Elimination of Harmonics in Complex Power System Using Hybrid Active Power Filter

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Abstract- Now-a-days the advancement technologies are use in the world and the more and more electric power demand is increasing. Many consumer appliances demand for continuously power with quality with their operation. The performance of the end user equipment is heavily dependent on the quality of power supply. But the quality of power delivered to the end user is affected by various external and internal factors. They are like voltage and frequency variations, faults, outages etc. These power quality problems reduce the life time and efficiency of the equipment. Thus, to enhance the performance and efficiency of the equipment and also the overall performance of the system these problems should be mitigated. The main affect caused by the presence of harmonics. For this purpose there are many filters topologies present in the literature.
In this paper a hybrid power filter are use which is a combination of series active filter and shunt passive filter. This project presents the control strategy to control the filter in such a way that the harmonics are reduced. The proposed control strategy is simulated in MATLAB SIMULINK and the results are presented.

Key Words- Series Active Filter, Shunt Passive Filter, Hybrid Power Filter, Power Quality, Harmonics, Three phase system.

I. INTRODUCTION

The fast developing countries like India heavily depends on the availability of constant, reliable and quality of electric power supply. In generally to meet the power demand crisis we have to upgrade our transmission and distribution networks, rigorous planning is done for the addition of new generation and the expansion of existing transmission and distribution networks. However, on the other side due to rapid growth in population, industrialization and the development in the IT sector the energy demand is increasing rapidly. To meet this fast growing energy demand from the conventional generation in particular thermal generation is very difficult due to the depletion of coal mines and the severe environmental pollution and in future it will be a serious issue. The existence of harmonics in the power electrical systems is the key source of the electrical wave pollution that course so many problems. The indiscriminate escalation of non-linear loads has given rise to research into new compensation equipment centered on power electronics. The core design target for this system is the eradication of the harmonic present in the system and lessening of reactive power. Depending on the application type, series or parallel configurations or combinations of active and passive filters.

II. POWER QUALITY

Electric power quality, or simply power quality, involves voltage, frequency, and waveform. Good power quality can be defined as a steady supply voltage that stays within the prescribed range, steady a.c. frequency close to the rated value, and smooth voltage curve waveform (resembles a sine wave). In general, it is useful to consider power quality as the compatibility between what comes out of an electric outlet and the load that is plugged into it. There are many ways in which electric power can be of poor quality and many more causes of such poor quality power. The electric power industry comprises electricity generation (AC power), electric power transmission and ultimately electric power distribution to an electricity meter located at the premises of the end user of the electric power. The electricity then moves through the wiring system of the end user until it reaches the load. The complexity of the system to move electric energy from the point of production to the point of consumption combined with variations in weather, generation, demand and other factors provide many opportunities for the quality of supply to be compromised.

The quality of electrical power may be described as a set of values of parameters, such as:

- Continuity of service (Whether the electrical power is subject to voltage drops or overages below or above a threshold level thereby causing blackouts or brownouts)
- Variation in voltage magnitude
- Transient voltages and currents
- Harmonic content in the waveforms for AC power.

a. POWER QUALITY ISSUES:

The quality of power is affected when supply voltage transfer generation station to consumer there is any deviation in the voltage, current or frequency. The common problems that affect the sensitivity of the equipment are-

- Power Surges

- Transients
- Frequency Variation
- Electrical Line Noise
- Brownouts or Blackouts
- Power System Faults
- Improper grounding affect

The main affected problems are the production of harmonics. The presence of harmonics reduces the quality of power and may damage the end user equipment. The solution for improve the power quality by use of filters to reduce harmonics. The basic idea of using a filter is that it injects a compensating current that compensates the harmonics in load current.

There are different filter topologies such as- active, passive, hybrid. The passive power filters are used to filter out a particular order harmonics and has the problem of parallel resonance. The active power filters (APF) are use to other solution. There are different types of APF like series APF, shunt APF. The shunt APF is costly and is not used for large systems. The series APF works as a harmonic isolator and used to reduce the negative-sequence voltage. There is another filter topology which is a combination of passive filter and active power filter known as "Hybrid Filter".

III. HYBRID ACTIVE POWER FILTER

Hybrid Filter is a combination of active power filter and passive filter. Both filters are connected with the series and shunt combination. The characteristics of the passive filter are improved, avoiding the problems of series and parallel resonances. Due above advantages, the series APF with a shunt connected passive filter is widely used.

Thus, the control of series APF with shunt connected passive filter is studied and analyzed in this paper for the improvement of electric power quality and hence reducing elimination of harmonics.

The active power filters are better solution for power quality improvement but they require high converter ratings. So to overcome the above drawback for hybrid power filters are designed. The hybrid power filters are the combination of both active and passive power filters. They have the advantage of both active and passive filters.

There are different hybrid filters based on the circuit combination and arrangement. They are-

1. Shunt Active Power Filter and Series Active Power Filter
2. Shunt Active Power Filter and Shunt Passive Filter
3. Active Power Filter in series with Shunt Passive Filter
4. Series Active Power Filter with Shunt Passive Filter.

A. Shunt APF and Series APF:

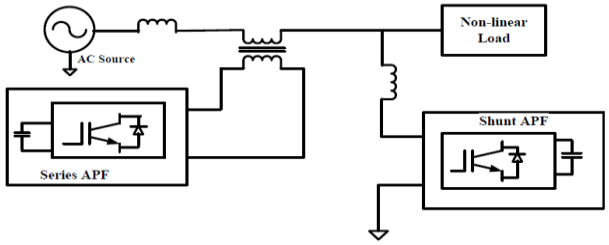

Fig.1: Shunt APF and Series APF Combination

The circuit diagram is shown in above Figure. The combination of both shunts APF and series APF. Elimination of voltage harmonics and that of shunt connected APF of eliminating current harmonics. This combination applies in Flexible AC Transmission Systems (FACTS). But the control of APF is complex and this combination involves two APF and hence the control of this filter configuration is even more complex. Thus, this filter combination is not used widely.

B. Shunt APF and Shunt Passive Filter:

The power rating of the APF depend on the order of frequencies it is filtering out. Thus, an APF used for filtering out low order harmonics have low power rating with reduced size and cost. This logic is used in designing this filter combination. The shunt connected APF filters out the low order current harmonics while the shunt connected passive filter is designed to filter out the higher order harmonics. The circuit diagram is shown in Figure.2

But the main disadvantage of this filter configuration is it cannot be suited for variable loading conditions. Since, the passive filter can be tuned only for a specific predetermined harmonic.

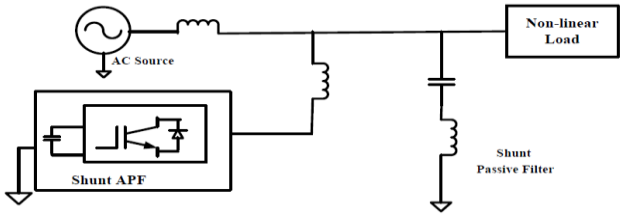

Fig.2: Shunt APF and Shunt Passive Filter

C.APF in Series with Shunt Passive Filter:

In this filter, the Active Power Filter is connected in series with a Shunt connected Passive Filter. The circuit diagram is shown in Fig. 3. The advantage the passive filter reduces the stress on the power electronic switches present in the APF.

This filter has its application in medium to high voltage ranges.

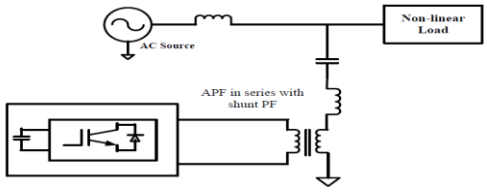

Fig.3: APF in Series with Shunt Passive Filter

D. Series APF with Shunt Connected Passive Filter:

The Series APF and Shunt APF combination seen in Fig.1 has the problem of complex control strategy. To overcome this drawback, the shunt APF is replaced by a shunt connected passive filter. The passive power filter does not require any additional control circuit and the cost is also less. This filter combination is shown in Fig. 4

Here the series connected APF provides low impedance (almost zero) for low frequency components whereas the shunt connected APF provides less impedance for high frequency components and filters out all higher order harmonics. So this filter configuration is the most beneficial of all others and has the advantage of reducing both current and voltage harmonics.

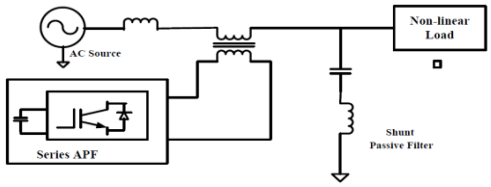

Fig.4: Series APF with Shunt Connected Passive Filter

IV. SHUNT HYBRID POWER FILTER

In a power distribution network causes various power problems with nonlinear loads related to its power quality. Power quality problems are major effects to the power generation and transfer equipments detrimental effects like overheating of electric motors and transformers winding etc. Harmonics are available in the power system can be eliminated by passive filters with the limitations like parallel and series resonance with system impedance. A power converter based active power filters are preferred for harmonic elimination. Active filters are tolerated due to its high dc link voltage requirements and high power (kVA) rating of the switches. In high power applications with effective compensation achieved by hybrid filter which consists of both passive and active filter.

In hybrid compensation scheme various topologies are presented for the reduction of harmonics and compensation of reactive power. Shunt hybrid filter scheme, which is the combination of active filter connected in series with single tuned passive filter. In this scheme active filter aid the compensation performance of the passive filter while the rating of active filter is small. A various control methods are suggested for hybrid filter, such as nonlinear and linear control, lyapunov control, adaptive control, control based on fuzzy logic, neural network control etc.

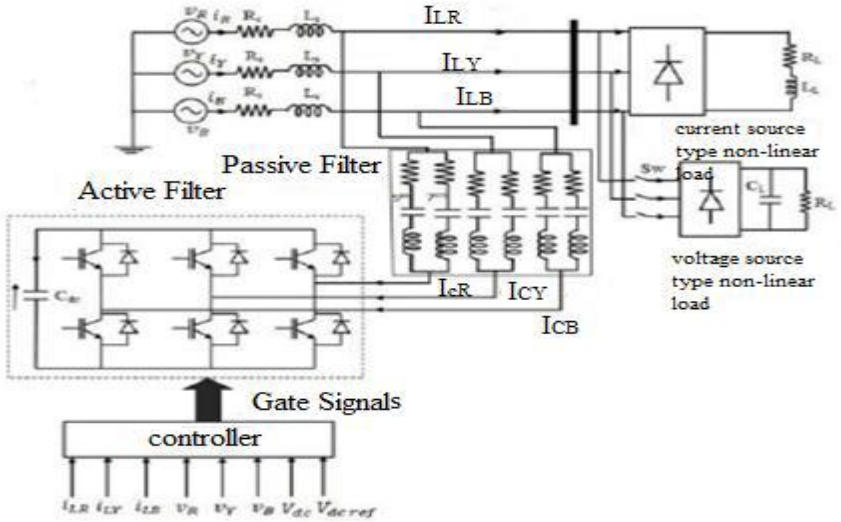

Fig.5: System Configuration

Using shunt hybrid compensator can be achieved by the following three stages.

- The reference current waveforms are generated by sensing the load current and filter current.
- In second stages; compensation current reference is extracted by p-q theory.
- The gating signals of the voltage source inverter are generated using hysteresis current controller for effective compensation.

The compensator must be designed properly to eliminate the oscillating components in the load. For the compensation of reactive power the dc bus voltage of the link capacitor must be maintained constant. In hybrid compensation technique active power flow in to the voltage source inverter is to be controlled for maintaining dc link voltage as constant. DC bus voltage regulation is more important for the increase filtering performance of the designed filter. Switching losses of the active power filter must be made equal to the active power flow into the hybrid filter for maintaining the dc-link voltage as constant. A PI regulator is designed to keep the dc bus voltage equal to the reference voltage $V_{dc.}$

V. SIMULINK MODEL AND RESULT OF SHUNT HYBRID FILTER

Simulation model of shunt hybrid power filter with non linear load power system is shown in Figure.6. The three phase ac mains connected with the three phase full bridge rectifier and non linear loads. The shunt hybrid power filter composed of parallel combination of 5th and 7th tuned selective harmonics elimination passive filters connected in series with IGBTs based active power filter terminated with dc link capacitor.

Here, by considering various types of nonlinear loads as given below, the performance of the designed compensator is evaluated:

1.) Current source type nonlinear load
2.) Voltage source type nonlinear load

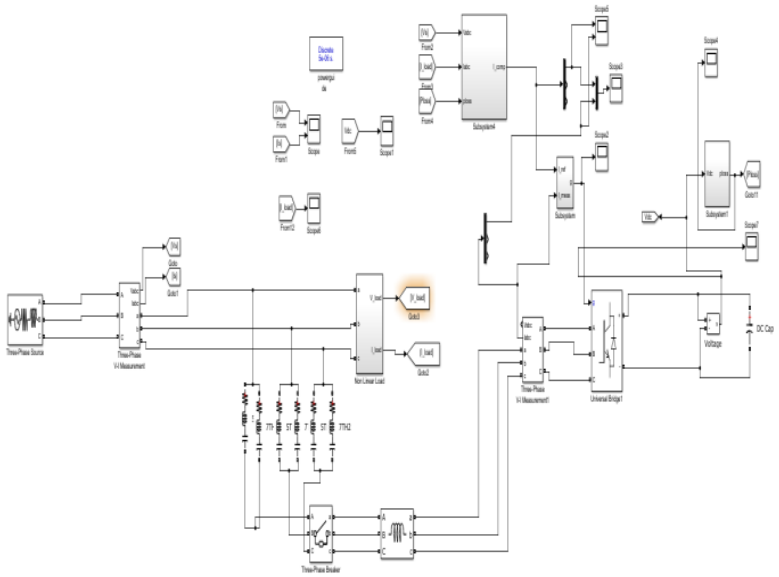

Fig.6: Simulation Model of Shunt Hybrid Filter

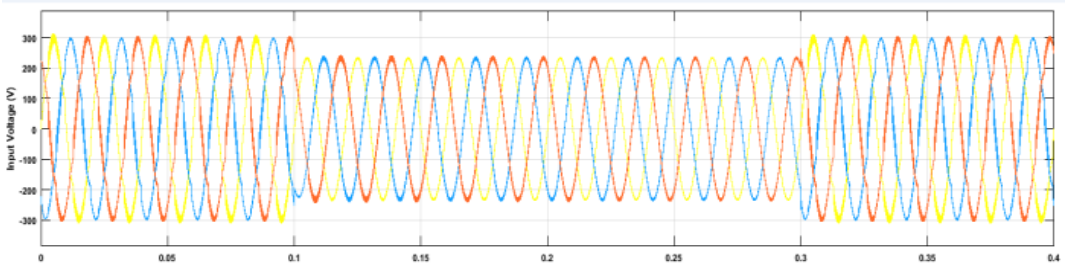

Fig.7: Input Voltage with respect to time of Shunt Hybrid Filter

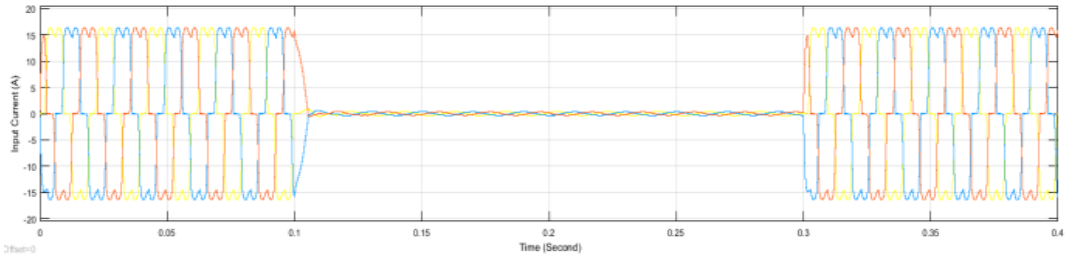

Fig.8: Input Current with respect to time of Shunt Hybrid Filter

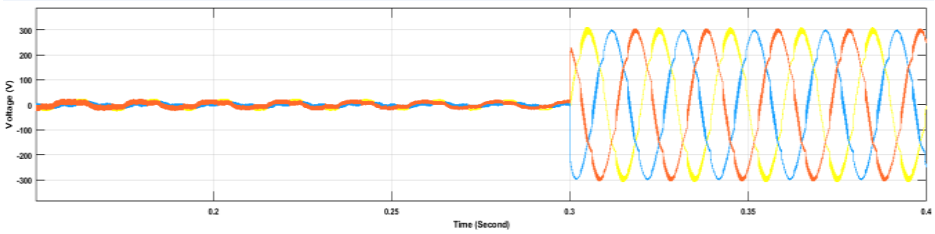

Fig.9: Load side voltages with respect to time of Shunt Hybrid Filter

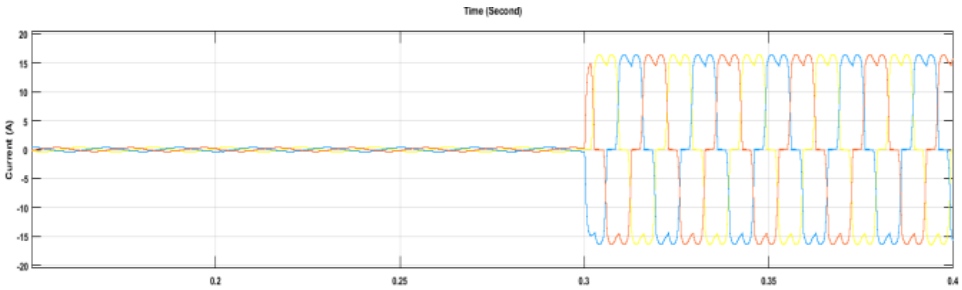

Fig.10: Load side current with respect to time of Shunt Hybrid Filter

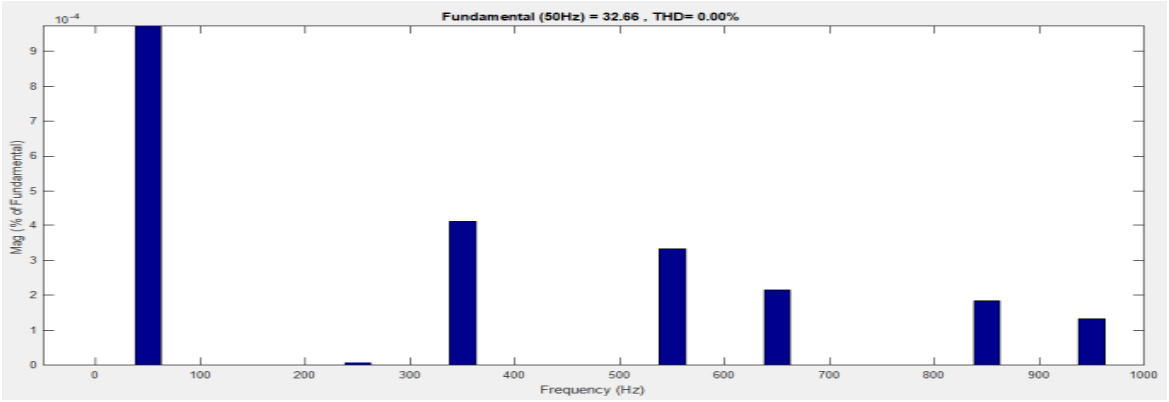

Fig.11: Load side current with respect to time of Shunt Hybrid Filter

VI. SERIES HYBRID FILTER

Power electronic switching device in conjunction with nonlinear loads causes serious harmonic problem in power system due to their inherent property of drawing harmonic current and reactive power from AC supply mains. They cause voltage unbalance and neutral currents problem in power system. With the distortion of current and voltage waveform due to presence of harmonic effect the power system equipment that are connected to maintain steady and reliable power flow in the power system. Various power quality issues such as increased harmonics and reactive power components of current from ac mains, low system efficiency and a poor power factor are created in power system, which can disturb

the other loads connected at the point of common coupling of the distribution network.

The series active filter is connected at the source side with a coupling transformer. It acts as a harmonic isolator. It provides very high impedance at harmonic frequencies and forces the load harmonics to circulate through the passive filter. In this way it prevents the load harmonics from reaching towards source and thereby improves the source waveforms.

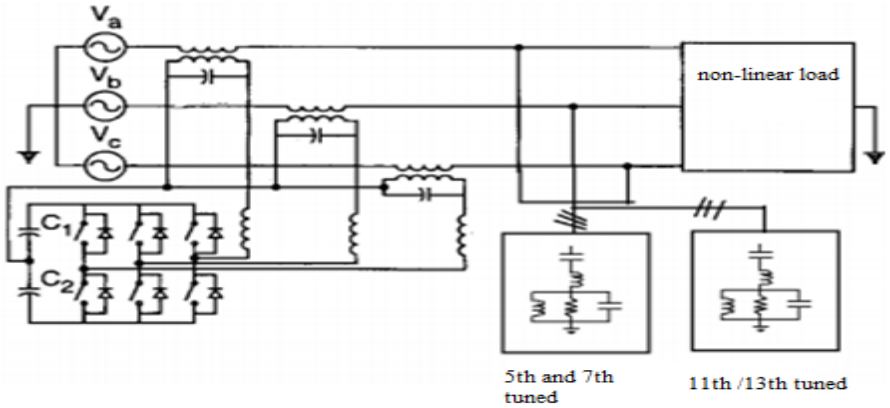

Fig.12: Proposed model with Series Hybrid Filter

The PI controller is used for the regulation of dc link capacitor voltage. The input to the PI controller is the difference of desired dc output voltage (Vdc_ref) and the actual dc output voltage. We can call this difference as an error between actual output and desired output. The PI controller processes this error and then the error is multiplied by the output of PLL, which is the frequency w, to get the error in the form of sinusoidal signal.

A hysteresis band controller is used for the generation of gating signals. It compares the actual load current with the reference current. When the actual load current crosses the lower boundary of reference current, upper switch is turned on. When the actual load current crosses the upper boundary of reference current, lower switch is turned on. In this way gating signals are generated for the active filter switches.

VII. SERIES HYBRID FILTER SIMULATION AND RESULT

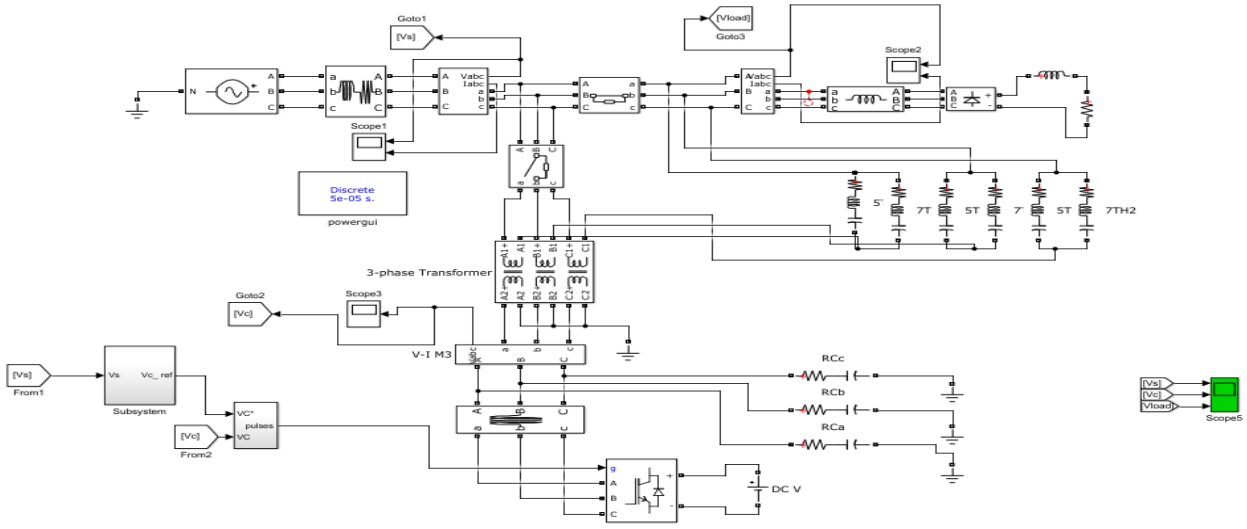

Fig.13: MATLAB Model of Series Hybrid Filter

A three phase series hybrid filter involving a series active filter and a shunt passive filter has been proposed here for the compensation of voltage and current harmonics, which has been simulated by a MATLAB based model. The series hybrid filter has been found capable of operating

satisfactorily. It has reduced the harmonics effectively below 5%, which meets the regulation of IEEE 519 standard.

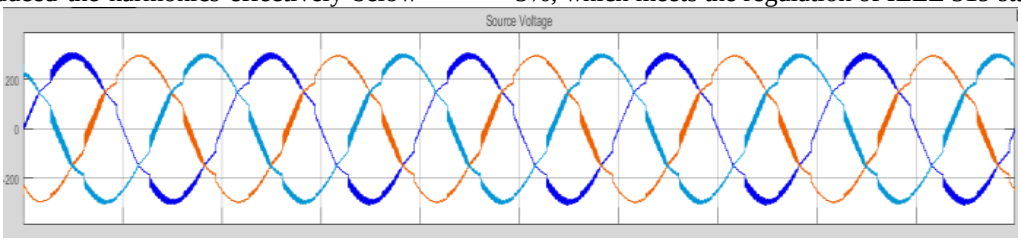

Fig.14: Input Voltage with respect to time of Series Hybrid Filter

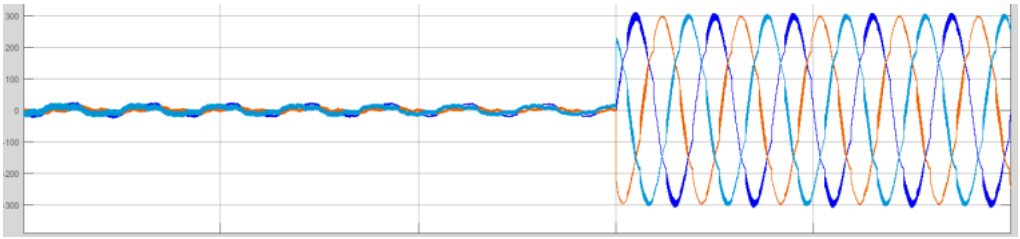

Fig.15: load side Voltage with respect to time of Series Hybrid Filter

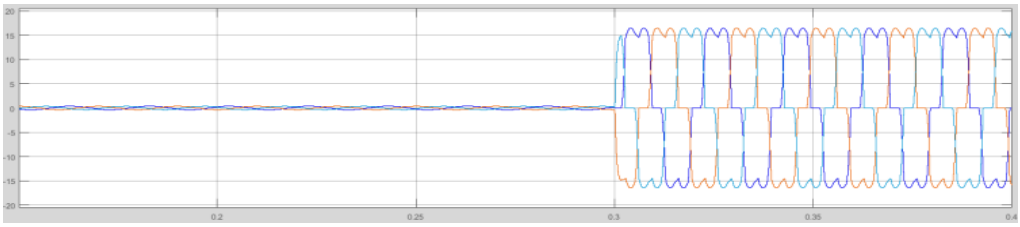

Fig.16: load side Current with respect to time of Series Hybrid Filter

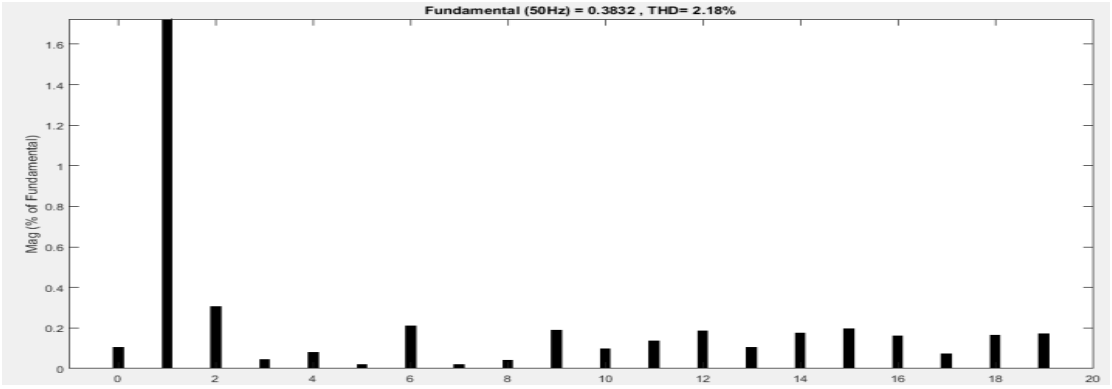

Fig.17: FFT analysis of Series Hybrid Filter

VIII. CONCLUSION

In this work a shunt hybrid compensator using p-q theory based control technique is suggested for harmonics mitigation and reactive power compensation in a distribution system feeding nonlinear loads. The performance of the designed compensator with the suggested control strategy is analyzed for voltage and current source type nonlinear loads.

The combination of 5th and 7th tuned filter strengthens the performance of the hybrid scheme in high power applications. The simulation results show that the THD caused by voltage source type nonlinear load has been reduced from 1.05 % and for current source type loads THD has been reduced from 2.18 %. The supply current waveforms are nearly sinusoidal in both the cases due to the presence of proposed filter. The dc link capacitor voltage is maintained constant during the operation of the filter ensures the reactive power compensation achieved by the proposed filter. The hysteresis control is a very simplest control method and also gives fast dynamic response.

A three phase series hybrid filter involving a series active filter and a shunt passive filter has been proposed here for the compensation of voltage and current harmonics, which has been simulated by a MATLAB based model. The series hybrid filter has been found capable of operating satisfactorily.

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