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A Review on Power Quality Issues and Enhancement Using Shunt Active Filter

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Abstract
In the distribution system, use of power electronic converteriscommon, but the power electronic converter with non-linear load produces harmonics. The harmonics produced by non-linear loads result in voltage distortion and leads to various power quality problems. This paper presents a comprehensive survey on different power quality issues, method for improving power quality, control methods adopted based on instantaneous power theory and different current control methods for employing shunt active filter. Its aim is to provide broad perspective on the status of shunt active power filter for power quality (PQ) enhancement.

Key words: Shunt Active Power Filters, harmonics and reactive power compensation, power quality, ANFIS controller, SPWM.

Introduction

PQ problem can be define as the problem related with the undesirable change in the magnitude or phase of system voltage and current or it may relate to the system frequency deviations that causes failure or mal-operation of customer equipmentwhich ultimately results in an economic burden to the user. It also has negative impact on the Environment [1]. Most of the power pollution issues created in power systems are due to the non-linear characteristic and fast switching of power electronic equipment. These PQ problems are closely related with power electronic in almost every aspect of commercial, domestic, and industrial applications[2].In a modern power system, increase of nonlinear loads demandthe compensation of the disturbances caused due to them. The simplest method to reduce line current harmonics and improving the power factor is the use of passive LC filters, combination of inductor and capacitor. The passive filters provide fixed compensation this is its main drawback. So, the increased severity of harmonic problem has attracted the attention of power electronics and power system engineers to create dynamic and adjustable solutions to the power quality problems, such equipment known as active power filters[3]-[15]. So,Active power filters is alternate solution for improvement of power which is more effective than other methods. The performance of an active power filter is depends on the technique used for computation of the reference current generation and control method used to inject the desired compensation current into the line.Many surveys have been carried out to specify the problems associated with electrical power system by nonlinear loads. This paper aims at presenting a comprehensive survey on the subject of PQ enhancement using shunt active power filters (SAF). An extensive range of publications [1]-[50] are reviewed and classified into 4 categories. The first [1]-[11] is on advanced research in power quality problems, the second [12]-[17] is the study of different APF configuration, the third [18-48] is study of control schemes, The fourth and final stage isconcluding remark on the reactive power and load-balancing compensation through ANFIS controller [49]-[55].

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Advanced Research in Power Quality Problems

The use of nonlinear load generates current and voltage harmonics which decreases the power quality. Therefore mitigation of harmonics becomes necessary. The non-sinusoidal currents drown from the ac mains by the non-linear loads cause reactive power burden and excessive neutral current their by reducing efficiency of the system. (PQ) problem can be detected from one of symptoms depending on the type of issue involved like- Lamp flicker, frequent blackouts, Voltage to ground in unexpected, Overheated elements and equipment, Communications interference. Power electronic devices are the most important cause of harmonics, notches, and neutral currents. Harmonics are produced by rectifiers, adjustable speed drives, Energy-efficient lighting, DC converters, soft starters, switched-mode powerSupplies, electronic ballast for discharge lamps. Equipment affected by harmonics includes transformers, motors, cables, and capacitors (resonance). Notches are produced mainly by converters, and they affect the electronic control devices. Neutral currents are produced by equipment using switched-mode power supplies, such as PCs, printers, photocopiers etc. Neutral currents seriously affect the neutral conductor temperature and transformer capability. According to information in the USA, they are losing 6.7 billion dollars every year due to the power quality disturbances and According to a survey realized by the Electric Power Research institute (EPRI) reveals that the harmonics are the source of 25% of all the power disturbances. All these problem issues can be found in [1]-[11].

Active Power Filtering for Harmonic Mitigation

In earlier days, a combination of inductor and capacitor has been used to mitigate harmonics and power capacitors to compensate the reactive power. This inductor capacitor combination provides fixed compensation. Active power filters have proved to be an important andflexible alternative to compensate for current and voltagedisturbances in power distribution systems. but their practical developmentwas made possible with the new improvements in powerelectronics and microcomputer control scheme as well aswith cost reduction in electronic equipment. Depending on the particular application in power system, active power filters can be classified as:

1.Shunt active power filters
2.Series active power filters
3. Hybrid active power filters

The shunt connected active power filter with a self-controlled DC bus used for reactive power compensation in power system.This shunt-connected active power filter, with a self-controlleddc bus, has a topology similar to that of a staticcompensator (STATCOM) used for reactive powercompensation in power transmission systems. Shunt activepower filters compensate load current harmonics by injectingequal-but opposite harmonic compensating current as shown in fig.1.Shunt active filters are used for reactive power compensation, voltage regulation, unbalance current compensation (for 3-phase systems), and neutral current compensation (for 3-phase 4-wire systems).

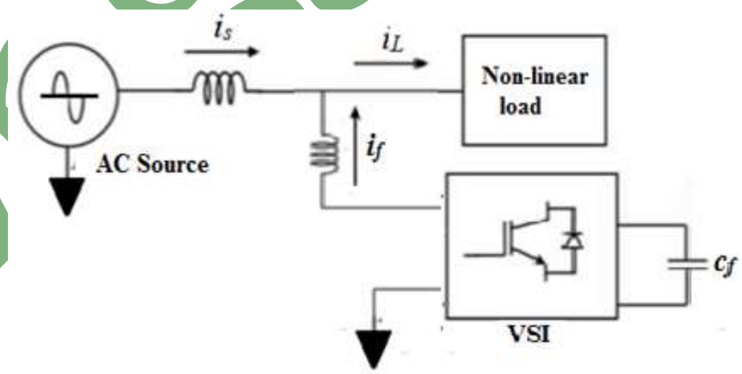

Fig.1 Shunt active power filter

Series active power filters were introduced by the end of the1980s and operate mainly as a voltage regulator and as aharmonic isolator between the nonlinear load and the utilitysystem. The series-connected filter protects the consumerfrom an inadequate supply-voltage quality. It is dual of the shunt active filter, and able tocompensate for distortion in the power line voltages, making the voltages applied to the load sinusoidal (compensating for

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voltageharmonics) as shown in fig.2. So, the series active filters are used for reactive power compensation, voltage regulation, compensation for voltage sag and swell, and unbalance voltage compensation (for 3-phase systems).

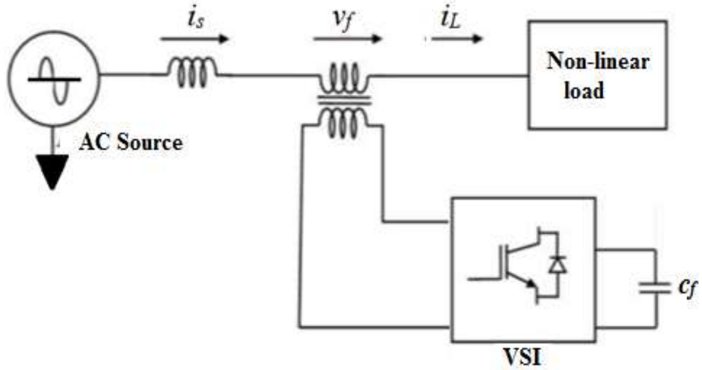

Fig. 2 Series active power filter

Another solution to solve the load current harmonics is to use hybrid active filter, as shown in fig.3 (a)this type of hybrid APF is a combination of shunt APF and a passive filter connected in parallel with the nonlinear load. Thus the function of the Hybrid APF is divided into two parts; the lower order harmonics are filtered by the shunt APF, while the higher order harmonics are filtered by the passive High Pass filter. The other system configuration of hybrid series APF is the combination of series APF and shunt passive filter as shown in fig.3 (b). By injection of controller harmonic voltage source in this hybrid series active filter is controlled to act as a harmonic isolator between the source and nonlinear load. This type of hybrid active filter is controlled so that it offers zero impedance at fundamental frequency and high impedance at all undesired harmonic frequencies. Passive filters are often easier and simple to implement and do not require any control circuit, so that both load voltages and the supplied currents are guaranteed to have sinusoidal waveforms.

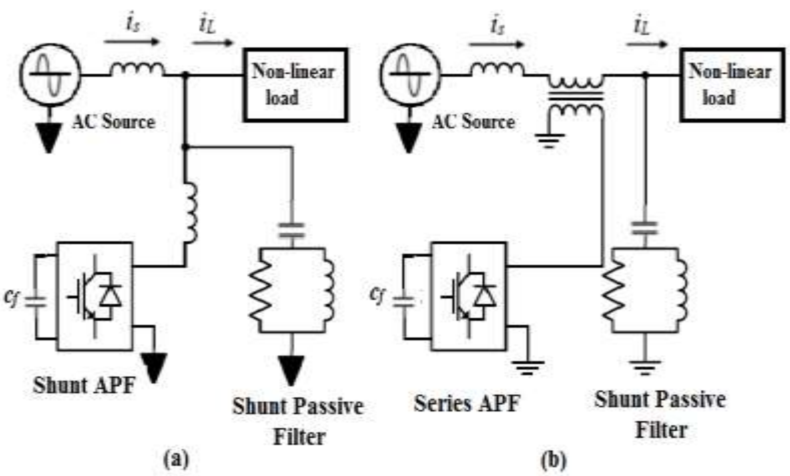

Fig. 3 Hybrid active power filter: (a) Combination of Shunt APF and Shunt Passive Filter, (b) Combination of Series APF and Shunt passive Filter

Hybrid APFs combinations are designed to compensate higher powers without excessive costs on high-power switching. But the major disadvantage of this configuration is the fact that passive filters can only be tuned for a specific predefined harmonic and thus cannot be easily changed for loads which have varying harmonics.

Shunt APF's allows the compensation of current harmonics and unbalance, together with power factor correction, and can be a much better solution than any other conventional approach. This filters mostly use for power quality enhancement. The analysis of all these filters is presented in [12-17].

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Control Techniques for Shunt Active Filter

Controller part is heart of the active filter. This control strategies applied to the active filter plays very important role on the improvement of the performance andstability of the filter. The control scheme is implemented in two stages,that is, reference current generation control scheme and PWM current controller.

In the first stage, derivation of compensating signals through the reference to current generation scheme is described, and this is based on frequency-domain or time-domain techniques [18-48]:

1.Frequency Domain Compensation Technique: Control strategy in the frequency domain is based on the Fourier analysis of the distorted voltage or current signals to extract compensating commands [18]-[23]. Using the Fourier transformation such as; Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT),Recursive Discrete Fourier Transform (RDFT), the compensating harmonic components are separated from the harmonic-polluted signals and combined to generate compensating commands. The on-line application of Fourier transform (solution of a set of nonlinear equations) is difficult in computation and results in a large response time.

2.Time Domain Compensation Technique:: Control methods of the active filter in the time domain are based on instantaneous derivation of compensating commands in the form of either voltage or current signals from distorted and harmonic-polluted signals. There are large numbers of control methods in the time domain, which are based onInstantaneous active and reactive power “p–q” theory based method [24]-[28],Instantaneous reactive power theory has been published in 1984. Based on this theory, the so-called “p-q method” was applied successfully in thecontrol of active filter. Zero-sequence component is neglected in this method, and because of that the p-q method is not accurate when the three-phasesystem is distorted or unbalanced.Instantaneous active and reactive current “I_d–Iq” theory based method, this is came by Park transformation. The three-phase load current can be decomposed in positive-sequence, negative-sequenceand zero-sequence component. The current in the d-q frame and can be transformed from the positive sequence and negative sequence using aPLL (phase locked loop). The division of the AC and DC components can be obtained across a low-pass passive filter. The reference current signal can beachieved by the AC component in d-q frame through a counter transformation.Synchronous reference frame method [29]-[31],in this method the real currents are transformed into a synchronous reference frame. The reference frame is synchronized with the AC mains voltageand is rotating at the same frequency. In this method, the reference currents are derived directly from the real load currents without considering thesource voltages. The generation of the reference signals is not affected by distortion or voltage unbalance, therefore increasing the compensation robustness and performance. Synchronous detection method [32]-[34], flux controller based method [35], notch filter method [36-38], P-I controller method [39],[40], sliding mode controller method [41]-[43], In P-I and sliding-mode controllers, either dc-bus voltage (in a voltage-source-inverter) or dc-bus current (in a Current-source-inverter) is maintained to the desired value and reference values for the magnitudes of the supply currents are obtained. By subtracting the load currents from reference supply currents,compensating commands are derived.The basic principle of all these methods are to extract the fundamental component and remove harmonic component using low pass filters (LPF).The instantaneous active and reactive power can be computed in terms of transformed voltage and current signals. The application of artificial intelligence is growing fast in the area of power sectors. The artificial neural network (ANN) is considered as a new tool to design control circuitry for (PQ) devices. However, with the advent of the various soft computing methodologies like neural networks, the fuzzy logic and the genetic algorithm combined with modern structure optimization techniques, a wider class of systems can be handled presented in [44].Recently, fuzzy logic controllers have generated a great deal of interest in various applications and have been introduced in the power-electronic field[45]-[48]. ANFIS is the other means of controlling technique of reference current generation as per its advantages. The different theories and concepts reported to support the various control methods can be found in [18]-[48].

In the second stage of control, the gating signals for the converter are generated using PWM current control techniques.The PWM current controller is principally used for providing gating pulse to the active filter.In this control of the AF's is to generate gating signals for the power electronic devices of the AF based on the derived compensating commands, in terms of voltages or currents[49]-[51].PWM Current controller techniques are: Hysteresis-band current control PWM, Synchronized carrier modulation, Sinusoidal PWM (SPWM), Space vector PWM (SVPWM).

Current Hysteresis Control: This control method follow the principle that the switching signals are derived from the comparison of the current error signal with a fixed width hysteresis band. This current control technique produces some unsatisfactorily results in features due to his simple, extreme robustness, fast dynamic, good stability, and automatic current limited characteristics. This current controller controls the load current by forcing it tofollow a reference. The switching action of the inverter keeps the current withinthe hysteresis band.

Triangle-Comparison PWM Control: This control method is also called linear current control. The conventional triangle-comparison PWM control principle is that the modulation signal achieved by a current regulator from the current error signal is intersected with the triangle wave. After that, pulse signals obtained and used to control the switches of the converters. With Analog PWM circuit, this control method has simple implementation with fast speed of response. Because the modulation frequency equals the triangle frequency, the current loop gain crossover frequency must be kept below the modulation frequency.

Space Vector Modulation (SVM): The aim of this method is to find the appropriate switching combinations and their duty ratios according to certain modulation scheme. The SVM operates in a complex plane divided in the six sectors separated by a combination of conducting or non-conducting switches in the power circuit. The advantages of 3-phase SVPWM are- Its output voltage is higher than regular SPWM for a given DC-link voltage, Total harmonic distortion (THD) is minimized, Excellent DC-link voltage utilization is achieved, The vectors can be arranged to give lower switching losses; or might want to approach a different result, such as centre-aligned PWM, edge-aligned PWM, minimal switching.

Conclusion

This review has been presented to provide a clear perspective on various aspects of the SAF. The power quality is very much affected by harmonic pollution as discussed, so for its enhancement, using shunt active filter with SPWM current control technique andANFIS controller found to be best method than any other, because ANFIS controller is independent of the source voltagedistortion and unbalance; fast and accurate tracing of fundamental component under balanced and unbalancednonlinear condition is possible;simple architecture; easy in implementation. Shunt Active Filter (SAF) accommodate itself to compensate for variation in non-linear currents. Recently, some methods based on ANFIS have been applied, in order to improveprocessing detecting time of harmonic current. The pastdecade has seen a dramatic increase in interest ANFIS which is characterized by itslearning ability and high speed recognition. The ANFIS have been applied in many uses inthe power electronic part of both machinery andfilters devices [52-55] where they have justified theireffectiveness. It is hoped that this survey on SAF's will be a useful reference to the users.

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