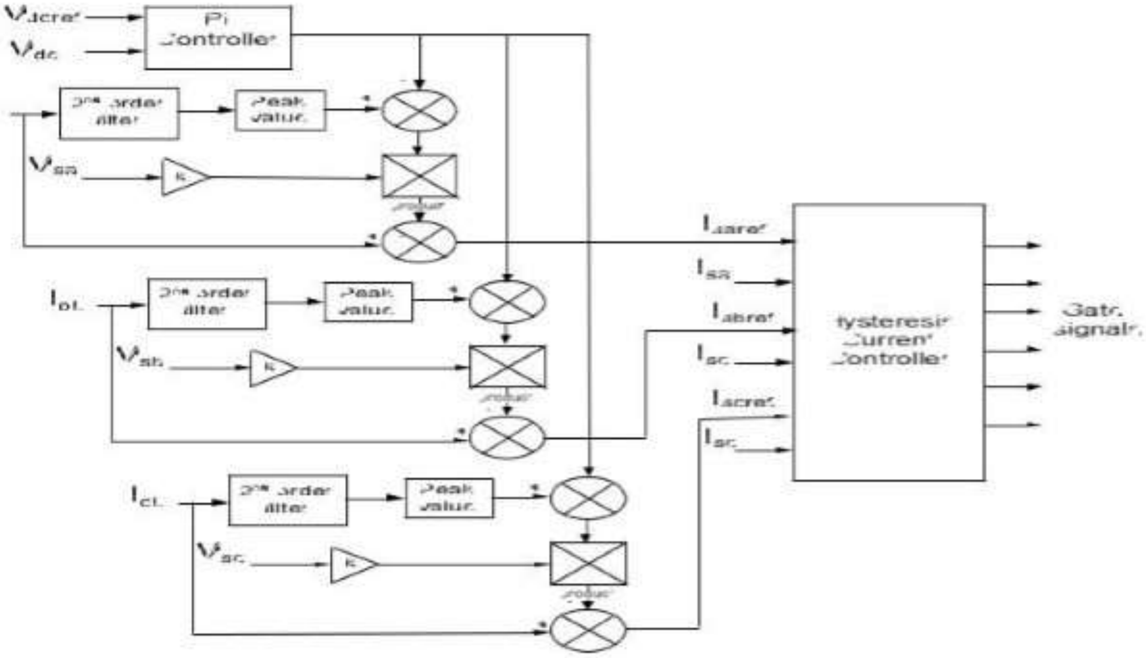


Fig.2.2 Generation of Reference currents required by Shunt Active Power Filter (SAPF)

Design of Hysteresis Current Controller for PWM Switching

The active filter is comprised of three-phase IGBT based current controlled VSI bridge. The upper device and the lower device in one phase leg of VSI are switched in complementary manner.

Ideal compensation requires the mains current to be sinusoidal and in phase with the source voltage, irrespective of the load current nature. The source reference currents, after compensation, can be given as

$$i^*_{sa} = I_{sp} sin\omega t$$

$$i^*_{sb} = I_{sp} sin\omega t - 120^0$$

$$i^*_{sc} = I_{sp} sin\omega t + 120^0$$

whereI_{sp} is the amplitude of the desired source current, while the phase angle can be obtained from the source voltages. Hence, the waveform and phases of the source currents are known, and only the magnitudes of the source currents need to be determined.

MULTI LEVEL INVERTER BASED ACTIVE POWER FILTER

The main operating concept of these inverters is to divide the DC link potential into multiple sections, so that each phase leg can switch between multiple voltage levels (rather than the two voltages only of a two-level inverter). This reduces the burden on the switches and there by switching losses.All the four basic topologies of MLIs have their own strengths and weaknesses.Therefore, the use of bulky and expensive multi-pulse transformers can be avoided, resulting in reduced stress of the power semiconductor devices, substantially smaller filters and consequently, a cost reduction of the system.

Recent trend is to focus on the multi-level inverter topologies, which significantly improve the output waveform spectrum of the inverter. In this paper a 3 level diode clamped MLI topology is used that can obtain the multiple voltage levels with a low cost string of DC capacitors. However this is done with an expense of fluctuations in capacitor voltages. This problem can somehow mitigated by using lowlevels. For this reason the analysis is limited to 3-level. The simulink model of 3level MLI used is shown in fig. 3.1 below.

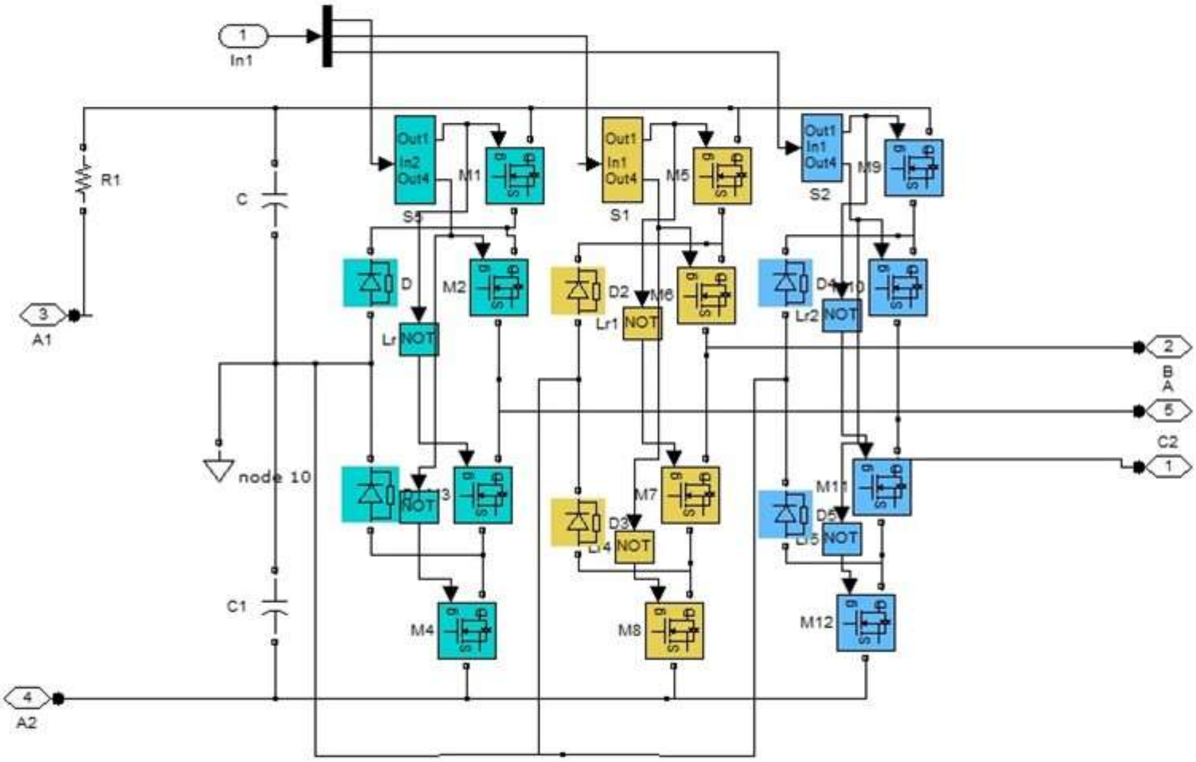
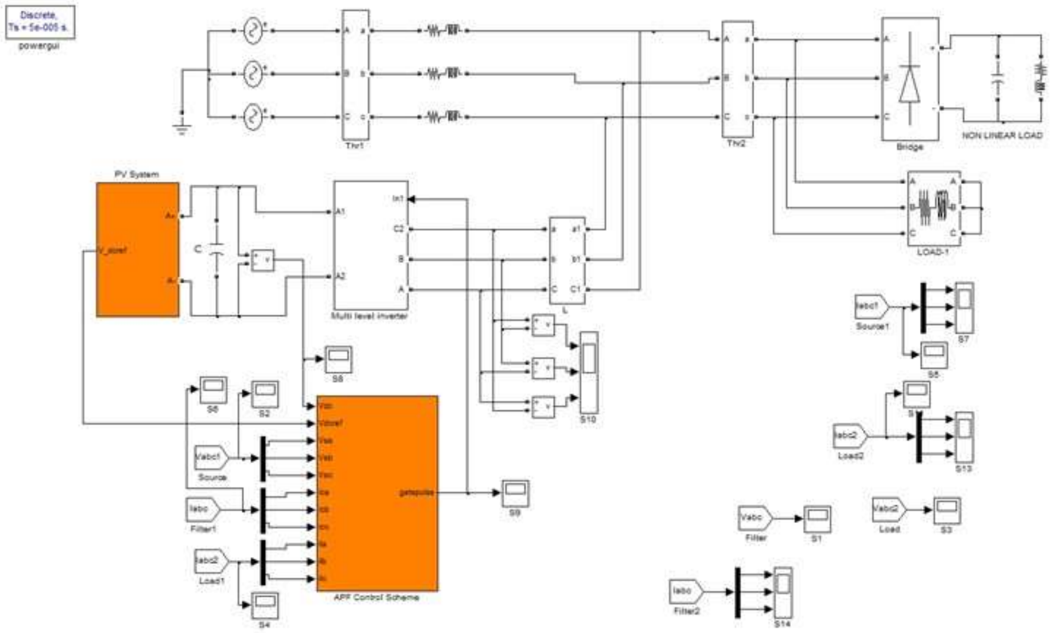


Fig.3.1 Two level Inverter used for Active Power Filter

SIMULATION RESULTS AND DISCUSSION

Following are the system parameters considered for the study of SAPF with proposed peak detection method for PI controller. V_s = 220 V (Peak), f = 50 Hz, R_s= 0.1 Ω, L_s= 0.03mH, L_f = 0.01 mH, In case of PI the gains chosen are k_p= 1 and k_i = 9. A Diode bridge is used as nonlinear load which feeds power to an RL load. A local RL load of R=10 Ω and L=20mH is also considered

The SIMULINK model of the system considered is shown in figure. 4.1



Performace Results of Active Power Filter

The performance results of two level and three level shunt active power filter are presented in Fig.6 below. Both load current and source current harmonic distortion are improved in three level APF. The filter currents and voltages are smoothened as shown in fig. which reduces the burden on filter operation.

Three phase filter voltages and three phase currents injected by two level inverter in compensating the harmonics and making source currents sinusoidal are shown in fig. 4.2 . It can be observed from these that the filter voltages are of large step size and filter currents are rich in harmonics compared to three level SAPF. Thus they impose more burden on the operation of SAPF eventually resulting in losses in the converter.

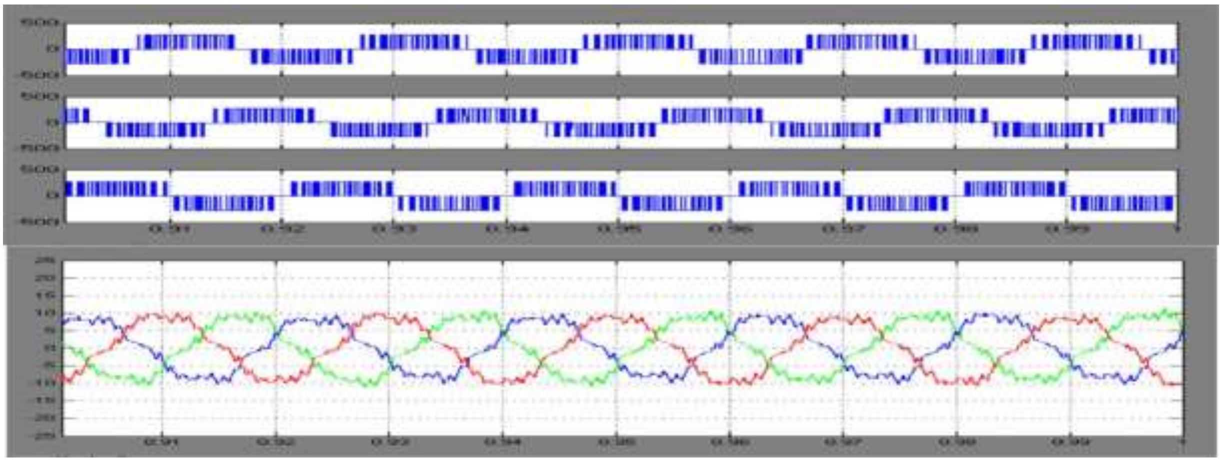


Fig. 4.2 Three phase Filter Voltages and currents of two level APF

The Load current and source currents of three phases of two level SAPF are shown in fig 4.3 below. Inspite of the nonlinearities in load currents, due to the presence of nonlinear load, the source currents are sinusoidal in nature due to the the operation of SAPF.

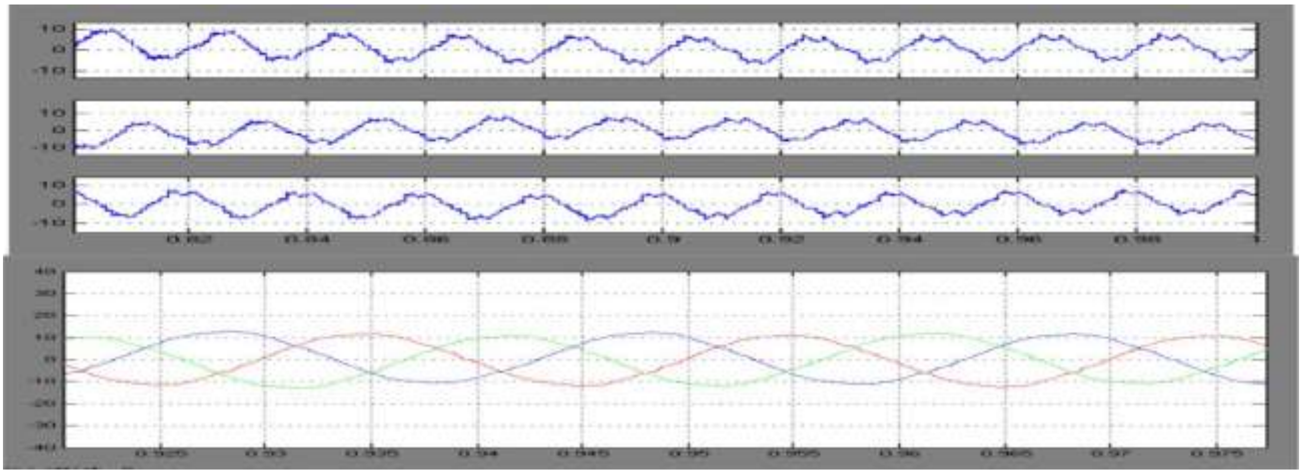


Fig.4.3 Load current &Source current with two level APF

The FFT analysis is performed for source and load currents of the system and are presented in Fig. 4.4 and 4.5 respectively. The source current THD is reduced to 1.32% when compared to 20.16% of Load current.

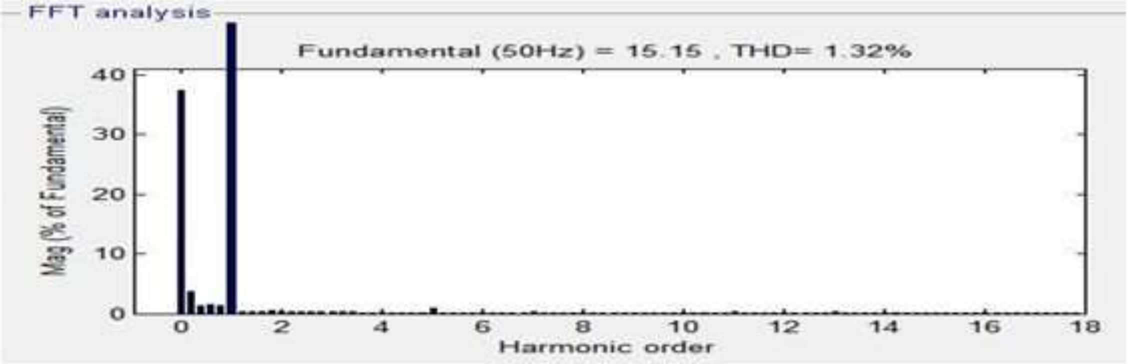


Fig.4.4 Source current THD with two level APF

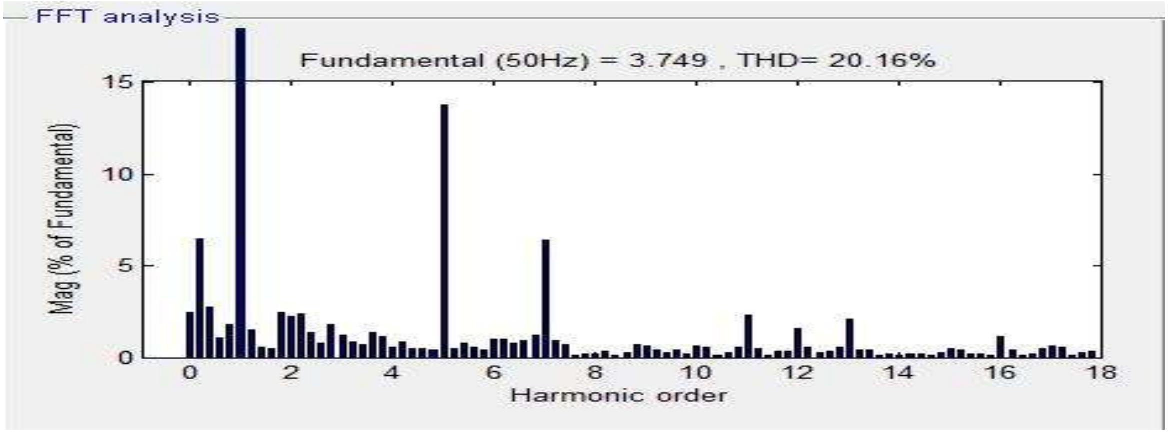


Fig 4.5Load current THD with two level APF

The operating voltages and injected currents of Three level APF are presented in fig. 4.6. when compared to two level APF, the filter voltages are of small step and smoothened. With this the voltage stress in the semiconductor devices is reduced. The injected filter currents are also smoothened compared to two level APF which reduces burden and switching losses in the VSI converter.

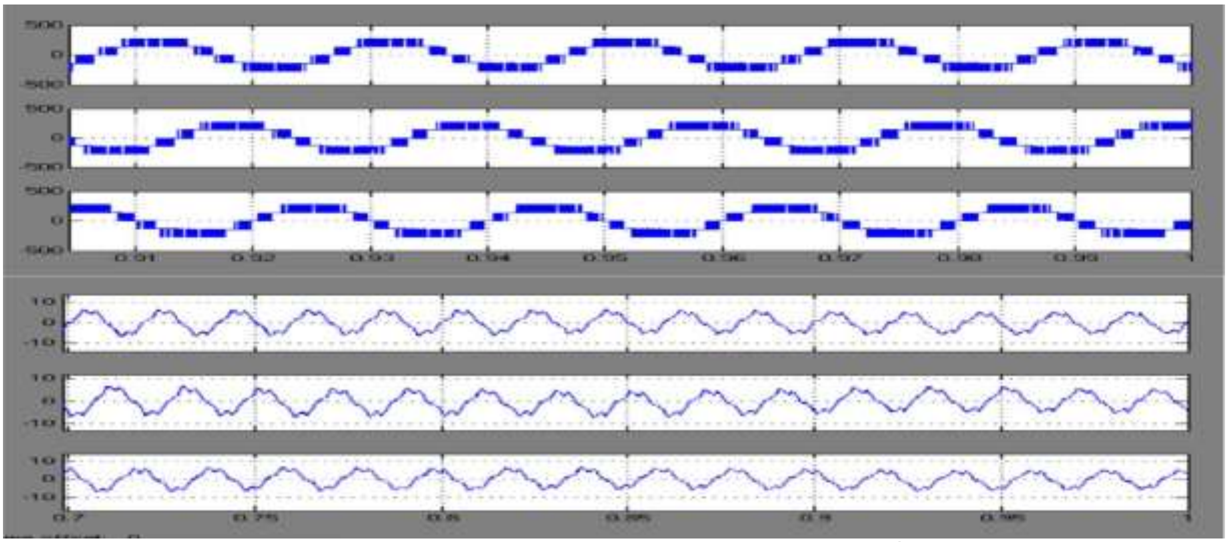


Fig. 4.6 Three phase Filter voltages and currents of three level APF

The performance results of the MLI(three level) SAPF are presented in the fallowing figures. Fig. 4.7 shows the Load and source currents of three phases. It is clear from these that when compared to two level SAPF both of these currents are improved and harmonic contents are considerably reduced.

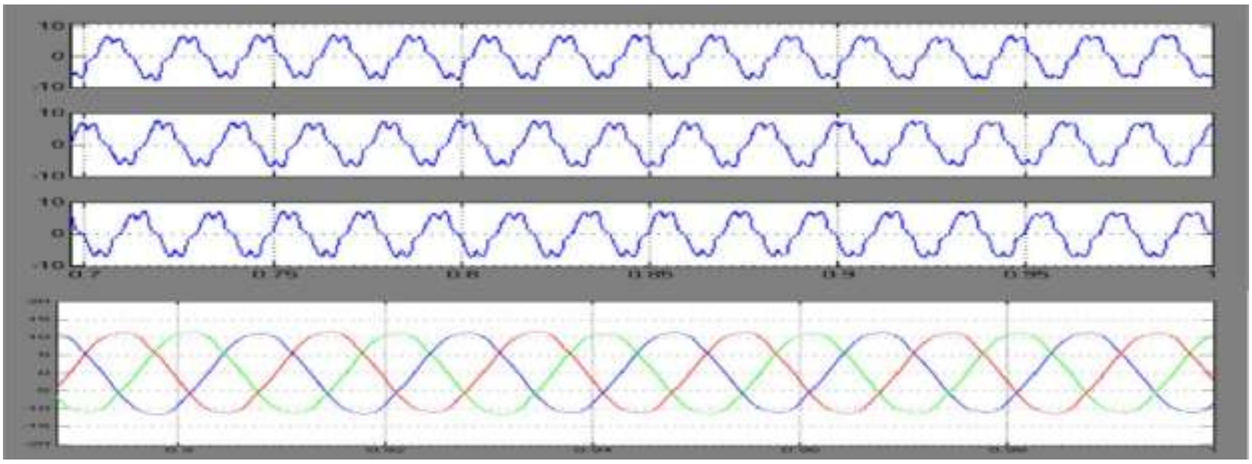


Fig. 4.7Load & Source current with three level APF

The THD analysis of these source and load currents are presented in the fig. 4.8and 4.9below. The THD percentage of these currents are considerably reduced to1.17% and 14.45% for source and load currents respectively.

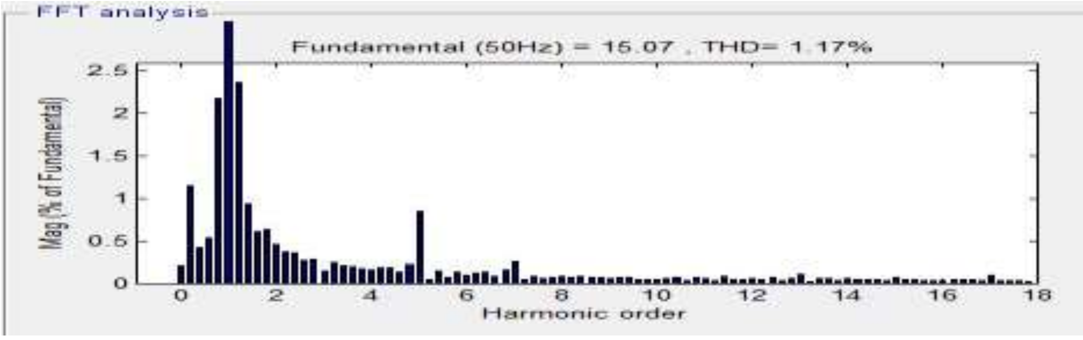


Fig. 4.8Source current THD of three level inverter

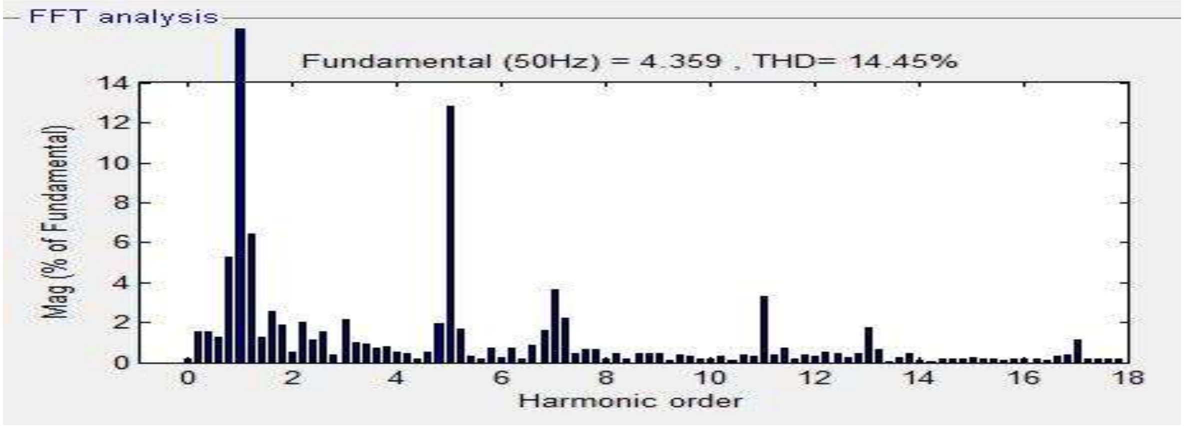


Fig.4.9 Load current THD of three level inverter

CONCLUSION

Proposed system helps us to know that to make a move towards the improvement of harmonic performance, the existing two level converter has been replaced by Multi Level Inverter. The results obtained reveals that for the same operating conditions, the THD of load and source currents are improved considerably in three level converter compared to two level. The filter voltages are also smoothened which reduces the burden on the operation of filter.Use of MLIs reduces stress on power electronic devices because they can be made to operate at low voltages compared to the conventional two level converters. The output voltage provided by MLIs has small voltage steps, that results in good power quality and low-harmonic components.Usage of Shunt Active Power Filter (SAPF) is responsible for compensation of harmonics and correction of the power factor of the system.By the use of MLIs the switching losses and voltage stress on power electronic devices can be considerably reduced because the power semiconductor devices can be made to operate at low voltages compared to the conventional two level converters.

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