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A Solution for Power Quality issues in Power System

K. B. Mohd. Umar Ansari¹, Sandeep Kumar², Satyendra Vishwakarma³

(B. E – EEE, M. Tech - EPES), Ex-Lecturer, Dept. of Electronics & Communication Engg., MIIT, Meerut, U.P., India¹

(B. Tech - EE, M. Tech - PS*), Lecturer, Dept. of Electrical Engg., Sri Ramswaroop University, Lucknow, U.P., India²

(B. Tech - EN, M. Tech - EPES), Dept. of EEEE., AKG Engineering College, Ghaziabad, U.P, India³

ABSTRACT: This paper summarized power quality problems in power systems and their solutions with the help of power electronics based equipment. Different types of active power filters are described. The increased severity of power quality in power networks has attracted the attention of power engineers to develop solutions to the power quality problems. The equipments designed for overcome the power quality issues, generally known as active filters, are also called active power line conditioners, and are able to compensate current and voltage harmonics, reactive power, regulate terminal voltage, suppress flicker, and to improve voltage balance in three-phase systems. The advantage of active filtering is that it automatically detects the changes in network and load fluctuations. They can compensate for several harmonic orders, and are not affected by major changes in network characteristics and also eliminating the risk of resonance between the filter and network impedance. Active power filters are differentiating on the type of converter, topology, control scheme, and compensation characteristics. The major classification is based on the topology such as series, shunt, and hybrid.

KEYWORDS: Power quality problems, Series active filter, Shunt active filter, Hybrid active power filter.

I. INTRODUCTION

For an increasing number of applications, conventional equipment is proving insufficient for mitigation of power quality problems. The proliferation of microelectronics processors in a wide range of equipments, from home VCRs and digital clocks to automated industrial assembly lines and hospital diagnostics system has increased the vulnerability of such equipment to power quality problems [1]. These problems include a variety of electrical disturbances, which may originate in several ways and have different effects on various kinds of sensitive loads. As a result of this vulnerability, increasing numbers of industrial and commercial facilities are trying to protect themselves by investing in more sophisticated equipment to improve power quality [2]. Moreover, the non-linear loads with large 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.

Between the different technical options available to improve power quality, active power filters have proved to be an important alternative to compensate for current and voltage disturbances in power distribution systems [3], [4]. Different active power filters topologies have been presented in the technical literature, [4] and any of them are already available in the market [1], [2]. Shunt active power filters, series active topologies, and hybrid schemes will be presented.

II. POWER QUALITY IN POWER SYSTEMS

Most of the more important international standards define power quality as the physical characteristics of the electrical supply provided under normal operating conditions that do not disrupt or disturb the customer's processes. Therefore, a power quality problem exists if any voltage, current or frequency deviation results in a failure or in a bad



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operation of customer's equipment. However, it is important to notice that the quality of power supply implies 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 adequacy (ability to supply the load), security (ability to withstand sudden disturbances such as system faults) and availability (focusing especially on long interruptions).

Power quality problems are common in most of commercial, industrial and utility networks. Natural phenomena, such as lightning are the most frequent cause of power quality problems. Switching phenomena resulting in oscillatory transients in the electrical supply, for example when capacitors are switched, also contribute substantially to power quality disturbances. Also, the connection of high power non-linear loads contributes to the generation of current and voltage harmonic components. Between the different voltage disturbances that can be produced, the most significant and critical power quality problems are voltage sags due to the high economical losses that can be generated. Short-term voltage drops (sags) can trip electrical drives or more sensitive equipment, leading to costly interruptions of production [5].

For all these reasons, from the consumer point of view, power quality issues will become an increasingly important factor to consider in order satisfying good productivity. On the other hand, for the electrical supply industry, the quality of power delivered will be one of the distinguishing factor for ensuring customer loyalty in this very competitive and deregulated market. To address the needs of energy consumers trying to improve productivity through the reduction of power quality related process stoppages and energy suppliers trying to maximize operating profits while keeping customers satisfied with supply quality, innovative technology provides the key to cost-effective power quality enhancements solutions. However, with the various power quality solutions available, the obvious question for a consumer or utility facing a particular power quality problem is which equipment provides the better solution.

III. SOLUTIONS TO POWER QUALITY PROBLEMS

There are two approaches to the mitigation of power quality problems. The first approach is called load conditioning, which ensures that the equipment is less sensitive to power disturbances, allowing the operation even under significant voltage distortion. The other solution is to install line conditioning systems that suppress or counteracts the power system disturbances. A flexible and versatile solution to voltage quality problems is offered by active power filters. Currently they are based on PWM converters and connect to low and medium voltage distribution system in shunt or in series. Series active power filters must operate in conjunction with shunt passive filters in order to compensate load current harmonics. Shunt active power filters operate as a controllable current source and series active power filters operates as a controllable voltage source. Both schemes are implemented preferable with voltage source PWM inverters, with a dc bus having a reactive element such as a capacitor. Active power filters can perform one or more of the functions required to compensate power systems and improving power quality. As it will be illustrated in this paper, their performance depends on the power rating and the speed of response. The selection of the type of active power filter to improve power quality depends on the source of the problem.

1) SHUNT ACTIVE POWER FILTERS

Shunt active power filter compensate 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° . This principle is applicable to any type of load considered a harmonic source. Moreover, with an appropriate control scheme, the active power filter can also compensate the load power factor. In this way, the power distribution system sees the non linear load and the active power filter as an ideal resistor. The current compensation characteristic of the shunt active power filter is shown in Fig 1.

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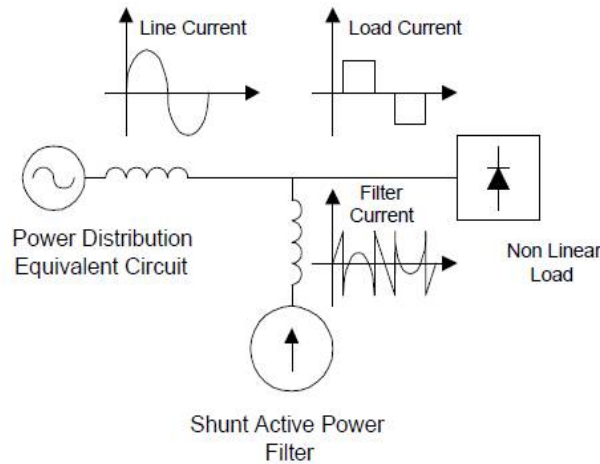


Fig.1. Compensation characteristics of a shunt active power filter [6]

2) SERIES ACTIVE POWER FILTERS

It is well known that series active power filters compensate current system distortion caused by non-linear loads by imposing a high impedance path to the current harmonics which forces the high frequency currents to flow through the LC passive filter connected in parallel to the load [5]. The high impedance imposed by the series active power filter is created by generating a voltage of the same frequency that the current harmonic component that needs to be eliminated. Voltage unbalance is corrected by compensating the fundamental frequency negative and zero sequence voltage components of the system.

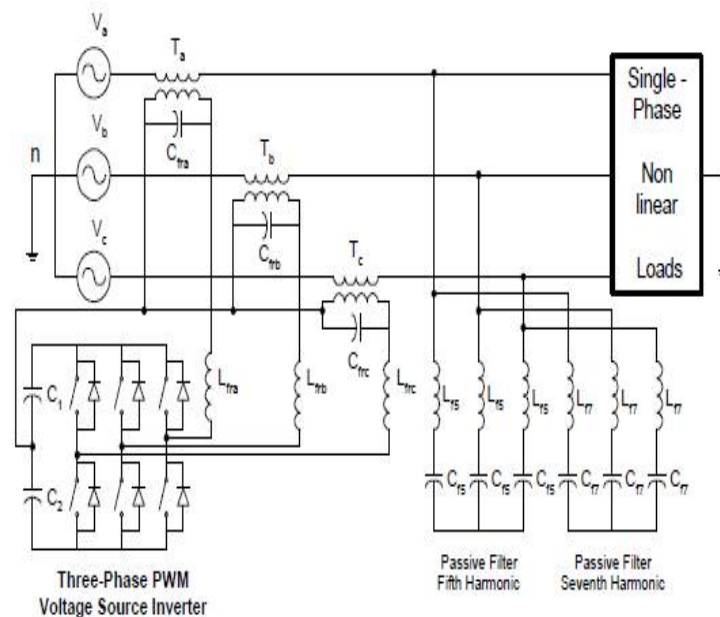


Fig.2. The proposed series active power filter topology. [7]

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3) HYBRID ACTIVE POWER FILTER

Active power filters can be used with passive filters improving compensation characteristics of the passive filter, and avoiding the possibility of the generation of series or parallel resonance. One example of this combination is the series active power filter shown in section V. In this scheme, (Fig. 2), if the passive filters are not connected, the series active power filter can compensate only voltage regulation, and voltage unbalance. If passive filters are not used in Fig. 2, the topology cannot compensate current harmonic components.

Another possibility to combine the compensation characteristics of passive and active power filters is by connecting the active passive filter in series with the passive one, as shown in Fig. 3. In this way, the compensation characteristics of the passive filter is significantly improved, since the active scheme generated voltage harmonic components across the terminal of the primary windings of the series transformer, forcing current harmonics generated by the load to circulate through the passive filter instead of the power distribution system.

By controlling the amplitude of the voltage fundamental component across the coupling transformer, the power factor of the power distribution system can be adjusted.

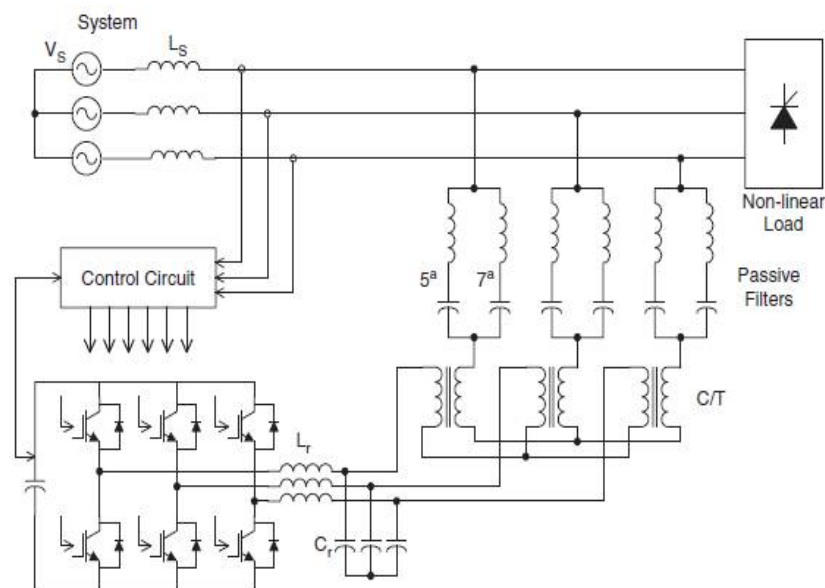


Fig. 3. The hybrid active power filter configuration. [8]

However, the control of the load power factor imposed a higher voltage across the filter capacitor. This consideration has to be considered when the filter capacitors are specified. This type of configuration is very convenient for compensation of high power medium voltage non linear loads, such as large power ac drives with cycloconverters or high power medium voltage rectifiers for application in electro wining process or for compensation of arc furnace. In all these applications passive filters do not have enough compensation capability to reduce current harmonics in order to satisfy IEEE Std.519.

IV. SIMULATION MODELING AND RESULTS

This example shows the use of a shunt active filter to minimize the harmonic content propagated to the source from a non-linear load. The circuit models a standard shunt AF with IGBT inverter and series inductor on the AC side and DC

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capacitor energization. The load consists of two diode rectifiers which are phase-shifted by 30 degrees. The Delta-Y connected rectifier is connected after 10 cycles to change the load from 6-pulse to 12-pulse.

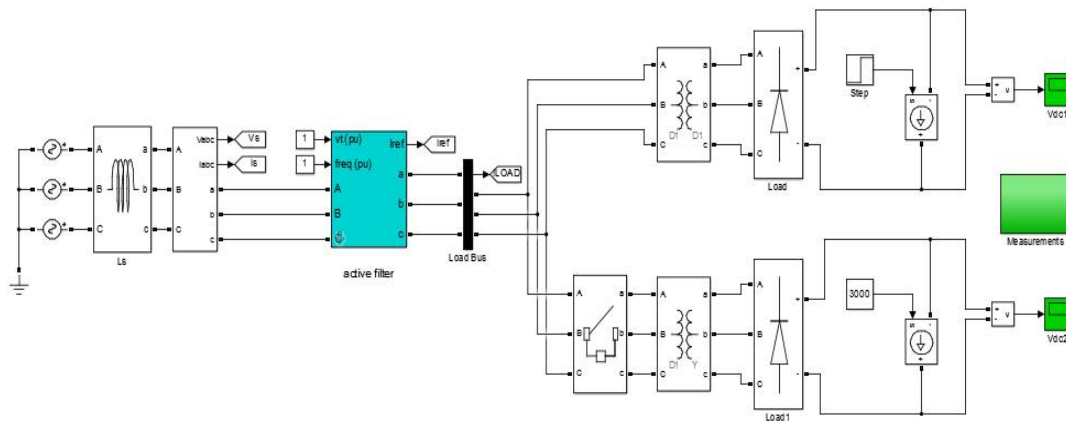


Fig.4. Three phase active filter with a non linear load [9]

The AF uses a PLL to generate a reference sinusoidal source current which is in-phase and has the same RMS gain as the load current. The current error between the load current and the reference current is generated by the IGBT Bridge through hysteresis switching. The AF aims to inject this current error at the point of common coupling in order to match the source current as closely as possible with the reference current.

1.1 Simulation Results

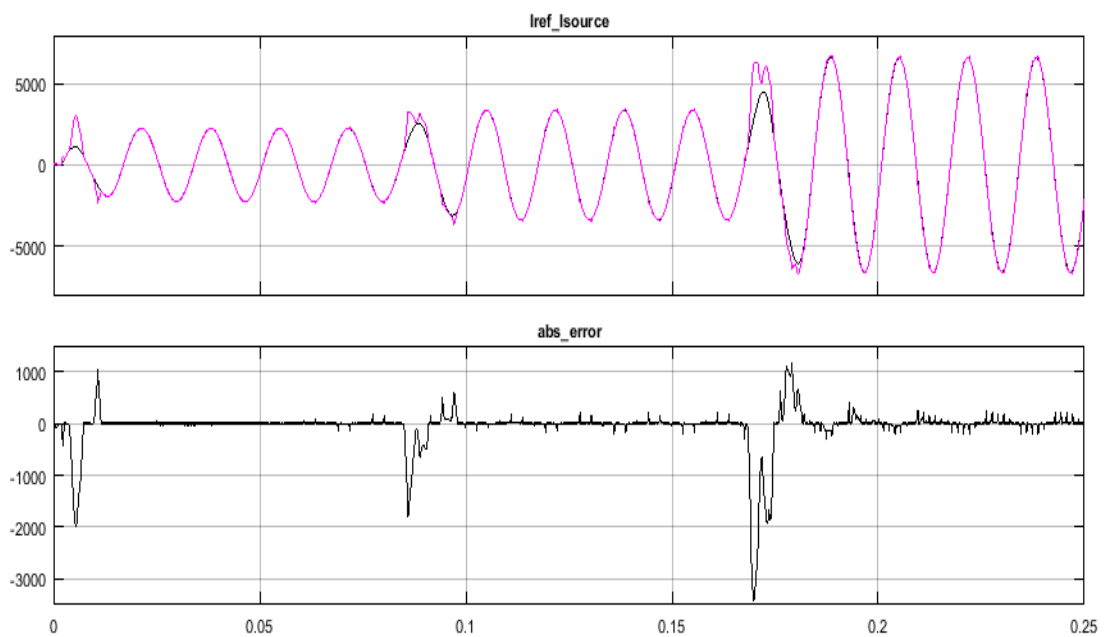


Fig.5 Reference current at source side

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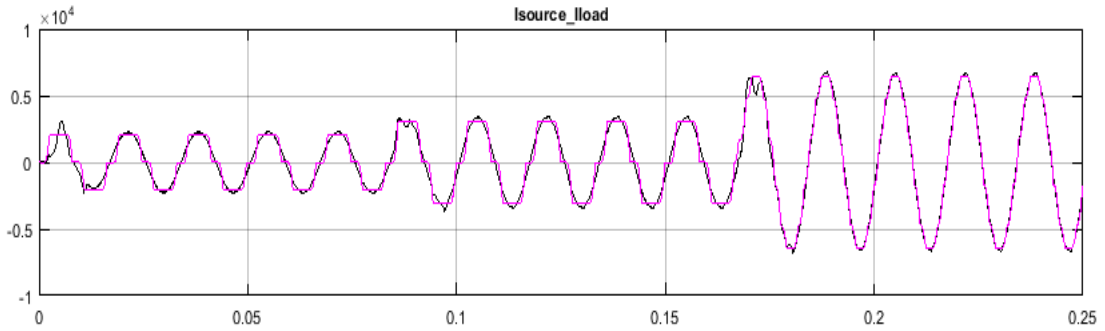


Fig.6 Source current

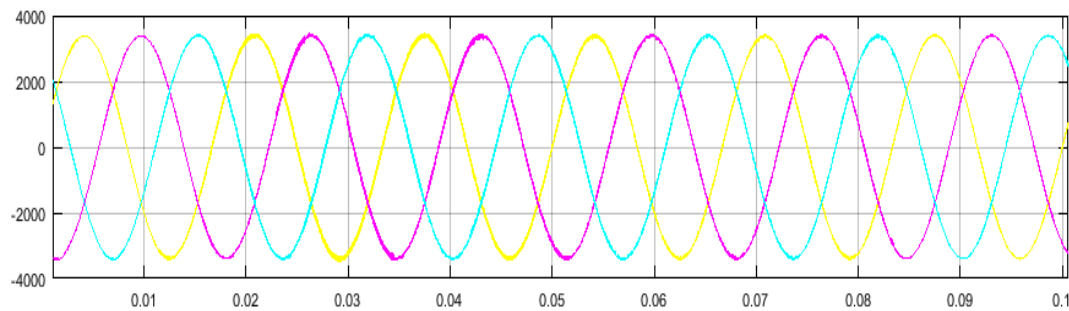


Fig.7 three phase source voltage

At simulation result I observe phase A reference and source current on scope 'Iref_Isource' and phase A source in fig.5 and load current on scope 'I_{source}_I_{load}' in fig. 6 .At t=0s, only the delta/delta connected diode rectifier is in-circuit. The DC current is set at 2000A. Observe from 'I_{ref}_I_{source}' that the AF captures the reference current within 1 cycle. FFT Analysis tool of Powergui show an FFT analysis of the load and source phase A current on the 3rd cycle. It is seen that the AF has effectively reduced the THD from 22.41% to 0.69%.

At t=5/60s, the DC current is increased from 2000A to 3000A. Observe that the AF effectively responds to this change in load and captures the new reference current within one cycle.

At t=10/60s, the delta/gye diode rectifier is connected, thus producing a 12-pulse load. Observe that the AF again captures the new reference current within one cycle. FFT Analysis tool of Powergui shows the load and source phase A current on the 13th cycle. It is seen that the AF has effectively reduced the THD from 4.80% to 0.92%.

System	THD (%)
Without filter	4.80
With filter	0.92

V. APPLICATIONS & FUTURE SCOPE

In recent years there has been interest in the development and applications of active filters, at distribution and consumer levels, and the need to control reactive power and voltage stability at transmission levels. Active power filters are the



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devices, which can perform the job of harmonic elimination. The active power filters are used to filter out higher as well as lower order harmonics in the power system.

This work can be extended to a multilevel inverter implemented for power conditioning. Three phase three wire system can be extended to three phase four wire system with different conditions. FPGA based controller for Active Filter can be developed to reduce the hardware requirement. For sustainable growth in power system, recently Renewable and Non-Renewable Energy source are gaining lot of attention. Hence such energy sources feeding the nonlinear load can be investigated for further work in the field of power quality. Another attractive aspect that can be investigated is the finding the solutions of power quality issues by other emerging Evolutionary algorithm. Thus, the quality of the power network can be enhanced, and high reliability can be provided.

VI.CONCLUSION

In this paper the use and advantages of applying active power filters to compensation power distribution systems has been presented. The principles of operation of shunt, series, also, a brief description of the active power filter has been described. The shunt active power filter performance in power system was discussed. Simulation results proved the viability of using active power filters to compensate Harmonics.

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