HARMONIC ELIMINATION IN THREE PHASE SYSTEM BY MEANS OF HYBRID ACTIVE 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. So the overheating of the equipment, insulation failure and over speeding of induction motors etc. The solution to overcome these problems is to filter out these harmonics. For this purpose there are many filters topologies present in the literature.

In this project 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, Power Quality.

1. INTRODUCTION

Electrical energy is the most important for the different stages of the users in our world because it is capable and attractive form of energy and the modern society is heavily dependent on the electric supply. The life cannot be imagined without the supply of electricity. The power quality is very important for the electric power supply company and the end user consumer.

The voltage and frequency ranges of the power dependent Generation Company to the consumers. If variation in the voltage and frequency of the electric power delivered from that of the standard values then the quality of power delivered is affected.

Now-a-days drastically improvement in the power electronics switching devices because of the advance technology is use in the power system. The semi-conductor devices got a permanent place in the power sector so easy to control of overall system. Moreover, most of the loads are also semi-conductor based equipment. 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. Major effects include overheating, capacitor failure, vibration, resonance problem, low power factor, overloading, communication interference and power fluctuation. Thus to improve the performance it is required to eliminate harmonics from power utility system. In order to maintain the quality of power delivered, the harmonics should be filtered out. Thus, a device named "Filter" is used which serves this purpose.

There are many filter topologies in the literature like- active, passive and hybrid. In this project the use of hybrid power filters for the improvement of electric power quality is studied and analyzed.

1.1 RESEARCH MOTIVATION

1.3.1 Power Quality Problems

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 deteriorates the quality of power and may damage the end user equipment. These harmonics causes the heating of underground cables, insulation failure, reduces the life-time of the equipment, increases the losses etc.

1.3.2 Solutions to Power Quality Problems:

The solution for improve the power quality by use of filters to reduce harmonics. The basic idea of using a filter is shown in Fig. 1.1, where the filter 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".

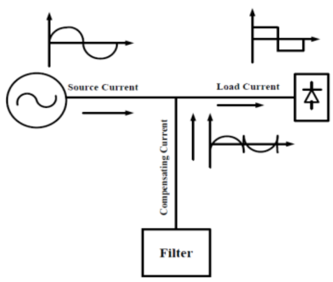

Figure 1.1 Basic Operation of Filter

1.3.3 Advantages of Hybrid 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 project for the improvement of electric power quality.

1.4 THESIS OBJECTIVES

The main objective of this project is to reduce the harmonics by using the controlling of the hybrid filter. The control algorithm has the following objectives-

- To control the voltage injected by APF such that it compensates the reactive power and load current harmonics.
- To improve the passive filter performance.
- To make the whole compensating equipment to act as linear, balanced, resistive load on the system.

2. TYPES OF FILTERS

2.1 INTRODUCTION

In power system electric power transfer where various problems like as transients, noise, voltage sag/swell, which lead is to the production of harmonics and affect the quality of power delivered to the end user. The harmonics may exist in voltage or current waveforms which are the integral multiples of the fundamental frequency, which does not contribute for the active power delivery. Thus the response at these frequencies should be restricted from affecting the behavior of the system. To achieve this filter is used at the Point of Common Coupling (PCC) where the load is connected to the supply. This filter filters out the harmonics and improves the performance of the system. There are different types of filters available for this purpose. Each of them is explained in detail in this chapter.

2.2 FILTER CLASSIFICATION

Three different types of filters are present and there are classifications of filters are shown in figure 2.1. Active Filters and Passive Filters and Hybrid filter. Each type has its own sub classification.

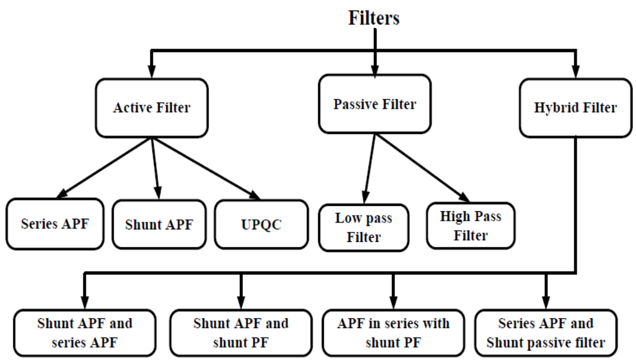

Figure 2.1 Classifications of Filters

2.2.1 Passive Power Filters:

These passive filters consist of elements like- capacitor, inductor and resistor. These are widely used because of their low cost and ease of control. The passive filters are also providing reactive power apart from filtering the harmonics. The performance of these filters is heavily dependent on the system impedance. These are again classified into two types- low pass and high pass.

A. Low Pass Filter:

The low pass filter is a tuned LC circuit that is tuned to provide low impedance for a particular harmonic current. These filters are also used for power factor correction. In power system these filters are generally used to filter 5th and 7th order harmonics. The line diagram of the low pass filter is shown in Fig. 2.2.

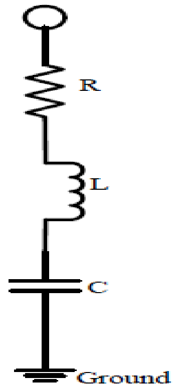

Figure 2.2 Low Pass Filter

B. High Pass Filter:

The high pass filter made of passive elements like inductor and capacitor but show low impedance for harmonic current above a particular corner frequency. All the harmonics present above that corner frequency are filtered using this filter. This filter is use like single-order, two-order and third-order etc., based on the number of passive filters used in it. The two-order filter is widely used. Fig. 2.3 shows the line diagram of a high pass filter.

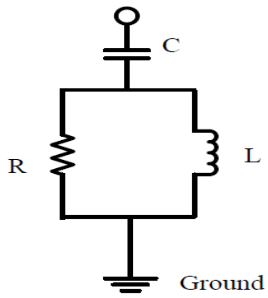

Figure 2.3 High Pass Filter

But there are some disadvantages with passive filter, like-

-The filter characteristic has strong dependence on the System impedance.

-Possibility of over load in the passive filter because of Harmonic current circulation generating from power Electronic loads.

-The change of the load impedance can detune the filter, so it is not suitable for variable loads.

-The problem of series and/or parallel resonances can be Originated which causes instable operation.

-Limited operation that is used to eliminate either a Particular order or fewer harmonics.

-Component aging Because of the above disadvantages the Passive filters cannot provide an effective solution to enhance the quality of the power system. Thus, the active power filters are employed to overcome the above drawback

2.2.2 Active Power Filters (APF):

To overcome the drawback of passive filter, active compensation known as Active Power Filter is used recently. The APF is a Voltage Source Inverter which injects the compensating current or voltage based on the network. APF's are fast switching devices, low power loss and fast digital processing devices. APF's are divided into three types and each one is explained in detail below.

A. Shunt Active Power Filter:

The voltage sourced inverter based Shunt APF is connected in shunt at the PCC. It's similar to the STATCOM. It injects the current which is equal and opposite of the harmonic current. It acts as a current source injecting harmonics and is suitable for any type of load. It also helps in improving the load power factor. The shunt connected APF circuit diagram is shown in Fig. 2.4. The cost of these filters is relatively higher and so not preferred for large scale systems.

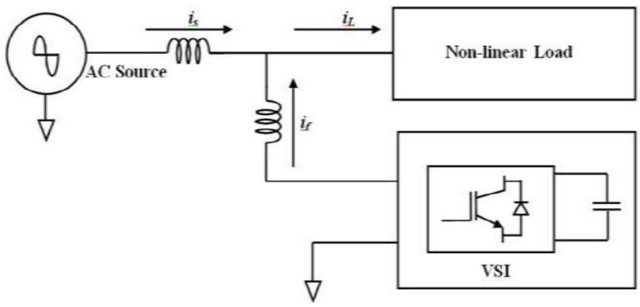

Figure 2.4 Circuit Diagram of Shunt active power filter

B. Series Active Power Filter:

As the name indicates, these filters are connected in series with the line through a transformer. This filter injects the compensating voltage in series with the supply voltage. Thus, it acts as a voltage source which can be controlled to compensate the voltage sag/swell. These filters have their application mainly where the load contains voltage sensitive devices. The circuit diagram of the series connected APF is shown in Fig. 2.5. These filters are not used practically since they are required to handle high current ratings which increase the size of the filter as well as the losses occurring in the filter.

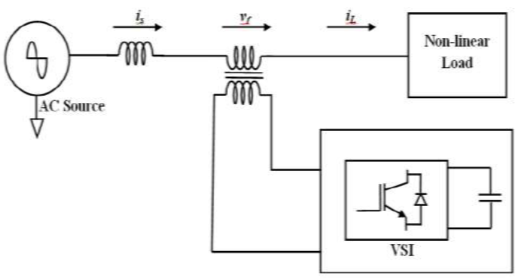

Figure 2.5 Circuit Diagram of Series active power filter

C. Unified Power Quality Conditioner (UPQC):

The UPQC is a combination of series and shunt active power filters. It has the advantage of both series APF and shunt APF. It compensates both the voltage and current harmonics. Therefore, this filter can compensate almost all types of power quality problems faced by a power system network. The circuit diagram is shown in Fig. 2.6.

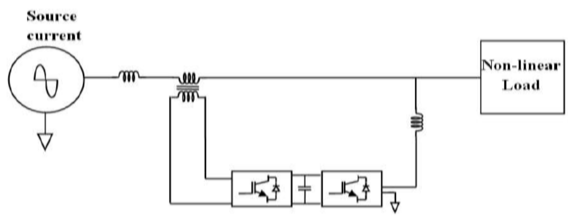

Figure 2.6 Circuit Diagram with UPQC

2.2.3 Hybrid Power Filters:

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:

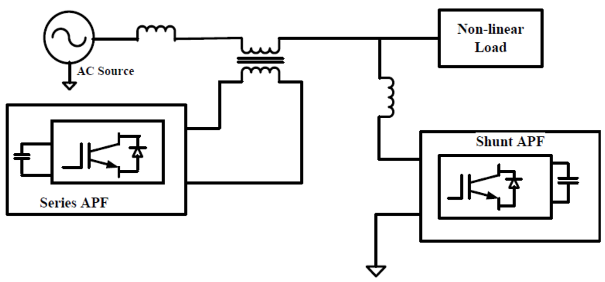

Figure 2.7 Shunt APF and Series APF Combination

The circuit diagram is shown in above Fig. 2.7. 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 Fig. 2.8.

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.

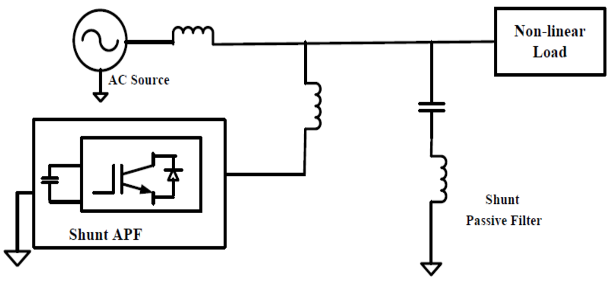

Figure2.8 Shunt APF and Shunt Passive Filter Combination

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. 2.9. 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.

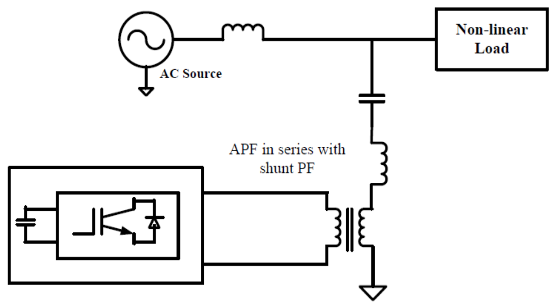

Figure 2.9 APF in series with Shunt Connected Passive Filter

D. Series APF with Shunt Connected Passive Filter:

The Series APF and Shunt APF combination seen in Fig. 2.7 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. 2.10.

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.

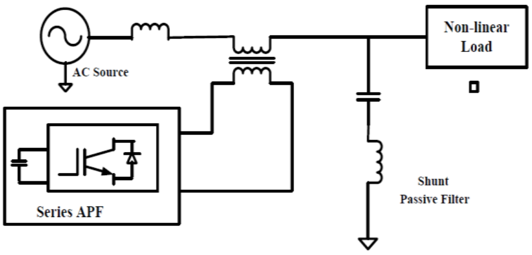

Figure 2.10 Series APF with Shunt Connected Passive Filter

3. SHUNT HYBRID POWER FILTER

3.1 INTRODUCTION:

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.

3.2 SYSTEM CONFIGURATION:

The Shunt hybrid active power filter is shown in figure 6.1. It combination of an active power filter connected in series with 5th and 7th tuned passive filters connected in parallel. Both passive as well as active filter and also provide effective compensation of harmonics with cost effective solutions. The problem of series and parallel resonance present between the system impedance and passive filter can be suppressed inherently by this configuration.

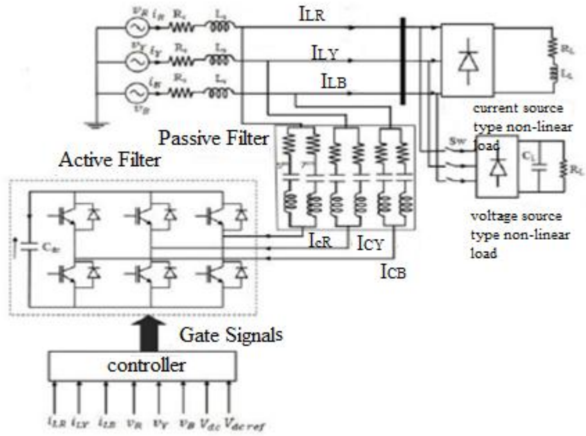

Figure 3.1 System Configuration

3.3 INSTANTANEOUS POWER THEORY:

The p-q theory can applied to the reference current signal from the harmonic polluted load current generated by the nonlinear loads. Instantaneous p-q theory is applicable for transient and steady state analysis for both the three wires and four wire distribution system. For a given active power filter, the switching signals of IGBT's is obtained from reference current deduced from distorted load currents.

Instantaneous voltage and current of the three phase distribution system can be obtained by expressing the three phase system quantities mathematically by three instantaneous space vectors. Three phase system currents and voltages are converted in to αβ0 coordinates by the following equations.

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \quad (3.1)$$

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad (3.2)$$

For balanced three phase three wire system, zero sequence components will be eliminated, hence *v0* and *i0* can be neglected from the analysis. Finally using α and β coordinates phases of the instantaneous voltage and currents are

$$v = v_\alpha + jv_\beta \quad (3.3)$$

$$i = i_\alpha + ji_\beta \quad (3.4)$$

The instantaneous complex power is-

$$S = vi^* = (v_\alpha + v_\beta)\,(i_\alpha - ji_\beta)$$

$$= p + jq \quad (3.5)$$

Where, p and q are instantaneous active and instantaneous reactive powers respectively,

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (3.6)$$

Further, currents are deduced from the above equation as-

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \quad (3.7)$$

3.4 PROPOSED CONTROL METHOD:

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. The active and reactive powers obtained from equation (3.6) can be divided in to steady and oscillating components as explained below.

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} \overline{p} + \tilde{p} \\ \overline{q} + \tilde{q} \end{bmatrix} \quad (3.8)$$

Where,

p- and q- are the average active and reactive powers

P~ and q~ are the active and reactive powers of oscillating component.

Separation of oscillating components can be achieved by low pass filters. If the filter is designed for reactive power compensation and harmonic reduction, it is essential to eliminate the oscillating components of real and reactive powers along with average component of reactive power. The reference current in coordinate is required to obtain necessary compensation and it has been be calculated from the equation (3.7) as shown below.

$$\begin{bmatrix} i_{\alpha\ ref} \\ i_{\beta\ ref} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} \\ \overline{q} + \tilde{q} \end{bmatrix} \quad (3.9)$$

The reference current in abc coordinate for switching signal generation can be found from the above equation as follows

$$\begin{bmatrix} i_{a.ref} \\ i_{b.ref} \\ i_{c.ref} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{\alpha.ref} \\ i_{\beta.ref} \end{bmatrix} \quad (3.10)$$

6.4.1 Hysteresis Current Control:

The reference current is obtained from the distorted current and the error signal is obtained by comparing the reference current with measured filter current. The error signal is used to generate the gating signal for voltage source inverter using hysteresis current controller. Hysteresis controller is implemented with two level comparators where, switching commands are issued when the error signals exceeds a tolerance band ‘⍰ h’. The proposed control scheme with hysteresis controller is shown in Figure 3.2.

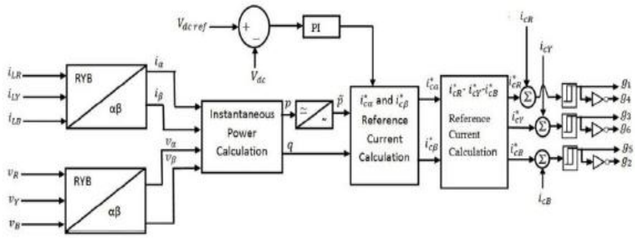

Figure 3.2 Schematic of Control Circuit

3.4.2 DC Link Voltage Control:

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}

3.5 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 3.3. 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.

The simulation of power distribution system with the proposed control strategy has been implemented using power system block set of MATLAB/ Simulation software. 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

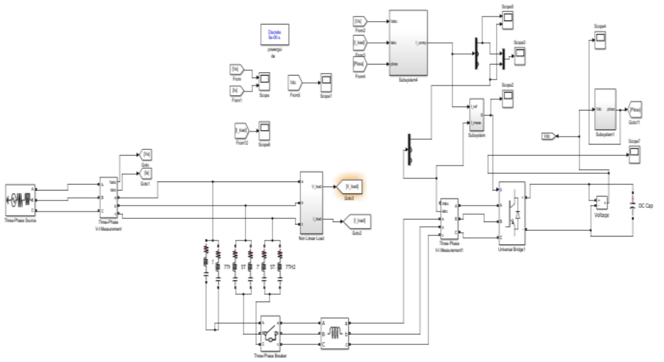

Figure 3.3 Simulation Model of Shunt Hybrid Filter

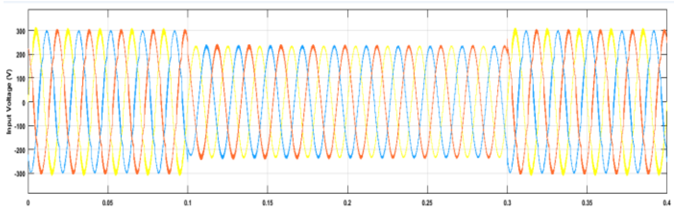

Figure 3.4 Input Voltage with respect to time of Shunt Hybrid Filter

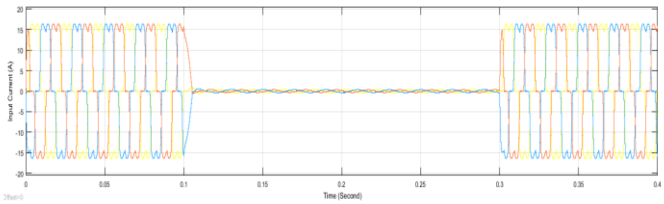

Figure 3.5 Input Current with respect to time of Shunt Hybrid Filter

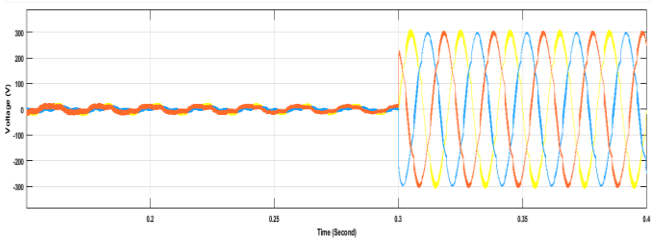

Figure 3.6 Load side voltages with respect to time of Shunt Hybrid Filter

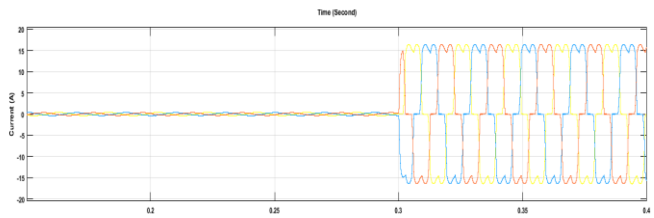

Figure 3.7 Load side current with respect to time of Shunt Hybrid Filter

3.5.1 FFT Analysis:

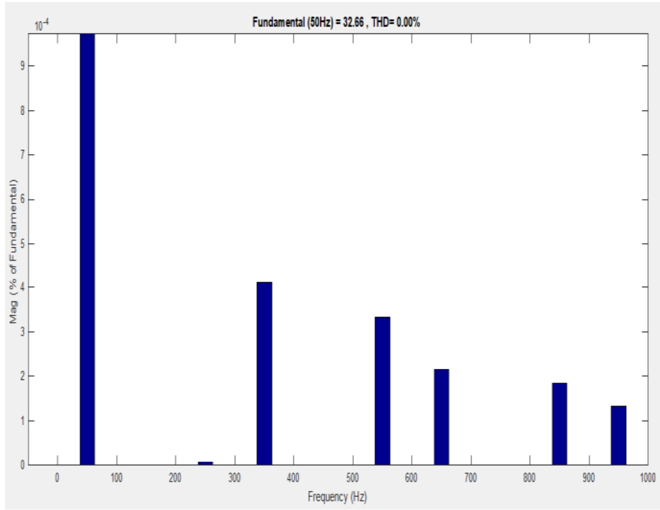

Figure 3.8 Load side current with respect to time of Shunt Hybrid Filter

4. SERIES HYBRID FILTER

4.1 INTRODUCTION:

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.

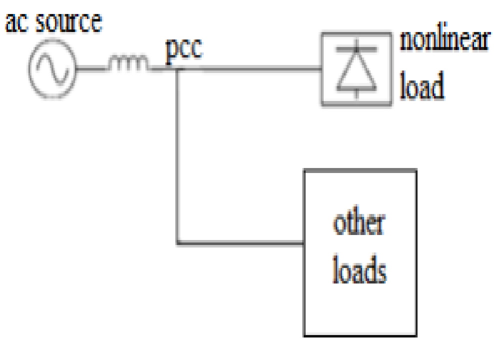

Figure 4.1 Power System

Solution of this problem is to use passive filter, which is tuned to eliminate a particular harmonic frequency. It may be single tuned or double tuned as shown in figure 4.2.

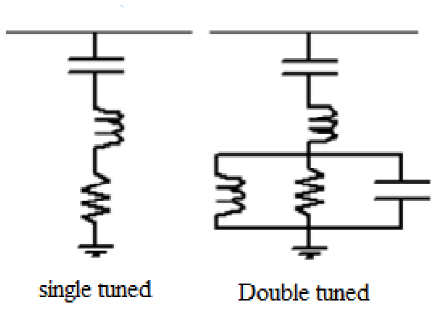

Figure 4.2 Basic Compensation Principal of Series Active Filter

Disadvantages of passive filters are fixed compensation, resonance, and large size. Passive filters are economic and have simple structure. Following figure shows the basic compensation principal of series active filter.

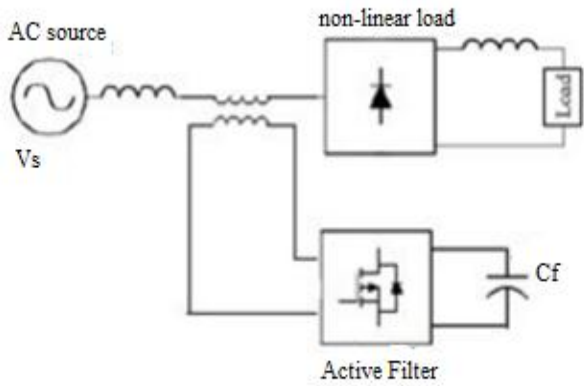

Figure 4.3 Basic Compensation Principal of Series Active Filter

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.

Active filter can solve various power quality issues such as harmonic minimization, reactive power compensation, voltage imbalance, voltage flicker, and power factor improvement. Even though the active filters are an effective compensation system yet their cost is very high with the high power rating. This is the major drawback of active filters.

To reduce the power rating and hence the cost of active filters, the hybrid filters [2, 4, 5, 6, 7, 8, 9, 10, 11] have been developed, which are the combination of active filters and passive filters. Following figure shows the proposed topology of Hybrid Filter.

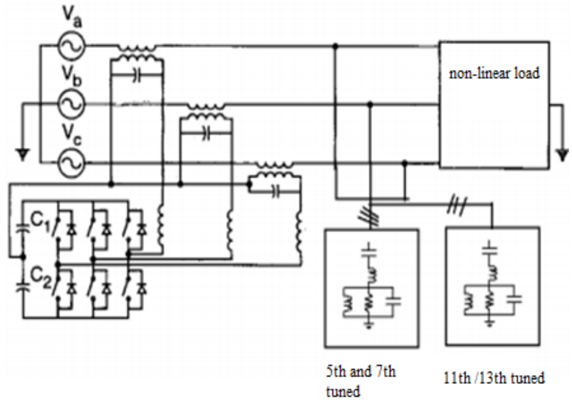

Figure 4.4: Proposed Topology

4.2. CONTROL STRATERGY:

For proper operation of active filter, an appropriate control strategy is necessary. The control strategy is designed to generate the gating signals for IGBTs used in active filter.

The control strategy is divided into three parts.

1. Generation of reference compensating current.

2. DC voltage regulation.

3. Generation of gating signals.

1. Generation of Reference Compensating Current:

For the generation of reference compensating current, synchronous reference theory is used, which uses park transformation. It converts the 3-ϕ time domain signals from stationary abc coordinates to rotating dq0 coordinates. It reduces the 3-ϕ ac quantities (e.g. U_a, U_b, and U_c) into two dc quantities (e.g. U_d, U_q). For balanced system the 0 component is zero. The main purpose of this conversion is that the dc quantities are easier to filter and control.

The d-component of the signal consists of fundamental and harmonics active components, i.e., id = $i_{df} + i_{dh}$. The q-component consists of fundamental and harmonics reactive components, i.e., $i_q = i_{qf} + i_{qh}$. The fundamental active and reactive components (i_{df} and i_{qf}) are separated by low pass filters and subtracted from the complete d and q components respectively to get the harmonics active and reactive (i_{dh} and i_{qh}) components. These harmonics components are then transformed back from d_q coordinates to abc coordinates.

2. DC Voltage Regulation:

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 (V_{dc}_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.

This error is then added to the abc output of inverse park transform. The result is then the reference compensating current.

3. Generation of Gating Signals:

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.

4.3 SERIES HYBRID FILTER SIMULATION AND RESULT:

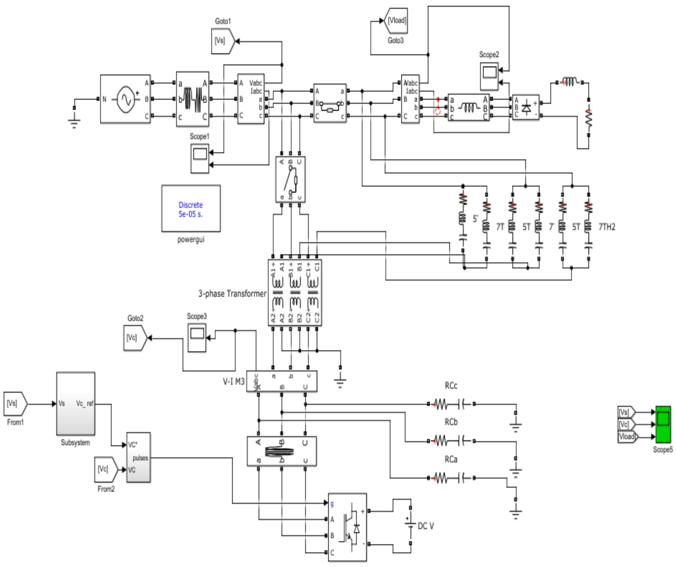

Figure 4.5 MATLAB Model of Series Hybrid Filter

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.

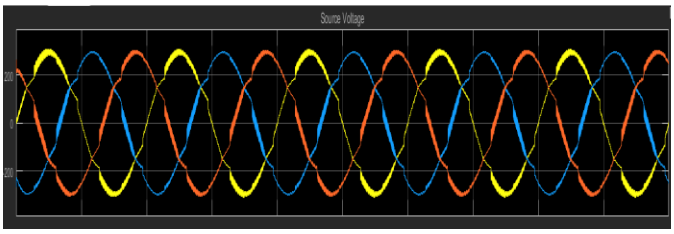

Figure 4.6 Input Voltage with respect to time of Series Hybrid Filter

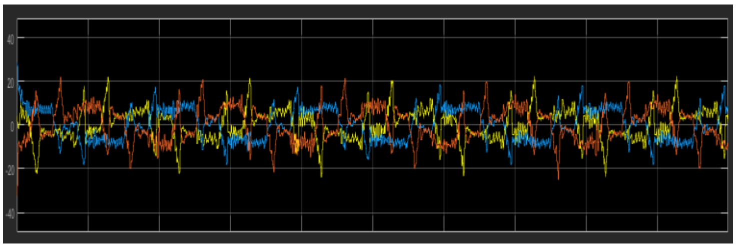

Figure 4.7 Capacitor Voltage with respect to time of Series Hybrid Filter

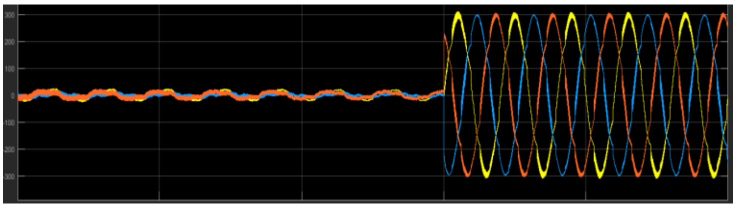

Figure 4.8 load side Voltage with respect to time of Series Hybrid Filter

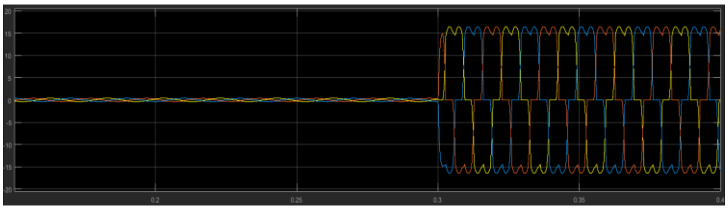

Figure 4.9 load side Current with respect to time of Series Hybrid Filter

4.3.1 FFT Analysis:

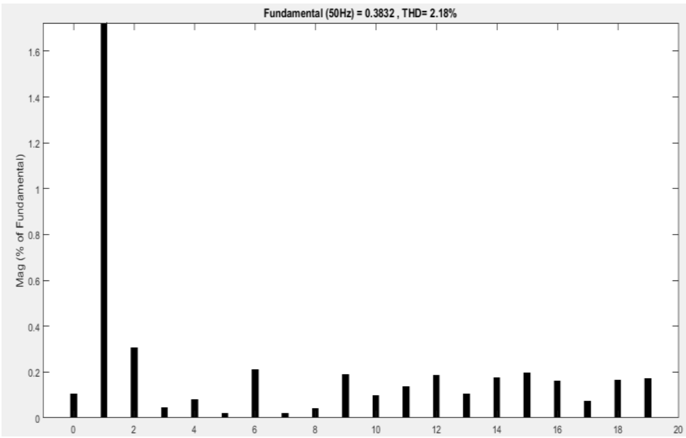

Figure 4.10 FFT analysis of Series Hybrid Filter

5. 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. DC link bus voltage of the proposed topology has been maintained to the reference value under different types of loading conditions.

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.

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