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Control of Three Phase Shunt Active Power Filter (SAPF) By Using Instantaneous Reactive Power Theory

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ABSTRACT: The power quality issues are becoming more severe and point of concern in many studies. Non linear loads in industries produce harmonic currents which are then injected in supply system. It creates some power quality issues. Shunt Active Power Filter (SAPF) is widely to reduce these power quality issues. SAPF can improve voltage profile, harmonics can be reduced and power factor is also improved. Great reduction in total harmonic distortion is seen while using SAPF. Reference current generation is the key factor of Active power filter. Reference current generation and hence controlling SAPF using instantaneous reactive power (IRP) theory is explained and presented in this paper. Instantaneous reactive power theory is effectively used to generate reference currents and to control Active Power Filters (APF).MATLAB/simulinkis used for modeling of this technique.

KEYWORDS: *S*APF, IRP Theory, THD, Power quality, MATLAB/simulink.

I. INTRODUCTION

Current harmonics were generated by electronic equipment with nonlinear load. Harmonics are electric voltage and current on an electric power system that can cause the power quality problem. Nonlinear load includes all equipment by using thyristor, variable speed drive(VSD), controlled by rectifier arc furnace, large electrical machines, static power converters etc are connected to the system. The power supply current draw by these loads are not perfectly sinusoidal. This arise power quality issues because they cause harmonic disturbances in supply system. The house hold equipment shaving power electronic devices also have major impact on power quality. Initially, to compensate these harmonics passive filters had been used to improve the power factor but it was having some remarkable drawbacks like limited compensation, series resonance and large size of compensating devices [1]. It causes load and series resonances. The performance of this filter is dependent on load, it gets remarkably affected due to change in source impedance, values of component of the filter, tolerance, and source frequency. The main objective of power system is generation, transmission and distribution of clean and pollution free power to the end users. But due to above mentioned aspects, now-a-days quality of power is being deteriorated. There might be many reasons for this to cause. Some of them are like widely increasing industrialization, internally connected systems, increasing use of non-linear loads, use of power electronic devices for human comfort, etc. End users also face some problems like interruptions, sagging, switching transients, flickering.

Following disturbances affects power quality of the system:

- Harmonic Isolation
- Harmonic Compensation
- Voltage regulation
- Reactive power compensation

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Major Reduction in these problems is seen by using Shunt Active Power Filter (SAPF). Following goals can be achieved by using Active Filters [2]:

- Harmonic Isolation
- Harmonic Compensation
- Voltage regulation
- Reactive power compensation

The problems which are faced while using passive filters are overcame by Active Power Filters (APF). Total harmonic distortion (THD) can be lowered to 5% by using active power filters. There are three configurations of Active Power Filters based on system connection which are Series APF, Shunt APF and Series-Shunt APF. Here we will discuss Shunt Active Power Filter (SAPF). Basic block diagram of SAPF is indicated below in fig 1. The generation of reference current for controlling SAPF is one of the key factors.

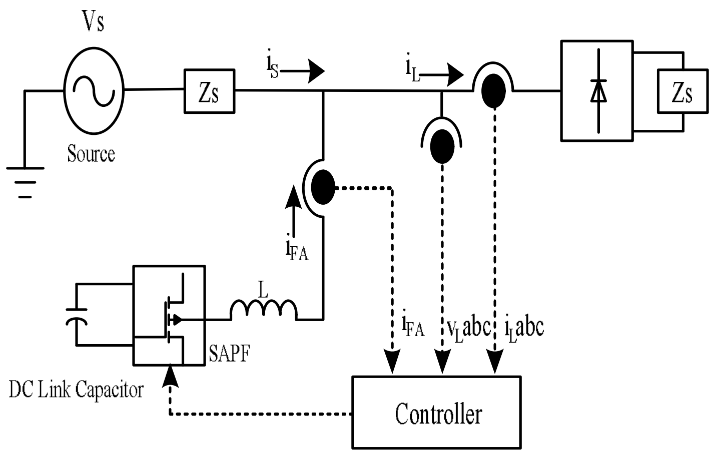

Fig1. Single line daigram of Shunt Active Power Filter

Here in this paper briefly explain reference current generation using IRP theory is discussed.

II. LITERATURE REVIEW

The performance improvement of active power filter can be achieved by various methods. In the present topologies following different method are involved namely scalar control, (Chandra etal., 2000), synchronous detection method, (medalek in 2003). Active power filter to be consider a more effective to improve technology of power semiconductor device. Further the concept of active power filter was firstly establish L. Gyugui. in 1970s. Control technique for active power fiter (APF) is described as three mode, supply current detection, load current detection, voltage detection. This control technique firstly developed by H.Akagi [3], provide effective solution to improve power quality. Conventional PI controller and flux controller, (Bhattacharya et. al., 1996). Find the application of power controller for active filter by chen & joos in 2008s. In the late 1984s, H. Akagi et. al. [3], was introduced new approach for active and reactive power theory also known as instantaneous reactive power theory which is used to compensate the signal [8]. The newly applied method in Active filter is On-off controller, Neural network controller, Fuzzy logic controller. The first neural network model is designed by McCulloch and Pitts (1943). In [9] a new learning algorithm for linear neural networks (ADALINE) Widrow & Hoff (1960). In [4] Adaline based control method is presented and it is compared against traditional PID controller based approach. With the use of this artificial neural network algorithm, the functionality of the shunt active filter is enhanced.

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III. CONTROL TECHNIQUE

The control methodology of APF for effective solution to mitigate the harmonics. In this paper we will discuss the method of instantaneous reactive power for controlling SAPF. The instantaneous real and imaginary power theory, also known as “p-q Theory”. p-q theory explain in terms of α-β-0 transformation or namely Clarke transformation . This p-q theory described for convert three phase voltage and line current into α-β-0 coordinate which is corresponding to reference frame. In this p-q theory zero sequence component are present. This zero sequence component can be easily eliminate from the system, which is one of the most advantage in α-β-0 transformation. Clark transformation and its inverse transformation α-β as used to obtain instantaneous real and imaginary power in terms of three phase voltage and line current. But it consists of harmonic or oscillating and non ac or dc component are present. High pass filter it used to reduce these oscillating component and compensating command signal are evaluated by taking inverse α-β in terms of either voltage or current.

The block diagram of purposed method to the reference current generation is shown in fig 3. In this method reference current is generated from the active reactive power of the non-linear load. APF uses the IGBT fired circuit to cancel current harmonic and improve the power factor. This current harmonic eliminated by active filter to inject the main supply due to nonlinear load. This control technique power is to be transformed. Average power also evaluate. For Reference current generation, active power and reactive power evaluated in terms of voltage and current. PID controller of inverter to obtain voltage reference signal. Then finally these signal compared with source current to produce the reference current. This reference current is fed to the current control circuit to generate the signal for PWM. Simply these PWM signals are fed to the inverter for harmonic reduction.

For measurement of 3 phase voltage and current to hysteresis band comparison of line current and current reference are used. For generation of six switching pulses compensating current and reference current are compare by using hysteresis comparator. The problem taken for this paper contains nonlinear current harmonic with large reactive power requirement therefore three phase SAPF used for reactive power compensation. For mathematical calculation 3-phase voltage and current are expressed in instantaneous space vector and excluding zero phase sequence component are consider. Here, instantaneous phase voltage and line current convert the a-b-c coordinate to α-β coordinate which is corresponding to stationary axes. These coordinate of a, b and c axes are displaced by 2π/3 radian from each other while α-β axes are orthogonal. In proposed technique, 3-phase current signals and voltage signals are transformed into αβ0 using p-q theory. Connection diagram of proposed technique is shown in fig 2 below. Using instantaneous reactive power theory generation of reference current is achieved. These currents so generated are used for generating gate signals for IGBTs in inverter. The transformation used in the IRP theory is shown in fig.3.

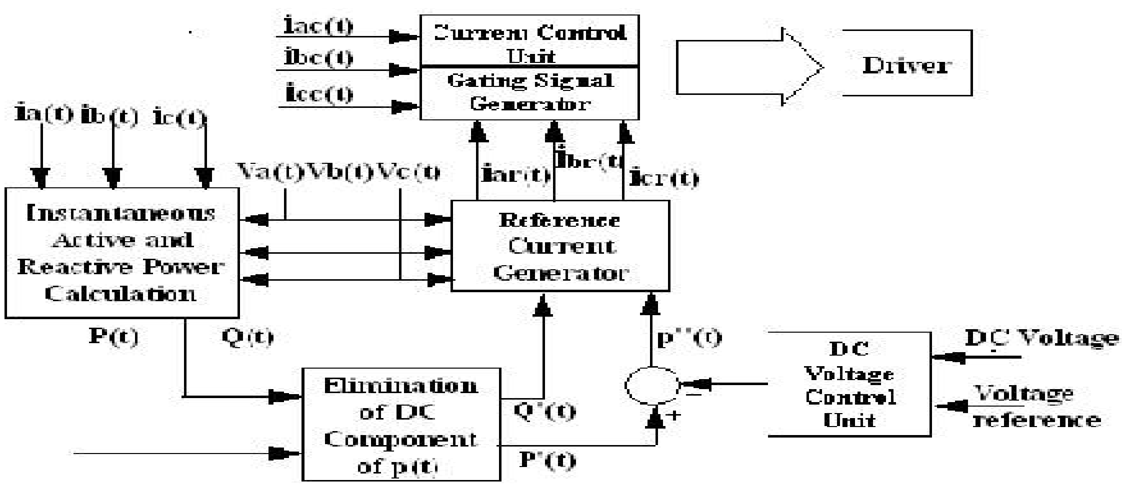

Fig 2. Control block diagramof SAPF

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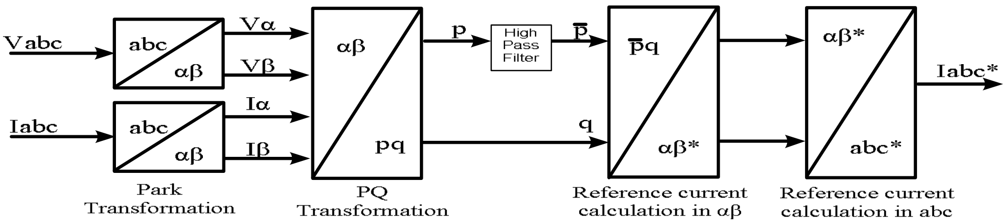

Fig 3. Block diagram for Reference current generation

These signals are used widely to generate compensating signals. This method is termed as Clark's Transformation for 3Φvoltage & currents [5].

In this transformation we generally transform 3Φ signals of current & voltage into α-β-0 stationary reference frame. Following equations are used to transform 3Φ signals into α-β form [2],

$$i\alpha\beta = \sqrt{2/3}\begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} iabc \tag{1}$$

$$V\alpha\beta = \sqrt{2/3}\begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} .Vabc \tag{2}$$

Equations 3 & 4 will give active power & reactive power as follows,

$$p = v\alpha \cdot i\alpha + v\beta \cdot i\beta \tag{3}$$

$$q = v\alpha \cdot i\beta - i\alpha \cdot v\beta \tag{4}$$

If we arrange above equations in matrix form, it will look like equation 5

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} V\alpha & V\beta \\ -V\beta & V\alpha \end{bmatrix} \cdot \begin{bmatrix} i\alpha \\ i\beta \end{bmatrix} \tag{5}$$

Equation 5 gives us Active power & reactive power which has AC component & DC component, these are given by equations 6 & 7

$$P = \bar{p} + \tilde{p} \tag{6}$$

$$q = \bar{q} + \tilde{q} \tag{7}$$

Further low pass filter is used to filter out high frequency components of active power & reactive power.

The IRP theory states that, 'P' is given by DC part of α-β reference current, which is stated in equation 8

$$i\alpha\beta^* = \frac{1}{V\alpha^2 + V\beta^2}\begin{bmatrix} V\alpha & V\beta \\ -V\beta & V\alpha \end{bmatrix}\begin{bmatrix} p \\ q \end{bmatrix} \tag{8}$$

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The 3Φ reference currents which are required are given by following equation 9

$$iabc^* = \sqrt{2/3}\begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \cdot i\alpha\beta^* \quad (9)$$

source current and these current compare to obtain the error. This error given to PI for generating final current this current is known as reference current for active power filter.

IV. SWITCHING SIGNAL GENERATION

There are different techniques for switching signal generation for controlling shunt active power filters based on current controller or voltage controller. Hysteresis comparator to generate the six switching pulses by comparing compensating current with reference current. These pulses are used to turn on and turn off IGBTs. Figure 4 shows the simulation models for Switching Signal Generation Technique.

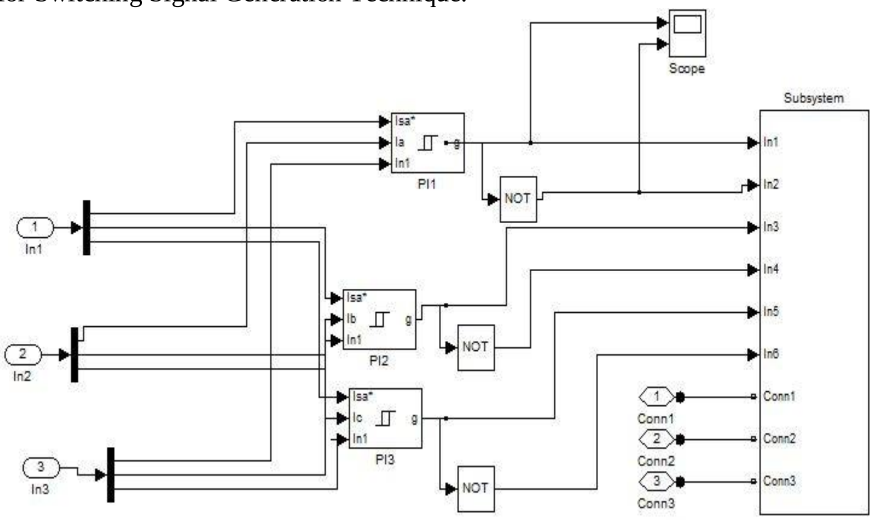

Fig 4. MATLAB model Hysteresis Current Controller

V. SIMULATION RESULTS

The MATLAB environment is used to simulate proposed technique. Nonlinear load draws non sinusoidal current in terms harmonic with the large value of reactive power requirement. In this simulation, VSI-based shunt AF is used to reduce reactive power and harmonics elimination. MATLAB model of shunt active power filter and also describe the IRP theory given in fig 5.

Simulation diagram for shunt active power filter is given in fig 5.It is connected through 400 V phase to phase voltages. A load side is nonlinear one having R-L-C components in it which will create harmonics in source current. Shunt active power filter is connected at PCC through coupling transformer. Inputs to reference current generation are source voltage, source current and output of PI controller. It is closed loop system where feedback is given through PI controller. Reference currents are generated using P-Q theory block as shown in figure 5. These generated reference currents will be given to the hysteresis current controller shown in figure 4 to generate PWM pulses. These generated pulses will be used to trigger inverter switches. In hysteresis current controller (HCC) three inputs are there like source current, reference current and one feedback signal. From HCC six signals will be given to the six switches of inverter.

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Further inverter will give 3 filter currents. These filter currents will be injected in the system through coupling inductor at point of common coupling (PCC). 3Φ balanced nonlinear load is used for simulation, the results so obtained are explained as follows,

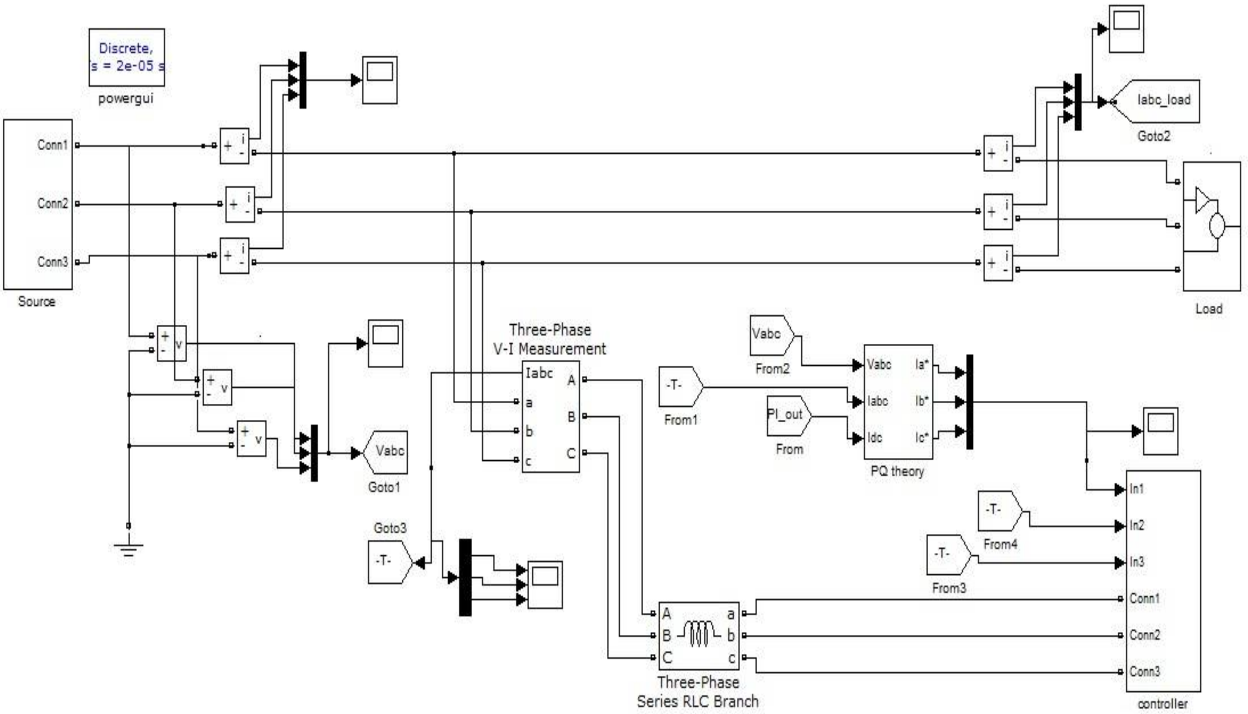

Fig 5. MATLABmodel of SAPF with IRP theory

3Φ source voltages are shown in fig.6 below

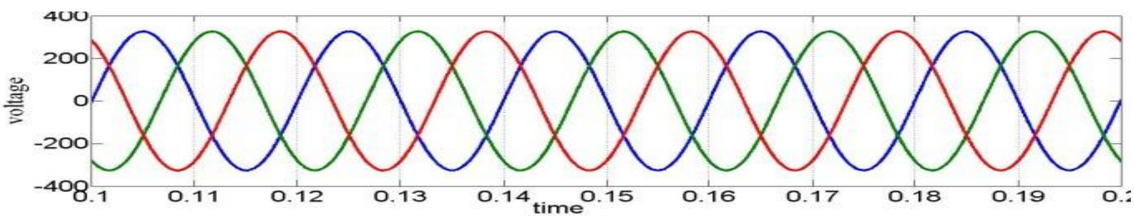

Fig 6. Three phase Source voltages

Fig 7 & fig 8 gives us the source currents before connecting SAPF and after connecting the same.

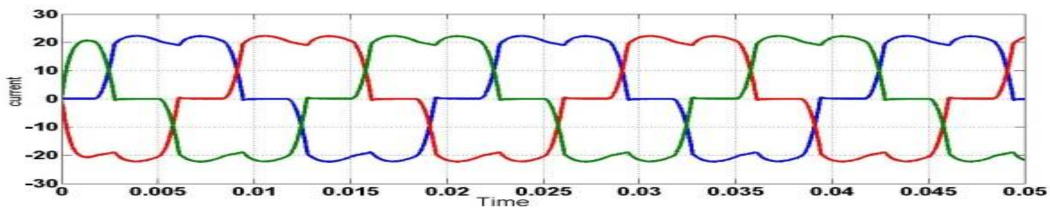

Fig 7. Earlier Source currents without compensation

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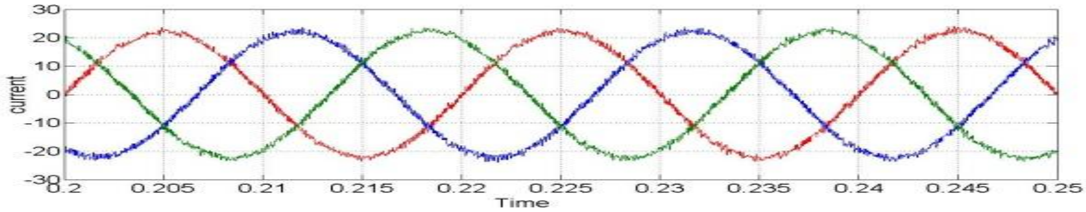

Fig 8. Compensated Source current signlas

Table: comparison of results before and after compensation

Power quality Issues	Before compensation	After compensation
THD	25.09	2.91

The results are analyzed considering %THD. In IRP theory the %THD is reduce from 25.09% to 2.91%. Beside IRP, other methods have been proposed in literature for reference current generation in SAPF such as Preductive Fiteration (PF) and Self Tuning Filter (STF) methode. The reference current tracking capabilities of inner current control loop is of vital importance in SAPF, as it can introduce delays and degrade performance. Out of above three methods namely IRP, PF and STF, the IRP methode provides a simple and most accurate current tracking ability technique[11].

The three phase load current is shown in fig 9 and filter currents which are used to compensate harmonics are shown in fig 10 below.

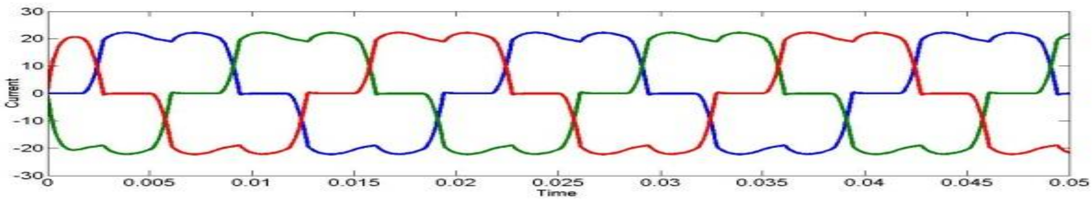

Fig 9. Wave from of Three phase load Current

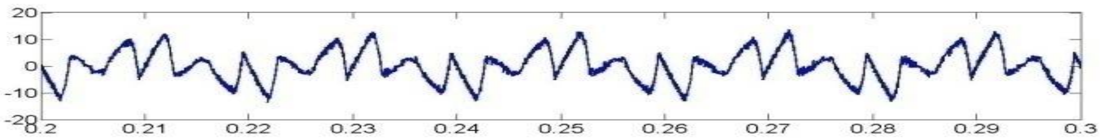

Fig 10. Active filter current

The total harmonic distortionwhich is 2.91% is shown in fig 11

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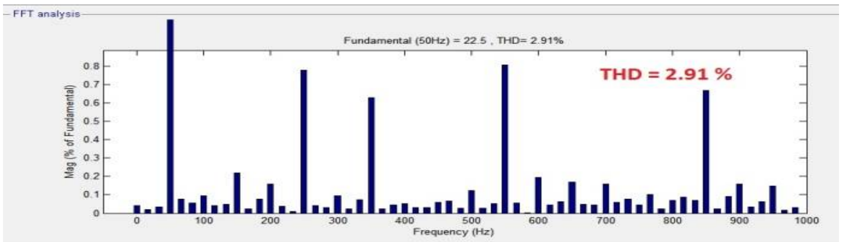

Fig 11. FFT analysis result of THD.

VI. CONCLUSION

Reference current generation is very important factor to control shunt active power filter. Gate signals are generated using the reference currents. Shunt active power filter reduces harmonics to acceptable limit as per IEEE. The THD of system is found 2.91%. There by Shunt active power filter improves power quality of the system. IRP theory can easily implemented and it has very less mathematical calculations making very effective to give efficient solution to control SAPF.

REFERENCES

[1] H. Akagi, E. H. Watanabe, M. Aredes "Instantaneous power theory and application to power conditioning" *IEEE Press, 2007*.

[2] Musa Yusup Lada, Ismadi Bugis, MdHairuNizamTalib, "Simulation a Shunt Active Power Filter using MATLAB/Simulink" , *The 4th International Power Engineering and Optimization Conf.* (PEOCO2010), Shah Alam, Selangor, MALAYSIA: 23-24, June 2010.

[3] H. Akagi, Y.Kanazawa, A. Nabae, "Generalized theory of the Instantaneous Reactive Power in three phase circuits", *International Power Electronic Conference*, *Tokyo,Japan*,pp.1375-1386, 1983

[4] P.K. Lim, D.S. Dorr, "Understanding and resolving voltage sag related problems for sensitive industrial customers", IEEE transactions on Power Quality, vol. 4, no. 12, 2000.

[5] M. A. Farahat , A. Zobah ," ACTIVE FILTER FOR POWER QUALITY IMPROVEMENT BYARTIFICIAL NEURAL NETWORKS TECHNIQUE" Zagazig University, Zagazig ~ Egypt.

[6] Bhim Singh and Jitendra Solanki," A Comparison of Control Algorithms for DSTATCOM*" IEEE transactions on industrial electronics, vol. 56, no. 7, july 2009*.

[7] Bhim Singh ,Jitendra Solanki," An Implementation of an Adaptive Control Algorithm for a Three-Phase Shunt Active Filter" *IEEE transactions on industrial electronics, vol. 56, no. 8, august 2009*

.[8] G.W. Chang,"A new method for determining reference compensating currents of the three-phase shunt active power filter*" IEEETransactionson Power Engineering Review,* vol. 21, no. 3, 2001.

[9] J. K. Phipps, J. P. Nelson, P. K. Sen, "Power Quality and Harmonic Distortion on Distribution Systems," *IEEE Transactions on Industry Applications,* vo1.30, no.2, pp.476484,1994.

[10]H. Akagi, Y. Nabae, "The p-q theory in three-phase systems under non-sinusoidal conditions," Europ. Trans. on Electric Power, ETEP, Vol. 3, No. 1, Jan./Feb. 1993, pp. 27-31.current generation technique

[11] Satish.U.Bhopale, satosh kumar rayarao "Comparison Of Various Reference Current Generation Techniques For Performance Analysis Of Shunt Active Power Filter Using a MATLAB simulation," International Journal Of Current Engineering and Technology, Vol.6, No.2,2016.