Shunt Active Power Filter to Enhance Power Quality: A Review

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Abstract - Most of the pollution issues created in power systems are due to the non-linear characteristics and fast switching of power electronic equipment. Power quality issues are becoming stronger because sensitive equipment will be more sensitive for market competition reasons, equipment will continue polluting the system more and more due to cost increase caused by the built-in compensation and sometimes for the lack of enforced regulations. Efficiency and cost are considered today almost at the same level. Active power filters have been developed over the years to solve these problems to improve power quality. Among which shunt active power filter is used to eliminate and load current harmonics and reactive power compensation.

Keywords: Facts Controller, Shunt Active Power Filter,

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. Various topologies of active power filters have been developed so far [1-12]. The shunt active power filter based on current controlled voltage source type PWM converter has been proved to be effective even when the load is highly non-linear [1,4,11]. Most of the active filters developed are based on sensing harmonics [7,10,11] and reactive volt-ampere requirements of the non-linear load [1,3,12,17] and require complex control. A new scheme has been proposed in [10], in which the required compensating current is determined by sensing load current which is further modified by sensing line currents only [8,13]. An instantaneous reactive volt-ampere compensator and harmonic suppressor system is proposed [13] without the use of voltage sensors but require complex hardware for current reference generator.

II. LITERATURE REVIEW

Shivansh et al. [1] presents the implementation and simulation of shunt active power filter with diode rectifier connected to RL Load. Generation of reference fundamental load current signal is done without calculating load active power.

Sudarshan et al. [2] proposed a new weighted adaptive Hysteresis Band Current Controller (WAHBCC) for three phase Shunt Active Power Filter. In WAHBCC, hysteresis band is adaptively changed in order to reduce the total harmonic distortion of source current to a minimum value, while maintaining the switching frequency and switching losses to an optimum minimum value so the total cost of the system is minimized.

Salem et al. [3] proposed an energy-based Lyapunov function control technique is developed for a three-phase shunt hybrid active filter (SH-AF) to compensate harmonics generated by nonlinear loads and is applied for balanced operation.

Abdelhamid et al. [4] proposes a novel topology for a three-phase hybrid passive filter (HPF) to compensate for reactive power and harmonics. The HPF consists of a series passive filter and a thyristor-controlled-reactor-based variable-impedance shunt passive filter (SPF).

Alexander et al. [5] A hybrid-series AFP based on a low-rated multilevel inverter, acting as a high-harmonic impedance, and a shunt passive filter acting as a harmonic-current path, were developed and tested.

Avik et al. [6] attempts to improve the dynamic performance of a shunt-type active power filter. The predictive and adaptive properties of artificial neural networks (ANNs) are used for fast estimation of the compensating current.

Cesar et al. [7] Multilevel converters offer advantages in terms of the output waveform quality due to the increased number of levels used in the output voltage modulation.

Salem et al. [8] The first step is to extract the SAPF reference currents from the sensed nonlinear load currents by applying the synchronous reference frame method, where a three-phase diode bridge rectifier with R–L load is taken as the nonlinear load, and then, the reference currents are modified, so that the delay will be compensated.

III. PROPOSED METHODOLOGY

Power quality problems can be very costly to some of industrial plants and important for security of strategic customers. These customers may require premium quality power, free of disturbances, called custom power. Solutions for power quality problems would include installation of compensation devices or stand-by energy sources on customer site. On the other hand, DSO may build custom power parks – sites intended for customers willing to pay for higher quality and reliability of power supply.

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°.

In general, the objective of this dissertation is to investigate the various control strategies of shunt active power filter based on voltage and current controller has been presented to mitigate the current harmonics. At the same time, the other purpose of this dissertation is to utilize the learnt knowledge to the real application.

Facts controllers can be divided into four categories as follows:

3.1. Shunt compensators

3.2. Series compensators

3.3. Combined series-series compensators

3.4. Combined series-shunt compensators

They can be explained briefly as follows:

Shunt Compensators

The shunt Controllers may be variable impedance, variable source, or a combination of these. In principle, all shunt Controllers inject current into the system at the point of connection. Even variable shunt impedance connected to the line voltage causes a variable current flow and hence represents injection of current into the line. As long as the injected current is in phase quadrature with the line voltage, the shunt Controller only supplies or consumes variable reactive power. Any other phase relationship will involve handling of real power as well. The Shunt Compensator is shown in figure 3.1

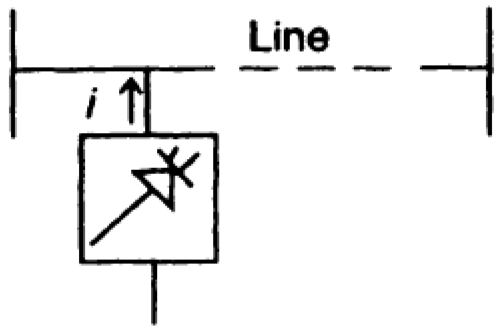

Fig. 3.1: Shunt Compensator

Series Compensators

The series Controller could be variable impedance, such as capacitor, reactor, etc., or a power electronics based variable source of main frequency, sub synchronous and harmonic frequencies (or a combination) to serve the desired need. In principle, all series Controllers inject voltage in series with the line. Even variable impedance multiplied by the current flow through it, represents an injected series voltage in the line. As long as the voltage is in phase quadrature with the line current, the series Controller only supplies or consumes variable reactive power. Any other phase relationship will involve handling of real power as well. Series Compensator is shown in fig. 3.2

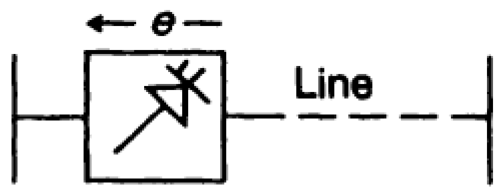

Fig. 3.2: Series Compensator

Combined Series-Series Compensators

This could be a combination of separate series controllers, which are controlled in a coordinated manner, in a multiline transmission system. Or it could be a unified Controller, Figure 3.3, in which series Controllers provide independent series reactive compensation for each line but also transfer real power among the lines via the power link. The real power transfer capability of the unified series-series Controller, referred to as Interline Power Flow Controller, makes it possible to balance both the real and reactive power flow in the lines and thereby maximize the utilization of the transmission system. Note that the term "unified" here means that the de terminals of all Controller converters are all connected together for real power transfer.

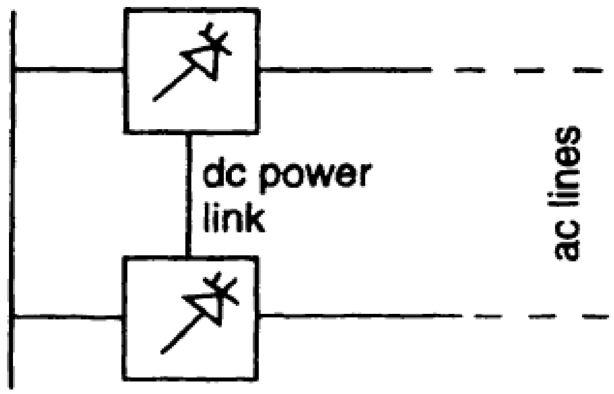

Fig. 3.3: Combined Series-Series Compensator

3.4 Combined Series-Shunt Compensators

This could be a combination of separate shunt and series Controllers, which are controlled in a coordinated manner Figure 3.4. In principle, combined shunt and series Controllers inject current into the system with the shunt part of the Controller and voltage in series in the line with the series part of the Controller. However, when the shunt and series Controllers are unified, there can be a real power exchange between the series and shunt Controllers via the power link.

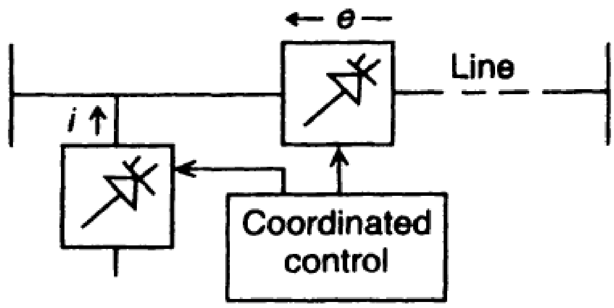

Fig. 3.4: Combined Series-Shunt Compensator

Shunt active power filter

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°.

The main aim of the Active Harmonic Filter (AHF) is to compensate for the harmonics and reactive power dynamically. The AHF overcomes the drawbacks of passive filters by using the switching mode power converter to perform the harmonic current elimination. Figure 4.1 shows general bloch diagram of SAF; there are three topologies of AHF: i) Series AHF, ii) Shunt AHF and iii) Hybrid AHF. We have selected Shunt AHF (i.e., Shunt Active Filter or Current Active Filter) for this study which is ideal for current harmonic compensation.

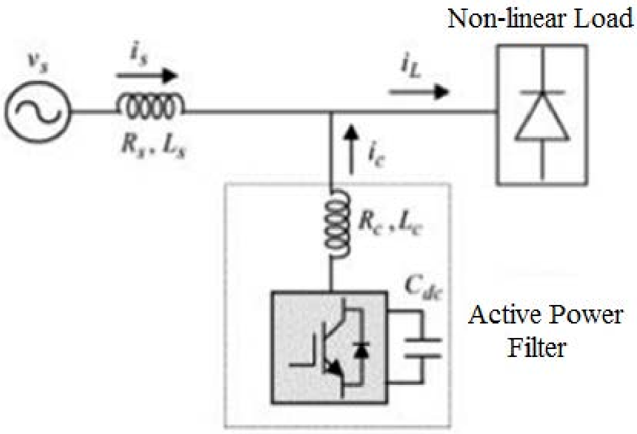

Fig. 4.1: General Block Diagram of Shunt Active Power Filter

In the circuit contains a three phase source, non linear load i.e. Electronics and power electronics load and a shunt active power filter i.e. PWM inverter with DC link capacitor.

There is the review of two control strategies for reference current generation for Shunt active power filters i.e. PWM inverter. 3 phase PWM inverter needs 6 gate pulses to work according to the current compensation and it is generated by different control techniques. Here we are discussing indirect current control technique and PQ theory with PI and With Fuzzy Logic controller.

IV. CONTROL SCHEMES

There is the review of two control strategies for reference current generation for Shunt active power filters i.e. PWM inverter named are:

(a) Indirect current control technique with PI controller

(b) Indirect current control technique with Fuzzy controller

(c) PQ theory with PI controller

(d) PQ theory with Fuzzy logic controller

V. CONCLUSION

A shunt active power filter has been investigated for power quality improvement. Various simulations are carried out to analyse the performance of the system. PI controller-based Shunt active power filter are implemented for harmonic and reactive power compensation of the non-linear load. A program has been developed to simulate the PI controller-based shunt active power filter in MATLAB. It is found from simulation results that shunt active power filter improves power quality of the power system by eliminating harmonics and reactive current of the load current, which makes the load current sinusoidal and in phase with the source voltage. The performance of both the controllers has been studied and compared. A model has been developed in MATLAB SIMULINK and simulated to verify the results.

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