New Control Strategy To Improve Power Quality Using A Hybrid Power Filter

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1. Brief Introduction

A new control algorithm for a hybrid power filter constituted by a series active filter and a passive filter connected in parallel with the load is proposed. The new control strategy is based on the dual formulation of the vectorial theory of electric power, so that the signal injected by the active filter is able to compensate the reactive power and the harmonics of the load current. To verify the developed theoretical analysis, the control strategy was verified by means of an experimental prototype. The results to verify the effectiveness of the proposed control algorithm are presented.

Key words: Harmonics, series active power filter, hybrid power filters, power quality, compensation, pq theory.

2. Background

The presence of harmonics in the power electrical systems is the main cause of the electrical wave pollution that so many problems carry. The indiscriminate increase of non-linear loads has given rise to investigation into new compensation equipment based on power electronics. The main design target for this equipment is the elimination of the harmonic present in the system and a reduction in the power reactive. Depending on the application type, series or parallel configurations or combinations of active and passive filters have been proposed [1,2].

When the objective is to compensate current-source nonlinear loads, named harmonic current source (HCS), a shunt configuration as compensation equipment is used. To eliminate harmonics in this kind of load, a shunt passive filter have traditionally been used, mainly due to their low cost and minimal maintenance requirements. As a result, this has been the adopted solution for systems with considerable power. However, shunt passive filters are not free from problems [3]. On the other hand, it is possible to improve the behaviour of passive filters in parallel connection by including a series active filter in the system. This improves the compensation characteristics of the passive filter [4].

Different techniques have been applied to obtain the control signal to the active filter series. One of them is to generate a proportional voltage to the harmonic of the source current [5]. However, the choice of the appropriate value for the proportional constant is an unsolved question since it is related to the value of the passive filter and the source impedance. Another technique of propose control is to generate a voltage waveform like to the voltage harmonic in the side load but in opposition. This strategy only prevents the shunt passive filter depending on the source impedance, [6]. Later, a control strategy that combining both the above have been used [6], but they continue to suffer the difficulty of an indefinite value for the constant k in most of the applications. A recent strategy proposes that the active filter generates a voltage which compensates the reactive power of the passive filter and load set and allows elimination of the current harmonics [7]. There, the control target is to achieve constant power in the source side.

In this paper a new control strategy based on the dual formulation of the vectorial theory of electric power [8-10] is proposed. It allows the voltage that the active filter has to generate to be determined so as to attain the compensation objective of achieving is to obtain a sinusoidal voltage in PCC. With this strategy it is possible to improve the compensation characteristics of the passive power filter without depending on the system impedance, since the set load-filter would have a behavior very similar to the one of a resistive element. It also avoids the danger that the passive filter will behave as a harmonic drain of near loads, and likewise the risk of possible series and/or parallel resonances with the rest of the system. In addition, the compensation is also possible for variable loads, not affecting some possible detuning of the passive filter.

The system has been verified by means of an experimental prototype, applied to a nonlinear three-phase load. The experimental results are presented.

3. Experimental results

The power circuit is a three-phase three-wires system fed by a sinusoidal balanced three-phase source. The converter consists of an IGBT bridge. In the dc side two capacitors are connected. In the ac side a LC filter has been included to eliminate the high frequency components. This set is connected to the power system by means of three single phase transformers. The passive filter is formed by two LC branches tuning to the 5th and 7th harmonics. The non linear load consists of a non controller three phase rectifier with an inductance of 55 mH and a resistance of 50 Ω connected in the dc side. The control was implemented in control and data acquisition cards of general application, compatible with Matlab-Simulink developed by dSPACE.

Fig. 1 shows the load current and voltage of the phase a, with the system without compensating. The THD of the current measured is 21.5% and the voltage THD 11.2%. The power factor measured is 0.96.

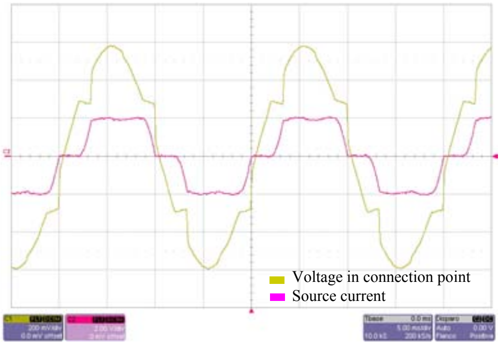

Fig 1. Voltage and current source, phase a.
System without compensating

The source current and voltage in the connection point when the shunt passive filter is connected have a THD of 5.1% and 4.3% respectively. The passive filter was only designed to compensate the source current harmonics; the reactive power was not taken into account. The power factor of the set load and passive filter is 0.86.

When the series active filter is connected, the THD of the source current falls to 1.0%. The waveform is shown in Fig. 2. Now, the power factor rises to 0.998. This allows us to verify the proposed control improvement in the compensation characteristic of the passive filter and it practically achieves unity power factor. The THD of the voltage in the connection point is 1.35%.

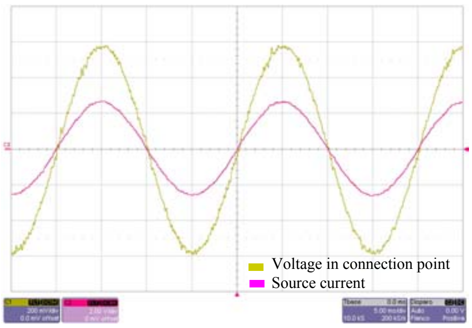

Fig 2. Voltage and current source, phase a.
System with active filter

4. Conclusions

A new control algorithm for a series active filter has been proposed. The control strategy is based on the vectorial theory of electric power. The new control approach achieves the following targets:

- The compensation characteristics of the hybrid compensator do not depend on the system impedance.
- The hybrid power filter and load set are behavior resistive. This fact eliminates the risk of overload due to current harmonics of non linear loads close to the compensated system.
- This compensator can be applied to loads with random power variation as it is not affected by changes in the tuning frequency of the passive filter. Furthermore, the reactive power variation is compensated by the series active filter.
- Series and/or parallel resonances with the rest of the system are avoided because compensation equipment and load are behavior resistive.

Therefore, with the proposed control algorithm, the active filter improves the compensation features of the passive filter and the power factor of the load.

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