A Brief Survey on Passive Filter Aided by Shunt Compensators

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Abstract - Harmonics and reactive power regulation and guidelines are upcoming issues and increasingly being adopted in distributed power system and industries. Vital use of power electronic appliances has made power management smart, flexible and efficient. But side by side they are leading to power pollution due to injection of current and voltage harmonics. Harmonic pollution creates problems in the integrated power systems. The passive filters are used to mitigate power quality problems in six-pulse ac-dc converter with R-L load. Moreover, apart from mitigating the current harmonics, the passive filters also provide reactive power compensation, thereby, further improving the system performance. For current source type of harmonic producing loads, generally, passive shunt filters are recommended. These filter apart from mitigating the current harmonics, also provide limited reactive power compensation and dc bus voltage regulation. However, the performance of these filters depends heavily on the source impedance present in the system, as these filter act as sinks for the harmonic currents. These filters block the flow of harmonic current into ac mains, by providing high impedance path at certain harmonic frequencies for which the filter is tuned. This research presents a detailed investigation into the use of different configurations of passive filter such as passive shunt filter and passive series filters. The advantages and disadvantages of both configurations are discussed.

Keywords- passive filters, power distribution, power filters, power quality.

I. INTRODUCTION

Early equipment was designed to withstand disturbances such as lightning, short circuits, and sudden overloads without extra expenditure. Current power electronics (PE) prices would be much higher if the equipment was designed with the same robustness. Pollution has been introduced into power systems by nonlinear loads such as transformers and saturated coils; however, perturbation rate has never reached the present levels. Due to its nonlinear characteristics and fast switching, PE create most of the pollution issues. Most of the pollution issues are created due to the nonlinear characteristics and fast switching of PE. Approximately 10% to 20% of today's energy is processed by PE; the percentage is estimated to reach 50% to 60% by the year 2010, due mainly to the fast growth of PE capability. A race is currently taking place between increasing PE pollution and sensitivity, on the one hand, and the new PE-based corrective devices, which have the ability to attenuate the issues created by PE, on the other hand.

Increase in such non-linearity causes different undesirable features like low system efficiency and poor power factor. It also causes disturbance to other consumers and interference in nearby communication networks. The effect of such non-linearity may become sizeable over the next few years. Hence it is very important to overcome these undesirable features.

Classically, shunt passive filters, consist of tuned LC filters and/or high passive filters are used to suppress the harmonics and power capacitors are employed to improve the power factor. But they have the limitations of fixed compensation, large size and can also exile resonance conditions.

Active power filters are now seen as a viable alternative over the classical passive filters, to compensate harmonics and reactive power requirement of the non-linear loads. The objective of the active filtering is to solve these problems by combining with a much-reduced rating of the necessary passive components.

The PQ issue is defined as "any occurrence manifested in voltage, current, or frequency deviations that results in damage, upset, failure, or misoperation of end-use equipment." Almost all PQ issues are closely related with PE in almost every aspect of commercial, domestic, and industrial application. Equipment using power electronic devise are residential appliances like TVs, PCs etc. business and office equipment like copiers, printers etc. industrial equipment like programmable logic controllers (PLCs), adjustable speed drives (ASDs), rectifiers, inverters, CNC tools and so on. The Power Quality (PQ) problem can be detected from one of the following several symptoms depending on the type of issue involved.

- Lamp flicker
- Frequent blackouts
- Sensitive-equipment frequent dropouts
- Voltage to ground in unexpected
- Locations

- Communications interference
- Overheated elements and equipment.

PE is the most important cause of harmonics, interharmonics, notches, and neutral currents. Harmonics are produced by rectifiers, ASDs, soft starters, electronic ballast for discharge lamps, switched-mode power supplies, and HVAC using ASDs. Equipment affected by harmonics includes transformers, motors, cables, interrupters, and capacitors (resonance).

II. POWER QUALITY SOLUTIONS

Modern customers uses nonlinear loads induces the appearance of the dangerous phenomenon of power quality problems in the electrical feeder networks, producing distortions in the current/ voltage waveforms. Voltage/current distortions have created problems in the design of AC power system [1]. Many technologies have been developed utilizing power electronics based concepts which are capable of mitigating the issues of power quality.

There are two approaches to the mitigation of power quality problems. The first approach is called load conditioning, which ensures that the equipment is made 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 counteract the power system disturbances. Passive filters have been most commonly used to limit the flow of harmonic currents in distribution systems. They are usually custom designed for the application. However, their performance is limited to a few harmonics, and they can introduce resonance in the power system. Among the different new technical options available to improve power quality, active power filters have proved to be an important and flexible alternative to compensate for current and voltage disturbances in power distribution systems. The idea of active filters is relatively old, but their practical development was made possible with the new improvements in power electronics and microcomputer control strategies as well as with cost reduction in electronic components. Active power filters are becoming a viable alternative to passive filters and are gaining market share speedily as their cost becomes competitive with the passive variety. Through power electronics, the active filter introduces current or voltage components, which cancel the harmonic components of the nonlinear loads or supply lines, respectively. Different active power filters topologies have been introduced and many of them are already available in the market.

A. Passive Filters

Power line conditioner intended to improve the quality of the power that is delivered to the load equipment. Conventionally, the most common method used for mitigation of harmonics was to install passive filters is a type of line conditioning system. The passive filter installed in a three phase system uses the passive components, are tuned for a particular frequency, thus provide a good solution because of their high efficiency, low- cost and simplicity. Passive filters are used as either to inject a series high impedance to block the harmonic currents or offer a low impedance path for specific high order harmonics thus act as a harmonic isolator. Series connected filters are imperiled to full line current and has lower the reactive power compensation capability whereas shunt coupled passive filters carry merely a fraction of line current. Moreover, the lower installation cost of shunt filters make them more preferable. (See figure 2.1)

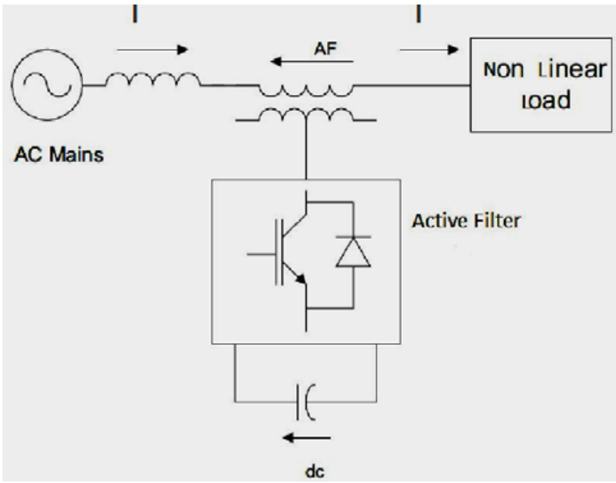

Figure 2.1 The Shunt Passive filter.

However, L-C filters are susceptible to source-sink resonances. L-C filters also attract harmonic current from ambient harmonic-producing loads and background distortion of grid voltages. Filter loading due to background distortion is a key design issue. In the varying utility system where the system configuration changes the filter performance is affected by component tolerances. In contrast for a stiff grid system, strident and precise tuning is required to sink a significant percentage of the load harmonic current thus pretense prodigious efforts for L-C filter design. Thus, after installation passive filters can neither replace the tuned frequency nor the size of the filter can be change.

B. Active Filters

The multifaceted design process, constrained capability to eliminate harmonics and immense losses of the passive filters has stimulated the enhancement of harmonic compensation by means of power electronic devices. Thus modern alternative to passive filters is Actitheve Filters (AF).(see figure 2.2)

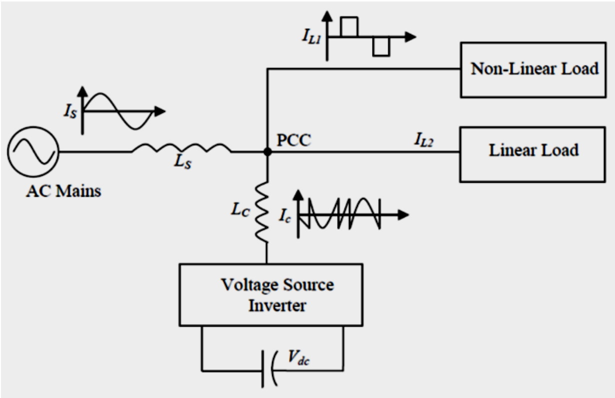

Figure 2.2 Shunt Active Filters.

In the initial phases of AF applications, mostly power MOSFETs and GTOs were operated. However, the existent progress in AF technology has acted on with the commencement of insulated gate bipolar transistors (IGBTs). Furthermore the evolvement of microprocessors, digital signal processors (DSPs), field programmable gate arrays (FPGAs) and inclusion of Hall Effect sensors and isolation amplifiers have spurred researchers and designers. Advancement has made it possible to implement competent control strategies for the AFs to decipher harmonic associated problems in the utility and industrial power systems. The basic principle of Active Filter is to use an inverter to introduce currents or voltages to cancel the load harmonic components.

III. RELATED WORK

T. D. C. Busarello, J. A. Pomilio and M. G. Simões,[1] Passive filters are widely used in electrical system for power quality improvements. Their first installations from 1940 s and their advantages make them an attractive and standard solution up to nowadays. However, passive filters have their filtering characteristics deteriorated due to parameter variation caused by aging or temperature. In addition, a capacitor bank for power factor correction is designed for specific loads and may not supply the right amount of reactive power when loads keep being added or changed. When these issues make the passive filter and the capacitor bank incapable to keep the system operating within acceptable level of power quality, an inconvenience arises and a solution must be provided. A common one is to replace both of them either by new elements or by active power compensators. However, replacing the passive filter and the capacitor bank may not be economically feasible, because they belong to a past investment. This research work presents a solution to overcome such inconvenience keeping the passive filter and the capacitor bank installed and unchanged. It consists of installing two shunt compensators specially designed for performing what the passive filter and the capacitor bank are incapable to do. The result is a reduced processed power in the compensators. The generation of the references is based on conservative power theory (CPT). A case study is presented to prove the compensators' efficacy and the power quality improvement.

T. D. C. Busarello and M. G. Simões,[2] Passive filters are widely used in electrical system for power quality improvements. Their first installations date from 1940s and their advantages make them an attractive and standard solution. However, passive filters have their filtering characteristics deteriorated due to parameter variation, caused by aging and temperature. Additionally, a capacitor bank for power factor correction is designed for specific loads and may not supply the right amount of reactive power when loads keep being added or changed. A solution to overcome such undesired effects is presented in this research work. There are two shunt compensators, with design and control based on the Conservative Power Theory. They are employed as supporting a tuned passive filter plus a capacitor bank. They contribute towards a better passive filter performance with reduced processed power. The addition of those shunt compensators would be cost-effective for weak grid conditions and smart grid advanced energy management control. A case study is presented in order to prove the compensators efficacy and the power quality improvement.

J. C. Leite, I. P. Abril, W. F. Silva, A. de Oliveira Castro, R. de Mendonça Nogueira and M. S. S. Azevedo,[3] Passive shunt harmonic filters are a convenient means of power quality preservation as well as effective reactive power compensators. The problem formulation for the optimization of passive filters has been addressed using various approaches as a single-objective or a multi-objective optimization problem. The present research work considers a new multi-objective formulation for the multiple passive filters selection and placement problem that includes the maximization of the reactive power compensation benefits accomplished by the passive filters as reactive compensators. While previous contributions solve the multi-objective problem by the minimization of a single objective function composite by several sub-objectives, the present research work use the Non-Dominated Sorting Genetic Algorithm (NSGA - II) for solving the problem. The algorithm is capable to determine the location and configuration of each filter (type, branch number, frequency tuning and quality factor). The presented algorithm find the best solution for all the buses simultaneously using many filters and also search the reactive power distribution by branch which offers the best results. The effectiveness of the proposed procedure is tested by solving a practical example.

S. Rahmani, A. Hamadi, K. Al-Haddad and L. A. Dessaint,[4] This research work proposes a combined system of a thyristor-controlled reactor (TCR) and a shunt hybrid power filter (SHPF) for harmonic and reactive power compensation. The SHPF is the combination of a small-rating active power filter (APF) and a fifth-harmonic-tuned LC passive filter. The tuned passive filter and the TCR form a shunt passive filter (SPF) to compensate reactive power. The small-rating APF is used to improve the filtering characteristics of SPF and to suppress the possibility of resonance between the SPF and line inductances. A proportional-integral controller was used, and a triggering alpha was extracted using a lookup table to control the TCR. A nonlinear control of APF was developed for current tracking and voltage regulation. The latter is based on a decoupled control strategy, which considers that the controlled system may be divided into an inner fast loop and an outer slow one. Thus, an exact linearization control was applied to the inner loop, and a nonlinear feedback control law was used for the outer voltage loop. Integral compensators were added in both current and voltage loops in order to eliminate the steady-state errors due to system parameter uncertainty. The simulation and experimental results are found to be quite satisfactory to mitigate harmonic distortions and reactive power compensation.

M. Jafar and M. Molinas,[5] This research work introduces, explains, and investigates the application of a transformerless series-connected reactive/harmonic compensator. The proposed compensator is applied to compensate the high reactive-power/harmonic demand of a 12-pulse line-commutated HVDC rectifier terminal. Simulation results reveal that the proposed strategy compensates the reactive power and harmonics of the HVDC converter satisfactorily. All of this is achieved using significantly smaller capacitance at the compensator dc link than the capacitance required in the state-of-the-art shunt compensators employing passive components. The compensator thus would eliminate the need of fundamental-frequency reactive power supply and minimize (or eliminate altogether) the requirement of passive shunt harmonic compensation. This would result into smaller shunt passive filters, smaller or no shunt capacitor banks, and smaller converter transformers, leading to a more compact HVDC terminal, the current size of which is considered to be the main hurdle in its application for integration of large-scale offshore wind energy. Experimental results from a small-scale setup validate the effectiveness observed in the simulations.

E. S. Sreeraj, E. K. Prejith and K. Chatterjee,[6] Load compensators have become popular because of the enhanced concern over deteriorating power quality figures caused due to the proliferation of power electronic based systems which pose themselves as non-linear type of loads to the utility. Modern load compensators have better filtering performance, small physical size, and more flexibility in application, but are still not very competitive in terms of its cost and increased losses compared to traditional passive filters, especially if it is used for compensating reactive power requirement of the load. Innovative and advanced controllers like one cycle control (OCC) having fast transient response and which do not require the service of a phase locked loop (PLL) have been used for active load compensation. But existing OCC based load compensators do not have the capability to distinguish between fundamental reactive component of the load current and its higher order harmonic components and end up compensating for both. This leads to an increase in the rating of the converter. The proposed OCC based shunt harmonic filter compensates only for the harmonic component of the load current, while retaining the advantages of the original OCC based schemes.

IV. PROBLEM STATEMENT

In modern electrical distribution systems there has been a sudden increase of single phase and three-phase non-linear loads. These non-linear loads employ solid state power conversion and draw non-sinusoidal currents from AC mains and cause harmonics and reactive power burden, and excessive neutral currents that result in pollution of power systems. They also result in lower efficiency and interference to nearby communication networks and other equipments. Mitigation of power quality problems is synonymous with reduction of harmonic currents or voltage distortion at ac mains. These problems can also be mitigated by improving the immunity of the equipment using better quality material along with proper protection arrangements, but it may not result in an effective and economical solution.

V. CONCLUSION

In this research different power control strategies have revived and discussed. filters plays an important contribution for the power quality improvement. The term power quality became most prominent in the power sector and both the electric power supply company and the end users are concerned about it. The quality of power delivered to the consumers depends on the voltage and frequency ranges of the power. If there is any deviation in the voltage and frequency of the electric power delivered from that of the standard values then the quality of power delivered is affected. To lessen the harmonics expectedly inactive L-C filters were utilized and additionally capacitors were utilized to enhance the power factor of the ac loads. At the same time the passive filters have a few drawbacks like settled recompense, vast size and reverberation issue. To relieve the harmonics issue, numerous exploration work advancement are created on the active power (APF) filters or active power line capacitors.

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