Power Quality Enhancement Using Active Power Filters

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Abstract: *This paper describes different power quality problems in distribution systems and their solutions with power electronics based equipment. Hybrid, shunt and series active power filters are described showing their compensation characteristics and principles of operation. Dissimilar power circuits topologies and control scheme for every type of active power filter are analyzed. The compensation characteristics of every topology with the individual control techniques are proved by simulation and experimentally.*
Keywords: *PWM inverters, Neutral-Point-Clamped, Active power filter.*

I. Introduction

The propagation of microelectronics processors in a broad variety of equipments, from home digital clocks to automated industrial assembly lines and sanatorium diagnostics systems has increased the susceptibility of such equipment to power quality problems. These harms include a variety of electrical disturbances, which may create in several ways and have dissimilar effects on various kinds of perceptive loads. As a result of this susceptibility, increasing numbers of industrial and commercial facilities are trying to protect themselves by investing in more sophisticate equipment to improve power quality. Furthermore, the propagation of non-linear loads with large rated power has increased the infectivity level in voltages and currents waveforms, forcing to advance the compensation uniqueness required to satisfy more rigorous harmonics standard. Different active power filters topologies have been presented in the technical literature. This paper will focus in the analysis of which to use with their compensation uniqueness. Shunt active power filters, series active topologies, and hybrid schemes will be existing and analyzed. At last, steady state and transient results for dynamic compensation, obtained as of simulated and trial setup will be presented.

II. Power Quality In Distribution Systems

A power quality problem exists if any voltage, current or frequency variation results in a failure or in a bad operation of customer's apparatus. Though, it is important to notice that the quality of power supply implies basically voltage quality and supply dependability. Voltage quality problems relate to any breakdown of equipment due to deviations of the line voltage from its nominal individuality, and the supply dependability is characterized by its adequacy and availability.

Power quality problems are widespread in most of commercial, industrial and utility networks switching phenomena resulting in oscillatory transients in the electrical supply. Between the different voltage disturbances that can be shaped, 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 apparatus, foremost to expensive interruptions of production. Intended for these reasons, the customer point of view, power quality issues will become a gradually more important factor to consider in order satisfying good productivity. For the electrical supply industry, the excellence of power delivered will be unique factors for ensuring customer faithfulness in this very spirited and deregulated market. To deal with the needs of energy consumers trying to get better efficiency through the reduction of power quality related process stoppages and energy suppliers trying to maximize operating profits while keeping customers satisfied with supply quality, pioneering technology provides the solution to money-spinning power quality enhancements solutions. Though, with the variety of power quality solutions obtainable, the palpable inquiry for a customer or utility facing a particular power quality problem is which apparatus provides the enhanced result.

III. Solution To Power Quality Problem

There are two approaches to the mitigation of power quality troubles. The primary approach is called load conditioning, which ensures that the apparatus is fewer responsive to power turbulence, allowing the operation even under significant voltage twist. The additional solution is to fix line conditioning systems that repress or counteracts the power system turbulence.

A flexible and adaptable solution to voltage quality troubles is obtainable by active power filters. At present they are based on PWM converters and connect to low and medium voltage distribution system in series or shunt. Series active power filters must operate in concurrence with shunt passive filters in order to equilibrium load current harmonics. Shunt active power filters function as a suitable current source and series active power filters operates as a suitable voltage source.

IV. 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 standard is appropriate to any type of load considered a harmonic source. Furthermore, with a suitable control technique, the active power filter can also reward the load power factor. In this way, the power allocation system sees the non linear load and the active power filter as an ideal resistor. The current compensation quality of the shunt active power filter is shown in Fig.1.
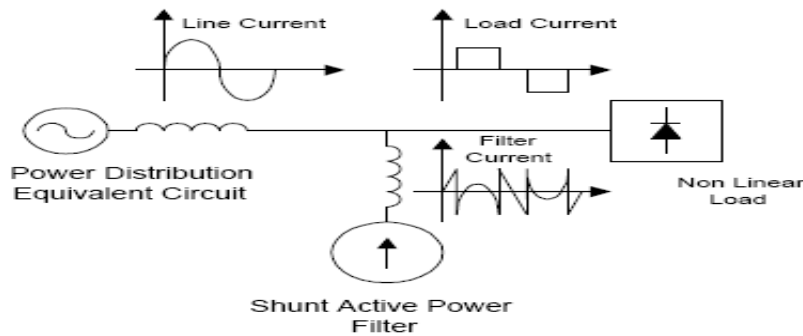

Fig. 1: Compensation characteristics of a Shunt active Power filter

V. Power Circuit Topology

Shunt active power filters are typically implemented with pulse-width modulated voltage source inverters. The PWM-VSI operates as a current controlled voltage source. Traditionally, two level PWM-VSI have been used to realize such system. Nevertheless, in the past years multilevel PWM voltage source inverters have been planned to expand active power filters for medium voltage applications. The use of two PWM-VSI of different rated power allows the use of dissimilar switching frequencies, dipping switching stresses and commutation losses in the overall compensation system.

Multilevel PWM inverters can be connected to high voltage source without a coupling transformer. The use of neutral-point-clamped (NPC) inverters allows equal voltage shearing of the series connected devices in each phase. However, the neutral point potential deviates, resulting in an excess voltage stress to either the upper or lower set of devices.

For active power filter applications the three levels NPC inverter output voltage must be able to produce an output current that follows the respective reference current which include the harmonic and reactive constituent required by the load. The power circuit topology of an active power filter implemented with a Neutral-Point- Clamped voltage-source inverter is shown in Fig. 2. The three levels NPC voltage-source inverter is linked in parallel through a link reactor to the power distribution system.
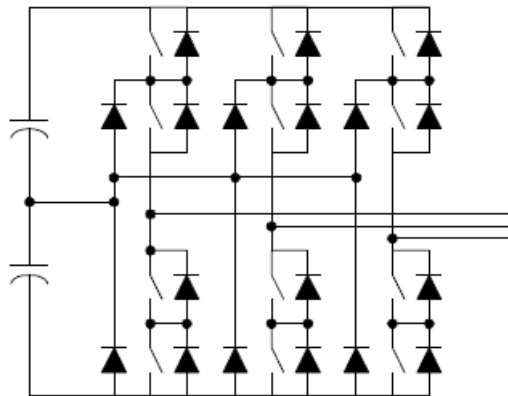

Fig. 2: An active power filter implemented with a three- level NPC voltage-source inverter.

VI. Control Scheme

The block diagram of a shunt active power filter control scheme is shown in Fig. 4 and consists of a current position generator, a dc voltage control and the inverter gating signals generator. There are many potential to expand this kind of control [5], [6]. Also, the compensation usefulness of an active power filter depends on its capacity to follow with a minimum error and time delay the reference signal calculated to compensated the indistinct load current. Lastly, the dc voltage control element must keep the total dc bus voltage constant and equals to a known reference value. The dc voltage control is achieved by adjusting the small quantity of real power fascinated by the inverter. This small amount of real power is attuned by varying the amplitude of the basic component of the reference current (Fig.3.).
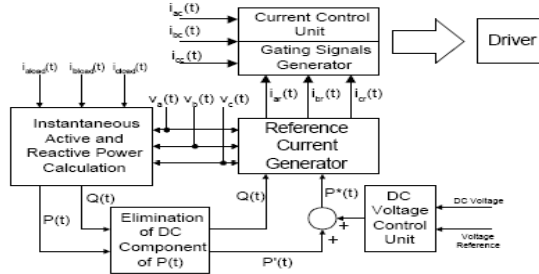

Fig. 3: The block diagram of a shunt active power filter control scheme.

VII. Series Active Power Filters

It is familiar that series active power filters compensate current system distortion caused by non-linear loads by impressive a high impedance path to the current harmonics which forces the high frequency currents to flow through the LC passive filter connected in parallel with the load [5].
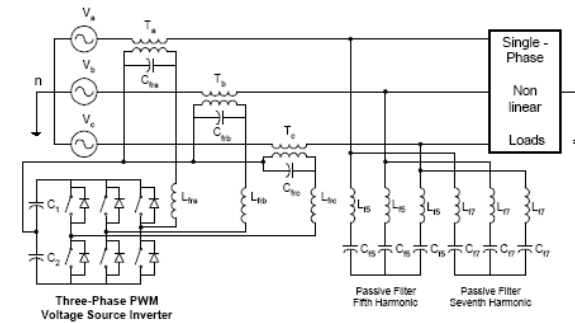

Fig. 4: The proposed series active power filters Topology.

VIII. Control Scheme

The block diagram of the proposed control scheme is shown in Figure 5. Current and voltage reference waveforms are obtained by using the Instantaneous Reactive Power Theory.
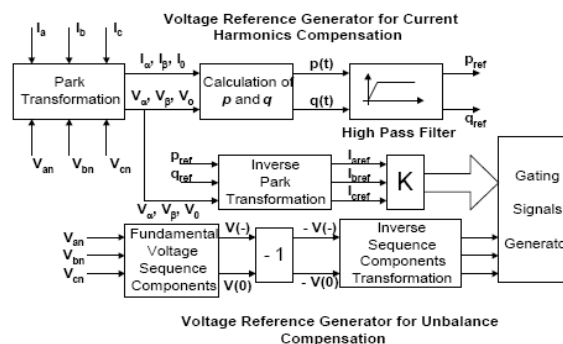

Fig. 5: The block diagram of the proposed series active power filter control scheme.

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

IX. Simulated Results

The feasibility of the proposed series active power filter has been established by simulation using P-Spice. Relevant results are shown in Figures 6, 7, and 8. In particular, Figure 8 shows the effect of voltage compensation with the current harmonic generator circuit not working, while in Figure 7, only the current harmonic compensator scheme is in service. In Figure 8 the series active power filter is compensating voltage unbalances and current harmonic components at the same time. The series active power filter starts compensating at 140ms.
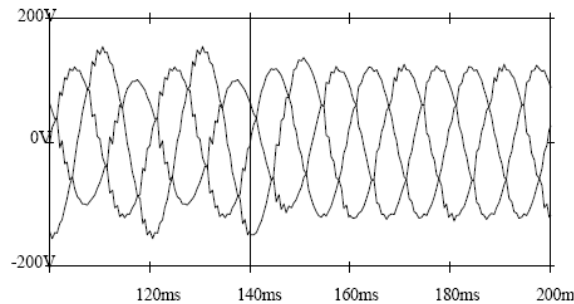
Fig. 6: Simulated waveforms for voltage unbalance compensation. Phase to neutral voltages at the load terminals before and after series compensation.
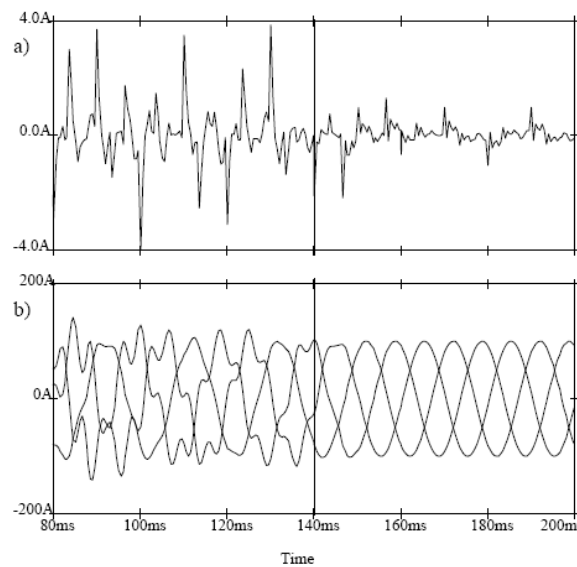
Figure 7: Simulated waveforms for current harmonic compensation. a) Current from neutral flowing to the mains before and after compensation. b) Line currents flowing to the mains before and after compensation.
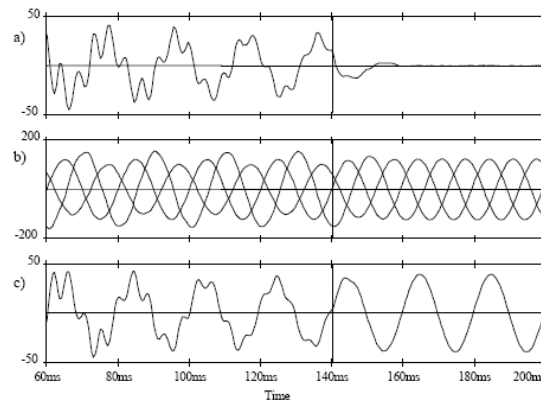
Figure 8: Simulated results for voltage unbalance and current harmonic compensation, before and after compensation. a) Ac mains neutral current. b) Phase to neutral load voltages. c) Ac source line current.

X. Conclusion

In this paper the presentation of an active power filter (APF) depends on the inverter characteristics, applied control method, and the accuracy of the reference signal generator. The correctness of the reference generator is the majority significant item in seminal the performance of APFs. This paper implemented an efficient reference signal generator composed of an enhanced adaptive predictive filter. The performance of the implemented reference signal generator was first established through a simulation with MATLAB.

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