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Harmonic Compensation using Shunt Active Power Filter in Power System using MATLAB

Neha Kumari[1], Isha Awashthi[2]

[1]IEC College of Engineering and Technology, India

[2]Assistant professor, IEC College of Engineering and Technology, India

Abstract: ***With the increased use of non linear load, the power quality is degrading. Thus, it is important to invent such methods and devices which will improve the power quality. Shunt active power filter is one such device. Shunt active power filter improve power quality very efficiently. The paper uses pi controller , hysteresis controller low pass filter, dc link capacitor .The controller for the generating reference current is unity template theory, this theory is very easy to implement and does not make use of heavy mathematical equations. The shunt active filter is placed in parallel to loads . Three phase three wire system is used. Mat lab/ Simulink method is used to show result. The target of paper is to reduce total harmonic distortion in the source current. This paper successfully lowers the THD within IEEE norms and satisfactorily works to compensate harmonic.***

Keywords: shunt active power filter, unity template method, pi controller, reference current generator, 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 damages devices in the powers system such as problems like resonance, overheating of neutral wire, low power factor, damaging microprocessor based equipment. Traditionally , L-C passive filters were used to solve the problem of harmonics to filter out current harmonics to get sinusoidal supply current . Drawbacks of passive filters are, it results in resonance with the source impedance. It gives fixed compensation, it have large configuration size. So to reduce the disadvantage s of the passive filters, active filters were introduced in the power system. Active filters are of three types;

- Shunt active power filter
- Series active power filter
- Hybrid filter

Drastic increase in the power semiconductor devices improved the active filters efficiency a lot. An active filter solves the problem of harmonic in industrial as well as in the commercial area. Target of this paper is to reduce total harmonic distortion (thd) below 5% as specifies by IEEE norms. This method depend on generation of the reference current .Current controller are also very important part of the procedure. Few of the very important method for generating gating pulse to feed the shunt active power filter finally are known as current controller.

- Hysteresis current controller method.
- Periodical sampling control
- Triangular carrier control
- Vector space control.

The paper makes use of Fourier transform (fft) analysis for evaluation of harmonics. Harmonics can be evaluated in two main forms firstly in time domain and secondly in the frequency domain methods. Other methods through which thd can be calculated. Other frequency domain techniques are;

- Discrete Fourier Transform (DFT) ,
- Recursive Discrete Fourier Transform(RDFT)

2. Shunt Active Power Filter

These devices are current controlled voltage source connected in parallel. It compensates the current harmonics and also helps in reactive power compensation and improves the power factor, increasing efficiency as result limits the losses caused by the harmonics. As a result the, the total current drawn from the AC mains gets sinusoidal. As a result harmonics get compensated.

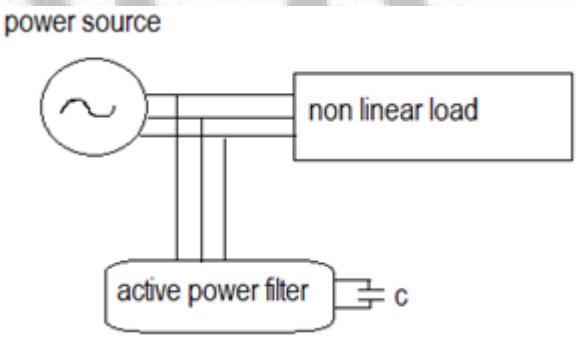

Figure 1: Connection of Shunt Active Power Filter

3. Compensation Principle

A current controlled voltage source inverter (VSI) is used to generate the compensating current. Shunt active power filter performs its function in such manner that it compensates current harmonics by supply equal but opposite harmonic compensating current. This cancels out the harmonics components drawn by the non linear current and keep the source current sinusoidal. As a result the thd reduces below the standards of IEEE which is the target of our paper.

3.1 DC Link Capacitor

The dc link capacitor is the important component of the topology. It performs very important functions like;

- It keeps the a constant DC voltage
- It is storage device to provide real power difference between load and source during transient.

3.2 Pi Controller

Discrete pi controller is used in the paper. The input to the pi controller is error of the reference voltage and the actual voltage. It eliminates the steady state error DC component. Input to pi controller = Vd ref – Vdc. The figure below shows the pi controller used [7].

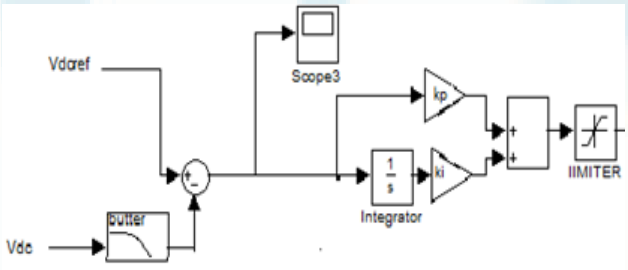

Figure 2: Working of pi Controller

4. Reference Current Generation

This is very important part of the working of the VSI based shunt active power filter. There are many methods available for the reference current generation. References current are generated through many methods like;

- Unity template method
- p-q theory
- Synchronous reference theory.

The paper is simulated using unity template method.

4.1 Unity Template Method

Unity template method is used in the present paper. This method is used as these methods have got very simple procedure when compared to other methods of reference current generation [5]. This method does not involve algebraic and other very hard mathematical calculations. The figure below shows the;

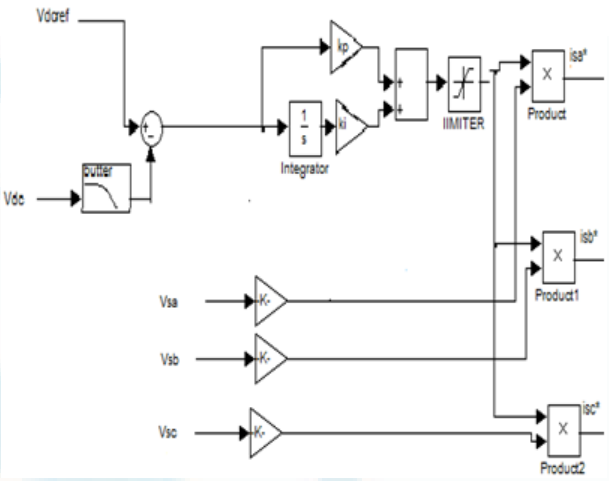

Figure 3: Unity Template Method

4.2 Synchronous Reference Frame Theory

This method is also used for the reference current generation. It is developed in time domain based reference current generation. This theory uses as it simple theory of and calculations, and uses only algebraic calculation. In this method 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 [1]. It can be represented by the set of equations

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

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

4.3 Hysteresis Current Controller

Among all current control method, the hysteresis current controller is used in the paper for, simplicity and easy implementation and fast response current loop. Along with these it has got added advantage that there is no need of 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 figure below is the diagram of the hysteresis current controller working.

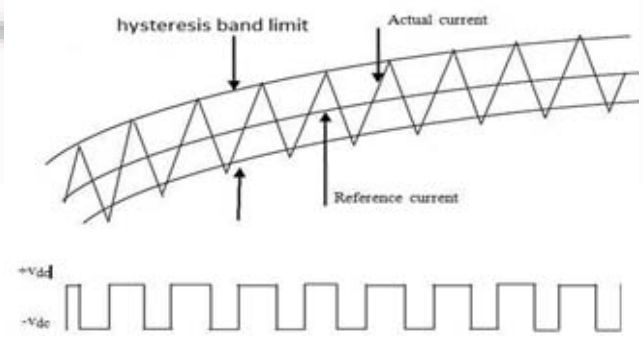

Figure 4: working of hysteresis current controller

The working procedure is that the measured load currents are compared with the references using hysteresis comparators. Let, each of the comparator determines the switching state of the corresponding inverter leg (Sa, Sb and Sc) such that the load currents are forced to be within the hysteresis band.

S1, S2, S3, S4, S5, S6 will be the switches of inverter circuit present in the VSI. The switching states of the shunt active filter are determined by the gating signals obtained which can be represented as Sa, Sb and Sc as evaluated as;

The gating signal Sa can take either of two value ether 0 or 1 and effects the switches in following way

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 either 0 or 1

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

Sc can take two values either 0 or 1

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

And vector ally can be expressed a

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

In fixed band current controller the hysteresis band is fixed over the fundamental period. H is the given hysteresis band limit. Mathematically is represented by equations below

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

Where,
iup = the upper band,
ilo =the lower band

The switching state is determine by the two

- 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 Result

The target of this paper is to compensate harmonics. The load used is non linear loads which produce harmonics current in excessive manner;

Case 1: when shunt active filter is not connected.
Case 2: when shunt active filter is connected.

Case 1: Simulation results when shunt active power filter is not connected .The source current is represented as by the waveforms if isa, isb, isc respectively. These waveform shows that the source current waveforms are highly distorted .The thd of the individual waveform is very high .The thd is calculated through the fft analysis. The thd of individual waveforms comes out to be 18.12%, 17.92%, 18.34% respectively for isa, isb, isc. From the waveform it can be seen that wave form of the source current are highly distorted. Thd is calculated from fft analysis and total harmonic distorted is very high.

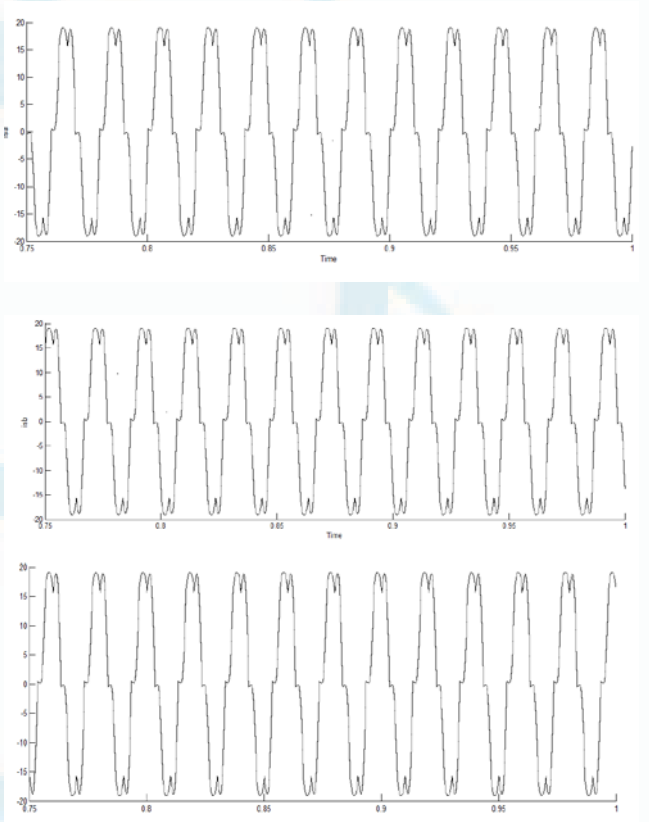

Figure 5: The three phase source current waveform before compensation

Case 2: when shunt active power filter is connected.

When the filter is connected to the power system, the thd of the source current isa, isb, isc decreases below the IEEE norms. The value of thd is calculated from fft analysis tool. The thd for the isa, isb, isc waveforms are 2.87%, 3.24%, 3.18%. Now in this waveform we see that the source current is more smooth and sinusoidal. Thus the power quality gets improved using shunt active power filter.

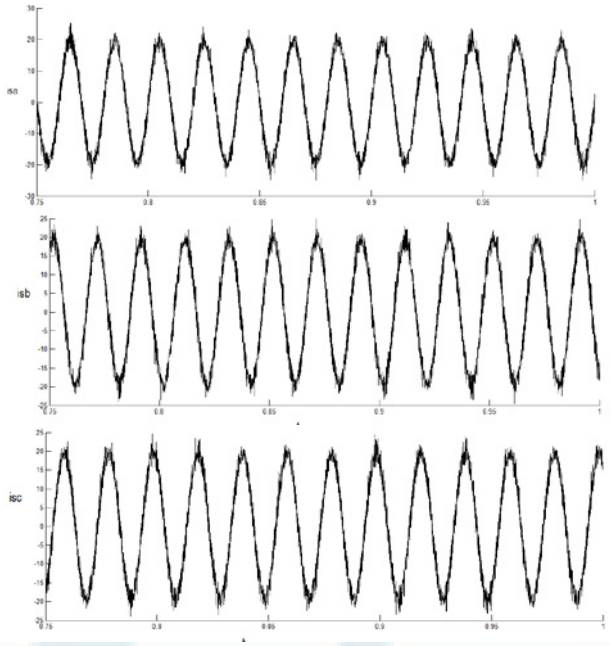

Figure 6: Waveform of three phase source current after compensation

6. Conclusion

Active power filters are modern day devices which are capable of compensating to a very large extend. Traditionally when passive filters where used, there were many problem associated with it. So, active filters were used excessively because of its inherent advantages. In the paper present, the two cases were analyzed through MAT LAB/Simulink model. Then after calculating thd in both cases the results showed that by using shunt active power filer compensates harmonics by reducing thd below the IEEE norms.

6. 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 and reference current can be generated using many methods available. Thus it can be developed more effective.

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