# Shunt Hybrid Active Power Filter for Eradication of Current Harmonics

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**Abstract** Here in this project present the design of Shunt Hybrid passive harmonic filter and Shunt hybrid active power filter to compensate harmonic current produced by a nonlinear load. An improved synchronous reference frame control based on moving average filter is used in current control method in order to generate the required reference current for shunt hybrid active power filter (SHAPF) to solve harmonics problem in power system network. Here, the passive elements of SHAPF have been used for compensation of reactive power and to eliminate the lower order harmonics and the active part have been used to eliminate the higher order harmonics. The system is simulated using MATLAB/SIMULINK software program.

***Key Words***: Passive filter (PF), Tuning factor, Quality factor, Shunt hybrid active filter, synchronous reference frame theory(SRF)

## 1. INTRODUCTION

Nowadays, relating to power quality there are so many issues which have become so severe to many non-linear equipment. Due to their highly usage, the systems are becoming so much contaminated and the whole things have become so sensitive. These things happen because of the excess amount of harmonics in the system and this harmonics causes undesired power losses in electrical equipment. Several methods have been developed to reduce the power quality Problem by eliminating the harmonics. Passive filters can be a solution in such cases as they are Simple and less expensive. But this filter has some several drawbacks including drawbacks including fixed compensation, bulky devices and the resonance problem of the L-C filters. Hence, active power filter (APF) has been developed for complete compensation of distortions. For this power quality issue active power filters have been considered as an effective solution. Apfs have the ability of compensate the harmonics and also have the quality to convert the unbalanced load to a balanced. Different types of apfs have been proposed to improve the power system quality, but these got drawbacks like high in cost and rating constraints by power devices. Shunt Hybrid filter topology has been chosen which is a combination of a parallel-connected passive filter and a small rated active filter .Hybrid active power filter (HAPF) gives the advantages over APF and PF and provides cost effective solution.

## 2 HAPF –SHUNT APF AND SHUNT PPF

The shunt APF can be connected to the distribution power system through coupling inductor (L) with or without CT, while the shunt PPF can be a tuned LC filter or high pass filter or any combination of them.

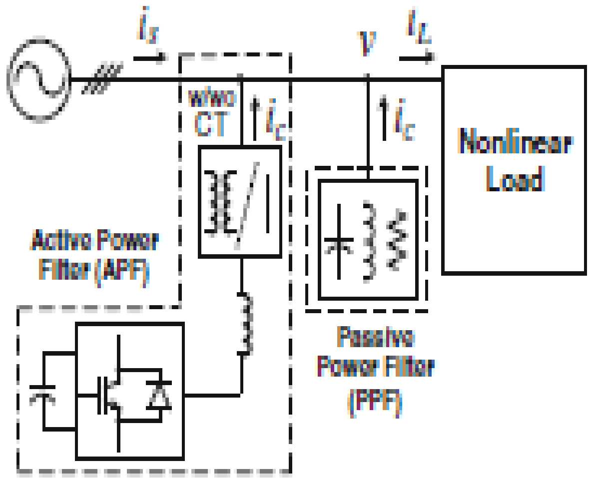


**Fig -1**: HAPF topology 2–shunt APF and shunt PPF

Under this HAPF configuration, the PPF acts as the main compensator and the APF is used to compensate the remaining current harmonic contents, which have been filtered by the PPF, so as to improve the system filtering performances. Thus, this HAPF topology aims to reduce the current rating of the APF. In addition, the advantages of this topology are the shunt APF applicable if the shunt PPF already exists and reactive power controllable. Moreover, it can prevent the parallel resonance phenomenon. However, the APF cannot change either the voltage across the PPF or the current through the PPF. Therefore, large circulating current will be generated by the PPF if the PPF impedance is low at the voltage distortion frequency. In order to prevent the harmonic current flows to the supply, the required APF current rating will still be high. If the APF is directly connected to the distribution power system without CT, its required voltage rating is also high. By adding CT, its voltage rating can be reduced; however, using CT will increase the system cost, size, and loss. By choosing the PPF as a high pass filter, this HAPF topology can avoid obtaining low PPF impedance at the voltage harmonic frequencies. However, high pass filters (with resistance) increase the filter loss and reduce the filtering effectiveness at the tuned frequency.

## 3. MOVING AVERAGE

As the name implies, the moving average filter operates by averaging a number of points from the input signal to produce each point in the output signal. In equation form, this is written

$$y[i] = \frac{1}{M}\sum_{j=0}^{M-1} x[i+j]$$

Where *x* [ ] is the input signal, *y* [ ] is the output signal, and *M* is the number of points in the average. For example, in a 5 point moving average filter, point 80 in the output signal is given by:

$$y[80] = \frac{x[80] + x[81] + x[82] + x[83] + x[84]}{5}$$

As an alternative, the group of points from the input signal can be chosen *symmetrically* around the output point: Symmetrical averaging requires that *M* be an *odd* number. Programming is slightly easier with the points on only one side; however, this produces a relative shift between the input and output signals.You should recognize that the moving average filter is a *convolution* using a very simple filter kernel. That is, the moving average filter is a convolution of the input signal with a rectangular pulse having an area of one

## 4. SYNCHRONOUS REFERENCE FRAME BASED

The performance of an active power filter depends mainly on the technique selected to generate reference compensating current. The template to generate the reference current must include amplitude and phase information to produce the desired compensating current while keeping the voltage across the DC bus capacitor constant. The chosen technique must operate satisfactorily under both steady state and transient conditions. In the proposed model, the technique chosen for extracting reference currents and with the synchronous reference frame (SRF) method.

SRF-based controller was employed in a hybrid APF solution for improving passive filter performance in high power applications, whereas in the SRF-based controller was used to generate the sinusoidal compensating current references applied to a three-phase line-interactive UPS system. In this work, for this purpose, an algorithm based on SRF is also used. In the SRF-based algorithm the fundamental terms of voltage and/or current of the abc-phase stationary reference frame are transformed into continuous quantities

into the dq synchronous axes, in which they rotate at a synchronous speed in relation to the spatial vectors of voltage and/or current. In the dq-axes, the harmonic contents of voltage and/or current can be represented by alternate quantities, which are superposed on the continuous components. Therefore the fundamental component can be easily obtained by means of HPFs. The estimation of the utility grid phase-angle (θ) can be performed by using PLL algorithms, allowing the generation of the unit vector coordinates (sin θ and cos θ) used in the SRF-based algorithm.

### 4.1 SRF-Based Controller for Current Compensation

In this method the measured load currents are transformed into the rotating reference frame (d-q frame) that is synchronously rotating at the line voltage frequency using (1) and (2).The line frequency components of the load currents become DC quantities and the harmonic components are frequency shifted by ωt in the d-q reference frame.

Clark's Transformation

It transforms sensed source current signal from a-b-c stationary to α-β stationary coordinate system by following equation

$$\begin{bmatrix} I_\alpha \\ I_\beta \\ I_o \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} I_{ca} \\ I_{cb} \\ I_{cc} \end{bmatrix} \quad (1)$$

Park's Transformation

Now this signal α-β is converted in d-q frame by using equation

$$\begin{bmatrix} I_d \\ I_q \end{bmatrix} = \begin{bmatrix} \cos\omega t & \sin\omega t \\ -\sin\omega t & \cos\omega t \end{bmatrix} \begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} \quad (2)$$

A high pass filter in the d-q frame, with a cut-off at the line frequency can be used to extract the DC components.

Reverse Park's Transformation (α-β to d-q)

$$\begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} = \begin{bmatrix} \cos\omega t & -\sin\omega t \\ \sin\omega t & \cos\omega t \end{bmatrix} \begin{bmatrix} I_d \\ I_q \end{bmatrix} \quad (3)$$

Currents to transform them back to original frame, the inverse transformation from d-q to α-β frame, and then to a-b-c frame is carried out utilizing (3) and (4).

iv. Reverse Clark's Transformation (d-q to a-b-c)

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix} . \begin{bmatrix} I_\alpha \\ I_\beta \\ I_o \end{bmatrix} \quad (4)$$

Reference compensating currents ($i_{ca*}, i_{cb*}, i_{cc*}$) generated using current SRF controller which shown in figure 4.1

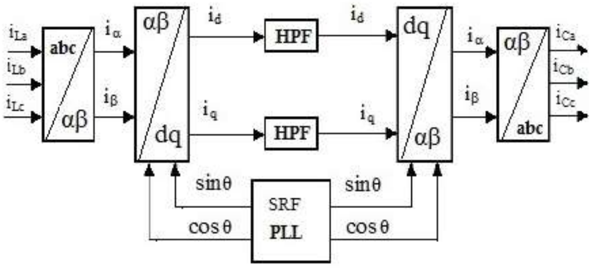


**Fig -2**: Reference compensating currents generated using SRF theory

**5. PROPOSED METHOD**

In SRF theory the distorted three phase harmonic load current ( *ILa* , *ILb* , *ILc* )are achieved in a-b-c coordinates by the three phase measurement block and these quantities are transformed into d-q coordinates (Rotating reference frame) by using equation (1) and cosine and sine functions from phase locked loop. The extraction of harmonic component present in the load current is done with the use of SRF theory

$$\begin{bmatrix} I_d \\ I_q \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \sin\theta & \sin\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) \\ \cos\theta & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \end{bmatrix} \begin{bmatrix} I_{La} \\ I_{Lb} \\ I_{Lc} \end{bmatrix}$$

After transformation on d-q axes fundamental components become D.C quantities,5$^{th}$,7$^{th}$ , order harmonics and so on. For the required compensation high pass filtered d-axis and q-axis component will be considered reference current. The d-component of load current represents active component of the current and q-component of load current indicates capacitive current drawn by the PF and also reactive power demand by the load. The high pass filter can be realised by a moving average filter (MAF), whose output is subtracted by original signal.

$$\begin{bmatrix} I^*_{La} \\ I^*_{Lb} \\ I^*_{Lc} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \sin\theta & \cos\theta \\ \sin\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ \sin\left(\theta + \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \end{bmatrix} \begin{bmatrix} I^*_d \\ I^*_q \end{bmatrix}$$

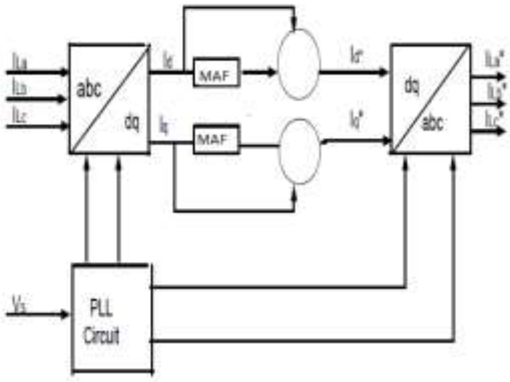


**Fig -3**: Block diagram of SRF control technique with MAF

The output of MAF extract only dc quantities and attenuates the ac components corresponding to harmonic frequency .Since the output of LPF are D.C. so it will not suffer any magnitude or phase error. One of the advantage of using low cut-off frequency of LPF is that it improves closed loop system stability margin. The output of MAF is and this output Id*,Iq* is transformed into $I_{CA}$,$I_{CB}$ ,$I_{CC}$ by using inverse SRF transformation in and it is used as reference current of hysteresis controller

**6. HYSTERESIS CURRENT CONTROL METHOD**

Hysteresis current control method of generating the switching signal for the inverter switches in order to control the inverter output current. It is adopted in shunt active filter due to easy implementation and quick current controllability.

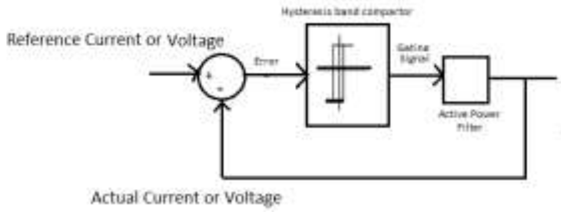


**Fig -4**: Block diagram of hysteresis current controller

It is a fed back current control method, where the actual current continuously tracks the reference current in the hysteresis band .The reference and actual current is compared with respect to hysteresis band which decides switching pulse of voltage source inverter. As the current crosses a set hysteresis band, the upper switch in the half-bridge is turned off and the lower switch is turned on. As the current exceeds the lower band limit, the upper switch is turned on and the lower switch is turned off.

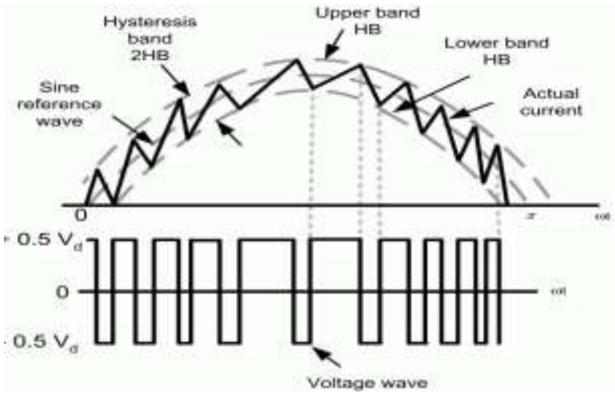


**Fig -5:** Hysteresis tolerance band

The switching frequency depends on how fast the current changes from upper limit to lower limit and vice versa. This, in turn depends on voltage $v_d$ and load inductance.

**7. MATLAB SIMULINK RESULTS**

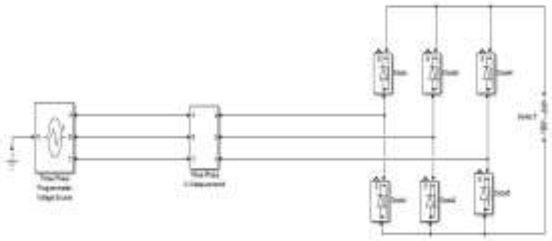

Fig -6: simulation model without compensator

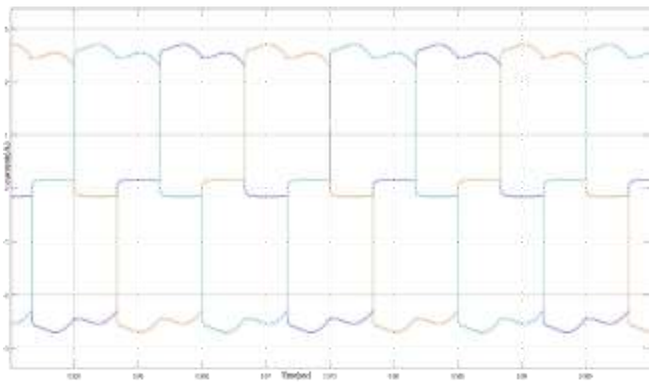

Fig -7: current harmonics in line without compensator

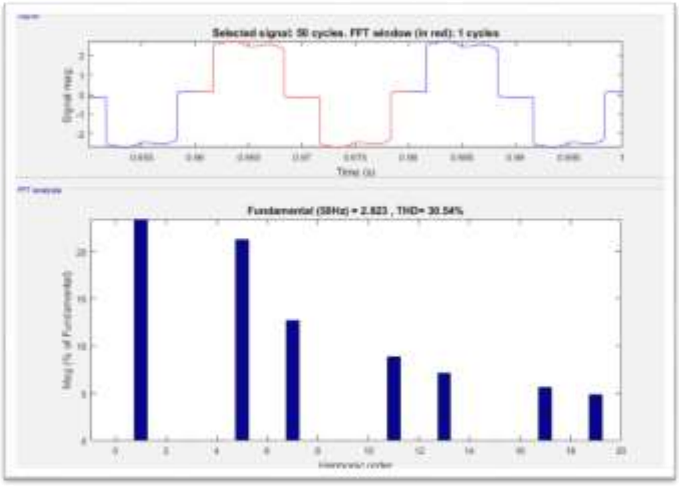

Fig -8: FFT analysis for current wave without compensation

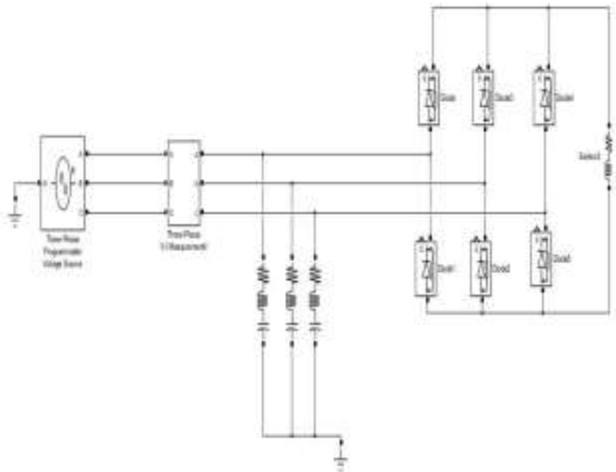

Fig -9: simulation model with passive filter

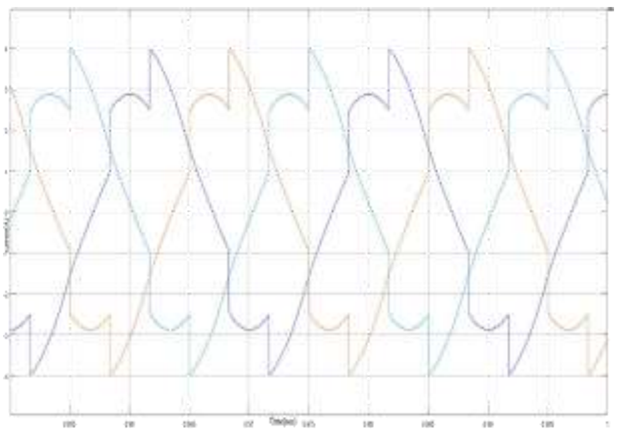

Fig -10: current harmonics in line with passive filter

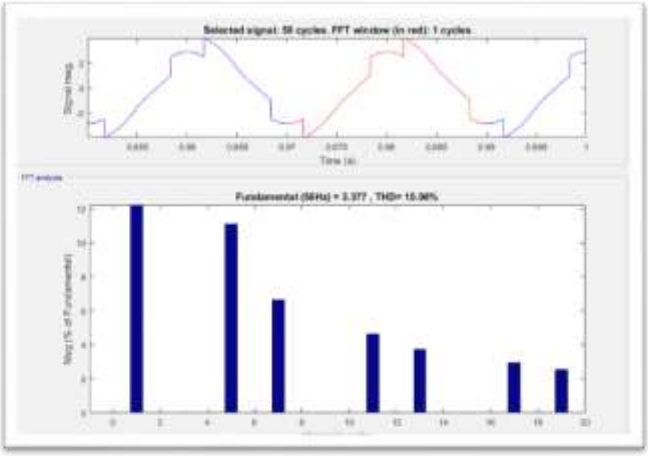

Fig -11: FFT analysis for current wave with passive filter

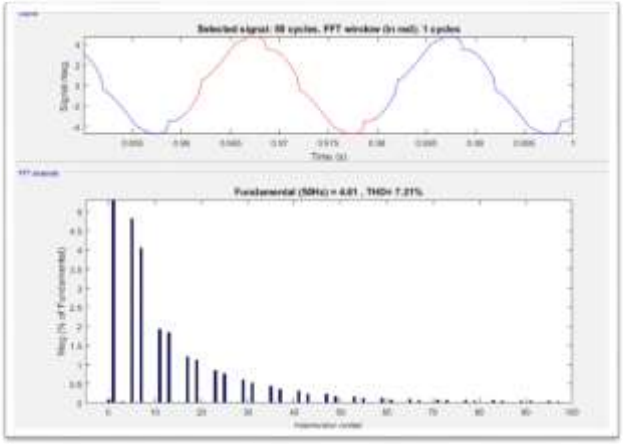

Fig -14: FFT analysis for current wave with active filter

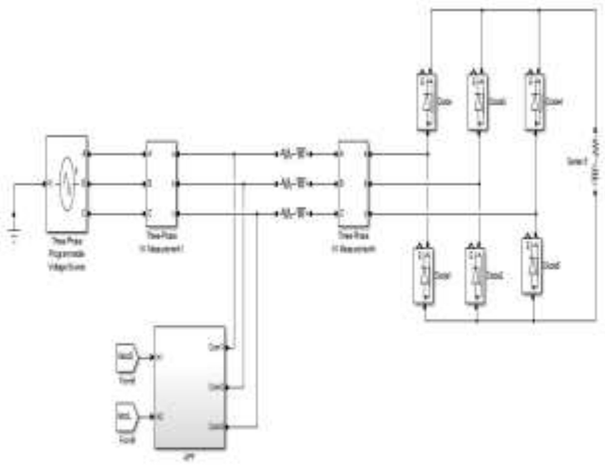

Fig -12: simulation model with active filter

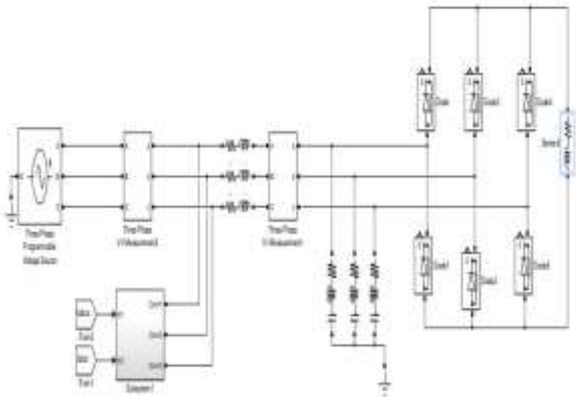

Fig -15: simulation model with hybrid filter

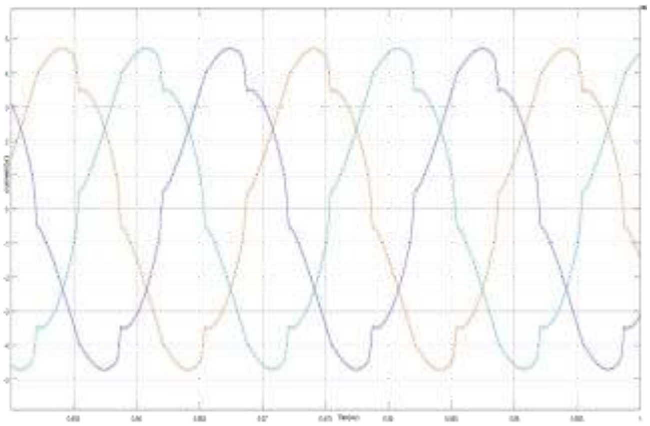

Fig -13: current harmonics in line with active filter

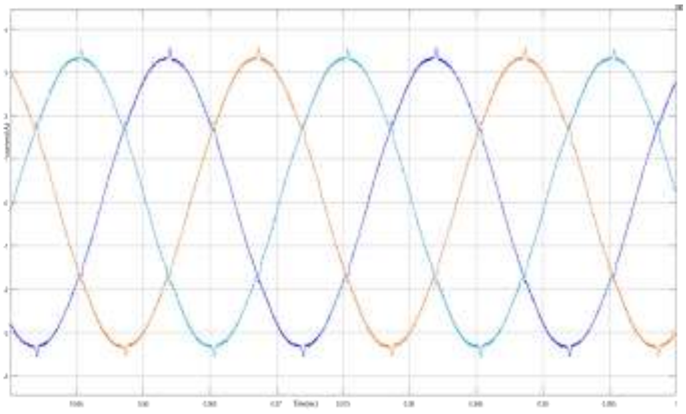

Fig -16: current harmonics in line with hybrid filter

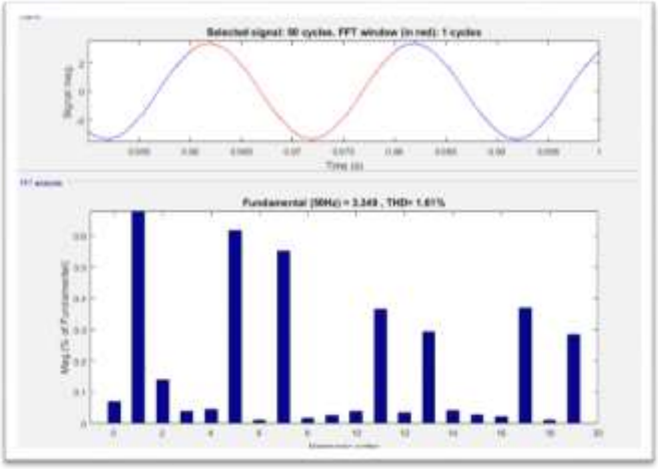

Fig -17: FFT analysis for current wave with hybrid filter

**7.1: RESULTS**

| PARMEMTER | Without compensator | Passive filter | Active filter | Hybrid filter |
|---|---|---|---|---|
| Current harmonics (THD-I %) | 30.54 | 15.96 | 7.21 | 1.61 |

**8. CONCLUSION**

An improved synchronous reference frame control based on moving average filter, a control technique for shunt hybrid active power filter (SHAPF) has been designed to improve power quality. The THD has been reduced 30.54 %to 1.61%.The load current is found linear after using SHAPF for both different sources. Therefore, with the modified SRF theory approach, SHAPF can be considered as a reliable harmonic reducer for its fast response and high quality of filtering.

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