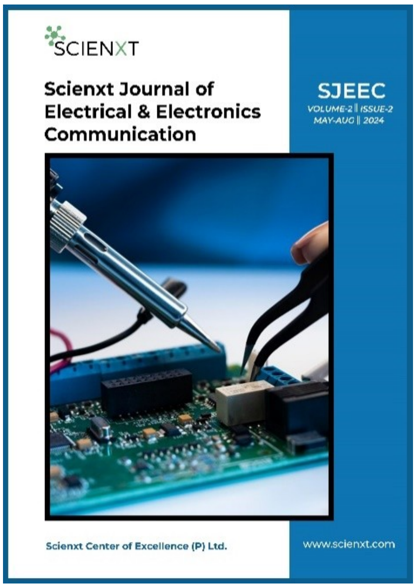

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Application of rent controller in shunt active power filter

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Abstract:

This paper presents the analysis and the application of rent controller in an active power filter (APF). The two capacitor banks in which the DC-capacitor a PWM voltage-source electronic converter with three legs and has to be split to accommodate the neutral wire of the SAPF four wires. The neutral wire is connected to the middle point. In this way a traditional three-leg electronic converter can be of the DC-capacitor voltage. The controller is a two-level nested controller. This paper focuses on the neutral-wire current control and on the balance control of the DC-capacitor voltage.

Keywords:

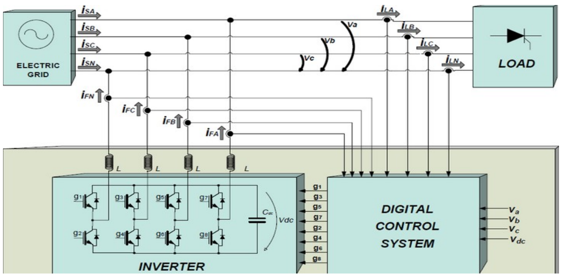
Harmonic control, Power quality Shunt active power filters, Voltage-source inverters

1. Introduction:

The increasing use of rectifiers, thyristor power converters, arc furnaces, switching power supplies and other nonlinear loads is known to cause serious problems in electric power systems [1]. These problems can be partially solved with the use of passive filters, however, this kind of filtering cannot adapt to variations of the loads, and they also can produce undesired resonances [2]. One solution to avoid these problems is the Shunt Active Power Filter. These devices work as current sources, connected in parallel with the electric grid, and they are capable of providing the harmonics and the reactive power required by the loads Three-phase four-wire Shunt Active Power Filters are also capable of compensating unbalance and zero sequence currents, minimizing the neutral current. In this way, the mains only supply the fundamental, balanced currents with a unitary power factor, avoiding voltage distortion and reducing power losses in the transmission lines. This paper appears in sequence of the work developed at the Energy and Power Electronics Laboratory, which had as main objective to develop prototypes of Shunt Active Power Filters to be used to demonstrate the applicability and advantages of this kind of devices in real facilities. With the help of low cost Power Quality Monitors, various electrical power plants were monitorized. Based in the data collected with the miniaturizations, four installations were chosen to exhibit the operation of the Active Power Filters. To show the major advantages and the ability of Active Power Filters to compensate any type of load disturbance, the selected facilities have very different characteristics. The first facility selected is in a large textile industry, and consists in a electrical switchboard that feeds a bulky machine for cloth whitening, comprising many variable speed drivers. The second chosen installation is the switchboard of a computational centre. The third place consists in the electrical switchboard of a clinical analyses laboratory, in a hospital. The fourth site is the main electrical switchboard of a medical drugs distribution warehouse. A summary involving the major topics of this paper is described as follows. The developed Active Power Filters configuration, and a set of equations describing the control theory based on the Instantaneous Reactive Power theory for three-phase four-wire systems are presented in Aspects related to the construction of the Active Power Filter prototypes are detailed in results are presented and analysed. Finally, conclusions and suggestions for further works are presented.

2. Active power filter configuration:

The power stage of the developed Shunt Active Power Filters is composed by a standard two-level, four-leg Voltage Source Inverter (VSI) that uses eight IGBT and an electrolytic capacitor in the DC side. Fig. 1 shows the block diagram of the three- phase four-wire Shunt Active Power Filter. The inductors (L) are used to connect the inverter to the electric grid. The controller requires the three phase to neutral system voltages the DC link voltage (V_{dc}), the four load currents, and the four inverter currents. When the Shunt Active Power Filter is connected, the source currents become balanced and sinusoidal, and the neutral source current (iSn) becomes practically zero. The control strategy is based on the Theory of the Instantaneous Reactive Power (p-q theory) introduced by and expanded to three-phase four-wire systems. It applies an algebraic transformation (Clarke transform) of the three-phase system voltages and load currents in the a-b-c coordinates to the α-β-0 coordinates. After the transformation, the p-q theory components are achieved by the expressions (1-3), where p is the instantaneous real power, q is the instantaneous imaginary power (by definition) and p is



the instantaneous zero sequence power.

Figure. 3: phase four wire shunt active power filter

Each one of the instantaneous power components can be separated into an average value and an oscillating value. The physical meaning for each of the instantaneous power components is: p Average value of the instantaneous real power, p. Corresponds to the energy per time unit transferred from the source to the load, in a balanced way, through the 3 phases p

$$p = v_\alpha \cdot i_\alpha + v_\beta \cdot i_\beta$$

Oscillating value of the instantaneous real power, p. It is the energy per time unity that is exchanged between the power source and the load, through the 3 phases q Instantaneous imaginary power, q. Corresponds to the power that is exchanged between the phases of the load. This component does not imply any transference or exchange of energy between the power supply and the load, but is responsible for the existence of undesirable currents in the electrical feeder’s p Mean value of the instantaneous zero-sequence power p. It corresponds to the energy per time unity that is transferred from the power source to the load through the zero-sequence components of voltage and current Oscillating value of the instantaneous zero-sequence power. It means the energy per time unity that is exchanged between the power source and the load through the zero-sequence components of voltage and current. The capacitor voltage can be kept constant by a control algorithm that exchanges the required energy with the electric grid. To accomplish this task, in addition to the standard power components, one new component is also used to regulate the capacitor voltage. The power components that will be injected by the shunt Active Filter, px and qx, include the undesired power quality effects to be compensated harmonics currents, current unbalance and reactive power.

3. Prototypes implementation:

The developed work began with computational simulations on control strategies, switching techniques and hardware topologies. The first results were obtained using the simulation tool PSCAD validate the proposed control algorithm. From previous experience, it is possible to verify that if the simulation model is accurately modelled and the details of hardware implementation are taken into consideration, the simulation results are very similar to the ones measured in the developed prototype. A second phase consisted in implementing a laboratory prototype of the described Shunt Active Power Filter, and testing the proposed control theory and switching technique. It is possible to see the implemented laboratory prototype. It uses a Texas Instruments DSP, and the control system was implemented using only fixed point calculations in order to enhance performance in terms of execution time. Hall effect sensors were used to measure the voltages and currents. The inverter stage was implemented using 4 SEMIKRON IGBT modules. Two of the most important aspects when an equipment prototype is installed in field environment are security and reliability. The security of the human operators, the security of the industry plant, and the integrity of the equipment are factors that must be evaluated carefully. Therefore, it is very important to protect the Active Power Filter against phenomena that usually do not exist in a laboratory environment, but that may occur in industry. To accomplish these estrangements, the laboratory prototype was designed to be assembled in an electric board. To prevent that anomalous operations can damage the Active Power Filter components or other equipment connected to the electrical grid, various protections schemes were implemented. A supervisory and protection system was developed to permanently monitorize the Active Power Filter operation parameters, and to disconnect the device if any anomalous values are detected. Some of the protections implemented have two levels of actuation, in a first level the problem can be detected through software algorithms, and the Active Power Filter is softly turned off if the problem persists. More extreme malfunctions will activate implemented hardware protections that instantaneously disconnect the Active Power Filter from the electric grid and also discharge the DC side capacitors. The supervisory and protection system also has the responsibility to correctly operate the Active Power Filter. It is responsible for the soft connection of the Active Power Filter to the electric grid, performing the pre-charge of the DC capacitors. Some of the implemented protections are protection against abnormal system voltages protection against over currents produced by the Active Power Filter Protections against high temperature are also implemented through temperature sensors assembled in various representative points. Temperature sensors also allow the ON/OFF control of the electric board ventilation fans, which are responsible for cooling the heat sinks of the IGBT modules, and the inductors.

4. Experimental results:

The developed prototypes are demonstrated in operation in four different installations. The target installations were previously monitorized and simulation models of each installation were developed using the PSCAD simulation tool. The simulation models were used to foresee the Active Power Filter behaviour and to help sizing the hardware components and the protection limits. According to these previous studies, four Shunt Active Power Filters were constructed within three different compensation ranges.Two 20kVA prototypes to be used in the computation centre and in the hospital, a 35 kVA prototype to be used in the textile industry installation, and a 55 kVA prototype to be applied in the medical drugs distribution warehouse. The experimental results achieved in the four demonstration installations are presented in the next topics.

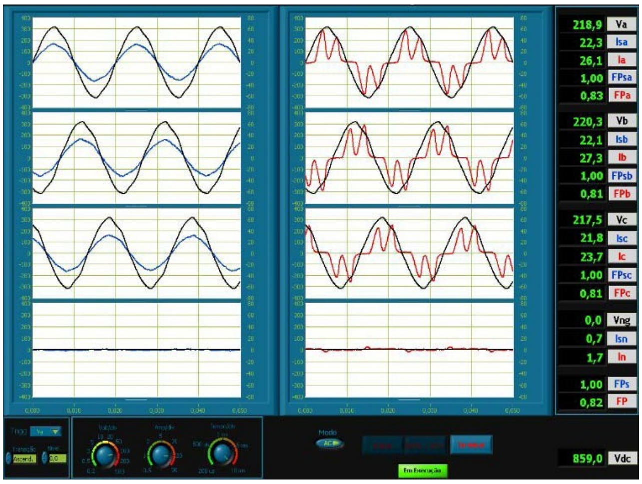


Figure. 2: System voltages and currents waveforms at Load and Source sides, registered in installation 1 (Textile Industry)

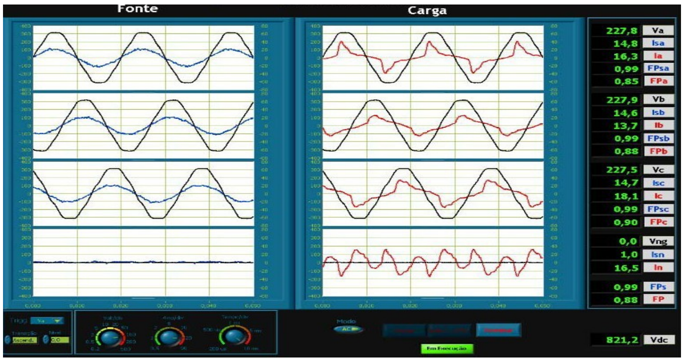


Figure. 3: System voltages and currents waveforms at Load and Source sides, registered in installation 2 (Computational Centre)

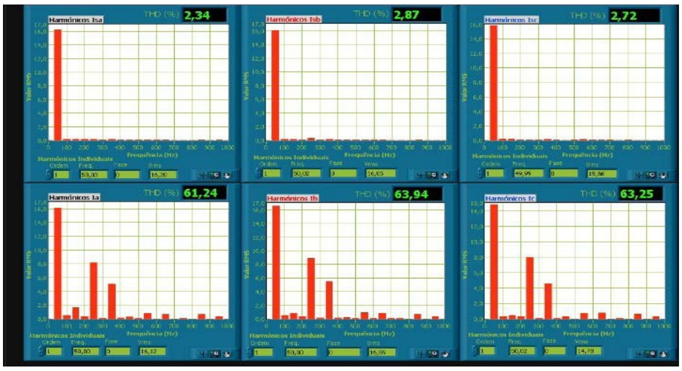


Figure. 4: Current harmonics and THD at Load and Source sides, registered in installation 1 (Textile Industry)

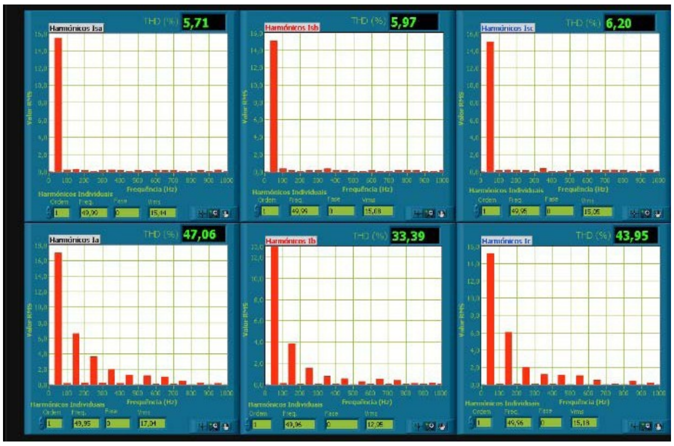


Fig. 5 Current harmonics and THD at load and source sides, registered in installation 2 (Computational Centre)

Desk Jet and laser printers, lighting, and air- conditioning circuits, at this electrical installation the load currents present a THD near to 50 %, the third harmonic is especially high, although other harmonics are present. The load presents significant unbalances at certain periods of the day, and the neutral current is high not only due to the unbalance, but specially due to the third order harmonic at the phase currents, resulting in a neutral current with a 150 Hz fundamental frequency. As a result of the Active Power Filter operation, the three phase currents are enhanced, the waveforms are approximately sinusoidal, with a THD around 6 %. At source side the three phase currents become balanced, the neutral current is reduced from 16.5 A to 1 A, and the total power factor is increased from 0.88 to 0.99.

5. Conclusions:

This paper presented prototypes of Shunt Active Power Filters, developed at the Energy and Power Electronics Laboratory in operation at four different electrical device facilities with college. The presented results confirm the ability of the Active Power Filters to compensate problems like current harmonics, current unbalance and power factor. The developed prototypes presented a good performance in both demonstration installations. The next steps in the evolution of the Shunt Active Power Filter development are performing electromagnetic compatibility (EMC) tests, and realizing some improvements to allow the utilization of these equipments in accordance to the Portuguese and European legislation. The presented Active Power Filters are currently in industrialization process by topologies and switching techniques for the inverters of the Active Power Filters, in order to improve the performance of the power stages, by reducing the noise injected in the electric grid and minimizing the operation losses. Passivity-based control can guarantee APF system dynamic stability. Hamiltonian model of APF is built. Instruction signal of harmonic currents is obtained by PI controller of the voltage harmonic where APF is located.

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