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Series Active Power Filter For Three Phase Diode Rectifier

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Abstract: Active Power filter (APF) is used to improve the power quality we introduced a series active power filter (SAPF) which resolve the power quality and voltage issues. This paper deals with the series active power filter which eliminates the voltage sag and swell and compensates harmonic current and voltage. Current harmonics are caused by non-linear loads as a rectifier, is connected to the system, it draws a current that is non-sinusoidal. The simulation analysis reduces the harmonic in the output voltage. The proposed filters can improve the distortion of non-linear loads. The non-ideal properties of the voltage source and harmonic currents create voltage distortion. This paper proposed a new circuit configuration for the three-wire series active power filter to eliminate voltage harmonic components. This series APF is made up of two-arm bridge power converter one is filter inductor set and another filter capacitor set and a set of capacitor/resistor filters. One phase of this three phase proposed APF without control of the power electronic devices connected directly with any single dc terminal.

Keywords: Active power filters (APF), Power quality (PQ), Harmonic compensation, diode rectifier.

I. INTRODUCTION

Power Quality is important in every power delivery system. Low quality of power may cause production loss, damage of equipment, increased power losses and interference in communication lines. Its widespread impacts the quality of electric power supply by generating voltages and current harmonics. Power quality mitigation equipment use passive elements and don't respond correctly as the nature of power system change. Active power filter (APF) is used for improving power quality. Harmonic current distortion generated by nonlinear loads is a very serious problem in power system. Three-phase diode rectifiers is used to adjust speed drives and dc power supplies the harmonics generated by the diode rectifier in the line current which is the main concern in power electronics. To eliminate the harmonic current the shunt active power filter (APF) or series APF will be an effective solution.

Power quality problem can be defined as imperfection in both load current and voltage supply from the normal sine wave, the lack of power quality causes production loss and power loss, damage of equipment This leads to the overheating of the equipment and insulation failure, and over speeding of induction motors. The solution to overcome these problems is to filter out these harmonics.so it is importantly to adjust a high standard of power quality. Consider a three-phase diode rectifier with a dc load, the dc load is modeled with a easily RL load. It can be justified even under the output capacitor filter condition in the inductor is used place in front of the capacitor is smooth the dc link current. There is no other mechanism to improve the input current quality of the diode rectifier, the input currents are polluted with series harmonic components. To less than the harmonic pollution, is dc link APF is proposed. This dc link APF is coupled to the ac input with three ac switch working at the line frequency and connected to the load, as shown in Fig. 1. It consists of two series-connected the bidirectional converters, which contained positive part components and negative part components.

ACTIVE POWER FILTER FOR DIODE RECTIFIER

Consider a three-phase diode rectifier with a dc load as shown in fig, the dc load is modeled with a simple RL load. It can be justified even under the output capacitor filter condition in that an inductor is usually placed in front of the capacitor to smooth the dc link current. If there is no other mechanism to improve the input current quality of the diode rectifier, the input line currents are polluted with series harmonic components. To alleviate the harmonic pollution, a dc link APF is proposed. This dc link APF is coupled to the ac input with three ac switches working at line frequency and connected to the load, as shown in Fig.

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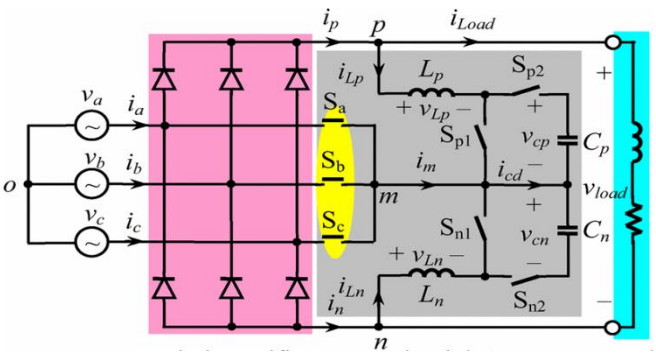
Diode Rectifier APF Load
Fig.1 active power filter for three-phase diode rectifier

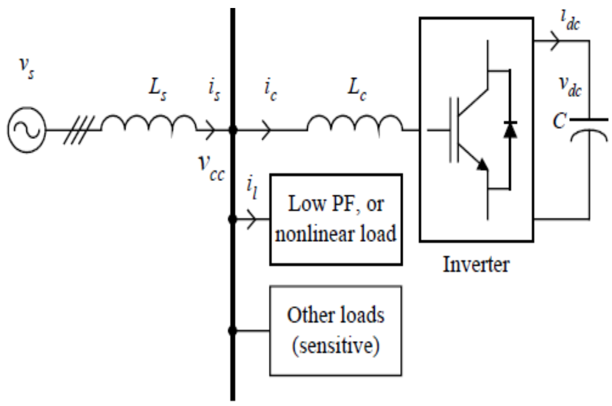

Fig.2 block diagram of APF

ACTIVE POWER FILTER

Active filters are using a combination of passive and active (amplifying) components, and require an outside power source. The operation principle of APF is basically cancelling the distorting harmonic currents by measuring them and generating a harmonic current spectrum in opposite phase to the measured current. The parallel active power filter is considered as a current source injecting harmonic current into the ac system with the same amplitude and in anti-phase that of the load current to obtain an undistorted sinusoidal source current. The Active filter topology is now more mature for providing compensation for harmonic, reactive power, or neutral current in ac networks. AF are also harmonics to regulate terminal voltage, to suppress voltage flicker, and to improve voltage balance in three-phase systems. This wide range of objectives is achieved either individually or in combination, depending upon the requirements and control strategy and configuration which have to be selected appropriately. Following the widespread use of solid-state control of ac power, the power quality issues are basically categorized into three types, namely, two-wire(single phase), three-wire and four-wire three phase configurations to meet the requirements of the three types of non-linear loads on supply systems. Many control strategies such as instantaneous power theory, synchronous frame d-q theory, synchronous detection method and notch filter method are used in the development of three-phase AF. Shows basic APF block diagram including non-linear load on the three phase supply condition. APF overcome the drawbacks of passive filters by using the switching mode power converters to perform the harmonic current elimination. A voltage source inverter (VSI) is used as the series active power filter is show in fig.

SERIES ACTIVE POWER FILTERS

It compensates voltage harmonic distortion caused by non-linear loads. The high impedance imposed by the series APF is created by generating a voltage of the same frequency that the current harmonic component that needs to be eliminated. Instantaneous supply current is detected by the controller Harmonic current extracted from the supply current. Voltage unbalance is corrected by compensating the fundamental frequency negative and zero sequence voltage components of the system.

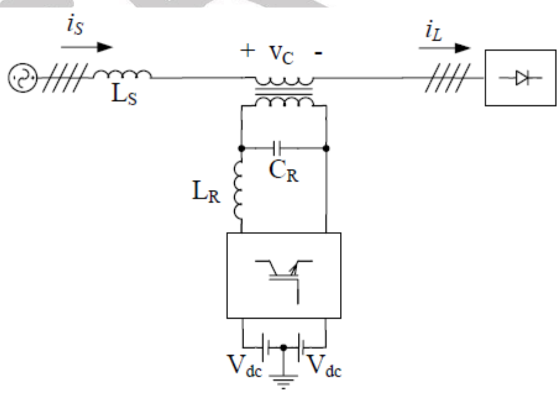

Fig.3 series active power filter

The active filter in this configuration produces a PWM voltage waveform which is added or subtracted, on an instantaneous basis, to/from the supply voltage to maintain a pure sinusoidal voltage waveform across the load. The main power-circuit configuration is shown. The inverter configuration accompanying such a system is a voltage-fed inverter without any current-control loops. Series active filters are less common industrially, than parallel active filters. This is because of the main drawback of series circuits, namely that they have to handle high load currents, which increases their current rating considerably compared

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with parallel filters, especially in the secondary side of the coupling transformer.

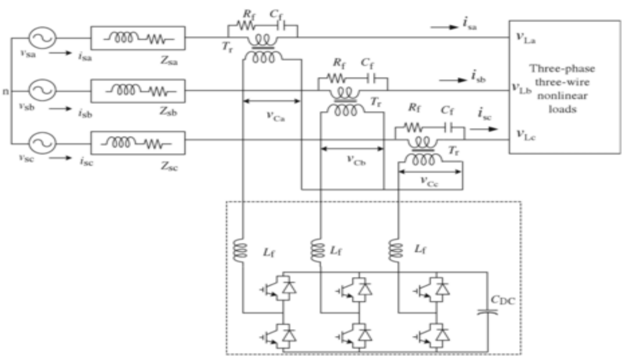

Fig.4 configuration of series active power filter

The main advantage of series filters over parallel ones is that they are ideal for eliminating voltage-waveform harmonics, and for balancing three-phase voltages. This, in fact, means that this category of filter is used to improve the quality of the system voltage for the benefit of the load. It provides the load with a pure sinusoidal waveform, which is important for voltage-sensitive devices

- It compensates voltage and current harmonic caused by non-linear loads.
- The high impedance of the series APF is created by generating a voltage of the same frequency that the current harmonic component that needs to be eliminated.
- Voltage unbalance is correct by compensating the fundamental frequency negative and zero sequence voltage components of the system.

Harmonic Power Filter:

Harmonic voltages and currents in an electric power system are a result of non-linear electric loads. Harmonic frequencies in the power grid are power quality problems. Harmonics in power systems result in increased heating in the equipment, misfiring in variable speed drives, and torque pulsations in motors. The steady increase in non-linear loads on the power supply network raises question about power quality and reliability. The challenge is knowing how to select and deploy harmonic filters correctly to achieve loads and what kind of filters must be used to effectively mitigate harmonics in the system satisfactory performance.

Elimination of Voltage Harmonics:

This block consists of a three-phase balanced and distorted voltage source. Supply/load currents also contain harmonics due to the distorted supply voltage. The linear load is modeled as a 25kw, 0.8 lagging power factor star connected real and reactive load. The series APF is connected in series with the load using three single-phase transformers.

Elimination of Current Harmonics:

It consists of three phase balanced and sinusoidal voltages. A voltage fed nonlinear load is modeled as a three phase diode bridge rectifier feeding power to a resistive load with a capacitor filter at its DC bus. The VSC of the series APF is modeled using IGBT switches with a DC capacitor connected at its DC bus. The series APF is connected in series with load using single phase the DC link. A Series APF is used for injecting the voltage such that the Harmonic in the supply/load current are eliminated under a voltage – fed nonlinear load.

II. MATHEMATICAL CONCEPTS OF SERIES APF

Reference Signal Generator the compensation characteristic of the series active power filter are defined mainly by the algorithm used to generate the reference signals required by the control system. These reference signals must allow current and voltage compensation with minimum time delay. Also it is important that the accuracy of the information contained in the reference signals allows the elimination of the current harmonics and voltage unbalance presents in the power system. Since the voltage and current control scheme are independent, the equations used to calculate the voltage reference signals are the following:

$$\begin{pmatrix} V_{a1} \\ V_{a2} \\ V_{a3} \end{pmatrix} = 1/\sqrt{3} \begin{pmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{pmatrix} \begin{pmatrix} V_a \\ V_b \\ V_c \end{pmatrix} \qquad (1)$$

The voltages va, vb, and vc correspond to the phase to neutral voltages before the series transformer. The reference voltage signals are obtained by making the positive sequence component, va1, zero and then applying the inverse of the transformation. In this way the series active power filter compensates only voltage unbalance and not voltage regulation. The reference signals for the voltage unbalance control scheme are obtained by applying the following equations:

$$\begin{pmatrix} V_{refa} \\ V_{refb} \\ V_{refc} \end{pmatrix} = 1/\sqrt{3} \begin{pmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{pmatrix} . \begin{pmatrix} V_a \\ 0 \\ V_c \end{pmatrix} \qquad (2)$$

In order to compensate current harmonics generated by the nonlinear loads, the following equations are used.

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$$\begin{bmatrix} i_{aref} \\ i_{bref} \\ i_{cref} \end{bmatrix} = \sqrt{2/3} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v & v \\ -v & v \end{bmatrix}^{-1} \begin{bmatrix} p_{ref} \\ q_{ref} \end{bmatrix} + 1/\sqrt{3} \begin{bmatrix} i_0 \\ i_0 \\ i_0 \end{bmatrix} \quad (3)$$

Where i0 is the fundamental zero sequence component of the line current and is calculated using the Fortes cue transformation (4).

$$i_0 = 1/\sqrt{3}\,(i_a + i_b + i_c) \quad (4)$$

In (3) pref, qref, va, and vb are defined according with the instantaneous reactive power theory [5]. The zero sequence fundamental component of the line currents are generated by the source voltage unbalance. Since the system voltage unbalance is eliminated by compensating the negative and zero sequence components present in the source voltage, the magnitude of the fundamental component of the line currents are significantly reduced, and therefore they need not to be compensated by the current control scheme. For this reason, the fundamental component of i0 from equation (3) is filtered, leaving only the zero sequence harmonic components of i0 (i0ref), which need to be eliminated from the source line current. Finally, the general equation that defines the references of the PWM voltage-source inverter required to compensate voltage unbalance and current harmonics is the following:

$$\begin{pmatrix} V_{refa} \\ V_{refb} \\ V_{refc} \end{pmatrix} = K_1 \left[\sqrt{\frac{2}{3}} \begin{pmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} v & v \\ -v & v \end{pmatrix}^{-1} \begin{pmatrix} P_{ref} \\ q_{ref} \end{pmatrix} + \frac{1}{\sqrt{3}} \begin{pmatrix} i_{0ref} \\ i_{0ref} \\ i_{0ref} \end{pmatrix} \right] + K_2 \left[\frac{1}{\sqrt{3}} \begin{pmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{pmatrix} \begin{pmatrix} -V_{s0} \\ 0 \\ -V_{s2} \end{pmatrix} \right] \quad (5)$$

where K1 is the gain of the series transformer which defines the magnitude of the impedance for high frequency current components, and K2 defines the degree of compensation for voltage unbalance, ideally K2 =1. Also, i0ref = i0 – i01, where i01 is the fundamental component of i0. The block diagram of the control scheme that generates (5) is shown . It is important to note that the references signals calculated with (5) allow the flow of only reactive power between the series active power filter and the compensated power system. In order to compensate voltage regulation, the positive sequence component of the line voltages must be included in (5).The compensation of voltage regulation requires generating active power from the active power filter to the power system. Since there is no active power storage element in this topology, this function cannot be achieved with the proposed scheme.

III. id-iq METHOD

In electrical (dq) direct-quadrature transformation is a mathematical transformation used to simplify the analysis of three-phase circuits. For balanced three-phase circuits application of the dqo transform reduces the three AC quantities to two DC quantities obviously in terms of current. Simplified calculations can then be carried out on these imaginary DC quantities before performing the inverse transform to recover the actual three-phase AC results. Again it is often used in order to simplify the analysis of three phase synchronous machines or to simplify calculations for the control of three-phase inverters Some time it is mistaken that three-phase system is combination of three separate single phase system; but in reality three phase system is different from three combined single phase circuit. Simply the load current in single phase system is square wave but in case of three phase system it is quasi square wave.

IV. SIMULATION MODEL OF SERIES APF

For evaluating performances of series active power filter using the voltage reference calculation with the hysteresis current control, simulation study is performed in MATLAB/ Simulink. The presented simulation results were obtained by using Mat lab Simulink Power System Toolbox software, for a three phase power system with a series APF. Shows the source voltage for the non-linear load containing harmonics. Fig. shows the arrangement of power circuit configuration which is made up of non-linear load, series transformer and voltage source inverter. In this section the simulation model of series APF for RLC load and the simulation results is shown.

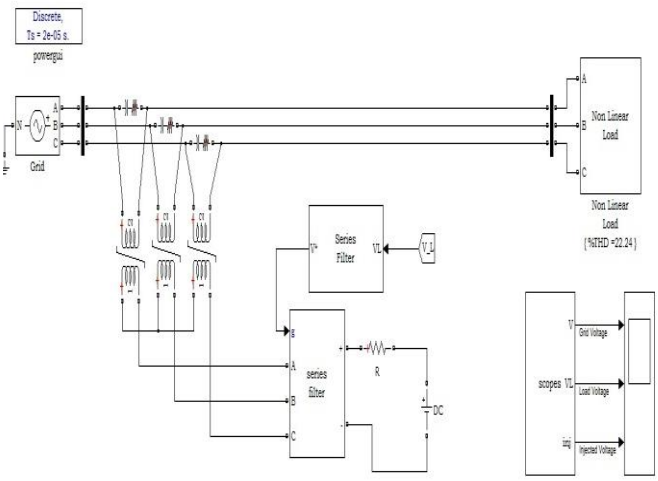

Fig.5 Simulation model of series APF

Fig.6 shows the improved load voltage for the non-linear RLC load when the compensation is done with series APF.

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It is observed that all the harmonics are considerably removed after compensation.

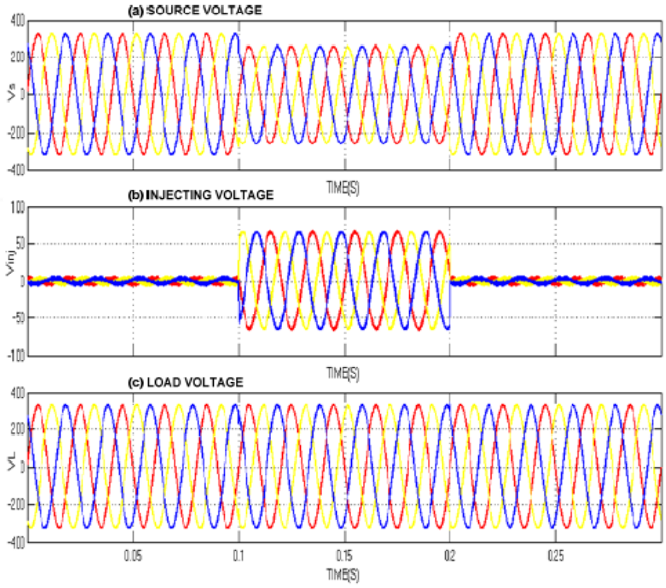

Fig.6 Simulation results (with 20% voltage sag)

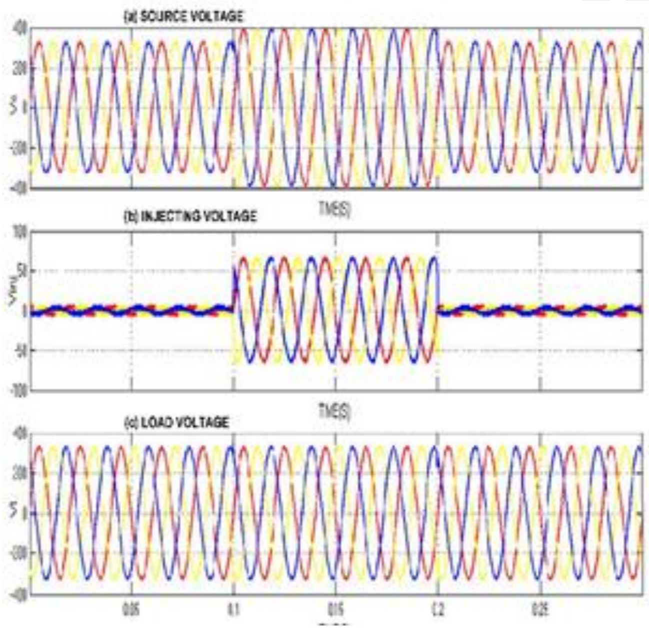

Fig.7 Simulation results (with 20% voltage swell)

In Fig.6 results shows series APF effectively compensates voltage sag and maintains load voltage constant. In figure results shows series APF can compensate voltage swell and maintains load voltage constant. In figure 6 results shows series APF can compensate voltage sag & swell and maintains load voltage constant. Simulation results have shown in Fig.7 presents load current which is same in during voltage sag, voltage swell and combination of both. In electrical system nonlinear loads are connected to the power system and it is supplied by the non-sinusoidal current. In this Series active power filter is used, harmonics are eliminated and it is given by a controller. First the references voltages are compare with the actual load voltages and the error signal is given tootle controller to generate the firing pulses for the switch of the inverter. The output of the series active power filter is connected to the main lines through series transformers so as to make the load voltage purely sinusoidal the harmonic voltage is absorbed or injected by the filter. Harmonic generated by the nonlinear Load and major problem of poor power quality. The harmonic elimination, in the model with active filter is using the better power quality.

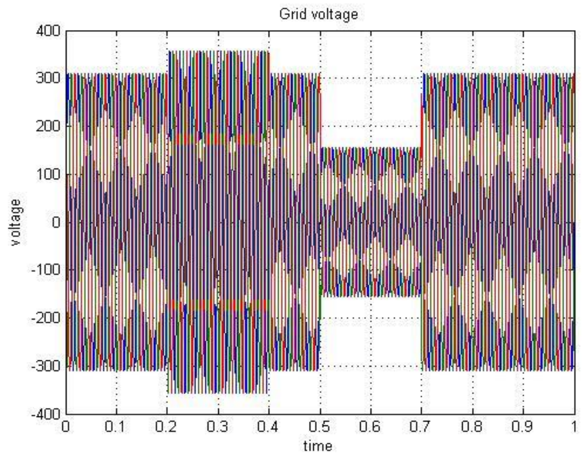

Fig.8 grid voltage

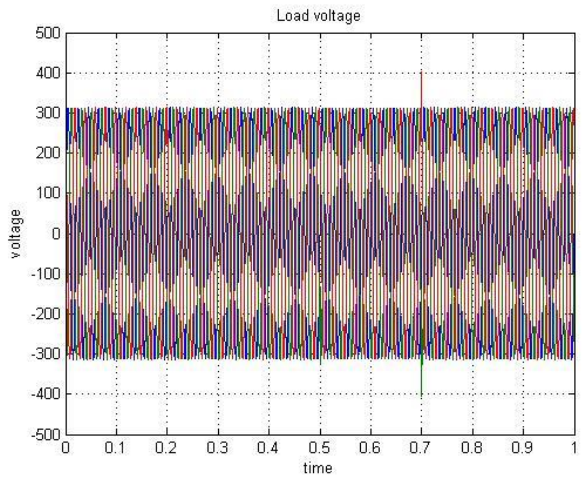

Fig.9 load voltage

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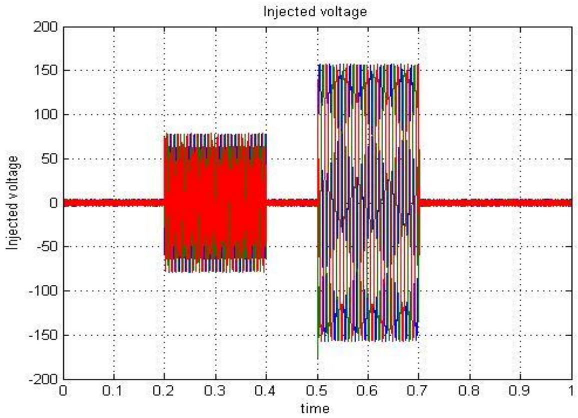

Fig.10 injected voltage

V. CONCLUSIONS

The simulation results show that the voltage sag & swell can be compensated by proposed control strategy. The load voltage waveforms are constant during voltage sag and swell conditions. This is verified by taking 20% voltage sag & swell. Harmonics generated by nonlinear loads are one of the major causes of a poor power quality. So, harmonic elimination, in the source or with active filtering, is needed to achieve a better power quality. The paper addresses the problem of active filtering in low power single phase networks and medium/high power three phase networks. In modern single phase low power equipment they should have a pre-regulator stage, achieving an almost sinusoidal input current. In medium/high power single or three phase networks when it is not possible to eliminate the harmonic currents in the input stage in some connection point, the active power filter is the solution to be implemented. The active filter operation in the harmonic elimination mode allows is increasing in the power quality due to the achieved sinusoidal current flowing in the network. The presented results obtained with a three phase active filter prototype show its effectiveness both in static and dynamic operation, namely with a high nonlinear load.

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