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ANALYSIS OF SHUNT ACTIVE POWER FILTER BASED HARMONIC MITIGATION AND REACTIVE POWER COMPENSATION

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Abstract

Traditionally when one imagine about power quality, images of classical waveforms comprising 3rd, 5th, 7th etc. harmonics come into picture .On this basis IEEE in team with industries and utilities and academia began to attack this problem in "power quality " from the 80s. However in last few years the term power quality has grown in meaning form a simple power system harmonics. Since the growth of the industries is inevitable with more complex and sensitive equipment's involving semiconductor etc. the power quality engulfed a whole new dimension of errors that appear in power system. In such a situation Active Power Filters have emerged as the solution in which SAPF is employed for removal of load current harmonics and reactive power compensation .Active filters for power conditioning offer the following:

Responsive power pay, Harmonic remuneration, consonant disengagement, symphonious damping, and consonant end, Negative arrangement current/voltage pay, Voltage direction. The phrasing dynamic channels are frequently observed in various fields separated from control handling.

In this work both PI controller based and Hysteresis Band controller, three phases SAPF is used to compensate harmonics and the reactive power by a non-linear load to better the quality and is implemented on three phase wire system. The simulation of the results done through MATLAB program, and number of simulation results of the method are observed under steady conditions.

Introduction

Now we address to the other important power quality issue i.e. Harmonics. With the increased usage of Semiconductor switching devices on a large scale in distribution networks, especially in household and commercial loads the Harmonics challenges have increased manifolds. These switching devices provide the ease to regulate and manage the electrical energy. These devices are both dependable and cost-effective. But these power electronic devices offer non-linear characteristics while operating, which results in disturbance in the voltage and current waveforms at the point where the device is installed. Gradually, these devices have emerged as the prime source of power quality degradation, the main pollution sources of the current power systems. These non-linear loads draw non-sinusoidal (distorted) current from the utility which contains harmonics. Harmonics are those frequency components that are integral multiple of the fundamental frequency (50Hz).

Removal of harmonics is necessary and to achieve this there are distinct techniques available such as active filter, passive filter,hybridfilter, and UPQC etc. With further improvements in active power filter technologies, these filters can be effectively for the compensation of harmonics and reactive power . Various control strategies and configurations are available using which reactive power compensation and harmonic mitigation of distribution system can be achieved. According to IEEE-519 standards the total harmonics distortions should be under 5% which is achieved in our work using SAPF.

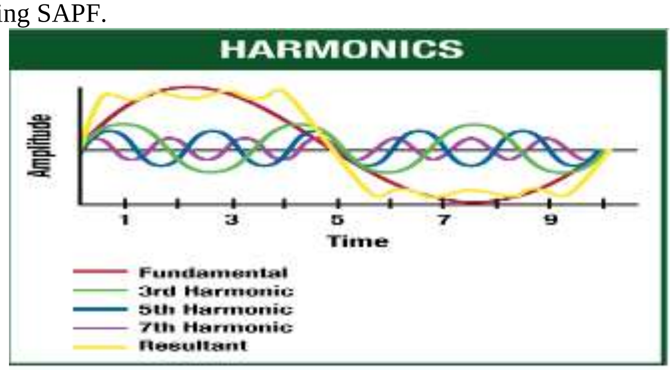

Figure 1:The fundamental wave, Resultant wave,3rd,7th&5th harmonics in system.

Principle of Basic Compensation:

Below given figure depicts the principle of Basic Compensation of a shunt active power filter. SAPF is regulated to cancel the current harmonics on the AC side by either drawing or supplying a compensating current from or to the system.

The curve 1,2 and 3 depicts the waveform of load current(curve1) , desired current(curve 2) and the compensating current (curve3) which is introduced in the system by the active filter. This compensating current displayed in curve3 is the one which turns the main current sinusoidal containing all the harmonics.

The mitigation of current harmonics and the compensation of reactive power can be achieved using SAPF.

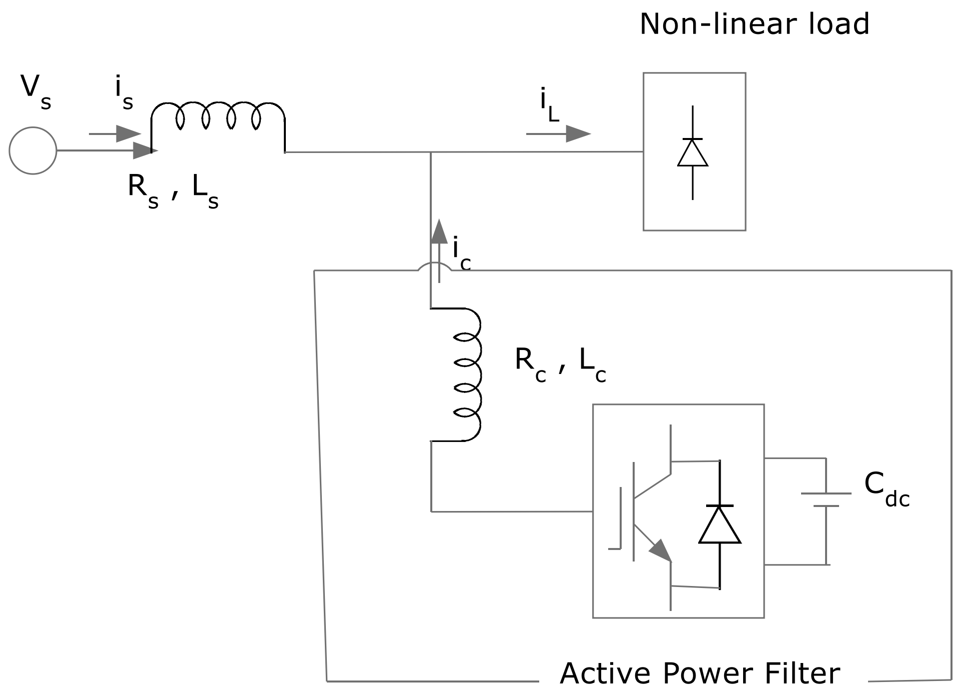

Figure 2:Compensation principle of SAPF.

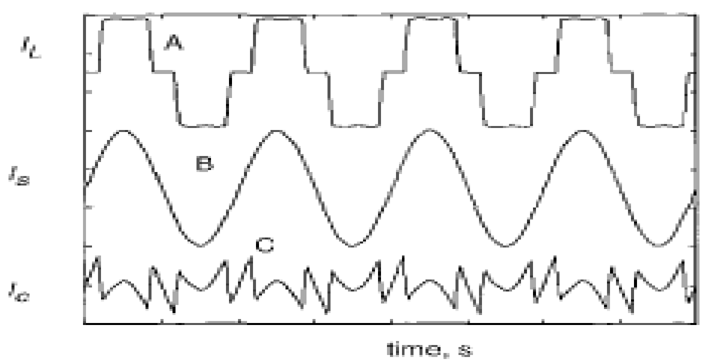

Figure 3: Shape of load current, source current and compensating current

Control Strategy Applied:

Figure 4 shows the entire simplified symbolic illustration of a shunt active power filter. Figure 5 represents the realization of control scheme applied in the form of Block diagram. This control technique employs two control loops, the outer loop is the voltage control loop. And an inner loop which is the current control loop. In the voltage control loop the actual dc link capacitor voltage is sensed and is compared with the set DC reference value , in PI controller the error output is processed . The maximum value of source is generated as the outcome of PI controller. A PLL (phase locked loop) block is used to generate unit sine vectors synchronized with the frequency of source voltage .These unit sine vectors signals are multiplied with the maximum value of source current to generate three phase sinusoidal source current , displaced by 120 degrees from each other. Or we can say that the reference currents are obtained by multiplying the output of PI controller (which is the maximum value of supply current and is obtained when the actual DC capacitor voltage is compared to set reference voltage, and the difference is processed in the controller) to the unit sine vectors which are synchronized with (or which are in phase with) the source voltages.

In the inner control loop the actual currents are compared with these three phase reference currents in a hysteresis controller to generate the required gate pulses for the inverter. The switching signals of the active filter are generated by hysteresis based current controller when the reference currents and actual currents are given to this controller. The switching procedure is performed by the difference of reference currents and actual currents. Either lower or upper switch of the voltage source converter is turned ON, for increasing or decreasing the value of the current of an individual phase that is for rising the current for an individual phase, lower switch of the active power filter is switched ON. And for diminishing the value of current, upper switch of the active power filter is switched ON. After performing the switching proceedings, inductor filter allows the flow of current to compensate the harmonics (current harmonic) and reactive power of the load so that the load receives only active power from the utility (source side).

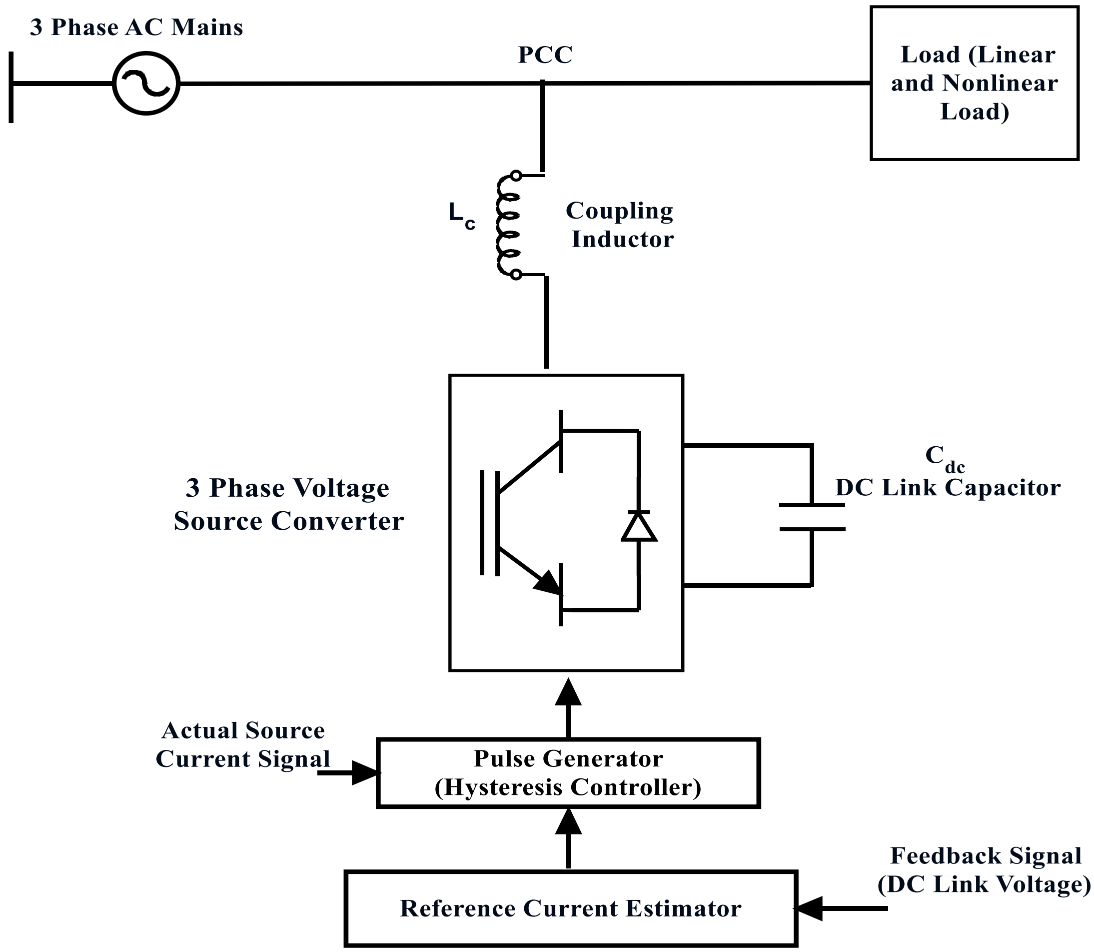

Figure 4: The schematic diagram of SAPF.

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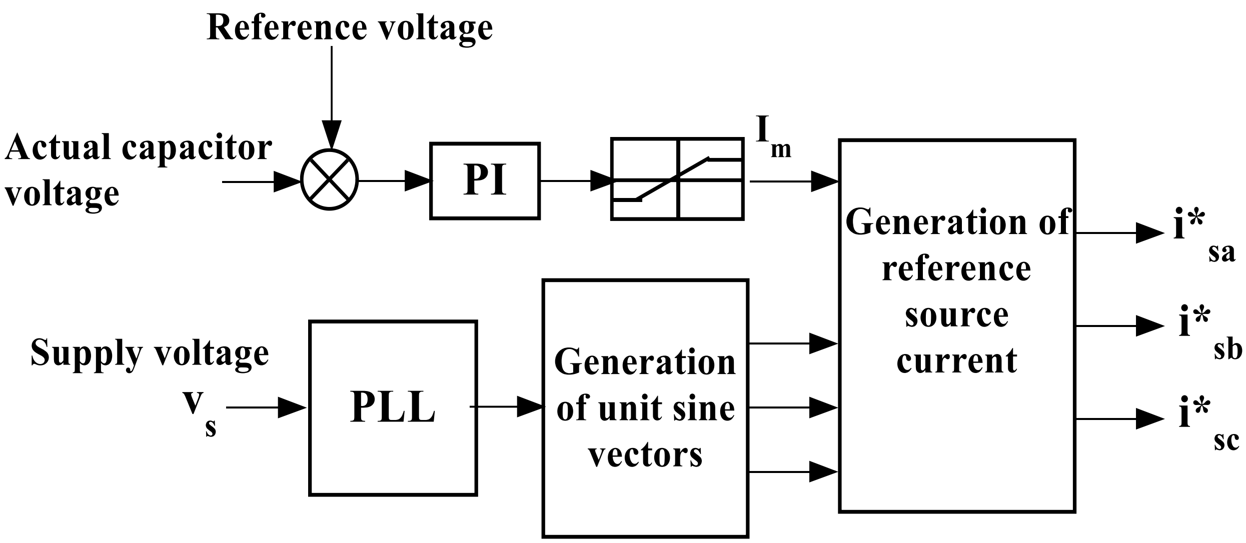

Figure 5: The control scheme

1. Result

A Discrete Rms value block is connected to measure the rms value of current and a display is connected at its output. A combination of Linear and Non-linear load is connected to the system through a three phase breaker as shown in figure 7.1. A step input is connected to the breaker. Load is changed at 0.4 seconds from P = 2kW and Q = 2 kVAR to P = 2 kW

And Q = 5 kVAR. That is the reactive load is increased, or can say the reactive power demand of load is increased after 0.4 seconds and this will be compensated by active power filter and therefore the rms value of current supplied by the source will not change as the source is used to supply only active power. System parameters are given in the following table Below given Table 1, Lists the system parameters .

Table 1: Lists the system parameters .

System Parameters	Values
Source Voltage	400 V (phase-phase rms voltage)
System frequency	50 Hz
DC link Capacitance	2000µf
Filter Impedance (R_c , L_c)	0.4Ω , 3.35 Mh
Source Impedance	0.1Ω , 0.15 Mh
Reference DC link Voltage	725 volts

Fig 6 shows the main Model of the work. In this Model the voltage source converter is shown which is connected at the load side. The Three phase source has its peak to peak rms voltage of 400 volts. Three phase voltage measurement block is used and current and voltage measurement is done for each phase using the blocks respectively. Label used for voltage is Vs_abc and for source current the label used is I_s_abc, similarly for compensating current I_c_abc , compensating voltage V_c_abc , load current I_L_abc and load voltage V_L_abc. These signal label can be used anywhere in the model using a ‘from block’ with the same ‘goto’ tag.

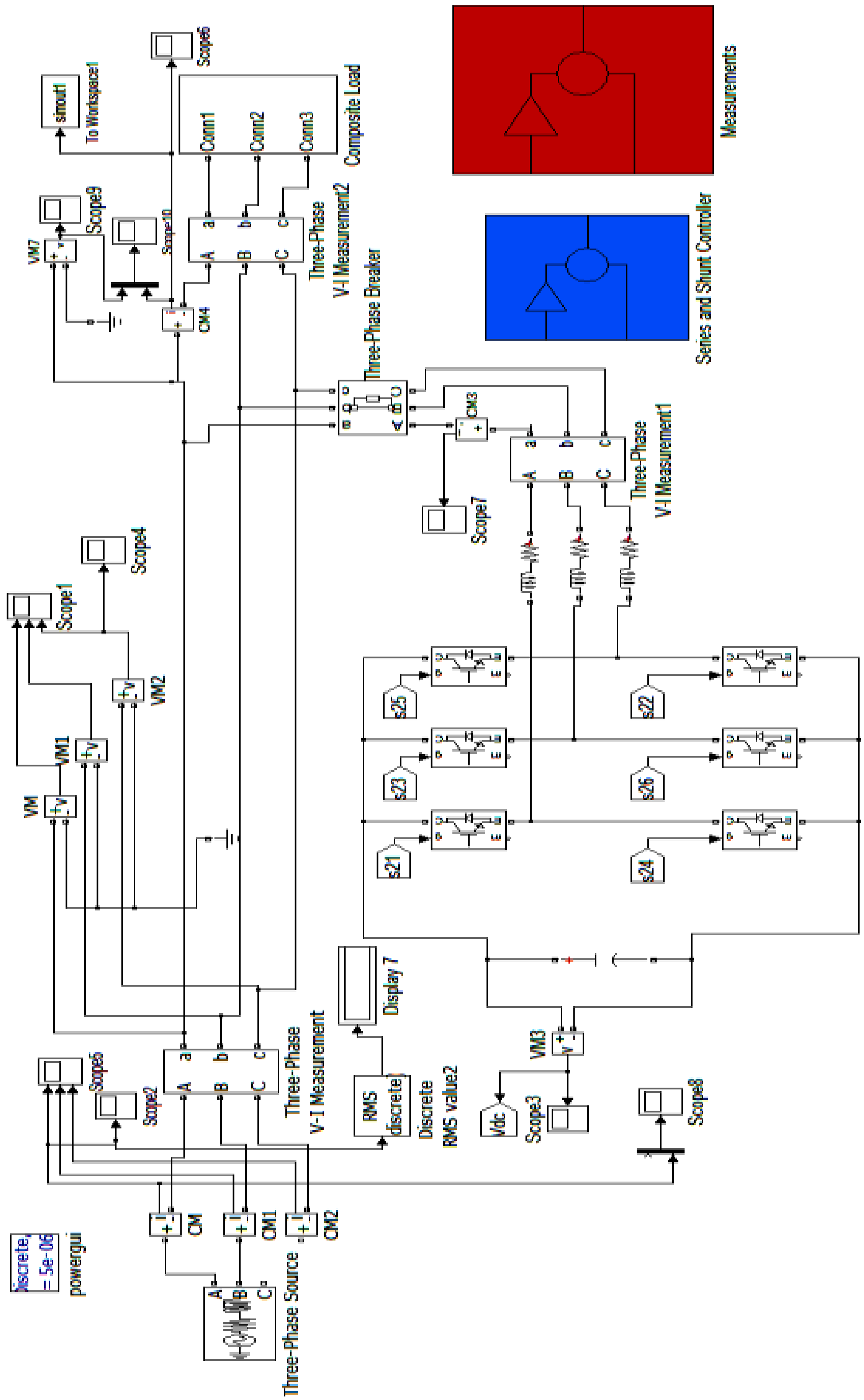

Figure 6: MATLAB Model of SAPF

Figure 7 and 8 shows the source voltage and source current, and load voltage and load current.

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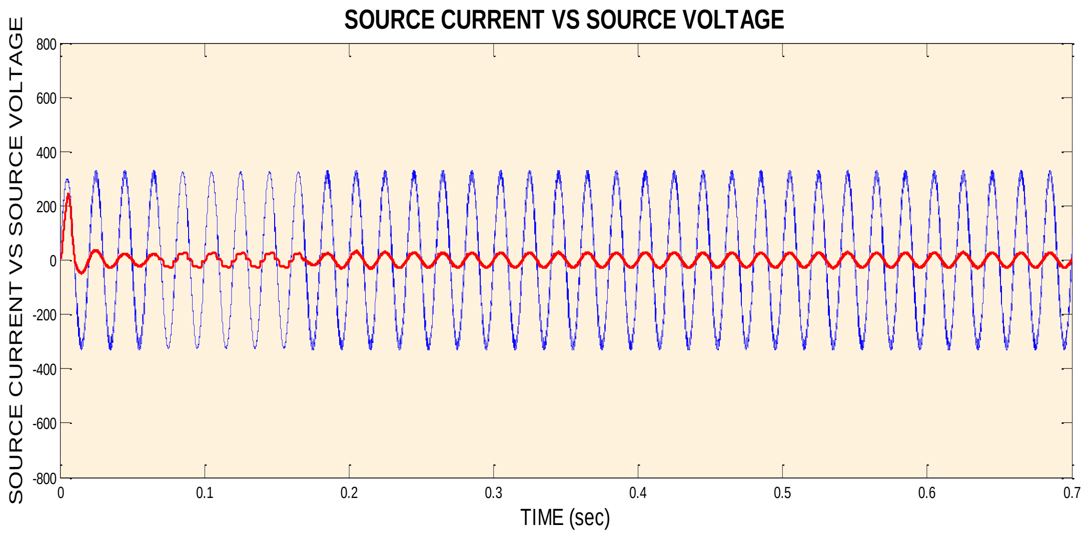

Figure 7:Source voltage and source current , in the absence of filter.

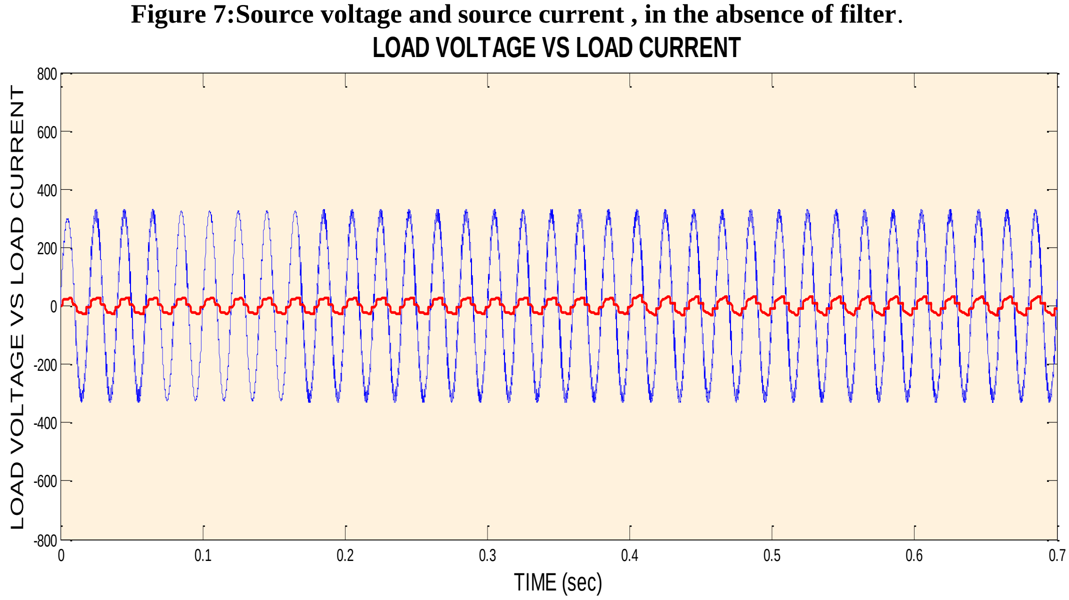

Figure 8: The load voltage vs load current

Figure 9,10 and 11 shows the total harmonic distortion in load current, source current with filter and in source current when the filter is connected. It is clearly seen in the figures that the total harmonic distortions are reduced from 23.78% to 3.48%.

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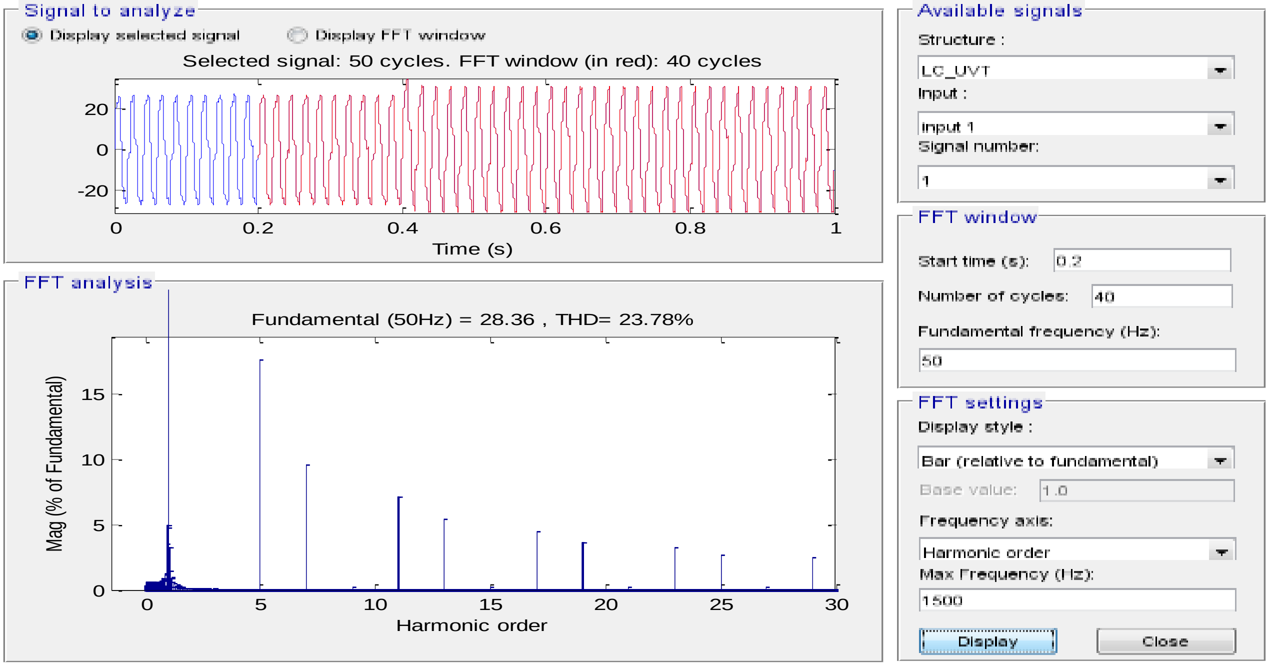

Figure 9: FFT analysis done to find Total Harmonic distortions in load current. Clearly the THD of load current is 23.78%

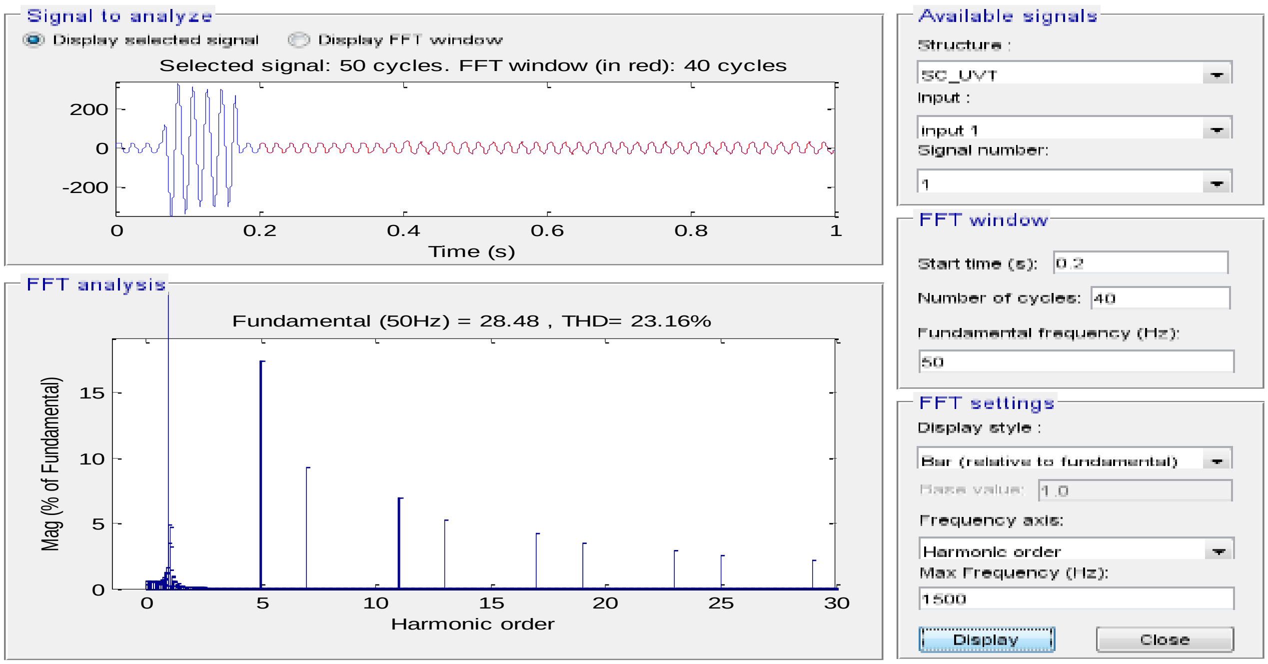

Figure 10:Harmonics produced in source current when filter was not connected to the system. In this case the THD of the system is 23.78%. same as THD present in load current .

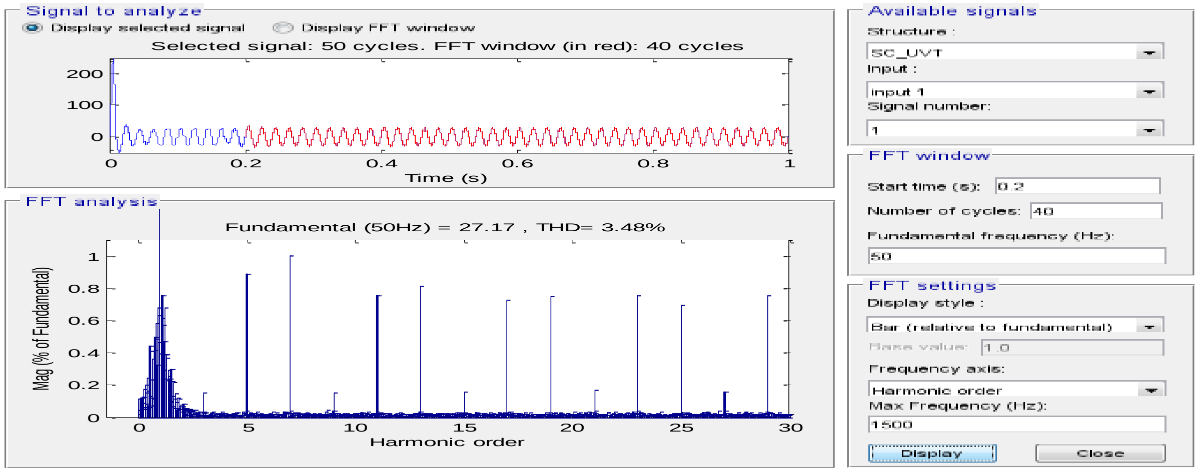

Figure 11 THD in source current after performing the FFT analysis, when the filter is connected to the system. In this case the harmonics in the system gets reduced and it is clear in the figure that the THD is reduced from 23.78% to 3.48%, which is less that 5% as per IEEE-519 standards.

Conclusion

Harmonics and Reactive power are severe problems amongst all the issues in power quality in todays world. This requirement of non-linear loads is a very serious issue. Active power Filter provides the proper solution to this problem. In ouw work a three phase shunt active power filter is modelled and simulated, and has proven to be effective for the compensation of reactive power and elimination of harmonics present in the system. Complete design parameters and control of shunt active power is presented in this work. Simulation has been done and simulation results show that how effective is the design and control presented in this work for harmonic power mitigation. The compensation process is easy to implement, instantaneous and simple, this can be concluded by simulation results. This method is simple because it only requires the sensing of line current, and the control method is also too simple, yet effective.+

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