International Journal of Scientific Engineering and Research (IJSER)
www.ijser.in
ISSN (Online): 2347-3878
Volume 1 Issue 3, November 2013

Harmonic Compensation Using Shunt Active Power Filter in Power System Using Matlab

Neha Kumari[1], **Isha Awashthi**[2]

[1, 2] IEC College of Engineering and Technology, Greater Noida, Uttar Pradesh, India

Abstract: ***This paper shows the method of improving the power quality using voltage source inverter based shunt active power filter. The procedure uses a simple method named synchronous reference current generation for reference current extraction .The proposed topic comprises of PI controller, high pass filter, phase locked loop, dc link capacitor. The switching signal generation for filter is from hysteresis current controller techniques. With the all these element shunt active power filter reduce the total harmonic distortion. This paper represents the simulation and analysis of the using three phase three wire system active filter to compensate harmonics .The proposed shunt active filter model uses balanced non-linear load. This paper successfully lowers the THD within IEEE norms and satisfactorily works to compensate harmonics. The model is made in MATLAB / SIMULINK and successfully reduces the harmonic in the source current.***

Keywords: shunt active power filter, passive filter, synchronous reference frame technology, total harmonic distortion, pi controller, hysteresis band current controller

1. Introduction

With the development in technology there has been drastic increase in the use of power electronic equipments resulting in the increase of harmonics in source current or ac mains current. Due to intensive use of power converters, various non linear loads and increasing use of office equipments like computers ,faxes ,printers are reasons for the increasing harmonics and as a result deterioration if sources current and source voltage. These harmonics causes very serious damage in the powers system. It causes problems like resonance; overheating of neutral wire, low power factor, damaging microprocessor based equipment. Conventionally, L-C passive filters were used to solve the problem of harmonics to filter out current harmonics to get sinusoidal supply current .Passive filters can be classified as single tune filter and high pass filter But the usage of passive filter lead few problems.

Disadvantages of passive filters are:

a) It results in resonance with the source impedance.
b) It gives fixed compensation.
c) It has large configuration size.

In order to overcome the problems of passive filters, active filters were developed and used to solve the problem of harmonics. In the recent years the technology of the active filter has improved a lot thereby giving very good results to reduce the problem of harmonics.

Development and improvement in the power semiconductor devices improved the active filters a lot. Active filters solve the problem of harmonic in industrial area as well as utility power distribution. The active power filter working performance is totally based on the techniques used for the generation of reference current. Now a days with the development various technologies results the lowering of harmonics below 5% as specifies by IEEE. The most efficient ways of generating reference current are p-q theory, synchronous reference current theory (SRF method). In this paper SRF method has been used. There are many current control technologies for active power filter, but the hysteresis current controller is proved to be very efficient in terms of fast current controllability and it also very easy to apply when compared to other method like sinusoidal PWM

Harmonics can be detected in two main forms firstly in time domain and secondly in the frequency domain methods. In this paper Fast Fourier Transform (FFT) is used to find harmonics in frequency domain. Other frequency domain techniques are discrete Fourier transform (DFT); recursive discrete Fourier transform (RDFT).The main target is to reduce THD of supply current with the help of hysteresis band current controller. There are two type of hysteresis current controller namely, adaptive hysteresis current controller and fixed band current controller. This paper deals with the use of fixed band hysteresis current controller. The model of shunt active power filter using hysteresis current controller has been used in matlab/simulink. Results have been successfully retrieved from model and followed by conclusion.

2. Shunt Active Power Filter

It a device used in parallel. It compensates the current harmonics and also helps in reactive power compensation there but improving the power factor, increasing efficiency, reduces the losses caused by the harmonics. As a result the total current drawn from the AC mains gets sinusoidal, thereby reducing to great extend.

2.1 Basic Working Principle

A current controlled voltage source inverter (VSI) is used to generate the compensating current. Shunt active power filter work in such a way it compensate current harmonics by

International Journal of Scientific Engineering and Research (IJSER)
www.ijser.in
ISSN (Online): 2347-3878
Volume 1 Issue 3, November 2013

supply equal but opposite harmonic compensating current. This cancels out the harmonics components drawn by the non linear current and keep the supply current sinusoidal. As a result this reduces which is the target of our paper. The figure 1 shows the block diagram of active power filters.

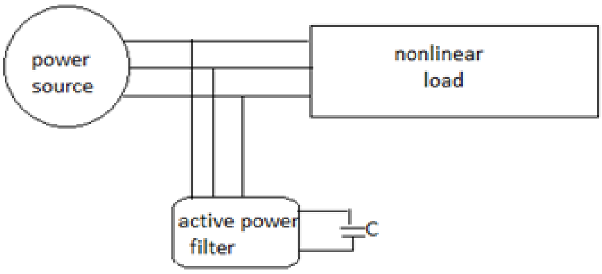

Figure 1: Block diagram of active power filters

2.2 Components of Shunt Active Filter

Dc Link Capacitor

It has two main functions

It keeps the a constant DC voltage

It is storage device to provide real power difference between load and source during transient.

PI Controller

Discrete pi controller is used. it takes the reference voltage and the actual voltage and the output it gives is the maximum value of the reference current depending on the error got from the reference and the actual values. It eliminates the steady state error DC component.

3. Synchronous Reference Frame Theory

This method of reference current generation is developed in time domain based reference current generation. This theory is extensively used as it simplicity of the calculations, and uses only algebraic calculation.

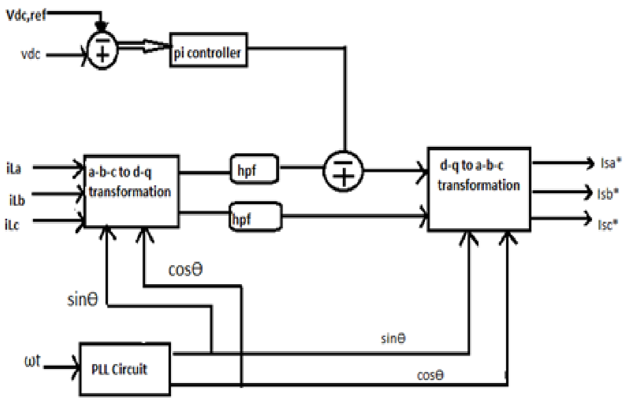

Figure 2

The three phase load current (iLa, iLb, and iLc) are transformed into the two instantaneous active (id) and reactive (iq) components in a rotating frame synchronous with the positive sequence of the system voltage. It can be represented by the set of equations. The basic working principle of SRF methods uses a direct (d-q) and inverse (d-q)-1 park transformation method, which allow the evaluation of a specific harmonic component of the input signals.

The reference frame transformation is evaluated by converting a three-phase $a - b - c$ stationery system to the two- phase direct axis (d) – quadratic axis (q) component rotating coordinate system. These three (a-b-c) phase space vectors stationary coordinates are easily transformed into two axis d-q rotating reference frame.

$$id=\frac{2}{3}\left[iLa \sin(\omega t)\ i+Lb \sin(\omega t-\frac{2\pi}{3})+iLc\sin(\omega t+\frac{2\pi}{3})\right] \quad (1)$$

$$iq=\frac{2}{3}\left[iLa \cos(\omega t)+iLb \cos(\omega t-\frac{2\pi}{3})\ +iLc\cos(\omega t+\frac{2\pi}{3})\right] (2)$$

The output of the transformation depends on the load currents (fundamental and harmonic frequency components) and on phase locked loop. The PLL circuit of rotation speed (rad/sec) of the rotating reference frame ωt set as fundamental frequency component. The PLL circuit is providing sinϴ and cosϴ for synchronization.

High pass filter is been used .it is used to extract out the dc component representing the fundamental frequency of current. Discrete high pass filter is used to remove the dc component of load side current. The band edge frequency of the high pass filter is selected as 50 Hz for eliminate the higher order harmonic components. The iLq current component is applied to inverse transformation is used to compensate the reactive power. iL0 must be used when the supply voltages are distorted or unbalanced[1]. The dc side capacitor voltage of active power filter kept constant and controlled so as to keep the normal working of the active power filter. When the diodes and rectifier of the active filter conducts there is always loss of energy due to conduction. Therefore a feedback voltage control circuit has been used to overcome the effect of losses.

Pi controller output is then subtracted from the direct axis(d axis) values of the harmonic current component. The value pi gain is, for kp 0.025=,ki=0.01.The method is further developed to get the desired reference current in d-q rotating frame is converted back into $a - b - c$ stationery frame. This ways reference current can be generated in a very easy method. The inverse transformation from $d - q$ rotating frame to $a - b - c$ stationery frame is achieved by the following equation.

Reference frame is rotates synchronous with fundamental currents. Therefore, time variant currents with fundamental frequencies will be constant after transformation procedure. As a result of this, currents would be separated to DC and AC components. AC components of d-axis and in q-axis current are used for harmonics elimination and reactive power compensation. Reference current signal can be represented by following equations:

$$Isa^* = id \sin(\omega t) + iq\ \cos \omega t$$

$$Isb^* = id \sin(\omega t\text{-}\frac{2\pi}{3}) + iq \cos (\omega t\ \text{-}\frac{2\pi}{3})$$

$$Isc^* = id \sin(\omega t\text{+}\frac{2\pi}{3})\ +iq \cos(\omega t\text{+}\frac{2\pi}{3})$$

4. Hysteresis Current Controller

Among all current control techniques, the hysteresis current controller is extensively used because of its simplicity of implementation and fast response current loop. In this technique there does not need any knowledge of load parameters. It has also the disadvantage that is the variation of switching frequency during load parameter variation of fundamental period [2]. The working of the hysteresis current controller is represented by the figure 3 below:

In working techniques the measured load currents are compared with the references using hysteresis comparators. Each comparator determines the switching state of the corresponding inverter leg (Sa, Sb and Sc) such that the load currents are forced to remain within the hysteresis band. Hysteresis controller can be of two types based on the band, fixed band and sinusoidal band hysteresis current controller. Fixed band current controller is considered in this paper.

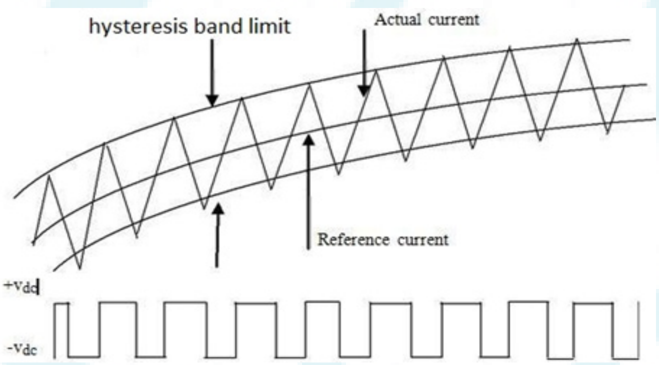

Figure 3: Working of the hysteresis current controller

As the name represents fixed band current controller the hysteresis band is fixed over the fundamental period. It can also be represented mathematically as,

iref = Imax sin(ωt)
iup = iref+H
ilo = iref-H

Where iup represents the upper band, ilo represents the lower band, and H is the given hysteresis band limit. S1, S2, S3, S4, S5, S6 are the switches of inverter circuit. The switching states of the active filter are determined by the gating signals Sa, Sb and Sc as evaluated as

Sa can take either of two value

1	If S1 is on and S4 is off
0	If S1 is off and S4 is on

Sb can take either of two values

1	If S2 is on and S5 is off
0	If S2 is off and S5 is on

Sc can take two values

1	If S3 is on and S6 is off
0	If S3 is off and S6 is on

and vectorally can be expressed a

$$S = \frac{2}{3}(Sa+Sb+Sc)$$

There can be two possibilities that decide the switching pattern of active filter. In one of the case if ia>iup, then S=0, which means that inverter output is negative in order to reduce line current. Secondly if ia<ilo, then S=1, where the inverter voltage is positive, in order to increase the load current.

5. Simulation results

5.1 Without Filters

The balanced supply system is present and feeder id stiff. The total harmonic distortion is very high which 30.79% is to reduce the THD passive filters were used. Simulink model is represented by the figure 4. The spectrum analysis of the supply current is given in the figure5.

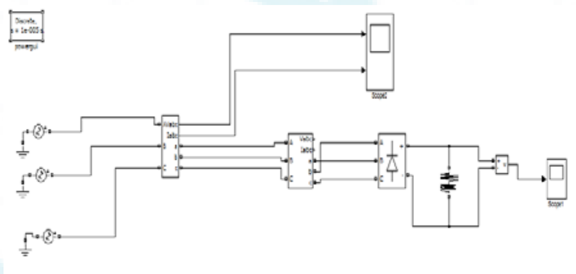

Figure 4: Simulink Model

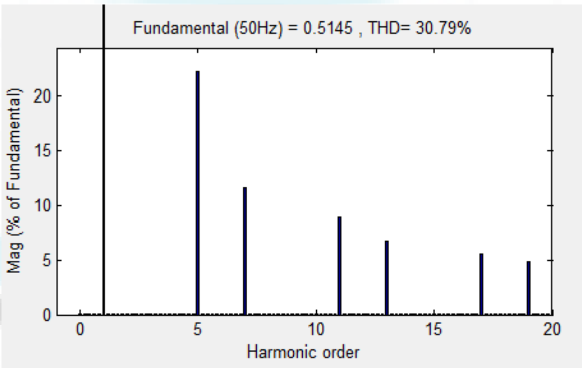

Figure 5: Spectrum analysis of the supply current

5.2 Simulation for passive filter

Traditionally, passive filters were used to migitate harmonics. The diagram consists of stiff sources, on-linear and passive filter. This is represented by the following figure 6. The spectrum analysis is represented by the figure 7.

International Journal of Scientific Engineering and Research (IJSER)
www.ijser.in
ISSN (Online): 2347-3878
Volume 1 Issue 3, November 2013

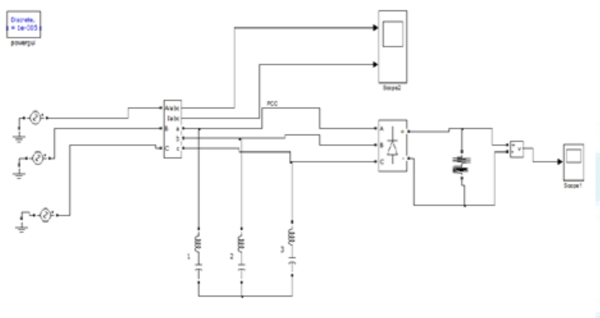

Figure 6: Stiff Sources, On-Linear and Passive Filter

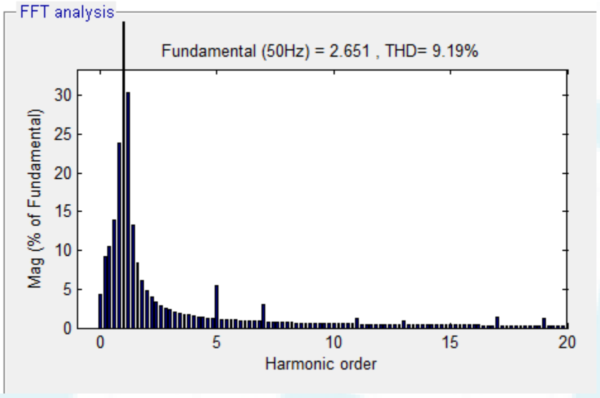

Figure 7: Spectrum Analysis

5.3 Simulation of Shunt Active Filter

With the usage of passive filters the total harmonic distortion is still very high. Therefore active power filters were used to improve THD and this make the supply current more sinusoidal. The system consists of shunt active power filter, balanced supply system, nonlinear load. It is shown by the figure 9 below;

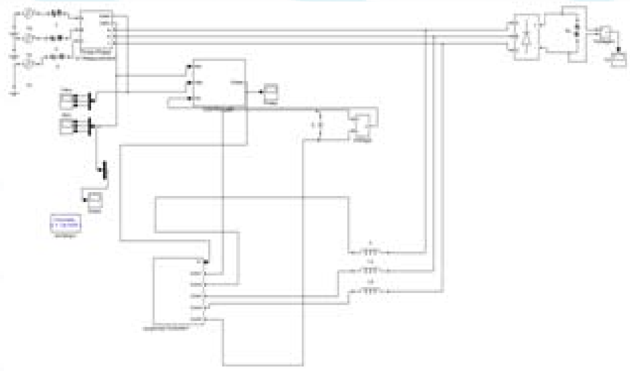

Figure 8

The spectrum analysis shows the spectrum analysis of supply current after compensation. The Total Harmonic Distortion of the supply current is reduced to 9.91% from 1.42%

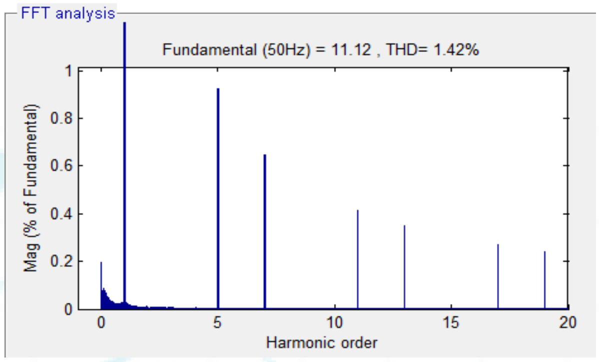

Figure 9

6. Components Used in the Simulation Model

Balanced three phase three wire system with supply voltage 230 v. Balanced Non-linear load used containing one three-phase uncontrolled diode rectifier supplying a RL load.

6.1 The values of parameters are as shown

Load	R= 5, L=10mh
Impedance	R=0.01 L=0.01µh
Passive Power Filter	L=15.17mh C=625µh
Active Power Filter	L=0.4mh
VDC	2000µh

7. Conclusion

A comparative study of Passive power Filter and Shunt Active Power Filter are used. When no filter filters were used the total harmonic distortion (THD) was very high 30.79%. Harmonics distortion can be reduced by using passive filters and when passive filter were used THD reduce to 9.19% but according to IEEE standard THD should be below 5%, therefore, using passive filters passive does not meet the requirement by IEEE. Therefore active filters were used. On using shunt active filter reduced to 1.42%. Hence it proved that by using active power filter for three phase three wire system is giving better results and supply current is more sinusoidal and less of harmonics.

8. Future Scope

Experimental investigations can be done on shunt active power filter by developing a prototype model in the laboratory to verify the simulation results for both P-I and hysteresis controllers.

Reference

[1] International Journal of Scientific and Research Publications, Volume 3, Issue 6, June 2013 1 ISSN 2250-3153

[2] VSRD International Journal of Electrical, Electronics & Communication Engineering, Vol. 2 No. 10 October 2012

[3] VSRD International Journal of Electrical, Electronics & Communication Engineering, Vol. 2 No. 10 October 2012

[4] 2009 American Control Conference Hyatt Regency Riverfront, St. Louis, MO, USA June 10-12, 2009
[5] International Journal of Computer Applications (0975 – 8887) Volume 4 – No.3, July 2010
[6] ISBN 978-952-5726-00-8, 978-952-5726-01-5 (CD-ROM) Proceedings of the 2009 International Symposium on Web Information Systems & Applications (WISA'09) Nanchang, P. R. China, May 22-24, 2009, pp. 100-103.

Author Profile

Neha was born in 1987. She is pursuing her final M. Tech in the field of Electrical Power System under the supervision of Professor Miss Isha Awasthi. She completed B. Tech in 2010 Her point of interest is in the field of improving power quality and current pursuing research in that improving power quality.

Isha Awasthi is Assistant Professor in IEC College of Engineering and Technology. She completed her M. Tech in 2012 from the branch Electrical Power System. Her research field is protection of transmission line by line using artificial neural network.