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A SIMPLIFIED CONTROL TECHNIQUE FOR A DUAL UNIFIED POWER QUALITY CONDITIONER

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Abstract: This paper presents a simplified control technique for a dual three-phase topology of a unified power quality conditioner. The Dual UPQC is composed of two active filters, a series active filter and a shunt active filter (parallel active filter), used to eliminate harmonics and unbalances. Different from a conventional UPQC, the Dual UPQC has the series filter controlled as a sinusoidal current source and the shunt filter controlled as a sinusoidal voltage source. Therefore, the pulse width modulation (PWM) controls of the Dual UPQC deal with a well-known frequency spectrum, since it is controlled using voltage and current sinusoidal references, different from the conventional UPQC that is controlled using no sinusoidal references. In this paper, the proposed design control, power flow analysis, and experimental results of the developed prototype are presented.

Key Words: Active filters, control design, power line conditioning, unified power quality conditioner (UPQC).

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INTRODUCTION

The usage of power quality conditioners in the distribution system network has increased during the past years due to the steady increase of nonlinear loads connected to the electrical grid. The current drained by nonlinear loads has a high harmonic content, distorting the voltage at the utility gridand consequently affecting the operation of critical loads. By using a unified power quality conditioner (UPQC), it is possible to ensure a regulated voltage for the loads, balanced and with low harmonic distortion and at the same time draining undistorted currents from the utility grid, even if the grid voltage and the load current have harmonic contents. The UPQC consists of two active filters, the series active filter (SAF) and the shunt or parallel active filter (PAF).

The PAF is usually controlled as a non-sinusoidal current source, which is responsible for compensating the harmonic current of the load, while the SAF is controlled as a non-sinusoidal voltage source, which is responsible for compensating the grid voltage. Both of them have a control reference might be through complex methods. Some works show a control technique to both shunt and SAFs which uses sinusoidal references without the need of harmonic extraction, in order to decrease the complexity of the reference generation of the UPQC .An interesting alternative for power quality conditioners was proposed in and was called line voltage regulator/conditioner. This conditioner consists of two single-phase current source inverters where the SAF is controlled by a
current loop and the PAF is controlled by a voltage loop. In this way, both grid current and load voltage are sinusoidal, and therefore, their references are also sinusoidal.

Some authors have applied this concept, using voltage source
inverters in uninterruptable power supplies and in UPQC. In this concept is called “dual topology of unified power quality conditioner”, and the control schemes use the p–q theory, requiring determination in real time of the positive sequence components of the voltages and the currents. The aim of this paper is to propose a simplified control technique for a dual three-phase topology of a unified power quality conditioner to be used in the utility grid connection. The proposed control scheme is developed in ABC reference frame and allows the use of classical control theory without the need for coordinate transformers and digital control implementation. The references to both SAF and PAFs are sinusoidal, dispensing the harmonic extraction of the grid current and load voltage. This paper is organized as follows. The Dual UPQC circuit is presented, and its operation is explained in detail.

II. LITERATURE REVIEW

The conventional UPQC structure is composed of a SAF and a PAF. In this configuration, the SAF works as a voltage source in order to compensate the grid distortion, unbalances, and disturbances like sags, swells, and flicker. Therefore, the voltage compensated by the SAF is composed of a fundamental content and the harmonics. The PAF works as a current source and it is responsible for compensating the unbalances, displacement, and harmonics of the load current ensuring a sinusoidal grid current. The series filter connection to the utility grid is made through a transformer, while the shunt filter is usually connected directly to the load, mainly in low-voltage grid applications. The conventional UPQC has the following drawbacks: complex harmonic extraction of the grid voltage and the load involving complex calculations, voltage and current references with harmonic contents requiring a high bandwidth control, and the leakage inductance of the series connection transformer affecting the voltage compensation generated by the series filter.

In order to minimize these drawbacks, is investigated in this paper, and its scheme. The scheme is very similar to the conventional UPQC, using an association of the SAF and PAF, diverging only from the way the series and shunt filters are controlled. SAF works as a current source, which imposes a sinusoidal input current synchronized with the grid voltage. The PAF works as a voltage source imposing sinusoidal load voltage synchronized with the grid voltage. In this way, the control uses sinusoidal references for both active filters. This is a major point to observe related to the classic topology since the only request of sinusoidal reference generation is that it must be synchronized with the grid voltage. The SAF acts as high impedance for the current harmonics and indirectly compensates the harmonics, unbalances, and disturbances of the grid voltage since the connection transformer voltages are equal to the difference between the grid voltage and the load voltage. In the same way, the PAF indirectly compensates the unbalances, displacement, and harmonics of the grid current, providing a low-impedance path for the harmonic load current.

III. DUAL UPQC

The conventional UPQC structure is composed of a SAF and a PAF, as shown in Fig. 1. In this configuration, the SAF works as a voltage source in order to compensate the grid distortion, unbalances, and disturbances like sags, swells, and flicker. Therefore, the voltage compensated by the SAF is composed of a fundamental content and the harmonics. The PAF works as a current source, and it is responsible for compensating the unbalances, displacement, and harmonics of the load current, ensuring a sinusoidal grid current. The series filter connection to the utility grid is made through a transformer, while the shunt filter is usually connected directly to the load, mainly in low-voltage grid applications. The conventional UPQC has the following drawbacks: complex harmonic extraction of the grid voltage and the load involving complex calculations, voltage and current references with harmonic contents requiring a high bandwidth control, and the leakage inductance of the series connection transformer affecting the voltage compensation generated by the series filter.

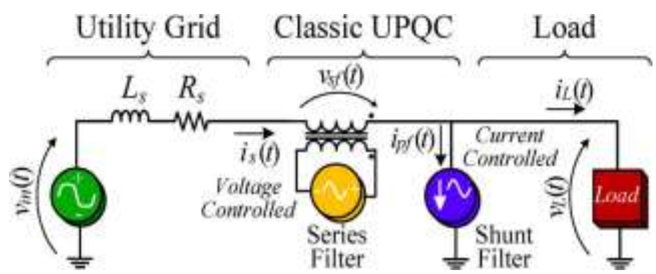

Fig.1. Conventional UPQC

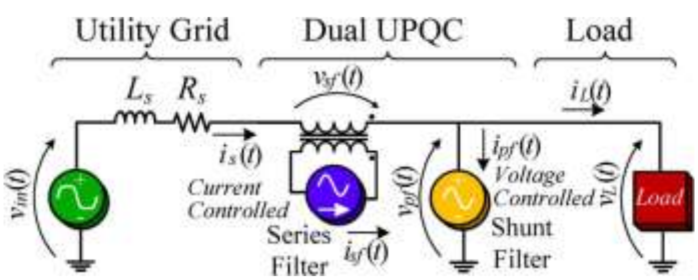

Fig.2. Dual UPQC

In order to minimize these drawbacks, the iUPQC is investigated in this paper, and its scheme is shown in Fig. 2. The scheme of the iUPQC is very similar to the conventional UPQC, using an association of the SAF and PAF, diverging only from the way the series and shunt filters are controlled. In the iUPQC, the SAF works as a current source, which imposes a sinusoidal input current synchronized with the grid voltage. The PAF works as a voltage source imposing sinusoidal load voltage synchronized with the grid voltage. In this way, the iUPQC control uses sinusoidal references for both active filters. This is a major point to observe related to the classic topology since the only request of sinusoidal reference generation is that it must be synchronized with the grid voltage. The SAF acts as high impedance for the current harmonics and indirectly compensates the harmonics, unbalances, and disturbances of the grid voltage since the connection transformer voltages are equal to the difference between the grid voltage and the load voltage. In the same way, the PAF indirectly compensates the unbalances, displacement, and harmonics of the grid current, providing a low-impedance path for the harmonic load current.

IV. POWER CIRCUIT

The power circuit of the proposed iUPQC is made up of two four-wire three-phase converters connected back to back and their respective output filters, as shown in Fig. 3. Three single-phase transformers are used to connect the SAF to the utility grid, while the PAF is connected directly to the load.

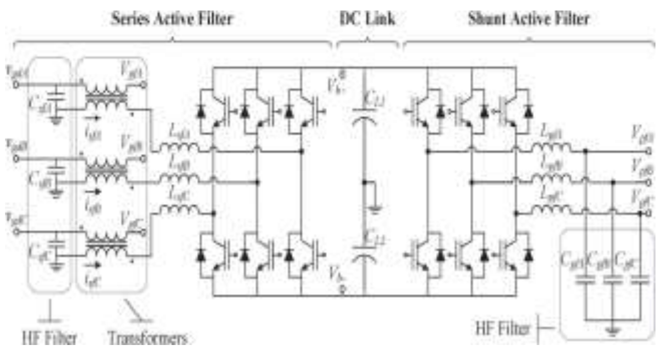

Fig. 3. Power circuit of the Dual UPQC

V. CONVERTER CIRCUIT FOR UPQC

In the circuits shown below we are analyzing the operation of basic converter circuits with and without faults. Further with the help of results with and without faults we will connect convectional UPQC in the simple converter circuit and with these results we will synchronize the circuit with Dual UPQC with the help of control system techniques.

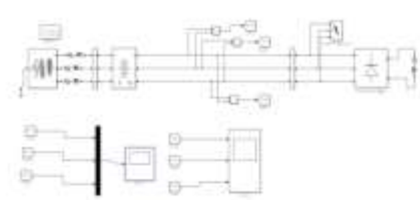

Fig.4. A simple converter circuit with Fault

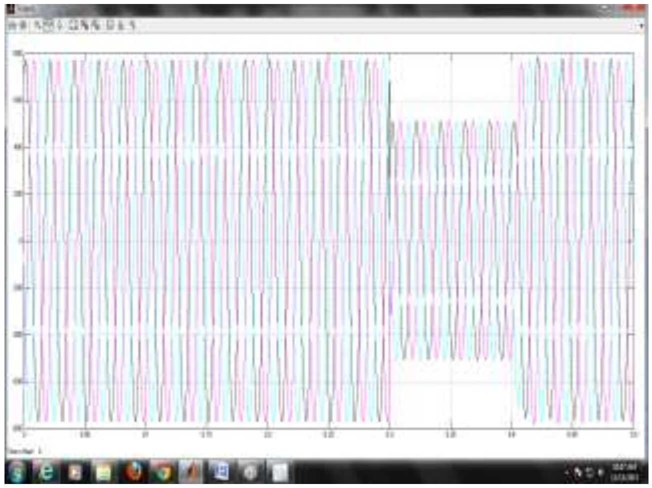

Fig.5. Result of a simple converter circuit with Fault

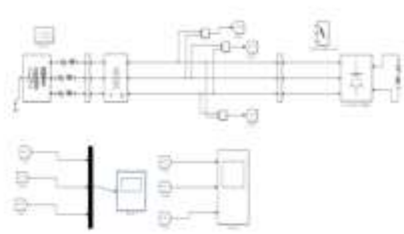

Fig.6. A simple converter circuit without Fault

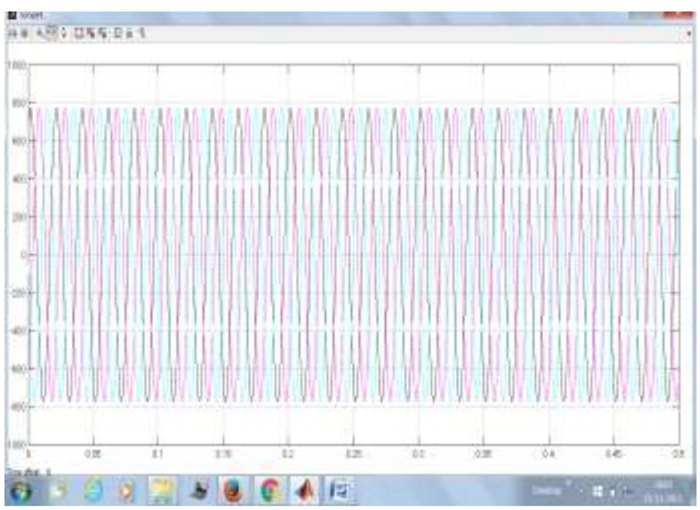

Fig.7. Result of a simple converter circuit without Fault

VI. PROPOSED CONTROL SCHEME

The proposed Dual UPQC control structure is an ABC reference frame based control, where the SAF and PAF are controlled in an independent way. In the proposed control scheme, the power calculation and harmonic extraction are not needed since the harmonics, unbalances, disturbances, and displacement should be compensated. The SAF has a current loop in order to ensure a sinusoidal grid current synchronized with the grid voltage. The PAF hasa voltage loop in order to ensure a balanced regulated load voltage with low harmonic distortion. These control loops areindependent from each other since they act independently in each active filter. The dc link voltage control is made in the SAF,where the voltage loop determines the amplitude reference for the current loop, in the same mode of the power factor converter control schemes. The sinusoidal references for both SAF and PAF controls are generated by a digital signal processor (DSP), which ensure the grid voltage synchronism using a phase locked loop.

VI.CONCLUSION

The results obtained with the Dual UPQC confirms that the proposed ABC reference frame control works very well and that it was able to compensate the nonlinear load currents and also ensure the sinusoidal voltage for the load in all three phases. The control also had a great performance during the load steps and voltage disturbances at the source. The main advantages of this proposed control in relation to the other proposed schemes were the utilization of sinusoidal references for both series and shunt active filter controls without the need for complex calculations or coordinate transformations. The Dual UPQC references do not have harmonic contents, and the only requirement is the synchronism with the grid voltage. Another positive aspect of the Dual UPQC in low-voltage applications (distribution system network) is the noninterference of the leakage impedance voltage of the SAF connection transformer in the load voltage compensation because the load voltage is directly controlled by the PAF. On the other hand, the leakage impedance interferes in the current loop bandwidth, decreasing its frequency response under distorted grid voltages. The results validate the proposed Dual UPQC control scheme, proving that the power quality can be meaningfully better with a simple control method which uses only synchronized sinusoidal references.

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