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A REVIEW OF POWER QUALITY IMPROVEMENT BY USING ACTIVE POWER FILTERS

NehaBhole*

Dr. P. J. Shah*

Abstract

This paper explains various power quality problems in distribution systems and its solutions with the help of power electronics based equipment. The equipment such as shunt, hybrid and series active power filters are described showing their compensation characteristics as well as principles of operation. Different power circuits topologies and control scheme for each type of active power filter are studied.

Keywords:
Power Quality improvement;
Active Filters

*** PG Students, Head, Electrical Engineering Dept.North Maharashtra University,Jalgaon.**

1. Introduction

Harmonics is one of the power quality problem that influence to a great extent transformer overheating, rotary machine vibration, voltage quality degradation, damage of electric power components and malfunctioning of medical services. The power quality improvement has been given considerable attention due to the intensive usage of nonlinear loads .These limitations were set to limit the disturbances and avoid major problems in power system. Therefore linear or non-linear single-phase loads are rapidly increasing; zero sequence component and current harmonics are generated. This reasons overheating of the associate

distribution transformers that may lead to a system failure, especially in frail networks .The proliferation of microelectronics processors in an extensive range of equipment, from home VCRs and digital clocks to automated industrial assembly lines and hospital diagnostics systems has enlarge the vulnerability of such equipment to power quality issues. These power quality problems include a variety of electrical disturbances, which may originate in several ways and have different effects on various kinds of complex loads. What were once considered slight variations in power, usually unnoticed in the operation of conventional equipment, may now bring whole factories to standstill. As a result of this susceptibility, improves numbers of industrial as well as commercial facilities are trying to protect themselves by investing in more sophisticate equipment to improve power quality. Moreover, the proliferation of non-linear loads with high rated power has increased the contamination level in voltages and currents waveforms, forcing to improve the compensation characteristics required to satisfy more stringent harmonics standard. Betweenthe various technical options available to improve power quality, active power filters have proved to be an essential

alternative to compensate for current and voltage disturbances in electrical power distribution systems. Different active power filters topologies have been discussed in the technical literature and many of them are

already available in the market. In this paper will focus in the analysis of which to use with their compensation characteristics. Shunt active power filters, series active topologies, and hybrid schemes will be discussed. Also, the control scheme characteristics for shunt and series schemes will be discussed [1] -[2].

2. Power Quality problems in Distribution Systems

Most of the more main international standards define power quality as the physical characteristics of the electrical supply delivered under normal operating conditions that do not interrupt or disturb the customer's processes. Therefore, a power quality problem occurs if any voltage, current or frequency deviation results in a failure and in a bad operation of customer's equipment. However, it is significant to notice that the quality of power supply includes basically voltage quality and supply reliability. Voltage quality problems relate to any failure of equipment due to deviations of the line voltage from its nominal characteristics, and the supply reliability is characterized by its capability and obtains ability. Power quality difficulties are common in most of commercial, industrial and utility networks. Natural phenomena, such as lightning are the most frequent source of power quality problems. Switching phenomena resulting in oscillatory transients in the electrical power supply, for example when capacitors are exchanged, also give substantially to power quality disturbances. Also, by joining the high power non-linear loads gives to the generation of current as well as voltage harmonic components. Between the different voltage disturbances that can be produced, the most significant and dangerous power quality problems are voltage sags due to the high economical injuries that can be generated. Short-term voltage sags can trip electrical drives or more complex equipment, leading to costly disturbances of production. For all these causes, from the consumer point of view, power quality problems will become an increasingly main factor to consider in order satisfying good productivity. On the other hand, for the electrical supply industry, the quality of power provided will be one of the individual factors for ensuring customer reliability in this very reasonable and deregulated market [3].

3. Solution on Power Quality Problem

There are two approaches to the mitigation of power quality difficulties. The first approach is called as load conditioning, which ensures that the equipment is less sensitive to power disturbances, permitting the operation even under significant voltage distortion. The other key is to install line conditioning systems that suppress and counteracts the power system disturbances. The flexible as well as versatile solution to voltage quality problems is accessible by active power filters. Presently they are based on PWM converters and link to low and medium voltage distribution system in shunt and in series. Series active power filters must operate in combination with shunt passive filters in order to compensate load current harmonics. Shunt active power filters work as a controllable current source and series active power filters works as a controllable voltage source. Both schemes are implemented desirable with voltage source PWM inverters, with a dc bus having a reactive element such as capacitor. Active power filters can perform one or more of the functions necessary to compensate power systems and improving power quality. As it will be explained in this paper, their performance depends on the power rating and the speed of response. The choice of the type of active power filter to improve power quality depends on the cause of the problem [4].

4. Active Filters Topology

Active filters are particularequipment's that use power electronic converters to compensate for current or voltage harmonics originated through non-linear loads, and avoidthose harmonic voltages might be applied to responsive loads. There are two types of active filters: the shunt type and the series type. It is achievable to have active filters shared with passive filters as well as active filters of both types acting together.

4.1 Shunt Active Power Filters

Active filters are unique equipment's that use power electronic converters to compensate for current and voltage harmonics originated through non-linear loads to avoid that harmonic voltages might be applied to susceptible loads. Shunt active power filter compensate current harmonics by inserting equal-but-opposite harmonic compensating current. In this case the shunt active power filter works as a current source injecting

the harmonic components generated by the load and phase shifted by180^0. This principle is related to any type of load considered a harmonic source. Moreover, with a proper control scheme, the active power filter can also compensate the load power factor.In this method, the power distribution system sees the nonlinear load as well as the active power filter as a perfect resistor.

The current compensation characteristic of shunt active power filter is shown in figure1.1 [5].

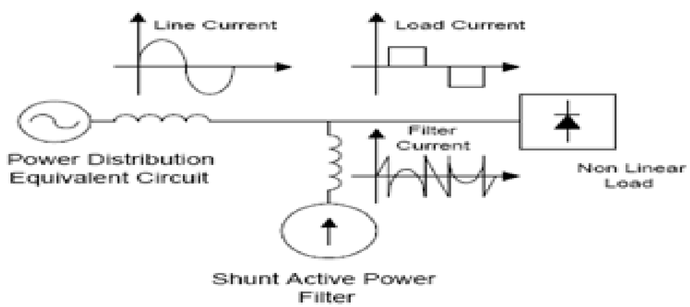

Figure 1.1 The Compensation characteristics of a shunt active Power filter

The Shunt active power filters are normally executed with pulse-width modulated voltage source inverters. In this typePWM-VSI works as a current controlled voltage source. Conventionally, 2 levels PWM-VSI have been used to implement such system. However, in the previousyear's multilevel PWM voltage source inverters have been proposed to progress active power filters for medium voltage applications. The active power filters implemented with multiple VSI connected in parallel to a dc bus but in series through a transformer or in cascade has been planned in the technical literature. Theusage of VSI connected in cascade is an interesting another to compensate high power non-linear load. The use of two PWM-VSI of dissimilar rated power allows the use of different switching frequencies, reducing switching stresses and commutation losses in the complete compensation system [6].Figure 1.2 shows the shunt active power filter topologies applied with PWM voltage- source inverters .In modern years, there has been an increasing interest in using multilevel inverters for high power energy translation, especially for drives as well as reactive power compensation. Multilevel PWM inverters can be coupled to high voltage source without a coupling transformer. The usage of neutral-point-clamped (NPC) inverters agrees equal voltage shearing of the series connected devices in each phase. Essentially, multilevel inverters have been established for applications in high voltage ac motor drives as well as static var compensation. For these types of applications, the output voltage of the multilevel inverter must be capable to generate an almost sinusoidal output current. In order to produce a near sinusoidal output current and the output voltage should not cover low frequency harmonic components [7].

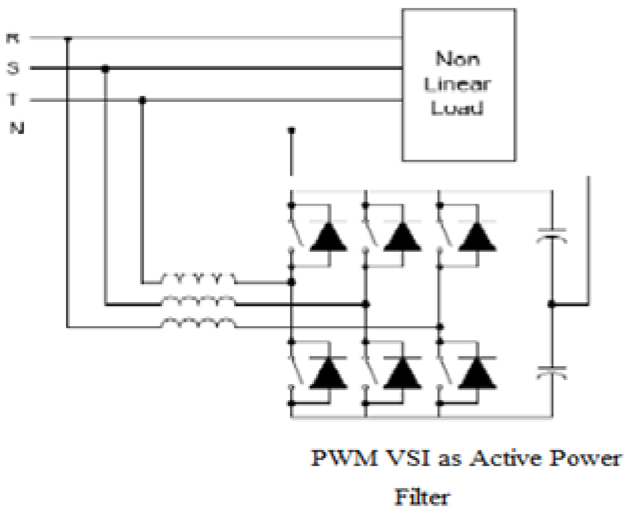

Figure 1.2The shunt active power filter topologies suitable with PWM voltage- source inverters

4.1.1 Control Schemeof Shunt Active Power Filter

The current reference circuit generates the reference currents necessary to compensate the load current harmonics and reactive power, and try to keep constant the dc voltage across the two electrolytic capacitors. There are many possibilities to expand this type of control.The basic block diagram of a shunt active power filter control scheme is shown in figure1.3 and consists of current reference generator, dc voltage control and inverter gating signals generator.

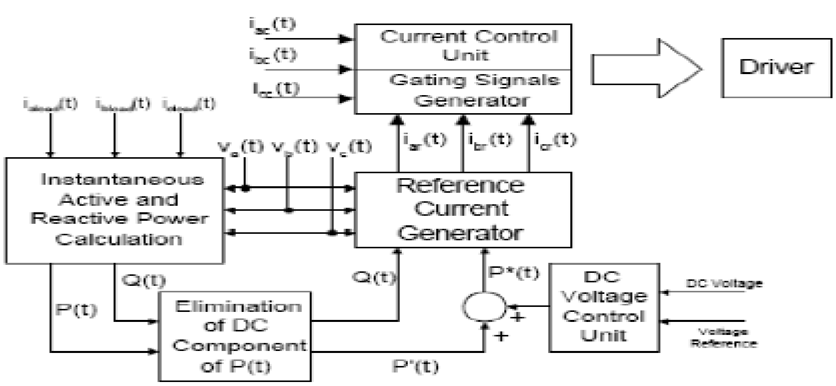

Figure 1.3 The block diagram of a shunt active power filter control scheme

The compensation use of an active power filter depends on its capability to follow with a minimum error and time delay the reference signal calculated to compensated the distorted load current. The dc voltage control unit must be the total dc bus voltage constant and equals to a known reference value. The dc voltage control is achieved by adjusting the small amount of real power absorbed by the inverter. This little amount of real power is adjusted by changing the amplitude of the fundamental component of the reference current [8].

4.2SeriesActive Power Filters

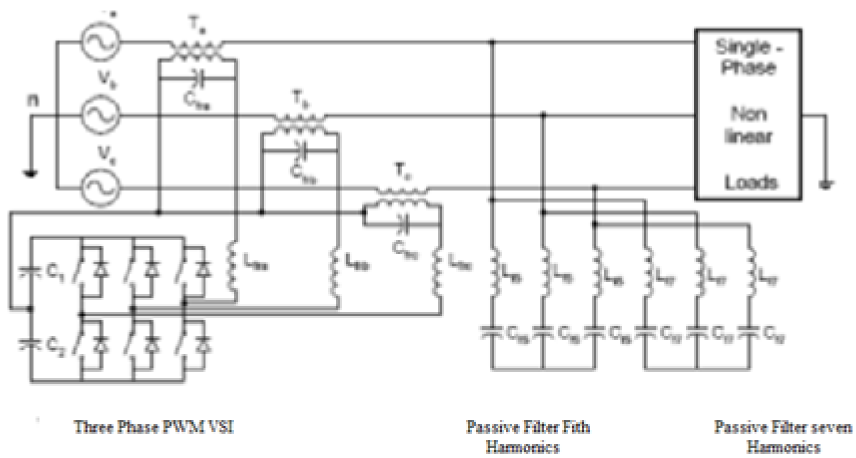

Figure 1.4Proposed series active power filter topology

It is well known that series active power filters compensate current system distortion produced by non-linear loads by imposing a high impedance path to the current harmonics which forces the high frequency currents to flow over the LC passive filter linked in parallel to the load. The high impedanceessential by the series active power filter is produced by generating a voltage of the same frequency that the current harmonic component that wants to be rejected. Voltage unbalance is adjusted by compensating the important frequency negative and zero sequence voltage components of the system. Figure 1.4 shows the proposed of series active power filter topology [8].Figure 1.5 presents the electrical scheme of a shunt activefilter for a three-phase power system with neutral wire, which, can equally compensate for current harmonics and do power factor correction. Furthermore, it allows load balancing, eliminating the current in the neutral wire. The power step is, basically, a voltage-source inverter with just a single capacitor in the DC side, controlled in a method that it acts as current-source.

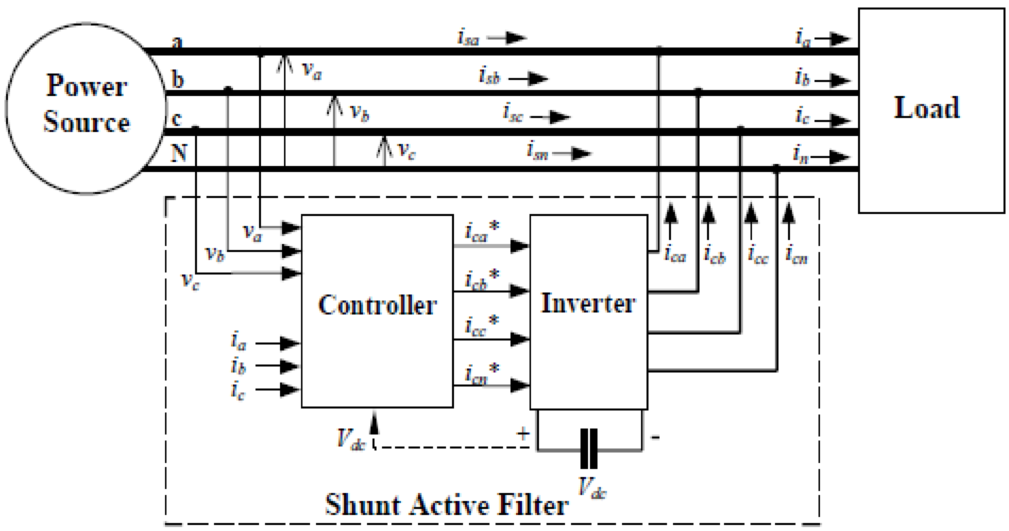

Figure.1.5 Shunt active filter in a three-phase power system.

From the measured values of phase voltages (v_a, v_b, v_c) as well as load currents (i_a, i_b, i_c), the controller calculates the reference currents ($i_{ca}^*, i_{cb}^*, i_{cc}^*, i_{cn}^*$) used through the inverter to produce the compensation currents. This solution requires 6 current sensors and 4 voltage sensors, and the inverter has 4 legs. For balanced loads without 3^{rd} order current harmonics there is no require tocompensate for the current in neutral wire. These tolerate the use of a simpler inverter andsimply 4 current sensors. It also eases the controller calculations.Figure 1.6 shows the method of a series active filter for a three-phase power system. It is the double of the shunt active filter, and is capable to compensate for distortion in the power line voltages, making the voltages applied to the load sinusoidal. The filterconsists of a voltage-source inverter and requires 3 single-phasetransformers to interface with the power system. The series active filter does not compensate for load current harmonics other than it acts as high-impedance to the current harmonics coming from the power source side.

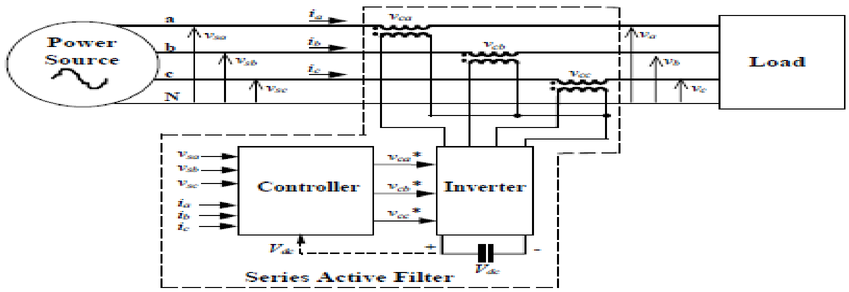

Figure 1.6Series active filter in a three-phase power system.

Another key to solve the load current harmonics is to make use of a shunt active filter mutually with the series active filter , so that both load voltages and the complete currents become sinusoidal waveforms. Shunt active filters are already commercially obtainable, although much research is being done, yet. The combination of series and series-shunt types of active filters are yet at prototype level [9].

4.2.1Control Scheme of Series Active Power Filter

Voltage unbalance is compensated via calculating the negative and zero sequence fundamental components of system voltages. Thebasic block diagram of the planned control scheme is shown in figure 1.7. The Current and voltage reference waveforms are obtained by using the Instantaneous Reactive Power Theory These voltage components are additional to the source voltages through the series transformers compensating the voltage unbalance at load terminals. In order to decrease the amplitude of the current flowing through the neutral conductor, the zero sequence components of the line currents are designed. In this way, it is not required to sense the current flowing through the neutral conductor.

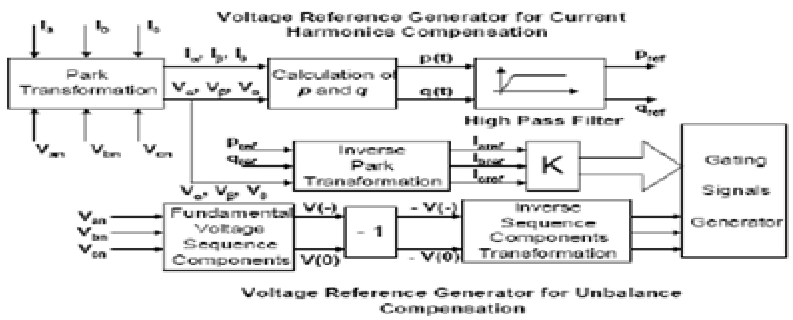

Figure 1.7 The block diagram of the proposed series active power filter control scheme

Where P_{ref} and q_{ref} are the instantaneous active and reactive power associated with harmonics current components.

5. Control Methods for Active Filters

The methods useful to control the active filters are important in achieving the goals of compensation, in the resolve of the filter power speed, and in their dynamic as well as steady-state performance. Essentially, the dissimilar approaches regarding the calculation of the compensation currents and voltages from the calculated distorted quantities can be grouped into two group first frequency-domain and second time-domain. The frequency-domain method implies the employ of the Fourier transform and its analysis, which

leads to a huge amount of calculations, making the control method very heavy. In the time-domain methods,

the traditional concepts of circuit analysis and algebraic transformations relatedwith changes of reference frames are use, simplifying the control job. The three-phase power delivered to a load via the source has the familiar expression:

$p_3(t) = v_a(t).i_a(t) + v_b(t).i_b(t) + v_c(t).i_c(t)$(1.1)

Where,$v_a(t)$,$v_b(t)$, $v_c(t)$represents the instantaneous load voltages which is referred to the neutral point, and $i_a(t), i_b(t), i_c(t)$are the load instantaneous currents. However, for the given voltages, there is more than one set of currents producing the similar instantaneous power. On the other hand it is well-known that for a balanced sinusoidal system, in voltage and current, the instantaneous power is invariable and so equivalent to active power, since this value corresponds to the average value of the instantaneous power. So, the best set of currents can be the one that leads to a constant instantaneous power. There are three time-domain approach methods used in the control of shunt active filtersone of them is explained below.

5.1 Frize-Buchholz-Dependenbrock (FBD) Method

The FBD technique, planned by *Depenbrock*decomposes the loadcurrents into power components and ineffective components. The objective is to compensate all the terms that do not produce power, but have the disadvantage of making the power factor less than one. With this reason the waycalculates an equivalent conductance for the load, given by the ratio between the obsessive average power and the squared RMS collective voltage value:

$$G = \frac{P_3}{V_\in^2} \qquad (1.2)$$

Where$V_\in$is the collective rms voltage defined as follows,

$V_\in = v_a + v_b + v_c$(1.3)

andv_a, v_b, v_c, are the RMS voltage values of phase a, b and$c$ respectively. $P_\in$is the mean value of the instantaneousthree-phase power, which corresponds to the active power.

6.Conclusions

In this paper the performance of an active power filter (APF) such as shunt active power filter and series active power filter depends on the inverter characteristics which are applied to control system, and the accuracy of the reference signal generator. The accuracy of the reference generator is the gravest item in determining the performance of APFs. An efficient reference signal generator composed of an improved adaptive predictive filter. Shunt active filters allow the compensation of current harmonics and unbalance, together with power factor correction, and can be a much better solution than the conventional approach.

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