Semana de Engenharia 2010
Guimarães, 11 a 15 de Outubro

NEW TOPOLOGY OF TRANSFORMERLESS UPQC TO COMPENSATE POWER QUALTITY PROBLEMS

J. G. Pinto, Carlos Couto and João L. Afonso
Department of Industrial Electronics
E-mail: gpinto@dei.uminho.pt

KEYWORDS
Power Quality, Active Power Filters, Transformerless Unified Power Quality Conditioner, Instantaneous Reactive Power Theory, Digital Phase Looked Loop.

ABSTRACT
This paper presents a new topology of Transformerless Unified Power Quality Conditioner (UPQC). The proposed topology can compensate almost all of the current and voltage Power Quality problems at the facility. The great innovation of this work is the use of bidirectional isolated DC-DC converters to interconnect the DC links of the Shunt and Series Active Power Filters that composes the UPQC, allowing the connection of the two Conditioners directly to the electrical grid without the use of power transformers. The proposed UQPC has been studied with the help of PSIM (Power Simulator) and the simulation results are presented. A laboratory prototype is under construction, and experimental results will be available soon.

INTRODUCTION
The increasing use of rectifiers, thyristor power converters, arc furnaces, switching power supplies and other non linear loads is known to cause serious problems in electric power systems (Bachry and Styczynski 2003). Therefore the development of electronic equipment that can mitigate problems that affect electrical installations is of great interest. The proposed UPQC consists of a Shunt Active Power Filter in conjunct operation with a Series Active Filter. The Shunt Active Power Filter works as a current source, connected in parallel with the electric grid, and it is capable of providing the harmonics and reactive power required by the loads (Pinto et al. 2007a). Three-phase four wire Shunt Active Power Filters are also capable of compensating unbalance and zero sequence currents, minimizing the neutral current (Pinto et al. 2009). Series Active Filters works as voltage sources connected in series with the electrical grid and they are capable to compensate voltage harmonics. Three phase Series Active Filters also can compensate unbalances in the phase voltages (Pinto et al. 2007b). The combined operation of the Series Active Filter with a Shunt Active Power Filter increases the compensation capabilities of the Series Conditioner, allowing the compensation of voltage harmonics, voltage unbalances, voltage sags, voltage swells and flicker (Fujita and Akagi 1998).

UPQC TOPOLOGY
The hardware of the UPQC consists in a three phase four wire Active Power Filter, three single phase Series Active Filters and three Bidirectional Isolated DC-DC Converters. Figure 1, shows the block diagram of the proposed Transformerless UPQC. In this topology, the Shunt Active Power Filter is responsible for compensate the current harmonics, the power factor and the current unbalances. The Shunt Active Filter also compensates the neutral current. In this way, the source currents become almost sine waves in phase with the system voltages, and the neutral current is eliminated. The Series Active Filter is responsible for compensate voltage harmonics, voltage unbalances, sags swells and flicker. With the Series Active Filter, it is possible to supply the loads with three sine wave voltages with a phase shift of 120º and constant amplitude.

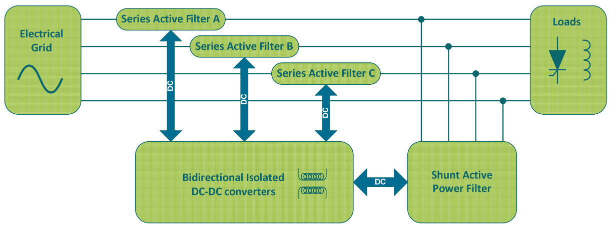


Figure 1: Block Diagram of the proposed UPQC

The Series Active Filter to compensate some of the voltage disturbances requires an energy exchange with the Shunt Active Power Filter. The bidirectional isolated DC-DC is responsible to provide this energy exchange.

UPQC CONTROL THEORY
Several algorithms was been developed in order to control the UPQC. The first algorithm (a digital Phase Locked Loop - PLL) is responsible for the synchronization of the controller with the source voltages. The PLL receives the three source voltages and returns two sine waves with unitary amplitude that are used as synchronizing signals. These synchronizing signals are used to calculate the compensation currents by applying the concepts described in the theory of instantaneous reactive power, also know as p-q theory. The synchronizing signals also are used to generate the compensation voltages of the Series Active Filters, by calculating the difference between the source voltages and the ideal desired load voltages.

SIMULATION RESULTS

In order to verify the proper operation of the proposed topology and their control algorithms, some simulations was carried with PSIM. Figure 2 a) shows the source voltages and the source currents. It is possible to see that the voltages are distorted and unbalanced but the currents are almost sine wave and the neutral current is near zero. Figure 2 b) shows the load voltages and the load currents. Was it can be seen the load voltages are sine waves with constant amplitude and the load currents are distorted and unbalanced resulting in a significant neutral current.

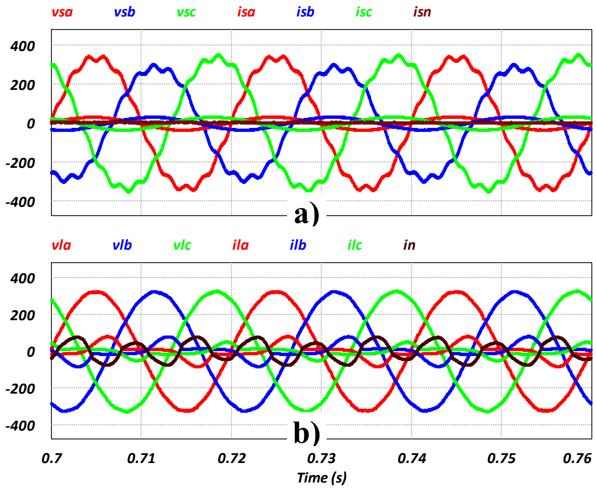


Figure 2: a) Source voltages and source currents.
b) Load voltages and load currents.

In according to the results presented in Figure 2, although the electrical grid voltages are distorted and unbalanced the load is supplied with balanced sine wave voltages with constant amplitude. This fact contributes to the correct operation of sensitive loads in the facility. Although the load currents are distorted and unbalanced, the electrical grid only supplies sine wave currents in phase with the voltages. This fact contributes to higher system performance, by reducing the losses in the production, transport and distribution subsystems.

CONCLUSIONS

This paper shows a newer topology of Transformerless UPQC. The proper operation of the presented topology and control algorithms was validated trough computer simulations. The presented results show a good performance of the topology and control algorithms to compensate current and voltage quality problems. A prototype of the UPQC is under construction and experimental results will be available soon.

ACKNOWLEDGMENT

This work was supported by FCT, project founding PTDC/EEA-EEL/104569/2008. J. G. Pinto is also grateful to FCT for supporting his PhD scholarship.

REFERENCES

A. Bachry; Z. A. Styczynski, “An Analysis of Distribution System Power Quality Problems Resulting from Load Unbalance and Harmonics”, IEEE PES – Transm. and Dist. Conf. and Exp., Vol 2, 7-12 Sept. 2003 pp.763–766.

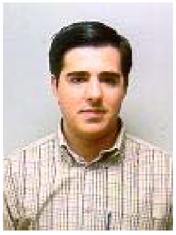
J. G. Pinto, Pedro Neves, Ricardo Pregitzer, Luís F. C. Monteiro, João L. Afonso, “Single-Phase Shunt Active Filter with Digital Control”, Proceedings of ICREPQ’07, 28-30 March Seville, Spain, ISBN:978-84-611-4707-6.

J. G. Pinto, Pedro Neves, D. Gonçalves, João L. Afonso, “Field Results on Developed Three-Phase Four-Wire Shunt Active Power Filters”, IECON 2009, 3-5 November, Porto, Portugal.

J. G. Pinto, R. Pregitzer, Luís. F. C. Monteiro, Carlos Couto, João. L. Afonso, "A Combined Series Active Filter and Passive Filters for Harmonics, Unbalances and Flicker Compensation”, POWERENG, 12-14 April, 2007, Setubal, Portugal, pp 54-59 ISBN: 1-4244-0895-4.

H. Fujita, H. Akagi, “The Unified Power Quality Conditioner: The Integration of Series and Shunt Active Filters,” IEEE Trans. Power Elect, vol.13, No.2, Mar 1998, pp. 315-322.

AUTHOR BIOGRAPHIES



JOSÉ GABRIEL O. PINTO was born in Guimarães, Portugal, on 1977. He received the degree in Industrial Electronics Engineering and the M.Sc. degree in Industrial Electronics from the University of Minho, Portugal, in 2001 and 2004, respectively. From 2002 to 2006 he worked as invited assistant at the Electrical Department of the Polytechnic Institute of Bragança. Since 2006, he works as investigator at the Group of Energy and Power Electronics of the University of Minho. Since 2008 he is a PhD student at the University of Minho. E-mail: `gpinto@dei.uminho.pt`

CARLOS A. M. C. COUTO was born in Mozambique on 1950. He received the B.S. degree in electrical engineering from the University of Lourenço Marques, Mozambique, in 1972, and the M.Sc. and Ph.D. degrees in Power Electronics from the Manchester Institute of Science and Technology, U.K., in 1979 and 1981, respectively. In 1976, he joined the University of Minho, Portugal, where, since 1995, he has been a Full Professor in the Dep. Industrial Electronics. His research interests are Microsystems, Instrumentation, and Power Electronics. E-mail: `ccouto@dei.uminho.pt`

JOÃO LUIZ AFONSO was born in Rio de Janeiro, Brazil, on 1963. He is Associate Professor at the Dep. Industrial Electronics of the University of Minho, Portugal, where he works since 1993. He finished his Engineering course and his MSc at the Federal University of Rio de Janeiro, Brazil, respectively in 1986 and 1991. He concluded his PhD in Industrial Electronics at the University of Minho in 2000. His researching activities are Active Power Filters, Power Quality, and Power Electronics for Renewable Energy Sources and for Electric Vehicles. E-mail: `jla@dei.uminho.pt`