HARMONIC REDUCTION: USING SHUNT ACTIVE POWER FILTER

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ABSTRACT

Active power filters are the emerging devices, which can diminish harmonic pollution effectively. Normally, the shunt APF is controlled such that it eliminates the load current harmonics and supplies load reactive power to achieve harmonic free source currents at unity power factor. However, these control objectives cannot be achieved simultaneously when the supply voltages are distorted and unbalanced (non-ideal). Hence, under such situation the shunt APF should be controlled optimally to achieve a maximum possible power factor without violating the current harmonics constraints recommended by IEEE Std. 519. Most of the proposed control strategies for power quality improvements have been reviewed with regard to performance and implementation. It has been seen that there has been a significant increase in interest of active power filters and its control methods. Model of Shunt Active Power filter is implemented with PI controller. Further simulation is done in MATLAB to verify the results.

Keywords:- *Harmonics, Filters, Shunt active power filter, Power Quality etc.*

1. INTRODUCTION

In the recent years, Power quality (PQ) is emerging as an issue of major concern, (globally as well as nationwide) requiring accurate monitoring, in-depth analysis and adoption of planned PQ improvement initiatives. The present scenario has changed in our country, with a large proportion of the industrial, commercial and domestic load now turning out to be non-linear due to growing use of power electronics, automation, computers and information technology. Widespread use of non-linear loads degenerate the quality of power in both transmission and distribution systems.All non-linear loads draw non-sinusoidal currents which cause distortion in the voltage waveform not only within the individual plant but also in the power supply network [3]. Harmonics propagate from one consumer to another, causing many undesirable effects on the power system. The harmonic current components do not represent useful active power due to the frequency mismatch with the source voltage [4]. A simple and effective technique for harmonic analysis is current injection model which is most commonly applied for harmonic simulation studies. This approach treats harmonic producing load as an injection current source to the system assuming steady-state condition. Consequently, all non-linearities in the system are represented as current injections of corresponding harmonic frequencies and therefore, the superposition principle can be applied.The control technique is applied on a medium-voltage asymmetrically controlled 12-pulse ac to dc current source converter, which follows a specific power locus with the SAPF connected via taps on the star connected secondary winding of the front end transformer, to compensate the mains current dominant harmonics (5^{th},7^{th},11^{th} and 13^{th}). This improves the individual harmonic factor of the compensated harmonic order, THD, and accounts for the delay effects introduced in the reference and actual signals. The open-loop strategy compensates all sources of delays and provides accurate mitigation of selected harmonic orders in the supply current, resulting in better harmonic factors in terms of the IEEE standard. The SHPF is the combination of a small-rating active power filter (APF) and a fifth-harmonic-tuned LC passive filter. A nonlinear control of APF was developed for current tracking and voltage regulation. Scheme of a SHPF-TCR compensator has been established, simulated, and implemented by using the DS1104 digital real time controller board of dSPACE. The shunt active filter and SPF have a complementary function to improve the performance of filtering and to reduce the power rating requirements of an active filter. It has been found that the SHPF-TCR compensator can effectively eliminate current harmonic and reactive power compensation during steady and transient operating conditions for a variety of loads.
Moreover, a closed-loop power control scheme is employed to directly derive the fundamental current reference without using any phase locked loops (PLL). Thus concluded that the proposed power control method ensures accurate power control even when harmonic compensation tasks are activated in the DG unit.

2. HARMONIC FILTERING SOLUTION

There are number of devices available to control harmonic distortion in the power supply networks by the use of filters. Filters are used to restrict the flow of harmonics current in the Power Systems. It is a LC circuit, which passes all frequencies in its pass bands and stops all frequencies in its stop bands. There are two basic types of filters categorized as:

Passive Filters

Active Filters

Passive filters comprise inductance, capacitance and resistance elements configured and tuned to control harmonics. They are designed either to shunt the harmonic currents off the line or block their flow by tuning the elements to create resonance at a selected frequency. Active filters, on the other hand, are designed to inject harmonic currents to counterbalance existing harmonic components as they show up in the distribution system.

3. SHUNT ACTIVE POWER FILTER

Active power harmonic filtering is a relatively new technology for eliminating harmonics which is based on the power electronics devices. An active power filter consists of one or more power electronic converters which utilize power semiconductor devices controlled by integrated circuits. The use of active power filters to eliminate the harmonics before they enter a supply system is the optimal method of dealing with the harmonics problem. . Active power filters could be connected either in series or in parallel to power systems; therefore, they can operate as either voltage sources or current sources. The shunt active filter is controlled to inject a compensating current into the utility system so that it cancels the harmonic currents produced by the non-linear load.

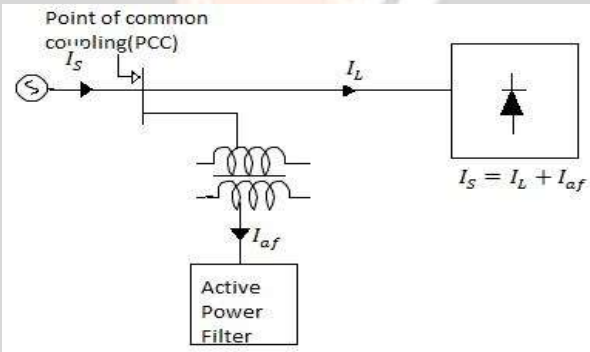

Fig – 1: Basic configuration of SAPF

The principal of active filtering for current compensation is shown in Fig.:1. The load current is non-linear due to the non-linear load. In this figure, the active filter is controlled to draw or inject a current I such that the source current I = I + I is sinusoidal.

4. BASIC COMPENSATION PRINCIPLE

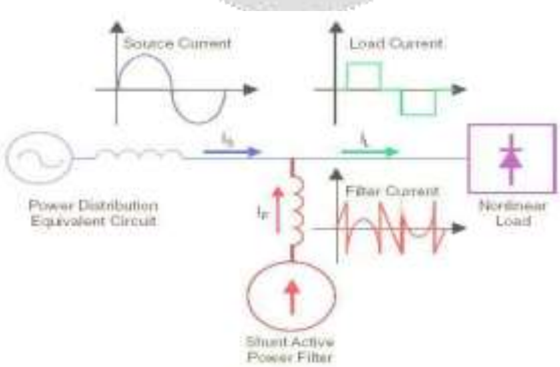

Fig -2: Filter current I_F generated to compensate load-current harmonics

Fig.2 shows the basic compensation principle of a shunt active power filter. It is controlled to supply a compensating current 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. Figure.3 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.

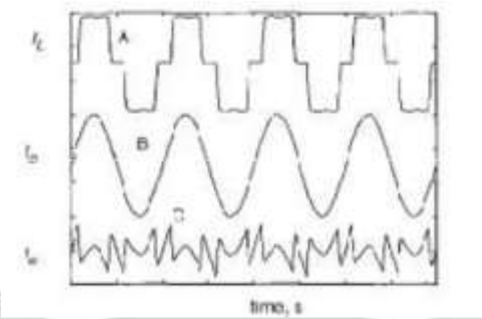

Fig – 3: Shunt active power filter-Shapes of load, source and desired filter current wave forms.

5. PI CONTROL SCHEME

Shunt Active Power Filter is connected in shunt with the load to suppress the harmonics. The complete schematic diagram of the shunt active power filter is shown in Fig.4 while Fig. 5 gives the control scheme realization. The actual capacitor voltage is compared with a set reference value. In figure 4 three-phase ac voltage source is connected to the three-phase voltage and current measurement block. The source currents are measured and output is shown in data acquisition scope1. On the other side non-linear load is connected to the three-phase voltage and current measurement block. The output current and voltage of non-linear load is seen in scope. APF is connected to the wires of source currents and the current of APF is measured in scope6. Capacitor voltage ( ) connected to APF is seen in scope 3. S1 to S8 are eight IGBT/diodes connected together anti parallel to each other to form APF circuitry.

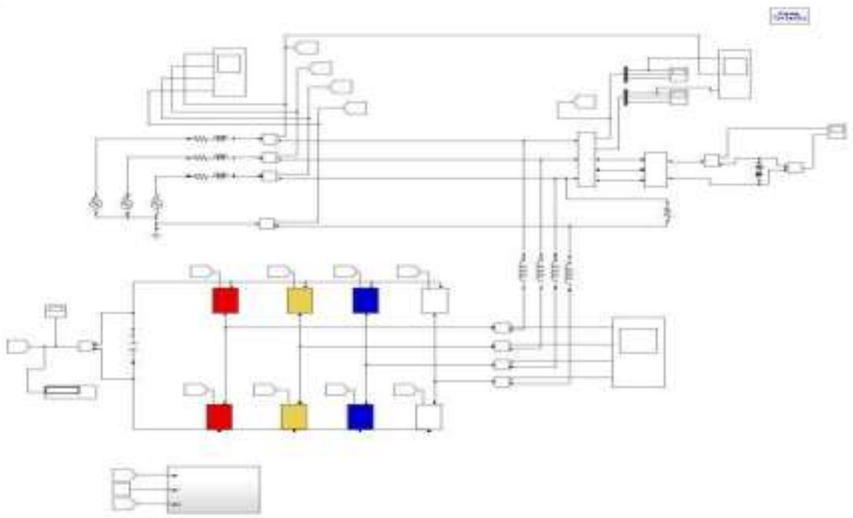

Fig – 4: Schematic diagram of shunt active power filter

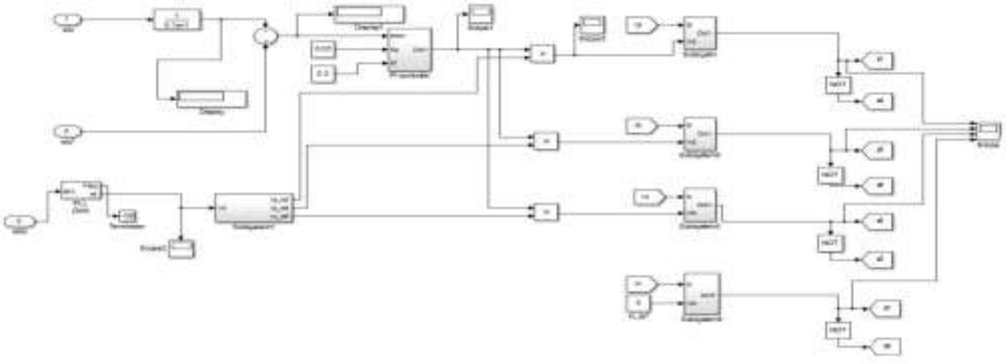

Fig – 5: APF Control Scheme

The error signal is fed to PI controller. The output of PI controller has been considered as peak value of the reference current. It is further multiplied by the unit sine vectors (,) in phase with the source voltages to obtain the reference currents (* , * *). These reference currents and actual currents are given to subsystem, subsystem 2, subsystem3 and subsystem 4 respectively. The difference of reference current and actual current decides the operation of switches. These switching signals after proper isolation and amplification are given to the switching devices. Due to these switching actions current flows through the filter inductor , to compensate the harmonic current and reactive power of the load, so that only active power drawn from the source.

6. SIMULATION RESULTS

The complete active power filter system is composed mainly of three-phase source, a nonlinear load, a voltage source converter, and a PI controller. All these components are modeled separately to simulate the system. The spectrum of different source current and voltages and load current and voltages are shown below.

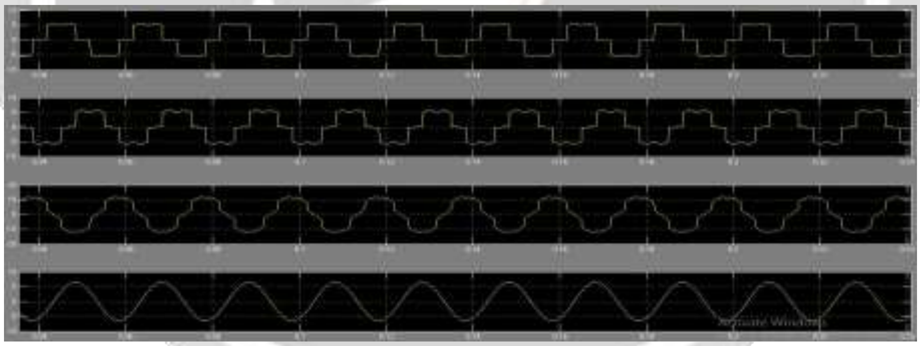

Fig – 6: Three-phase source voltages without APF

Fig.:6 show three-phase voltage sources when not connected to APF. There is lot of distortion seen in phase a, phase b, and phase c. All these harmonics are mitigated by connecting an SAPF (shunt active power filter) as can be seen in fig.:7

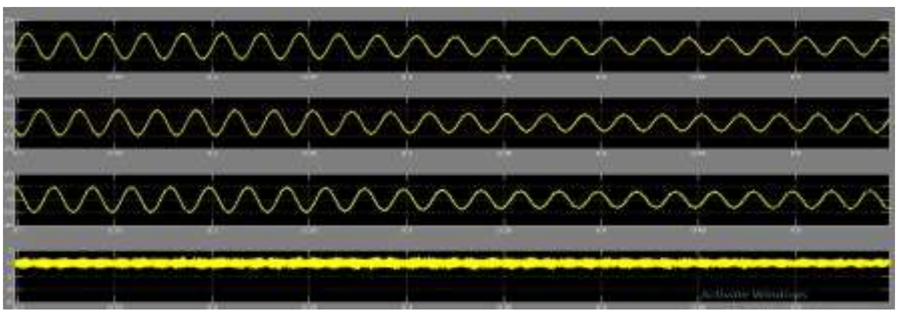

Fig – 7: Three-phase voltage sources with APF connected to the non-linear load.

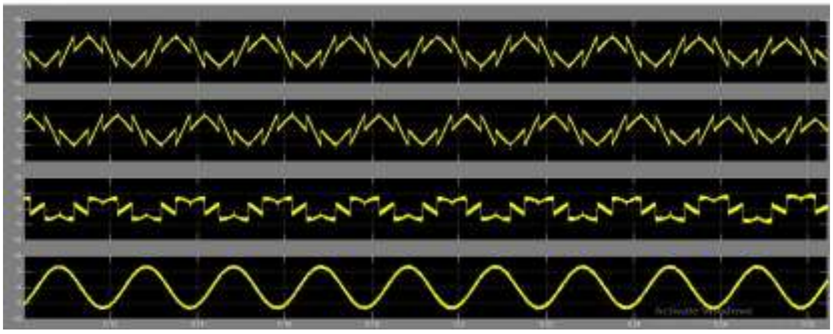

Fig – 8: Current generated by APF

Fig.:8 shows the current generated by Active Power Filter, when the filter is connected to the load/. Fig 9 shows the dc link voltage.

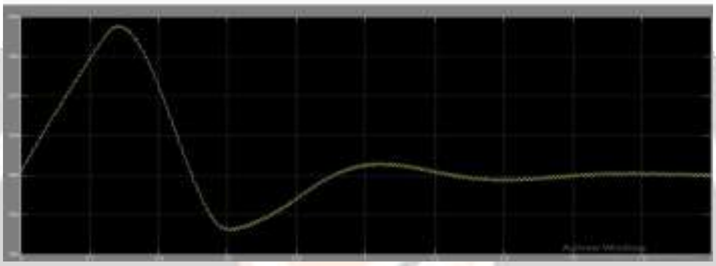

Fig – 9: Dc link capacitance voltage (Vdc)

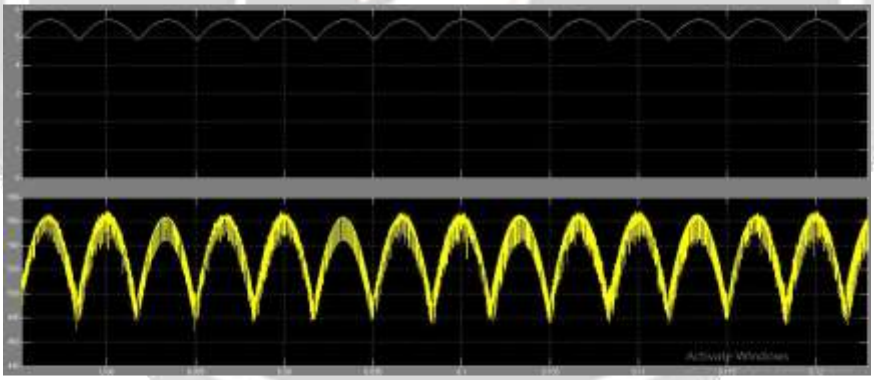

Fig – 10: Spectrum of current and voltage of non-linear load

Fig.:10 shows the spectrum of current and voltages of a non-linear load which is connected with the three-phase voltage source. Fig.:11 shows the spectrum of load voltage, source current and load current without APF connected to the system.

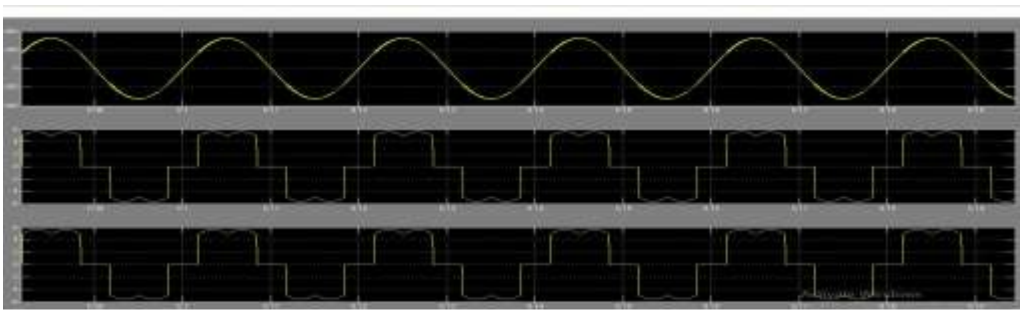

Fig – 11: Spectrum of load voltage, source current and load current without APF

Fig.: 12 shows the spectrum of load voltage, source current and load current when APF is connected to the system. It can be seen from the result wave-shape that APF does its work correctly by mitigating source current harmonics to great extent.

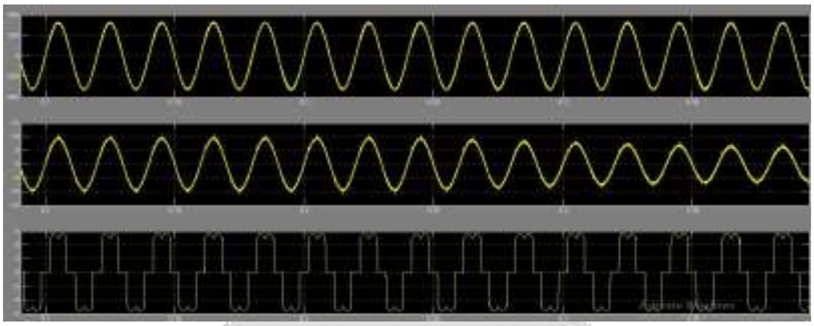

Fig – 12: Spectrum of Load voltage, Source Current and Load current when connected to APF.

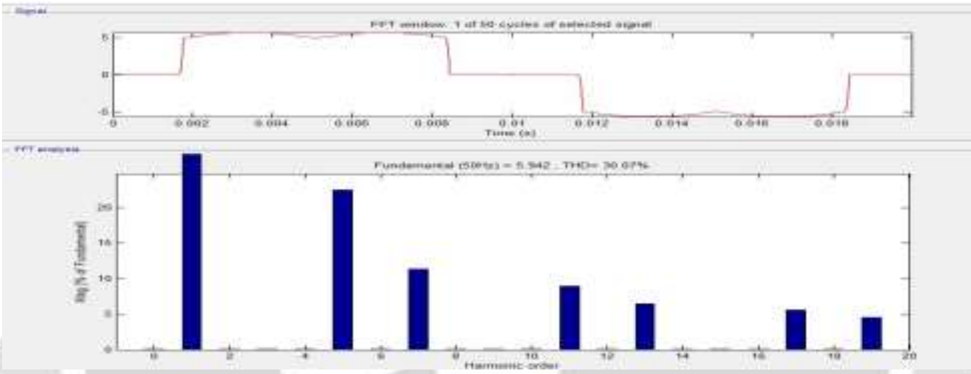

Fig – 13: FFT-analysis of load current without APF

Fig.:13 shows the FFT analysis of load current without APF connected to the system. Harmonics come out to be 30.07% in the source current. The bar diagram is also given describing the various orders of THD. Fig.:14 shows the FFT analysis with APF connected to the system. It is clearly seen that the THD in source current is reduced to 4.36% only.

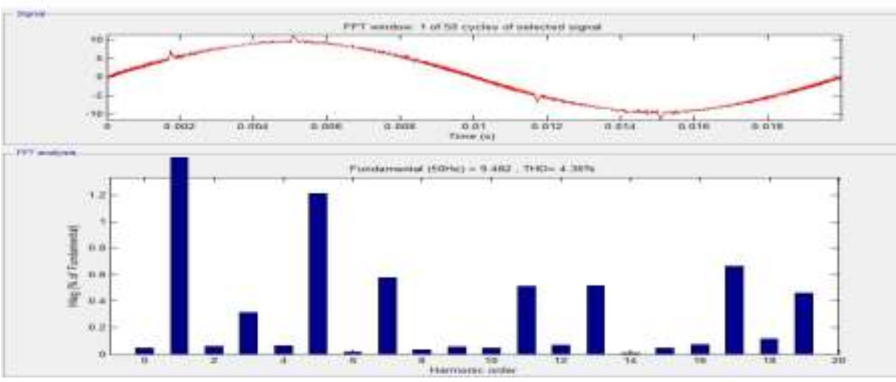

Fig – 14: FFT analysis of load current with APF

7. CONCLUSION

The model of the proposed new Shunt Active Power Filter is realized for mitigating harmonic distortion and power quality improvement. PI controller based Shunt active power filter is implemented for harmonic and reactive power compensation of the non-linear load. It is simulated using the highly developed graphic tool SIMULINK available in MATLAB. It is found from simulation results that shunt active power filter improves power quality of the power system by eliminating harmonics and reactive current of the load current, which makes the load current sinusoidal and in phase with the source voltage.There is an ample and increasing scope of harmonic assessments in the present scenario in our country. The harmonic measurements and analysis carried out in the present work has brought forth some interesting and unusual findings which need further in-depth investigations.

High resolution instruments can be used for measuring inter-harmonics which can indicate the presence of non-integral harmonics in the electrical network. Harmonic simulation can be carried out on Lab VIEW to obtain a better user interface with graphic programming facility.Experimental investigations can be done on shunt active power filter by developing a prototype model in the laboratory to verify the simulation results for PI controllers and Fuzzy controller and the result can be compared.

8. REFERENCES

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