A Review on Improvement of Power Quality by Shunt Active Power Filter

Mr. Bhushan S. Rakhonde[1] Mr. Chetan M. Bobade[2]
[1]M.E. Student [2]Assistant Professor & Head of Department
[1,2]Department of Electrical Engineering
[1]G.H.R.C.E.M. Amravati, Maharashtra, India

Abstract— Over the recent years, power quality has been given attention due to the intensively use of power electronic Controlled applications i.e. nonlinear load. The use of nonlinear load increasing day by day because it consumes less power as well as give some other benefits. Although these power electronics equipments make our life convenient, they inject harmonics into power system. Therefore the problem of Power Quality became very serious issue. The harmonics generated by the most common non-linear loads effects on amplitude and nature of source current hence the performance of the system. To overcome the above problems, new technique has been developed which is dynamic and adjustable solution to power quality problems. Such equipment is called an active filter and is able to compensate current and voltage harmonics.

Key words: Power Quality, Shunt Active Power Filter

I. INTRODUCTION

When a nonlinear load such as rectifier is connected to the system, it draws a current that is not necessarily sinusoidal, this change in waveform occurs due to harmonics. Thus nonlinear load such as rectifiers, cyclo- converters, variable speed drives and arc furnaces, large decaying DC components, asymmetrical loads and other electrical equipment like television set, computer, fridge, CFL etc. can cause high disturbances on the power system. The following problems are caused by harmonics in the power system:

- Harmonics increases losses hence heat increase
- Harmonics causes interference with communication line
- Failure of Transformer occurs
- Capacitor bank failure occurs
- Parallel and series resonance
- RMS and peak value of current increases
- Excessive losses and heating of induction, synchronous machine and other electrical equipment
- Dielectric breakdown of insulated cables due to harmonic over voltages
- Tripping of Circuit Breaker
- Damage of sensitive electronic equipment
- Lower order harmonics tend to dominate amplitude
- Unstable and abnormal operation of protection and control system occurs
- Also some indirect effects of harmonics such as cost, quality, efficiency and productivity of system

Due to these all above problems, elimination of harmonics is important power quality issue. This problem of harmonics traditionally dealt with passive filters. However, passive filters have many drawbacks. Therefore, to compensate harmonics SAPF is developed which is dynamic and adjustable solution to power quality problems.

A. Significance of Study

As we know that the harmonics generated by nonlinear loads affects on amplitude and nature of source current hence the performance of system. Nonlinear loads cause high disturbances on power system. As explained in above point harmonics cause many problems like heat, losses, failure of electrical equipment and interference with communication system. So, elimination of harmonics is important issue and to solve this problem shunt active power filter (SAPF) came into action. Significance of SAPF can be understood as follows. Assume that load connected to system is drawing unbalanced harmonic current. In addition, the load power factor is poor. This will obviously lead to unbalance and distortion in other system quantities which is undesirable. Therefore, it important to install some corrective measures in system to solve above problem. It is well known that shunt capacitor is good solution for correcting poor power factor. Similarly tuned filter are also used with power electronic loads to bypass harmonic currents. The problem of load balancing also has to solve by some method. However, all these problems can be solved by single device which is called shunt active power factor (SAPF). Principle of SAPF is to inject current in the system which is equal and opposite in polarity to harmonic current. It has many advantages over passive filter like reactive power compensation, voltage regulation also SAPF is smaller, more versatile, more selective, better damped and less prone to failure. They are studied widely and great Developments have taken place in theory and application of active power filters. The performance of SAPF depends on control algorithm used for reference current generation which is then used as a reference for filter current. Finally, this filter current is used for compensation of harmonics. In this way, harmonic mitigation and improve power quality, voltage regulation, load current unbalance, power factor etc. of power system.

II. FILTERS

Presence of harmonics creates lots of problems for power system. We know the causes and effects of harmonics on power system. To overcome this harmonic problem passive filter is introduced.

A. Passive Filter

Passive filters have been most commonly used to limit the flow of harmonics currents in distribution system. They are usually custom designed for application. However, their performance is limited to a few harmonics and they can introduce resonance in the power system.

Passive filters use reactive storage components, namely capacitors and inductors and they do not rely upon any type of external power source. In addition, they are not going to rely on transistors or any other type of active components for working. The inductors will block high frequency signals and conduct low frequency signals. The capacitors are going to do just the opposites. By tuning these elements passive filters are designed to shunt harmonics from the lines or block their flow through some parts of system. They have some advantages such as simplicity, reliability, efficiency, and cost. These filters are tuned and fixed according to the impedance of the point at which they will be connected and hence cannot be adjusted instantaneously in accordance to the load. As a result their cutoff frequency changes unexpectedly after any change in the load impedance resulting in producing a resonance with other elements installed in the system. Other drawbacks are interference with communication system, they are heavy and bulky, overloaded when the load harmonics increase. These all drawbacks are overcome with the use of active power filters.

Advantages of passive filter are

– Simple
– Reliable
– Cost effective alternative.

Disadvantages of passive filter are

– It may cause series and load resonance
– It gets overloaded when the load harmonics increase
– They are heavy and bulky.
– Their performance gets affected significantly due to variation in the filter component values, filter component tolerance, source impedance, and frequency of AC supply.

B. Active Filter

There are basically two types of active filters: the shunt type and the series type. Shunt active power filter is able to compensate for both current harmonics and power factor. Furthermore, it allows load balancing, eliminating the current in the neutral wire. Series active power filter is the dual of the shunt active filter, and is able to compensate for distortion in the power line voltages, making the voltages applied to the load sinusoidal (compensating for voltage harmonics). Depending on the particular application or electrical problem to be solved, active power filters can be implemented as shunt type, series type, or a combination of shunt and series active filters (shunt-series type). These filters can also be combined with passive filters to create hybrid power filters.

The shunt-connected active power filter, with a self-controlled dc bus, has a topology similar to that of a static compensator (STATCOM) used for reactive power compensation in power transmission systems. Shunt active power filters compensate load current harmonics by injecting equal-but opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase-shifted by 180°.

Series active power filters were introduced by the end of the 1980s and operate mainly as a voltage regulator and as a harmonic isolator between the nonlinear load and the utility system. The series-connected filter protects the consumer from an inadequate supply voltage quality. This type of approach is especially recommended for compensation of voltage unbalances and voltage sags from the ac supply and for low-power applications and represents an economically attractive alternative to UPS, since no energy storage (battery) is necessary and the overall rating of the components is smaller. The series active filter injects a voltage component in series with the supply voltage and therefore can be regarded as a controlled voltage source, compensating voltage sags and swells on the load side. In many cases, series active filters work as hybrid topologies with passive LC filters. If passive LC filters are connected in parallel to the load, the series active power filter operates as a harmonic isolator, forcing the load current harmonics to circulate mainly through the passive filter rather than the power distribution system. The main advantage of this scheme is that the rated power of the series active filter is a small fraction of the load kVA rating, typically 5%. However, the apparent power rating of the series active power filter may increase in case of voltage compensation.

The series-shunt active filter is a combination of the series active filter and the shunt active filter. The shunt active filter is located at the load side and can be used to compensate for the load harmonics. On the other hand, the series portion is at the source side and can act as a harmonic blocking filter. This topology has been called the Unified Power Quality conditioner. The series portion compensates for supply voltage harmonics and voltage unbalances, acts as a harmonic blocking filter, and damps power system oscillations. The shunt portion compensates load current harmonics, reactive power, and load current unbalances. In addition, it regulates the dc link capacitor voltage. The power supplied or absorbed by the shunt portion is the power required by the series compensator and the power required to cover losses.

Hybrid power filters are a combination of active and passive filters. With this topology the passive filters have dynamic low impedance for current harmonics at the load side, increasing their bandwidth operation and improving their performance. This behavior is reached with only a small power rating PWM inverter, which acts as an active filter in series with the passive filter. Multilevel inverters are being investigated and recently used for active filter topologies. Three-level inverters are becoming very popular today for most inverter applications, such as machine drives and power factor compensators. The advantage of multilevel converters is that they can reduce the harmonic content generated by the active filter because they can produce more levels of voltage than conventional converters (more than two levels). This feature helps to reduce the harmonics generated by the filter itself. Another advantage is that they can reduce the voltage or current ratings of the semiconductors and the switching frequency requirements. The more levels the multilevel inverter has, the better the quality of voltage generated because more steps of voltage can be created.

C. Shunt Active Power Filter

The concept of using active power filters to mitigate harmonic problems and to compensate reactive power was proposed more than two decades ago. It has proven its ability to control the grid current and to ameliorate the power quality. The theories and applications of active power filters have become more popular and have attracted great attention. SAPF appears to be a viable solution for reactive power compensation as well as for eliminating harmonic currents. As explained in above introduction SAPF is connected in parallel with the non-linear load to behave as another controlled non-linear load. The system of the non-linear load and the SAPF will be seen by the grid as a linear load connected to the PCC.

D. Basic Compensation Principle

The basic principle of a shunt active power filter is that it generates a current equal and opposite in polarity to the harmonic current drawn by the load and injects it to the point of common coupling, thereby forcing the source current to be pure sinusoidal. Harmonic and reactive currents are thus cancelled at the source end and the result is undistorted sinusoidal balanced currents.

Fig. 1 shows the basic compensation principle of shunt active power filter. It is controlled to supply a compensating current i_c into the system, so that it cancels current harmonics on the AC side, and makes the source current in phase with source voltage as explained in above principle. Fig. 2 shows different waveforms. Curve A is the load current waveform and curve B is the desired mains current. Curve C shows the compensating current injected by the active filter containing all the harmonics, to make mains current sinusoidal.

In this way, by eliminating harmonics from power system shunt active power filter plays an important role in power quality improvement. It also helps in reactive power compensation, voltage regulation etc. Shunt active power filter is smaller, more versatile, more selective, better damped and less prone to failure as explained in first chapter. Due to these advantages SAPF is most widely used solution for power quality problem.

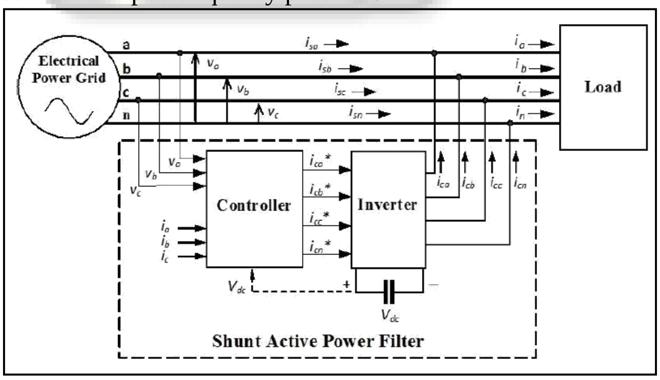

Fig. 1: Block diagram of Shunt Active Power Filter

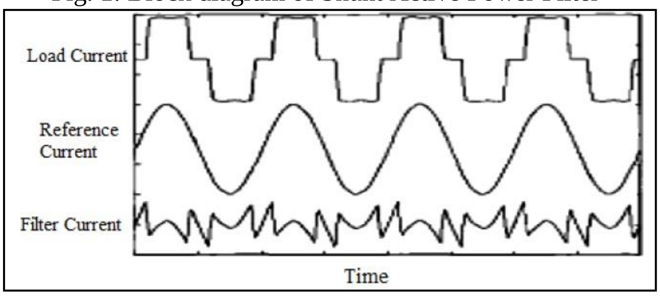

Fig. 2: Shunt active power filter-Shapes of load, source and desired filter current waveforms

III. ESTIMATION OF REFERENCE SOURCE CURRENT

In the above point we have seen that SAPF generates the filter current and injects into the system. In order to generate this filter current i.e. harmonic current which is to be injected into system, reference current is required. Reference current is calculated by special technique/control algorithm, this technique is called as reference current generation technique. The performance of SAPF depends on control algorithm used for extraction of reference current. This reference current generation technique is heart of SAPF. Many reference current generation methods have been proposed by researcher. They can be divided into two types namely, time domain technique and frequency domain. Time domain techniques are more familiar than frequency domain. Some of the methods of time domain techniques are based on the instantaneous active and reactive power and some other are based on the calculation of direct and indirect current components. Recently, the neural networks and the adaptive linear neural networks have been used in the extraction of harmonic components of current and voltage. Work is still going on new techniques of reference current generation of shunt active power filter.

REFERENCES

[1] Bhim Singh, J. Solanki, “A Comparison of Control Algorithms for DSTATCOM”, *IEEE Transactions on Industrial Electronics*, VOL. 56, NO. 7, Page(s): 2738 – 2745, JULY 2009.

[2] A. Bhattacharya, C. Chakraborty and S. Bhattacharya, “Shunt Compensation, Reviewing Traditional Methods of Reference Current Generation”, *IEEE Industrial Electronics Magazine*, Sept. 2009.

[3] Montero, M.I.M.; Cadaval, E.R.; Gonzalez, F.B., "Comparison of Control Strategies for Shunt Active Power Filters in Three-Phase Four-Wire Systems," *Power Electronics, IEEE Transactions on* , vol.22, no.1, pp.229,236, Jan. 2007.

[4] Bhim Singh, S. R. Arya, “Design and control of a DSTATCOM for power quality improvement using cross correlation function approach”, *International Journal of Engineering, Science and Technology*, Vol. 4, No.1, pp. 74-86, 2012.

[5] Soares, V.; Verdelho, Pedro; Marques, G.D., "An instantaneous active and reactive current component method for active filters," *Power Electronics, IEEE Transactions on* , vol.15, no.4, pp.660,669, Jul 2000.

[6] Zaveri, N.; Chudasama, A., "Evaluation of control strategies for parallel active filter under different supply voltage conditions," *Innovative Smart Grid Technologies - India (ISGT India), 2011 IEEE PES* , vol., no., pp.316,321, 1-3 Dec. 2011.

[7] Zaveri, N.; Chudasama, A., “Analysis of Different Real Time Reference Generation Techniques used for Harmonic Mitigation in Three Phase Shunt Active filters,” *International Journal of Recent Trends in Engineering*, Vol 2, No. 7, November 2009.

[8] Marei M. I.; Abdelaziz M.; Assad A. M., “A Simple Adaptive Control Technique for Shunt Active Power Filter Based on Clamped-Type Multilevel Inverters”,

Consumer Electronics Times, Vol. 2, Iss. 2, PP. 85-95, Apr. 2013.

[9] R.C. Dugan, M.F. McGranaghan, S. Santoso and H. W. Beaty, *Electrical Power Systems Quality*, Second Edition, McGraw-Hill.

[10] Khalid S.; Dwivedi B., "Power Quality Issues, Problems, Standards & Their Effects In Industry With Corrective Means," International Journal of Advances in Engineering & Technology, Vol. 1,Issue 2,pp.1-11, May 2011.