SUPPRESSION OF HARMONICS IN NON-LINEAR LOAD BY SHUNT HYBRID ACTIVE POWER FILTER SYSTEM

A PROJECT REPORT

SUBMITTED BY

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GOVERNMENT ENGINEERING COLLEGE BHARUCH

CERTIFICATE

This is to certify that the project entitled "SUPPRESSION OF HARMONICS IN NON-LINEAR LOAD BY SHUNT HYBRID ACTIVE POWER FILTER SYSTEM" has been carried out by ANUJ NARENDRAKUMAR PATEL (150140109004), PARASAR MALAVKUMAR RAJESHBHAI (150140109074), PATEL HARDEEPKUMAR (150140109084) AND VISHAL CHANDRA(150140109124) under the guidance in partial fulfilment of the degree of Bachelor Of Engineering in Electrical Engineering 7th semester of Gujarat Technological University, Ahmedabad during the academic year 2018-2019.

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ABSTRACT

The most popular technique that has been used for improving power quality, which is generally defined as any change in power (voltage, current or frequency) that interferes with the normal operation of electrical equipment, is Hybrid Active Power Filter (HAPF). This is because the performance of Passive filters is limited to a few harmonics and they can introduce resonance in the power system. Passive filters have larger components and therefore it has high cost. So HAPF can easily eliminate unwanted harmonics, improve power factor and overcome voltage sags and eliminate any harmonic frequencies. When a non-linear load, such as a rectifier is connected to the system, it draws a current that is not necessarily sinusoidal and it is possible to reduce it into a series of simple sinusoids, which start at the power system fundamental frequency and occur at integer multiples of the fundamental frequency called harmonics. In this project, a single phase shunt hybrid active filter design to minimize power quality issues in an electrical system has been discussed. The power stage of active filter is based on a full bridge inverter with a single capacitor or a dc source in dc side and a filter inductor in ac side. The shunt active filter designed to remove harmonics by injecting equal but opposite harmonic currents, such that system will become a sinusoidal waveform with low harmonic distortion. The control system is based on D-Q theory in α-β-0 reference frame, derived to be applied in single phase system.

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CHAPTER 1

INTRODUCTION

Decade ago most of the devices used were linear and passive in nature and have less number of non linear load, leads to less impact on the quality of supplied power. But in last few decades the trend has been changed. The electronics equipment has been taken Place a very important role in our day to day life. Excessive use of power electronics devices are the origin of harmonics disturbances. Harmonics are actually sinusoidal waveform of periodic waveform with the frequency that is integral multiple of fundamental frequency which disturbs the quality of supplied power.

Semiconductor devices are very common in most type of loads and these are a form of nonlinear load and they draw nonlinear current from the source. Power conversion is accomplished by frequent switching operations and causes discontinuous current. Due to this discontinuity and non-linearity there occurs harmonic current in system and it goes on to further distort the system voltage and that increasingly affect the system performance and give undesirable situation such as overheating problems, mechanical and electrical oscillation in alternator and prime movers, failure of insulation problems, failure of control system and unpredictable behavior of protection and relay connected in System etc. Since all these above said problems are severe for the electrical system, so the harmonic mitigation is important for both point of view of utilities and consumers end.

Harmonic filtering technique using passive filters is the one of the most used and earliest technology present in the system used to address the harmonic mitigation. The filters have been used very widely because of its very simple designing process and low cost factor. There are many filter topologies like- active, passive and hybrid. Along with the increasing demand on improving power quality which is generally defined as any change in power (voltage, current, or frequency) that interferes with the normal operation of electrical equipment, the most popular technique that has been used is Active Power Filter (APF); This is because Passive filters performance is limited to a few harmonics and they can introduce resonance in the power system. Passive filters are larger component sizes and therefore Costs high. So APF can easily eliminate unwanted harmonics, improve power factor and overcome voltage sags and eliminate any harmonic

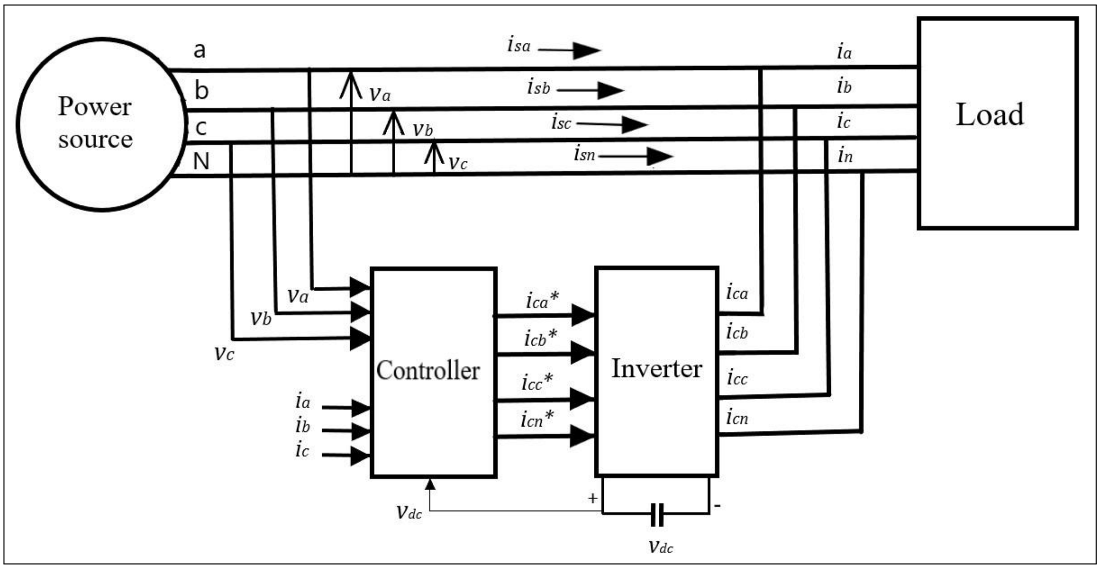

Fig. 1.1 Shunt active filter in a three-phase power system

frequencies.

Active filter are the equipment which are used to improve both current harmonics and/or voltage harmonics and compensate power factor, various researchers application shows that series active filter are used for compensate the voltage harmonics and shunt active power filter are used to improve the current harmonics. Figure 1.1 shown below represent active shunt power filter it uses the voltage source inverter with capacitor at its dc side act as energy storage device. Filter is controlled in a way that it acts as the current source. Three phase Converters used are having six MOSFET switches which are given pulses to store the energy in the capacitor and charge and discharge it when required. The supply voltage source provides the required active power and capacitor of shunt active power filter provides the reactive power for the load. The load is a diode rectifier supplying a R-L load. After applying the shunt active power filter the harmonics which occurs in the source side due to the non linear load has been removed which in return preserve other customers using same line. Also transformer overheating and misbehaving of measuring equipment has been stopped.

CHAPTER 2

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2.1 Harmonics

Harmonics are the by-products of modern electronics(3). They occur frequently when there are large numbers of personal computers, uninterrupted power supplies, variable frequency drives (AC and DC) or any electronic device using solid state power switching supplies to convert incoming AC to DC. Non-linear loads create harmonics by drawing current in short pulses, rather than in a smooth sinusoidal manner as shown in Figure 2.1. When the current with the harmonics flow through transmission line, it increases

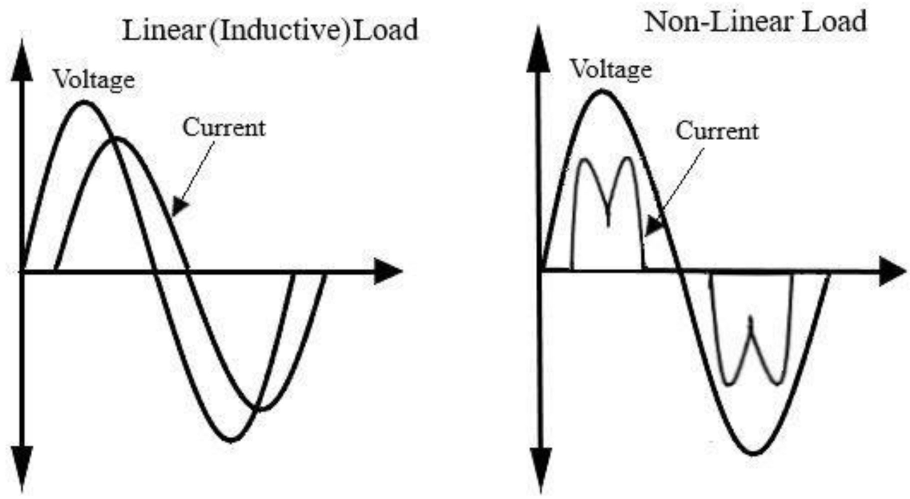

Fig. 2.1 Distortion in non linear load

the resistances of the conductors due to skin effect and causes an abnormal neutralground voltage difference. More the non linear load connected to the line, higher is the harmonics present in the line which leads to the overheating of transformer, distortion of feeder voltage, excessive neutral current. It may also lead to damage the circuit breakers, fuses resulting a low power factor and poor quality of power supply to the customers using that line. Static power converters such as single-phase and three

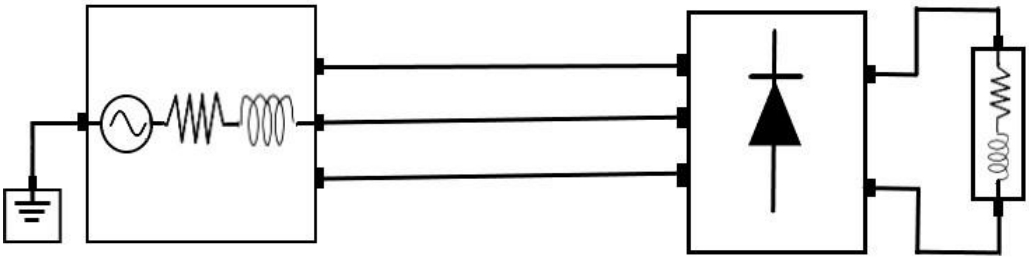

Fig. 2.2 Typical power system with Non-linear load

phase rectifiers, Semiconductor Controlled Rectifier converters and a large number of low-power electronic-based appliances, are nonlinear loads that generate considerable disturbance in the ac mains(6). A typical Non-linear load is as shown in Figure 2.2. Current harmonics, which may also be asymmetric, cause voltage drops across the supply network impedance as well as other undesirable phenomena like shunt and series resonance resulting in distorted supply voltages, and hence a reduction in the supply power quality.

2.2 Effects of Harmonics

The main effects of voltage and current harmonics in a power system are usually the potential amplification of some harmonics due to parallel or series resonance, reduced performance of energy generation, transport and usage systems, the premature ageing of insulation on grid components, leading to energy reduction, Poor functioning of the system or any of its components etc(2). Its effect on various devices are as follows

2.2.1 Capacitors

The Effects of Harmonics on Capacitors include additional heating and in severe cases overloading, increased dielectric or voltage stress, and unwanted losses. Also, the combination of harmonics and capacitors in a system could lead to a more severe power quality condition called harmonic resonance, which has the potential for extensive damage. Consequently, these negative effects will shorten capacitor life.

2.2.2 Transformers

Harmonics in transformers cause an increase in the iron and copper losses. Voltage distortion increase losses due to hysteresis and eddy currents and causes over stressing of the insulation material used. The primary effect of power line harmonics in transformer is, thus the additional heat generated. Other problems include possible resonance between the transformer inductance and the system capacitance, thermal fatigue due to temperature cycling and possible core vibrations.

2.2.3 Motors and Generators

Harmonic voltage and current cause increased heating in rotating machines due to additional iron and copper losses at harmonic frequencies. This lowers the machine efficiency and affects the torque developed. The flow of harmonic currents in the stator induces current flow in the rotor. This results in rotor heating and pulsating or reduced torque. Rotor heating reduces the efficiency and life of the machinery whereas pulsating or reduced torque results in mechanical oscillations causing shaft fatigue and increased ageing of mechanical parts.

2.2.4 Telecommunication

Electrical noise is another power quality phenomenon that can disrupt data-carrying signals. Noise can be electromagnetically coupled onto signal lines from power lines. Power systems transmit very high energy. Telecommunications systems transmit data at low power. Even though telecom systems are designed to reject a good amount of interference, these high power lines can cause poor transmission efficiency and disruptions. Power lines and telecom cables can run close together which leads to electromagnetic coupling and noise on the services are judged by the reliability and quality of their services. Power Quality phenomena can cause poor data transmission rates; disrupt transmissions and cause equipment malfunctions and failures.
Harmonics also causes problems like Skin effect in Transmission lines and malfunctioning of protective devices and measuring instruments. International standards concerning electrical energy consumption impose that electrical equipments should not produce harmonic contents greater than specified values. Use of the passive filters is one of the classic solutions to solve harmonic current problems, but they present several disadvantages- they only filter the frequencies they were previously tuned for; their operation cannot be limited to a certain load; resonances can occur because of the interaction between the passive filter and other loads, with unpredictable results. As a result, conventional solutions that rely on passive filters to perform a harmonic reduction are ineffective. Under these conditions it has been proved that the most effective solutions are active filters which are able to compensate not only harmonics but also asymmetric currents caused by nonlinear and unbalanced loads(17).

2.3 Total Harmonic Distortion

The electric power system is affected by various problems like transients, noise, voltage sag/swell, which leads to the production of harmonics and affect the quality of power delivered to the end user(5). The harmonics may exist in voltage or current waveforms which are the integral multiple of the fundamental frequency, which does not contribute

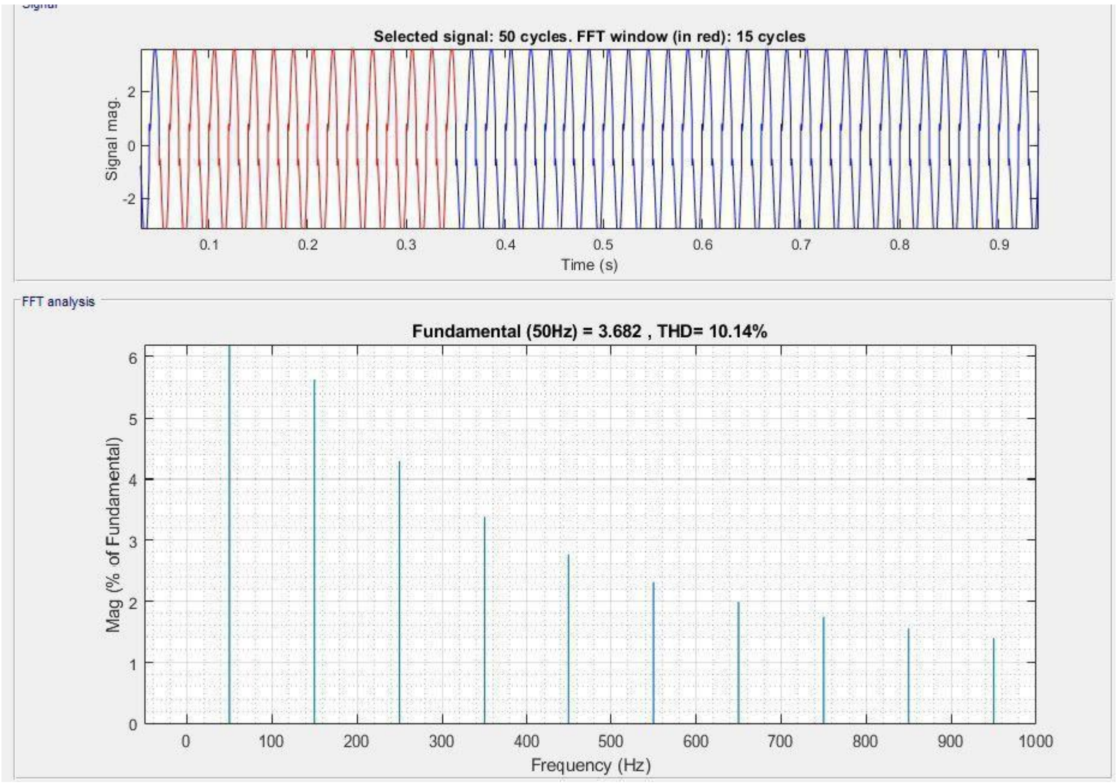

Fig. 2.3 THD of a balanced non linear load

for the active power delivery. It can be represented as Current THD and Voltage THD. Current THD represents the Total Harmonic Distortion of the current waveform. It is the ratio of the root-sum square value of the harmonic content of the current to the root-mean-square value of the fundamental current.

$$I_{\mathrm{THD}} = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + ...}}{I_1} * 100 \tag{2.1}$$

The design of the active filter is made keeping in mind that it minimizes the Total Harmonic Distortion to keep it within the limits specified in IEEE Std 519. From the figure 2.3, it is clear that the THD of power system without active filter is 10.14% which is very much higher than the IEEE standards.

2.4 Passive Filters

To overcome the problems caused by harmonics, filters are used. At first passive filters are used but they are dependent heavily on the system parameters. Passive Filters are composed of passive circuit elements such as resistors, capacitors and inductors. For Passive Filters, the aim is to adjust the resonant frequency of the filter to desired harmonic elimination. Passive filters are connected either in series or in parallel in the power network. Some of the Passive filters is as shown in Figure 2.4.

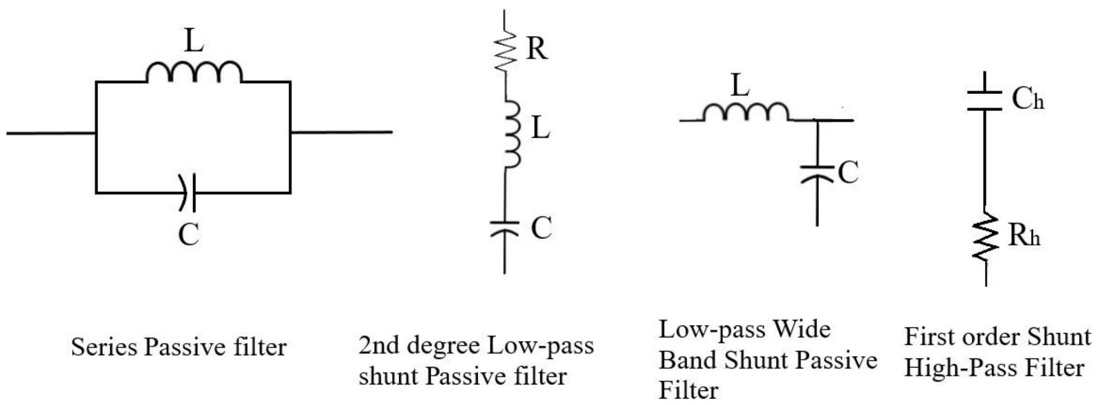

Fig. 2.4 passive filters

2.4.1 Series filters

Series filters provide high series impedance to block the relevant harmonics and they carry full-load current and be insulated for full-line voltage. In series filters the passive elements will be in parallel and produce a parallel resonance and hence block the relevant harmonics.

2.4.2 Shunt filters

Shunt filters divert the relevant harmonic currents to the ground by providing a low impedance shunt path and they carry only a fraction of the current that a series filter must carry.
Shunt filters can be classified into two types:

2.4.3 Tuned filters

2.4.3.1 Single tuned filter

Based on series resonance of RLC circuit : The circuit is designed to resonate at the frequency equal to the frequency of the component which needs to be filtered. It is confined to a particular frequency.

2.4.3.2 Double tuned filter

This filter is tuned to two frequencies equal to the frequency of the significant harmonic components in the magnitude spectrum.

2.4.4 Damped filters

These are also referred to as high-pass filters. These filters are designed such that all the components of frequencies higher than a particular frequency are filtered.

Earlier the technique used to compensate the harmonics present in the load current were these L-C passive filters but as the problem of undesirable resonance produced in the passive filter and LC passive filter could only absorb harmonic waves of a specific frequency because of these fall backs it is replaced by active filters. Active filters have less weight and size, no loading problem and cheaper due to absence of heavy and costly inductors. By using the filters, harmonics can be removed. Passive filter are generally not used because they will only filter out the frequency for which they are tuned and also resonance can occurred because of interaction taking place between passive filter and load connected to line. Therefore the use of active filter is done to compensate the harmonics value unlike over the large frequency range and without any resonance problem.

2.5 Active Power Filter

To overcome the drawback of passive filter, active compensation known as Active Power Filter is used recently. The Active Power Filter is a Voltage Source Inverter (VSI) which injects the compensating current or voltage based on the network configuration. It was proposed around 1970. But the recent advancement in power electronics technology, along with the theory of instantaneous active and reactive power which was presented in 1983, Active Power Filters are an up-to-date solution with fast switching devices, low power loss and fast digital processing devices at an affordable price(18). Depending on the circuit configuration and function, Active Power Filters are divided as Shunt Active Power Filter and Series Active Power Filter.

2.5.1 Series Active Power Filter

Series Active Power Filters are connected in series with the line. 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(12). These filters have their application mainly where the load contains voltage sensitive devices. In Series Active Power Filter, the inverter, which is connected in series injects voltage whose magnitude is same as that of the harmonic voltage but with a phase shift of 180 degree. Hence the voltage harmonics gets cancelled out. The point at which the voltage is injected shows an increase in the impedence preventing the flow of any harmonics generated in the load side to the supply side.

2.5.2 Shunt Active Power Filter

The voltage sourced inverter based Shunt Active Power Filter is connected in shunt at the Point of Common Coupling. It injects the current which is equal and opposite to 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 Active Power Filter is connected in parallel with a nonlinear load. The approach is based on the principle of injecting harmonic current into the ac system, of the same amplitude and reverse phase to that of the load current harmonics through a Hysteresis controller, which will generate switching sequel for the inverter(10). This will thus result in sinusoidal line currents and unity power factor in the input power system. In this case, only a small portion of the energy is processed, which may result in overall higher energy efficiency and higher power processing capability.

CHAPTER 3

SHUNT HYBRID ACTIVE POWER FILTER

Shunt Hybrid Active Power Filter(SHAPF) is a combination of both Passive Filter and Shunt Active Filter. Passive Filters are composed of passive circuit elements such as resistor, capacitor and inductor etc. For Passive Filters, the aim is to adjust the resonant frequency of the filter to desired harmonic elimination. Passive filters are connected either in series or in parallel in the power network. An inductor of 0.5 mH connected in series is implemented as the Passive Filter. Different control strategies for implementing active filters have been developed over the 5 years. One of the control method termed instantaneous active and reactive current component (id-iq) method, based on synchronous rotating frame derived from the mains voltages without the use of phaselocked loop is used in this project. Since the p-q theory is based on the time domain, this theory is valid both for steady-state and transient operation, as well as for generic voltage and current waveforms, allowing the control of Active Power Filter in the realtime; another advantage of this theory is the simplicity of its calculations, since only algebraic operations are required. Voltage source converters are used in the active power filter topologies, which have a DC capacitor or a DC voltage source as an energy storage device. Although a single pulse for each half cycle can be applied to synthesize an AC voltage, for most of the application which shows dynamic performance, pulse width modulation (PWM) is the most commonly used today. Hysteresis PWM technique applied to a voltage source inverter consist of chopping the DC bus voltage to produce an AC voltage of an arbitrary waveform. With Hysteresis PWM controller, the AC output of the filter can be controlled as a current or voltage source device.

Voltage source converters are preferred over current source converter because it is higher in efficiency and lower initial cost than the current source converters. They can be readily expanded in parallel to increase their combined rating and their switching rate can be increased if they are carefully controlled so that their individual switching times do not coincide. Therefore, higher-order harmonics can be eliminated by using converters without increasing individual converter switching rates.

This is a multiple harmonic elimination-based feedback controller for SHAPF to

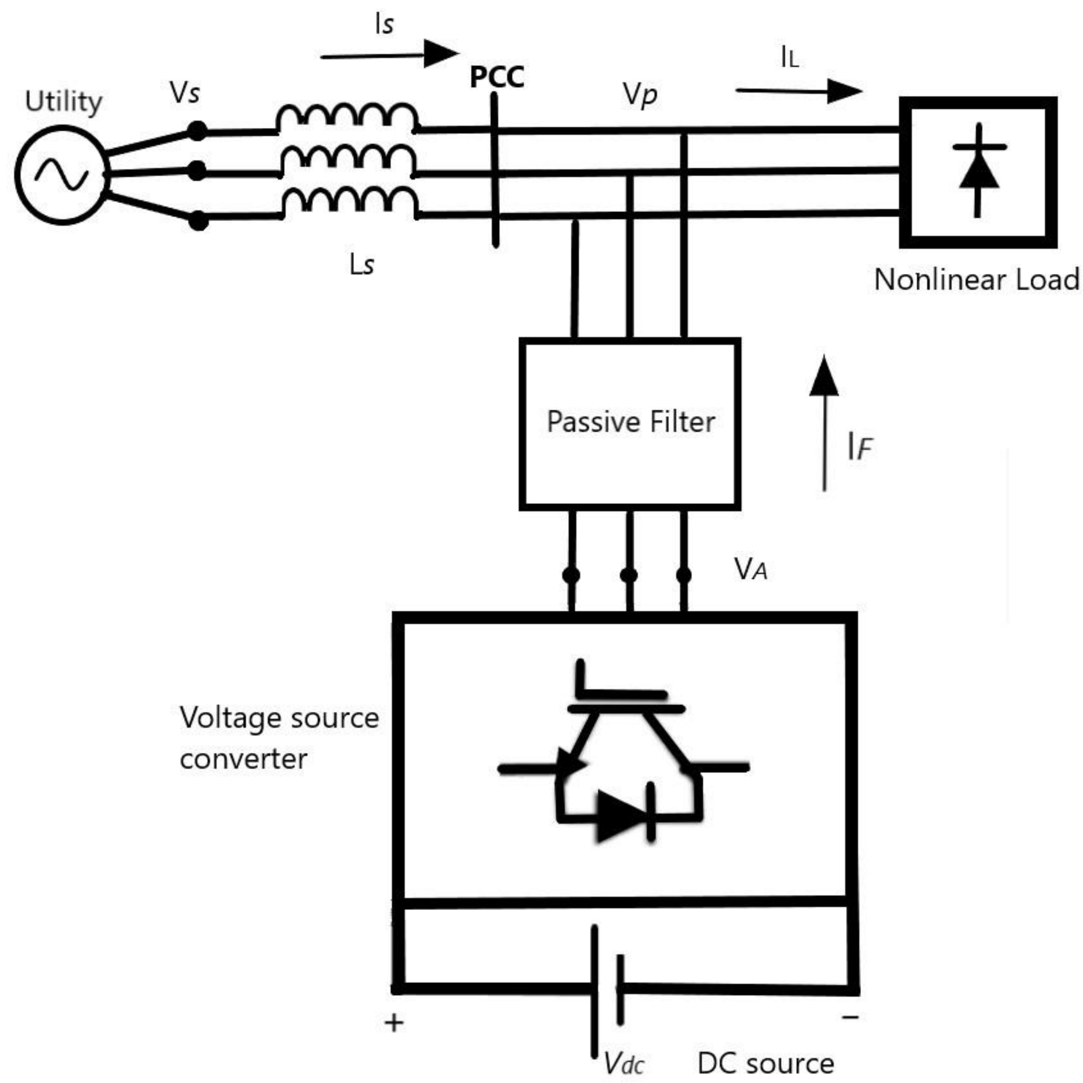

Fig. 3.1 Power circuit topology of SHAPF

increase the harmonic compensation performance. In the proposed controller, the conventional feedback controller is improved with multiple feedback loops which are applied for individual current harmonics. The proposed controller requires only the supply side current measurements to achieve the harmonic compensation control. The current harmonics are extracted from the supply side currents using the synchronous reference frame (SRF) method. The multiple feedback loops consist of proportional–integral (PI) controllers which regulate each d and q components of individual current harmonics separately.

3.1 Power Circuit Configuration of Shunt Hybrid Active Power Filter

The power circuit topology of SHAPF is formed from the series connection of a singletuned Power Filter and an Active Power Filter as shown in Figure 3.1. Singletuned Power Filter is generally tuned to low-order harmonic frequencies to filter a part of dominant harmonic currents of the load. Additionally, it supplies a capacitive reactive power for the reactive power demand of load. Active Power Filter consists of a voltage source converter (Inverter) and a dc-link capacitor bank. Voltage Source Converter is the main part of SHAPF that generates voltage across its terminals to compensate harmonics. The DC-link capacitor bank or a DC source is used as energy storage element to maintain harmonic compensation. In conventional Active Power Filter topology, the DC-link voltage must be kept higher than the peak value of supply voltage in order to control the active and reactive power flows and inject harmonic currents to grid. However, the capacitor of Power Filter holds the fundamental supply voltage across its terminals in SHAPF topology, so that Active Power Filter keeps required voltage on dc link only for the harmonic compensation. Thus, the voltage ratings of Voltage Source Converter and the dc-link capacitor bank are significantly reduced by the series connection of PF and Active Power Filter in SHAPF topology. By means of this advantage, low-voltage power switching devices and dc-link capacitors can be used, so that the size and the cost of Active Power Filter can be reduced. Additionally, the switching losses in Active Power Filter are considerably decreased.

3.2 Controller Design

For systems that do not have a neutral connection, the zero sequence does not exist and the mathematical equation will be presented in matrix form

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \tag{3.1}$$

The synchronous rotating frame or d-q theory is used as the main controller design without considering neutral wire. This method transforms three-phase in to d-q coordinates (rotating reference frame with fundamental frequency) using Park transformations. This theory is extensively used in active filter because of the simplicity of the control design. The equations to transform a-b-c coordinate into α-β-0 coordinate is presented in Equation below.

$$\begin{bmatrix} I_0 \\ I_\alpha \\ I_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_{\mathrm{La}} \\ I_{\mathrm{Lb}} \\ I_{\mathrm{Lc}} \end{bmatrix} \tag{3.2}$$

By employing Park transformation, the α-β-0 coordinate is transform into d-q coordi-

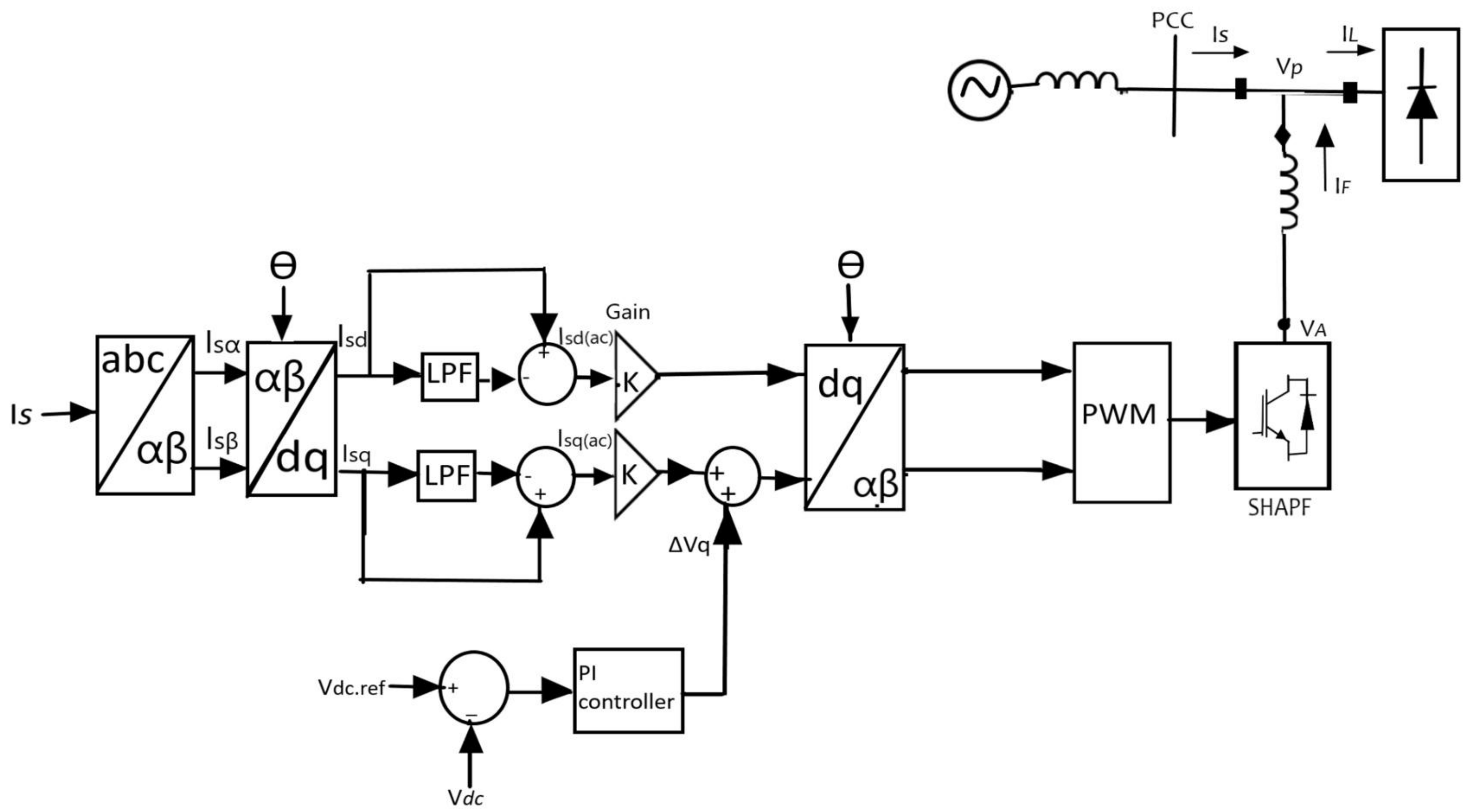

Fig.3.2 Blockdiagramofthecontroller

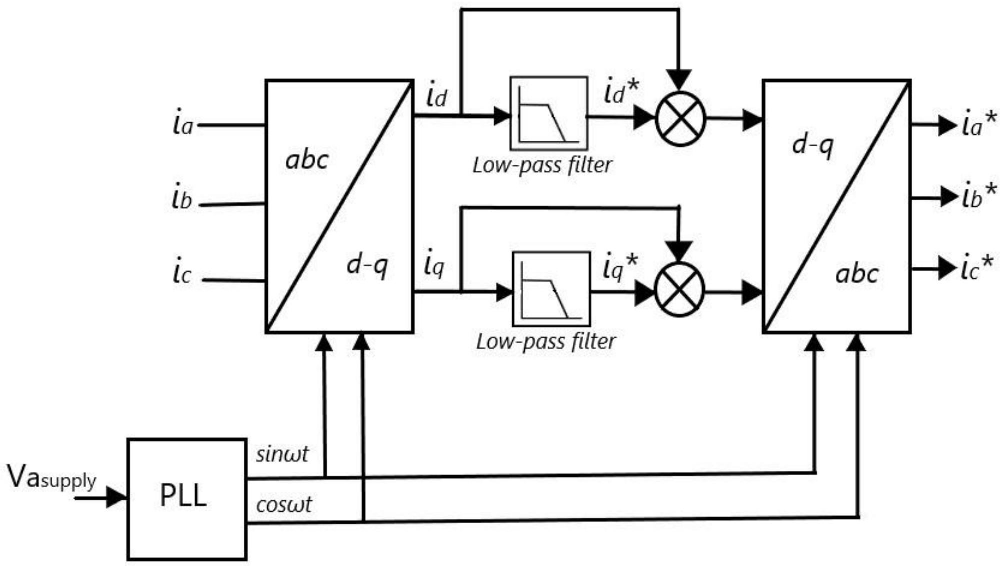

Fig. 3.3 The detecting principle of harmonics current using d-q theory

nate as shown(4) in Equation.

$$\begin{bmatrix} I_d \\ I_q \end{bmatrix} = \begin{bmatrix} cos\theta & sin\theta \\ -sin\theta & cos\theta \end{bmatrix} \begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} \tag{3.3}$$

Where;

$$\theta = tan^{-1}\left(\frac{V_\beta}{V_\alpha}\right) \tag{3.4}$$

The angular speed in d-q frame is same with fundamental frequency which makes the DC fundamental current component. By using low-pass filter (LPF) the DC component can be obtained. Subtracting the DC component with the previous component can determine the harmonics component for the system. Figure 3.3 shows the techniques to determine the harmonics component in the system.

As in figure 3.2, load current will be taken in to a feedback loop. The load current will be converted to the d-q reference frames and then it will be passed through a low pass filter. Thus we get the fundamental component in the load current at the output of low pass filter. The fundamental component obtained will be subtracted from the load current to obtain the harmonic components. This harmonic current has to be injected in 180 degree phase shift to the power line. After converting it back to 3 phase α-β, using suitable PWM technique, the compensating current is generated. The generated compensating current is then passed through a passive filter and injected to the power line.

CHAPTER 4

SINGLE PHASE SIMULATION

4.1 Simulation

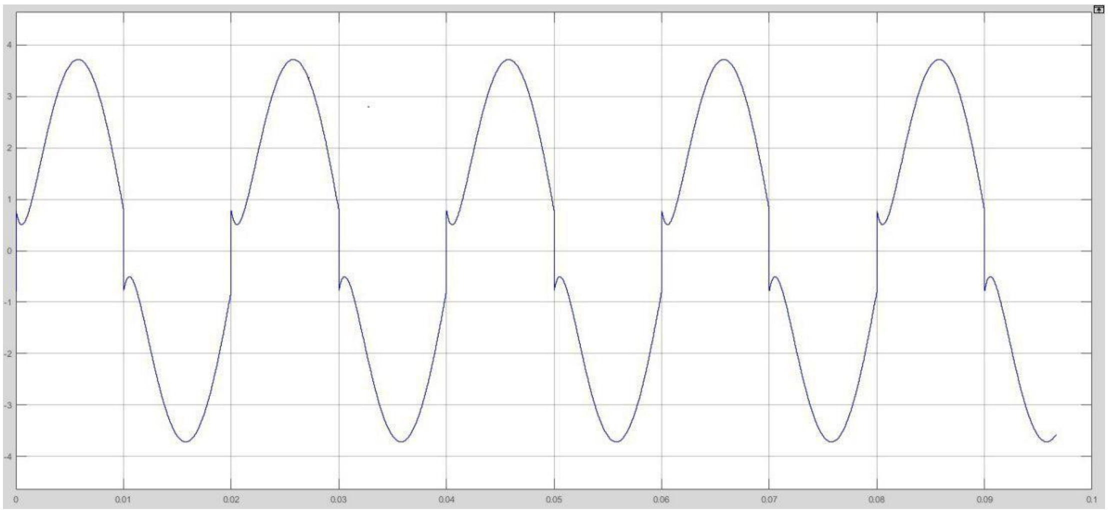

Fig. 4.1 Load current

Simulation in MATLAB involves the model and dynamic system behaviour. The distribution network is supplied with the voltage and the simulink model of the system is as shown in the figure 4.2. The rectifier fed RL load draws a non sinusoidal current from the source as shown in figure 4.1. When the SHAPF is connected with the circuit,

PARAMETER NAME	RATED VALUE
Input voltage	40 V
Input frequency	50 Hz
Load	Diode bridge rectifier
Load side resistor	10 Ω
Load side inductor	8 mH
Input DC source of inverter	50 V
Passive inductor	0.5 mH
Load current THD	10.14%
Source current THD	1.80%

Table 4.1 Simulated Circuit Parameters and its rated values

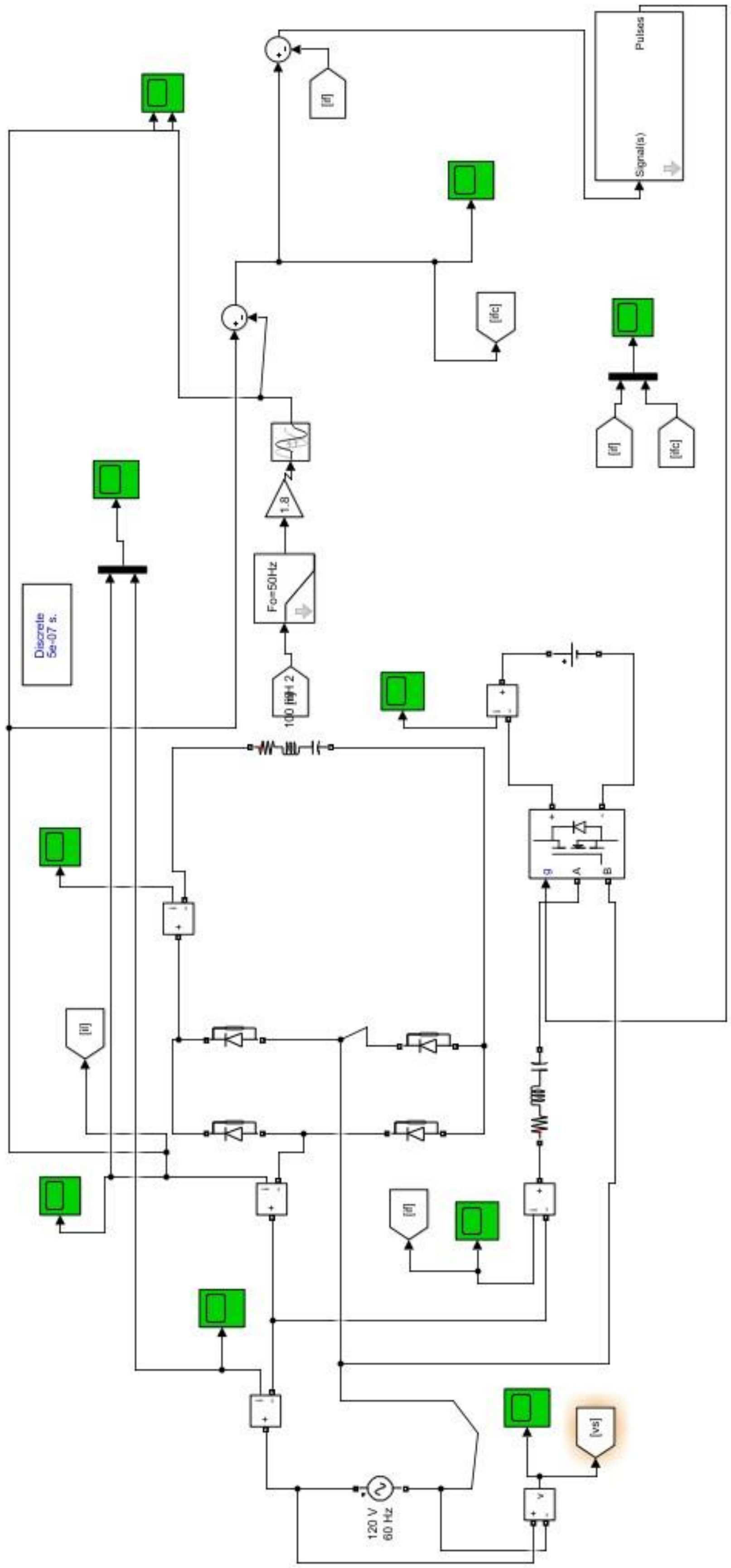

Fig.4.2 MATLABSimulation

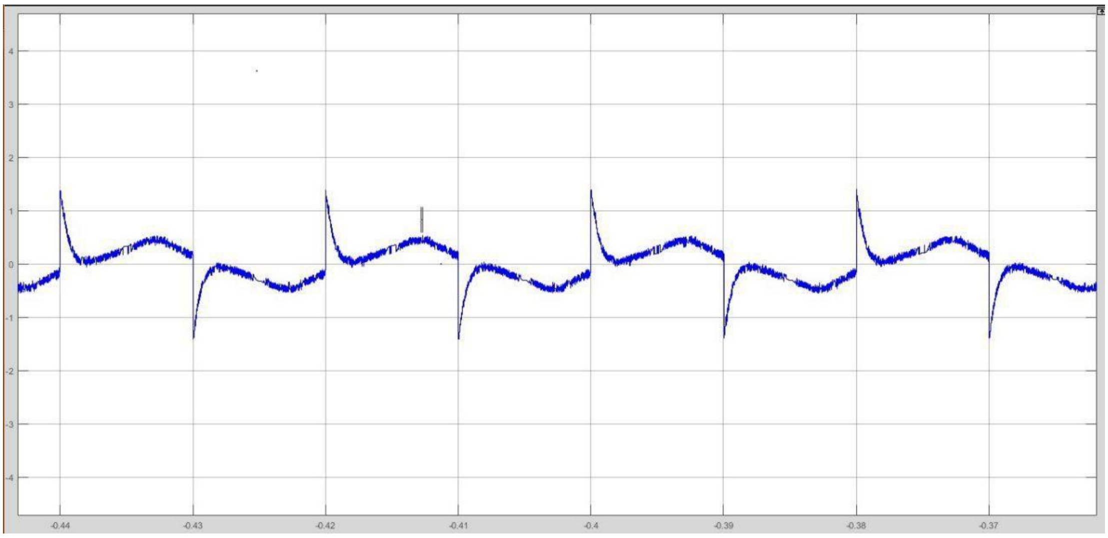

Fig. 4.3 Compensating current

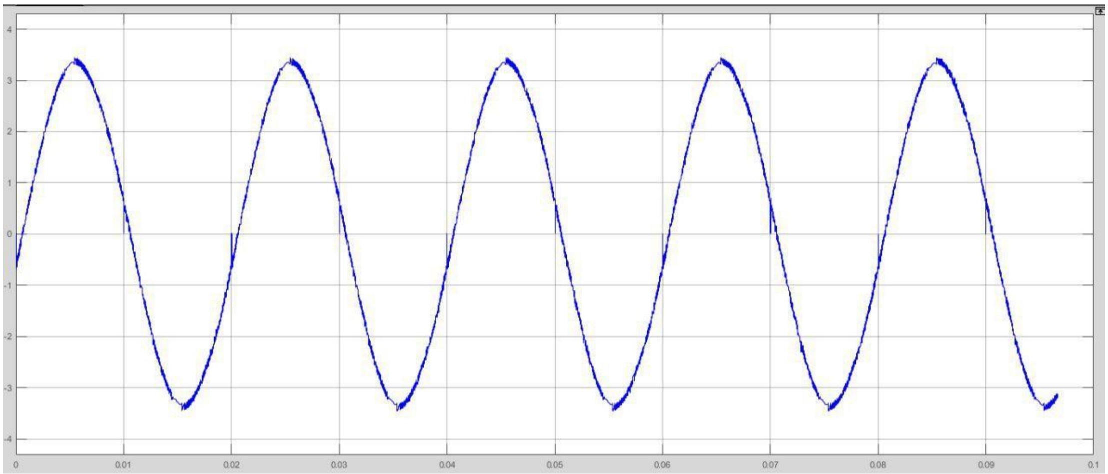

Fig. 4.4 Harmonic mitigated Source current

the load current changes. The change in load current is observed due to the compensation effected by the shunt active filter. The injected current through the SHAPF is as shown in figure 4.3. This compensation current when injected makes the source current sinusoidal and harmonic free as shown in figure 4.4. The parameters and its rated values are listed in table 4.1

CHAPTER 5

HARDWARE IMPLEMENTATION

The Project hardware mainly consists of a Power circuit, Control circuit and an Inverter circuit. The Non-linear load is taken as a Diode Bridge Rectifier circuit with a R-L load as shown in figure 5.1.

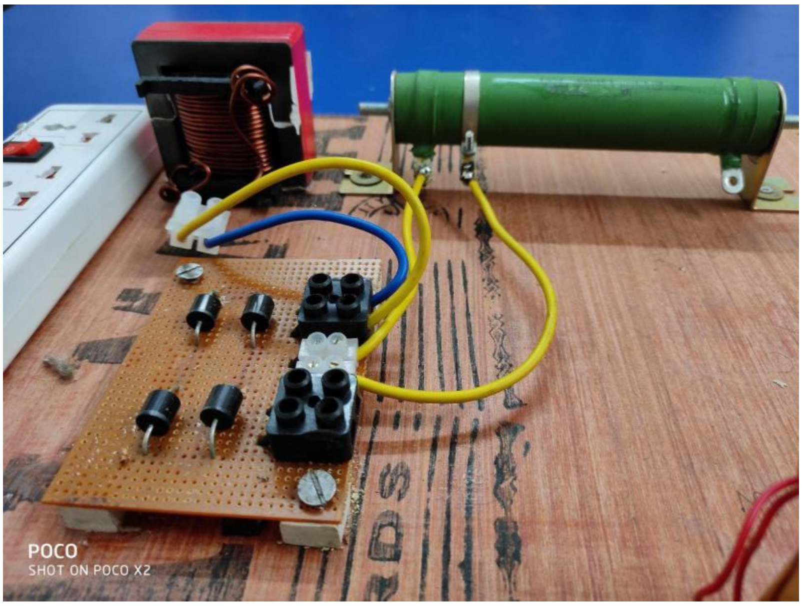

Fig. 5.1 Diode Bridge Rectifier with RL load

The values regarding the resistance and inductance is obtained through the Simulation Results using MATLAB. Therefore, as the first step Simulation on the three phase and single phase system is done. The values of different components are adjusted to obtain the desired outcome and the THD is found to be less than 5 percent.

Simulation results of single phase system is taken for consideration as the hardware is implemented for single phase system. The R-L load of the Rectifier circuit consists of a 10 ohm resistance and a customised 8mH inductance. The diodes in the rectifier circuits are of 6 Ampere rating. The inductor used as the load of the rectifier is customized and it uses EE 65/32/13 Ferrite core and wounded with 15 SWG copper wire. It has approximately 100 turns. The rectifier output is checked using a Digital Storage Oscilloscope and the rectified waveform is as shown in figure 5.2.

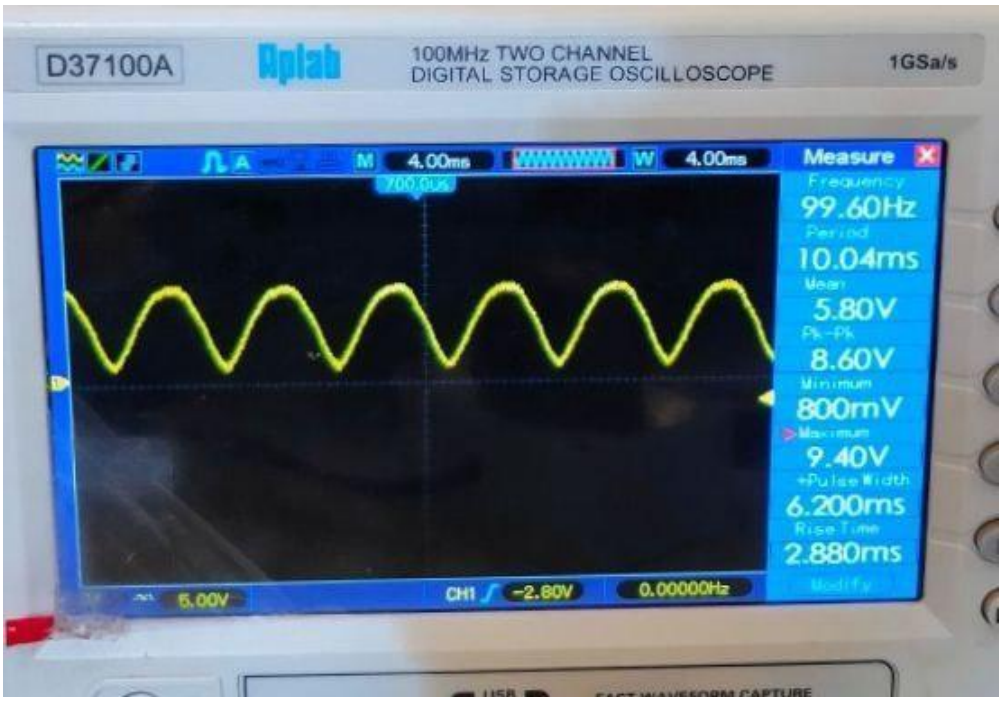

Fig. 5.2 Output of Rectifier Circuit

The Shunt hybrid active power filter is a combination of passive filter and an active filter which is connected in shunt to the power line at the load side. The inverter output will be controlled using pwm technique in such a way that, it will be equal in magnitude but opposite in phase of the harmonic current which is present in the power line. The passive filter of the system is a customised inductor of 0.5mH. It is tested using a LCR Meter. The Active Filter consists of an Inverter circuit with MOSFET IRF540 as switches. As the output from the control circuit cannot be given directly to the gate of the MOSFET, an isolation is required. This isolation is provided by a driver circuit as shown in figure 5.3.

The Core of the Driver circuit is a TLP Optocoupler IC, which will provide isolation between the control signals and the inverter gate. The pin diagram of TLP 250 IC is shown in figure 5.4.

As in figure 5.4, TLP 250 needs a 12V DC Supply. It is provided using a 24V Transformer Circuit. It consists of a diode bridge, LM7812 IC, and capacitors. The DC Supply arrangement is shown in figure 5.5. The output signal from each optocoupler is given to each MOSFET to drive the Inverter circuit. This transfer of signals was first tried using IR2110 IC but the output was not up to the desired form, hence switched to the Transformer circuit.

The output from the driver circuit is tested in the lab with IC 555 timer circuit as

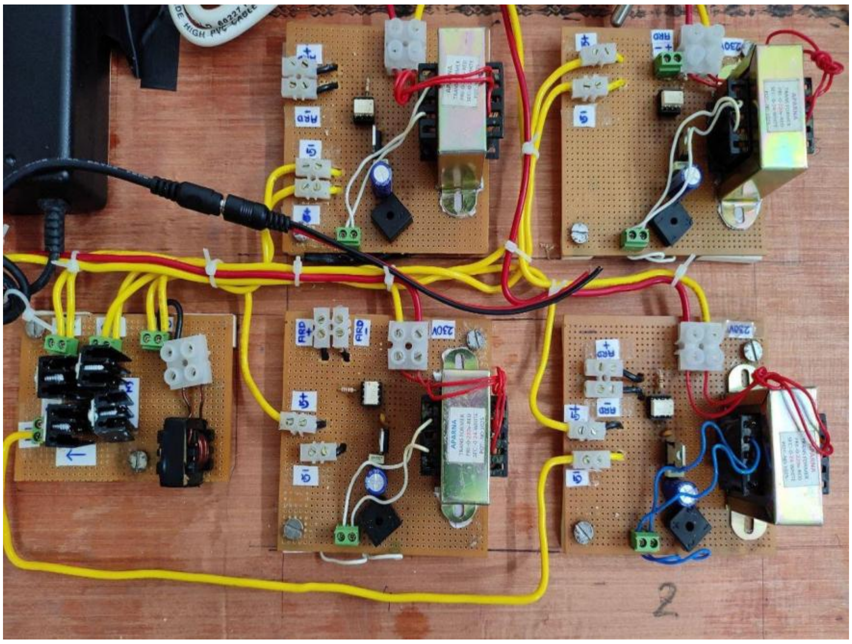

Fig. 5.3 Inverter with passive inductor and TLP250 Optocoupler Driver circuits

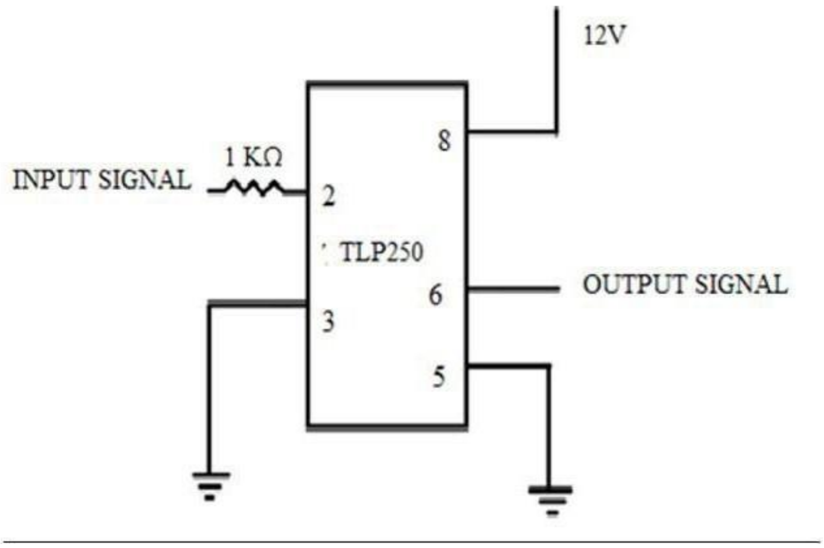

Fig. 5.4 TLP250 Pin diagram

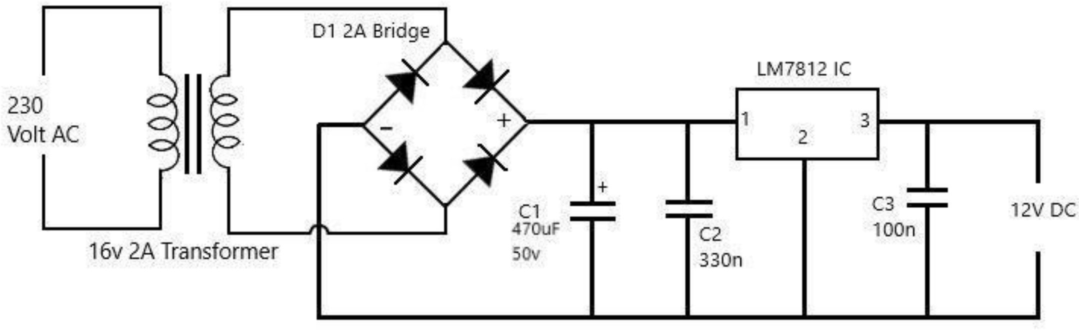

Fig. 5.5 12V DC Supply circuit for TLP250 Optocoupler

input instead of our actual control circuit. We made a square wave and an inverted square wave using IC 555 timer and NOT gate arrangement(IC7404). Then we tested the output of the isolation circuit using a Digital Storage Oscilloscope as in figure 5.6.

Fig. 5.6 Output from Driver circuit

The inverter consist of 4 IRF540 MOSFET switches to which heat sink is attached in order to protect the circuit from over heating and burn out. At the output of the Inverter a customised passive inductor of 0.5mH is connected. The core used for the inductor is EE 25/9/6 and wounded with 20 SWG copper wire. suitable air gap is provided while testing it with LCR meter.

At the input of the inverter there is DC source of 48V. In order to get a 48V DC Supply we designed a BOOST converter, which will convert 24V DC to 48V DC. The 24V DC is achieved from a 24V DC Adapter. The boost converter consists of an 2mH

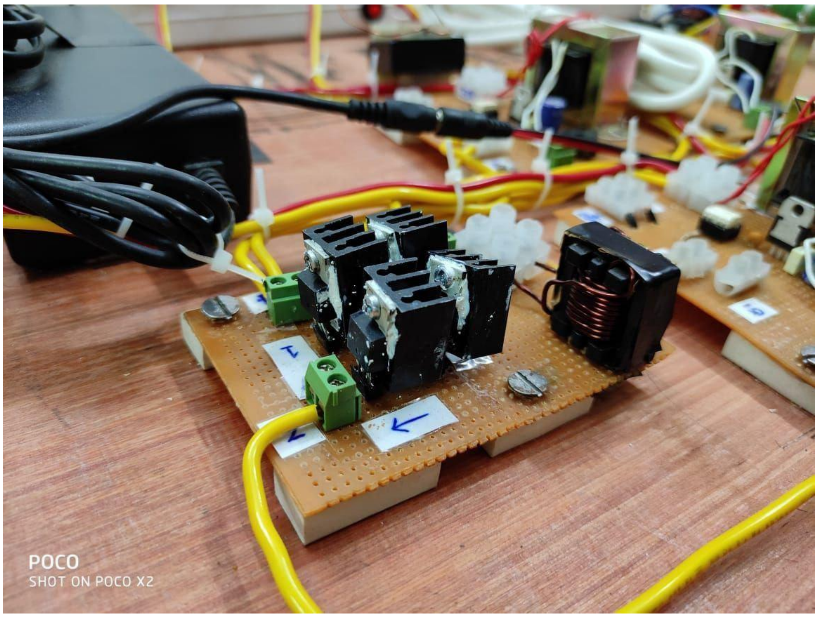

Fig. 5.7 Inverter circuit with passive inductor

inductor, 6A diode, IRF540 MOSFET switch and 470 micro Farad capacitor. The 2mH inductor is customised with EE 42/21/9 and wounded with 18 SWG copper wire. The boost converter is also simulated in MATLAB and we got satisfying steady state DC. The hardware of boost converter is shown in figure 5.8.

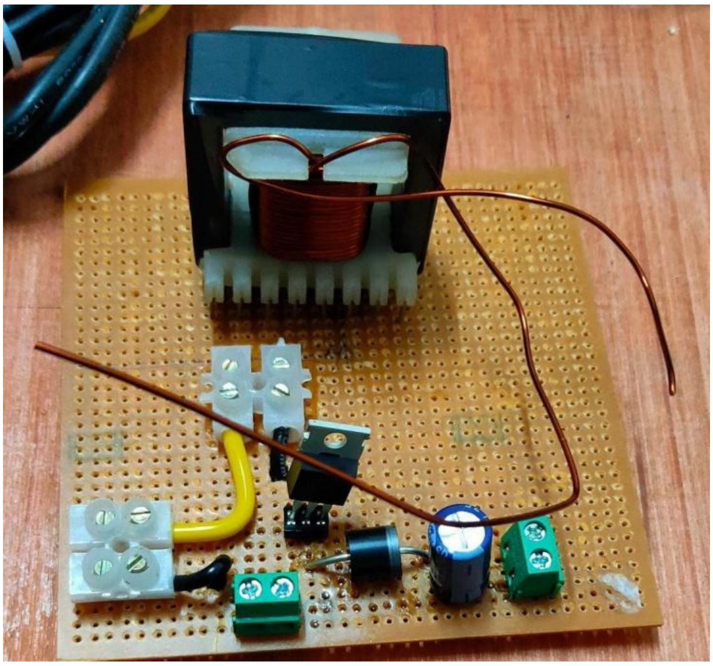

Fig. 5.8 Boost converter

The boost converter has a IRF540 MOSFET switch which is to be triggered with suitable pulses. Since we need to double the input voltage of the boost converter we can use a square pulse to trigger the MOSFET. The square pulses are generated using a IC555 Timer circuit. The circuit diagram is as shown in the figure 5.9. The pulses must be isolated from the gate terminal while connecting it. So we use an optocoupler circuit again. The timer circuit with its TLP250 Isolation circuit is shown in figure 5.10.

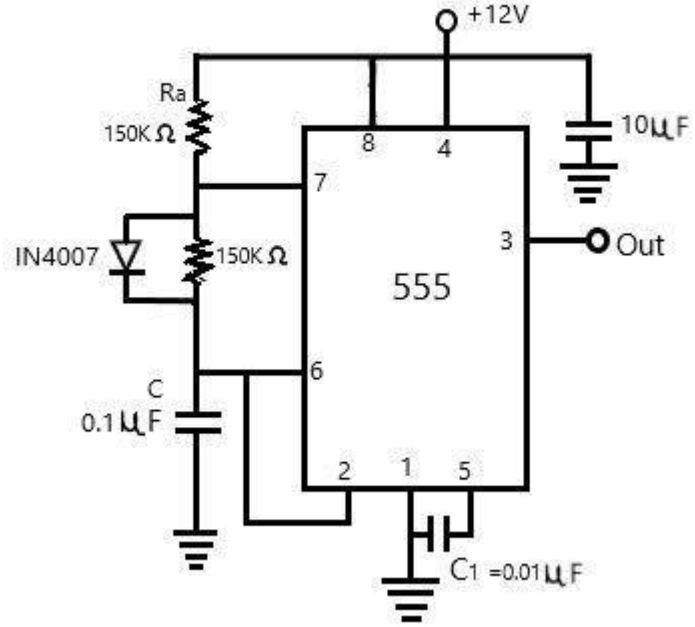

Fig. 5.9 IC 555 timer circuit

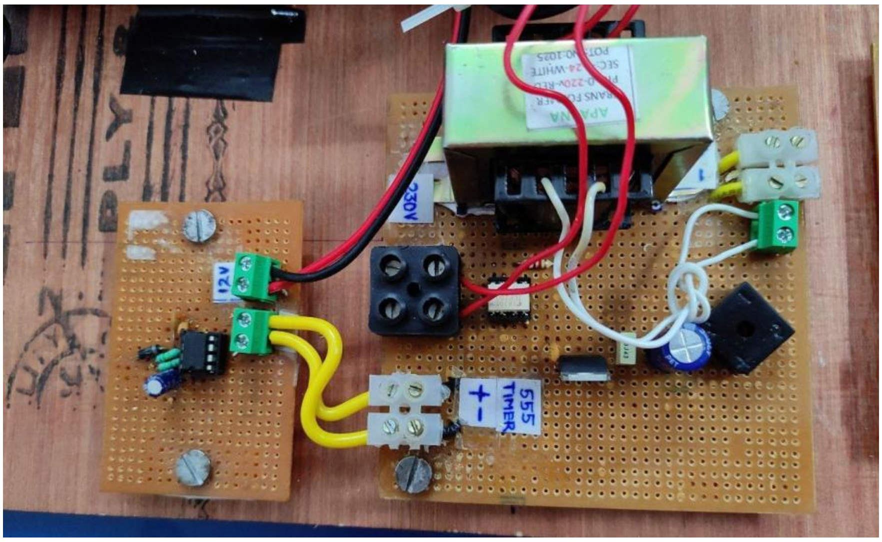

Fig. 5.10 555 Timer circuit with TLP250 Isolation circuit

As in the simulation, a diode bridge rectifier is connected to the system as a non linear load. The filter is hybrid, which is a combination of passive and active filters. The passive filter is designed as an inductor with inductance 0.5mH. The active filter is an inverter circuit which provide desired current wave forms at the output. The passive inductor is connected at the load side of the inverter in series. The inverter gates are triggered with suitable control pulses which is done using raspberry pi model 3B+. The load current must be measured using a current sensor and should be provided to the input of the control circuit. Thus the inverter output can be injected to the power line in order to cancel out the current harmonics in the line and maintain the THD below 5 percentage. The overall arrangement with out the control circuit and current sensors are shown in figure 5.11.

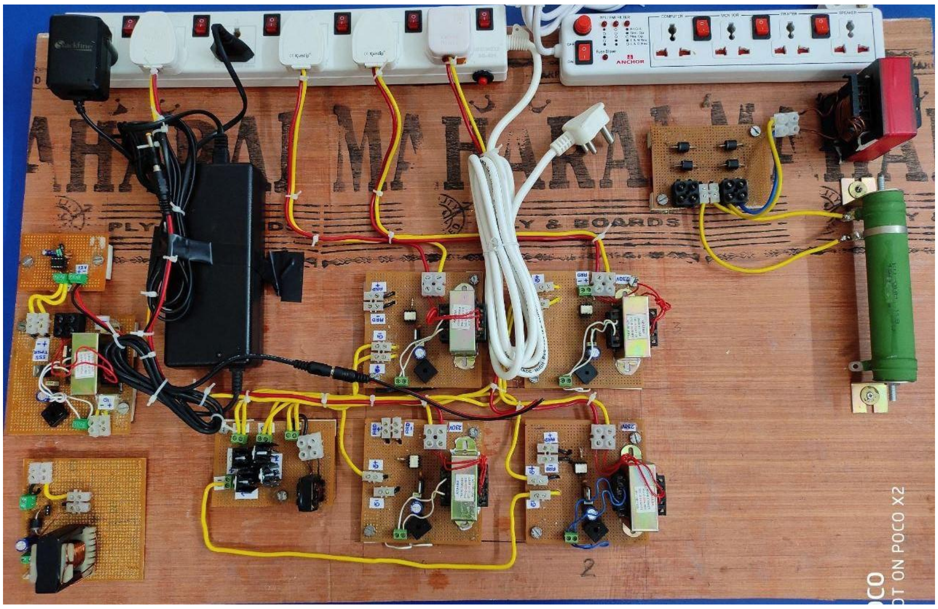

Fig. 5.11 Over all arrangement (Control circuit and Current sensors are not included)

CHAPTER 6

CONCLUSION

In recent years, the increasing usages of non-linear loads are causing harmonic and power factor problems in the power system. Passive filters are commonly used for filtration of the harmonic currents, but one of the major demerits is that, it can be tuned and filter out a particular frequency harmonic current only. So the technique that can be used to eliminate all the harmonic current from the power system is active power filter. D-Q theory can be implemented to control single phase active filter, which the theory widely used to control three phase active power filter.