IMPLEMENTATION OF A DIDACTIC STRUCTURE FOR POWER HYBRID FILTERING SYSTEMS

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***Abstract* - This paper presents the implementation of a learning tool for power hybrid filtering systems, providing the possibility of analysis containing passive, active, and hybrid filter topologies. In addition, this educational structure also allows the development and the test of various control strategies for the active filter in real time.**

***Index Terms* - Active power filter, harmonic compensation, hybrid power filter, power quality.**

I. INTRODUCTION

The increase of problems with power quality utility is related directly with the proliferation of nonlinear loads, such as a diode bridge rectifier, due to generation of harmonic current and / or voltage in different environments (industrial, commercial and domestic). That is why there is a growing in researches related with power conditioning in order to deliver the electrical energy with reliability and quality, mainly based on the fact that electronic and power electronic equipments have become more sensitive to utility disturbances. Energy conditioning systems have been developed to mitigate and to control the distinct current disturbances generated by nonlinear loads. As the source impedance does not have a value equals to zero, these harmonic currents cause the voltage distortion. Besides improving the power quality, these systems could increase the system stability too.

This paper presents the implementation of a learning tool for power hybrid filtering systems, providing the possibility of analysis containing passive, active, and hybrid filter topologies. In addition, this educational structure also allows the development and the test of various control strategies for the active filter in real time.

The study is divided in the following sections: in section II, a brief introduction of power filtering systems is presented; section III presents the basic idea of how the implementation was accomplished; the control methodologies for the active filter and for the practical implementation are treated in section IV. Finally, sections V and VI show, respectively, experimental results and conclusions.

II. POWER FILTERING SYSTEM

The passive filters are mainly composed by capacitors and inductors, which must present very low equivalent resistance (reduction of losses). When appropriately implemented, it works satisfactorily; however, its low losses increase the possibility of resonance, which may produce some undesirable effects like, for example, amplification of harmonic components. Normally, these filters are installed in the load terminals or in energy distribution substations.

These filters have the function of blocking undesirable current harmonics from the load to the power line considering the following methods:

- Using high series impedance for blocking these harmonic components;
- Forcing the undesirable harmonics to flow through a low impedance path.

The high cost of a series passive filter in power systems and the fact that the shunt passive filter can supply the reactive power in the fundamental frequency make the use of the shunt filter more viable than the other one.

The more common shunt passive filters configurations are the single frequency tuned and the high-pass types as Fig. 1 illustrates. These two types of filters have simple implementation, modest cost, and may have the function of displacement factor correction. Nowadays, the more used topologies of shunt passive filters are shown in Fig. 1.

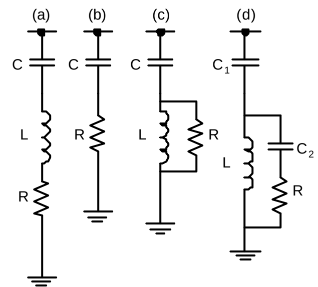

Fig. 1. Shunt passive filters. (a) Single frequency tuned filter. (b),(c),(d) 1st, 2nd and 3rd order high-pass filter.

Fig. 2 shows a three-phase shunt passive filtering system implemented using Matlab/Simulink and the obtained results are shown in Fig. 3.

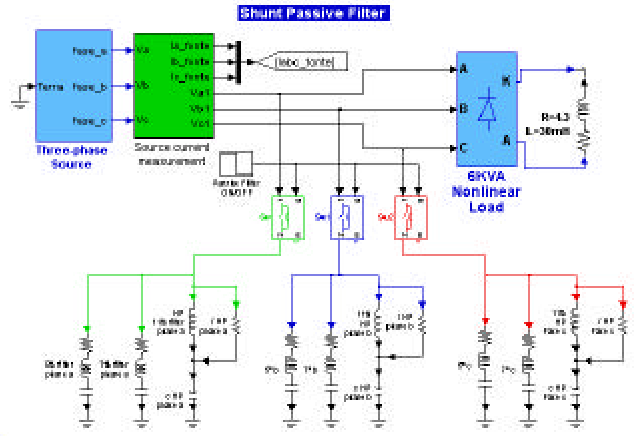

Fig. 2. Implementation of shunt passive power filtering with the software Matlab/Simulink using the toolbox Power System Blockset.

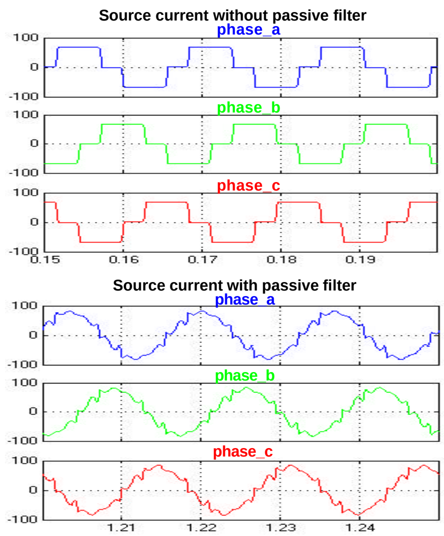

Fig. 3. Source current without passive filtering and with passive filtering.

The implementation of active power filters is proposed so that limitations of passive power filters can be compensated. These filters have been developed to compensate the disturbances brought about by nonlinear power electronic loads. One of the main functions of the active power filter is to suppress the voltage and/or current harmonic distortion. A control algorithm to separate the undesired harmonic components from the fundamental component is used in order to generate a reference for the active power filter. Furthemore, active power filters may have an implementation with high-power depending on the load to be attenuated. As the voltage references are nonsinusoidal the PWM inverters must have a large bandwidth.

Fig. 4 illustrates an example of active filter with the control based on the Synchronous Reference Frame (SRF) [1] using Matlab/Simulink. The simulation results for the implementation shown in Fig. 4 are illustrated in Fig. 5.

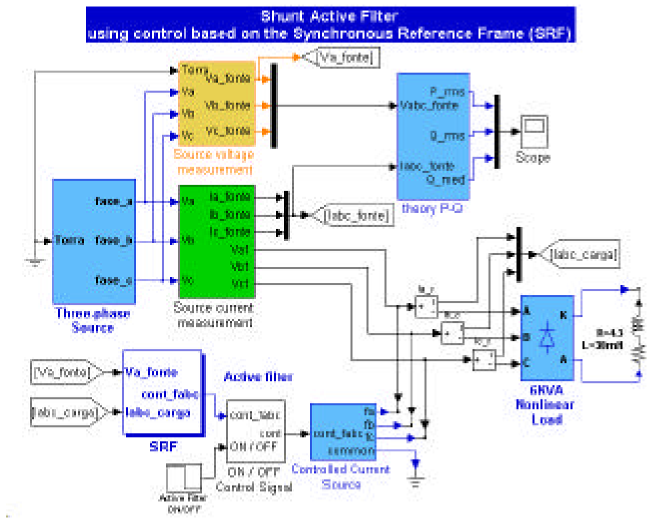

Fig. 4. Implementation of shunt active power filtering system with the control based on the Synchronous Reference Frame (SRF) using Matlab/Simulink.

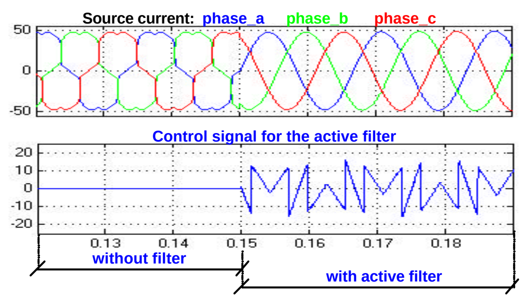

Fig. 5. Simulation results in different stages using active power filtering with control based on the Synchronous Reference Frame (SRF).

Hybrid power filters topologies consist of both active filters and passive filters in different configurations. Hybrid active filters effectively address and mitigate the problems of both passive filter and pure active filter solutions and provide a cost-effective and practical harmonic compensation approach, particularly for high power nonlinear loads. Hybrid active filters improve the compensation characteristics of the passive filters and thus realize a reduction in the rating of the active filter.

A shunt hybrid filter configuration is shown in Fig.6 and the simulation of distinct filtering stages is illustrated in Fig.7.

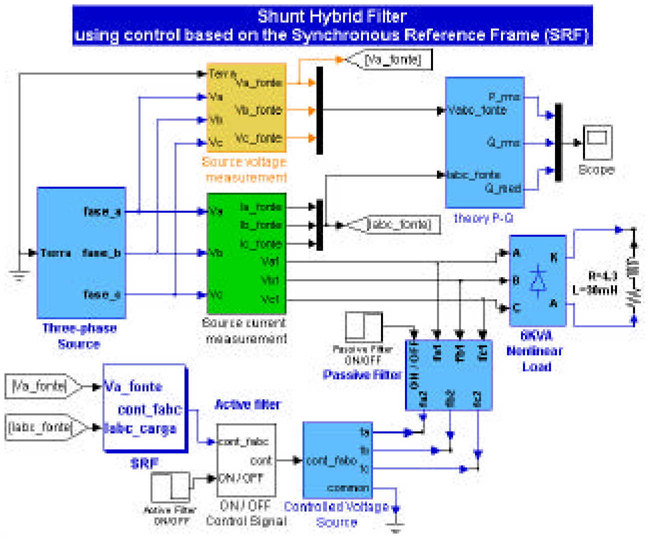

Fig. 6. Implementation of shunt hybrid power filtering system with control based on the Synchronous Reference Frame (SRF) using Matlab/Simulink.

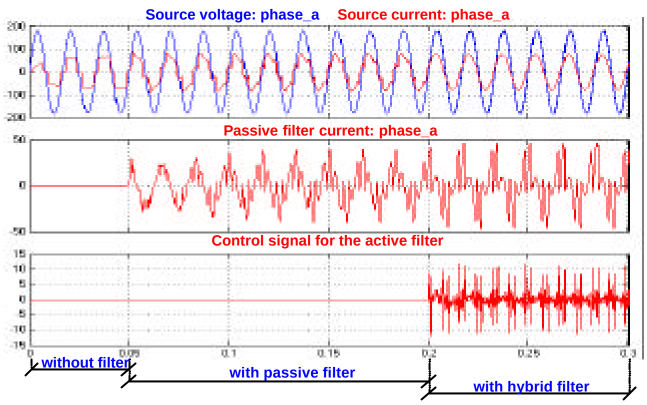

Fig. 7. Progressive filtering stages of the hybrid filtering.

III. IMPLEMENTION IDEA

The main reason for the implementation of the didactic filtering structure is based on the necessity of the development of a tool for educational propose of power filtering structures contempling implementation and tests via software and practical experimentation at the same structure.

The main characteristic of this didactic structure is the flexibility, because it is possible to connect distinct source systems and kinds of load. The didactic filtering structure allows the connection of external components like, for example, different line impedances.

The visualization of the implemented filtering structure is made through a schematic panel, which shows the diagram circuit of the configured power filtering system. This schematic panel is shown in Fig.9.

Figs.8, 9 and 10 show the implemented didactic structure.

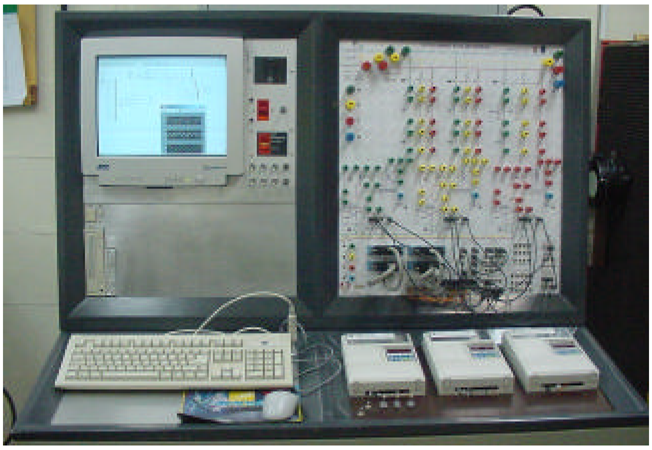

Fig. 8. Frontal visualization of the proposed structure.

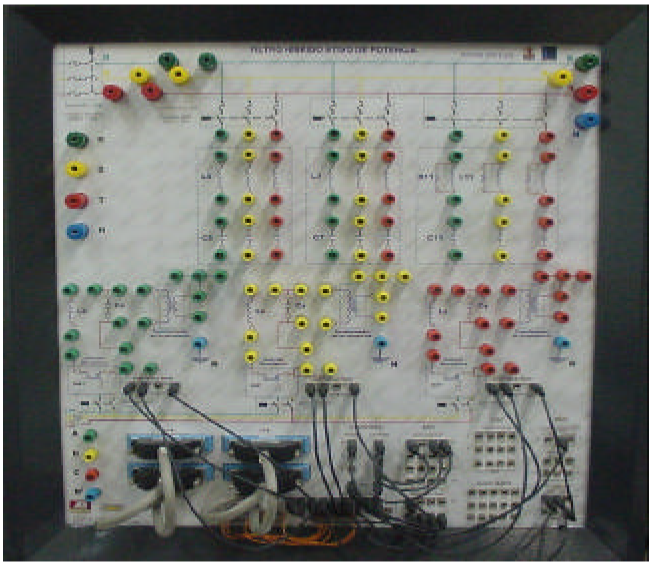

Fig. 9. Frontal panel with the circuit diagram.

Fig. 10. Internal visualization of the structure.

IV. CONTROL STRATEGIES IMPLEMENTATION

The implementation and application of distinct control techniques is made using Mathworks' Development Software, consisting of Matlab, Simulink (using mainly the toolbox "Power System Blockset") [7-10]. The proposed structure is composed by a DSP (Digital Signal Processor) DS1103 Controller Board from dSPACE [11], which it is possible to run a Simulink model in real-time on a remote processor. The PC-to-Real-Time-Processor Communicator is shown in Fig. 11.

The following three classical control methods for handling with hybrid power filters were implemented: Control based on the instantaneous Reactive Power (p-q) [4-5], control based on the extension of the p-q theory [6] and control based on the Synchronous Reference Frame (SRF) [1]. These control schemes were implemented using Matlab/Simulink.

To provide the functions to control, monitor and automate experiments and make the development of controllers more efficient in Real-Time implementations is used the ControlDesk (dSPACE's well-established experiment software) [12]. An example of ControlDesk interface is shown in Fig.12.

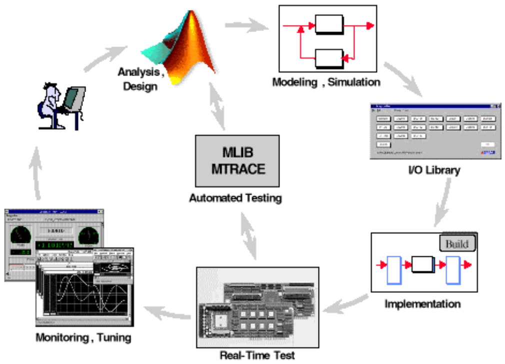

Fig. 11. Development cycle of the practical implementation using dSPACE.

Fig. 12. Visualization of ControlDesk interface.

V. EXPERIMENTAL RESULTS

This section shows experimental results obtained from the laboratory.

A simplified representation of the implemented shunt hybrid active filter using the didactic structure is illustrated in Fig.13.

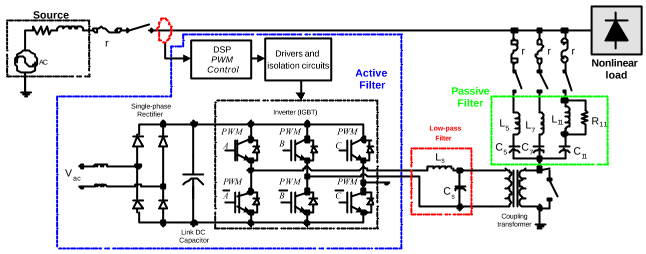

Fig. 13. Experimental circuit of the shunt hybrid active power filter.

The voltage and current source waveforms without filtering are shown in Fig.14. In this figure, it can be observed that the current waveform is characteristic from six pulse diode bridge rectifier with inductive filter in DC terminals. In this case the presented current total harmonic distortion is 28,1%.

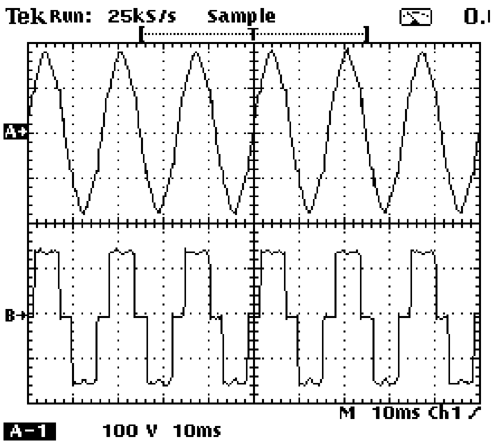

Fig. 14. Source voltage and source current without filtering.

Experimental results obtained after passive filtering are illustrated in Fig.15. In spite of the resonant effect caused by passive filter in the current source, the current waveform is approximately sinusoidal. The current impulses produced are generated owing to the fast di/dt in the load current. With the passive filtering the current total harmonic distortion reduced to 20,61%.

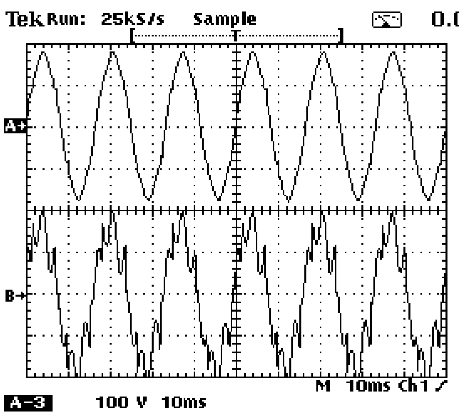

Fig. 15. Source voltage and current after passive power filtering.

Finally, the voltage and current source waveforms after the activation of the active filtering are shown in Fig.16. This figure presents the reduction of the resonance produced by the shunt passive filter. In this case the presented current total harmonic distortion is 12%.

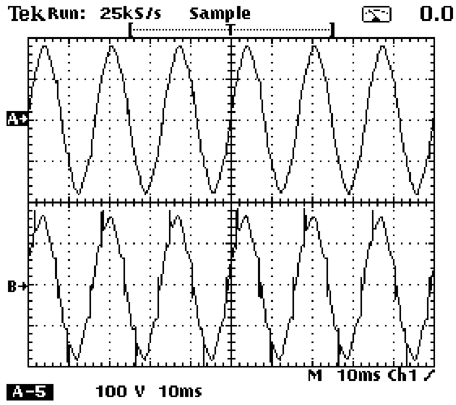

Fig. 16. Source voltage and current with shunt hybrid power filtering.

VI. CONCLUSION

The use of methods for energy conditioning and the development of new control techniques can increase the level of reliability in the electrical energy system and consequently a better exploitation of the consumed electrical energy. Amongst the presented filtering systems, the hybrid filtering has better alternatives to solution the problems related with perturbations and distortions generated by nonlinear loads, mainly harmonic distortion of current.

The implementation of the didactic structure was accomplished so that power quality teaching could be improved. This new technology comprises both simulation and practical implementation of experiences. Also, it is possible to test new control methodologies and power filtering strategies in real-time.

REFERENCES

[1] S. Bhattacharya, D. M. Divan and B. Banerjee, "Synchronous Frame Harmonic Isolator Using Active Series Filter", *EPE-Firenze*, Vol.3, pp.030-035, 1991.

[2] Z. Wang, Q. Wang, W. Yao and J. Liu, "A Series Active Power Filter Adopting Hybrid Control Approach", *IEEE Transactions on Power Electronics*, Vol.16, pp.301-310, 2001.

[3] H. Akagi. "Active and Hybrid Filters for Power Conditioning", *ISIE'2000*, Cholula, Puebla, Mexico, pp. 26-36.

[4] H. Akagi, Y. Kanazawa and A. Nabae, "Generalized theory of the instantaneous reactive power in tree-phase circuits",*Proc. JIEE-IPEC-Tokyo*, pp.1375,1983.

[5] H. Akagi, Y. Kanazawa and A. Nabae, "Instantaneous Reactive Power Compensators Comprising Switching Device without Energy Storange Components", *IEEE*

Trans. On Ind. App., vol. IA-20, No.3, pp.625-630, May/June 1984.

[6] A. G. G. Limaand and A. B. Greenhalgh, "Active Filters and the Zero Sequence Component", *COBEP' 93 (Brazilian Congress of Power Electronics)* ,Vol.1, pp.219-224.

[7] R. A. M. Braga, F. B. Lemos, F. B. Líbano. "Development Environment for Control of Hybrid Active Power Filters Using Matlab and dSpace DSP", *2001 IEEE Porto Powertech*, Vol.2, Porto, Portugal, September 2001.

[8] The Math Works, "User's Guide – Power System Blockset for use with Simulink", Version 1, January 1999.

[9] The Math Works, "User's Guide – Real-Time Windows Target for Real-Time Workshop", Version 1, January 1999.

[10] The Math Works, "User's Guide – Real-Time Workshop for use with Simulink", Version 3, January 1999.

[11] dSPACE Inc. "Solutions for Control", Catalog 1999 www.dspaceinc.com

[12] dSPACE Inc. "ControlDesk Experiment Guide", Version 2.1, July 2001.

BIOGRAPHIES

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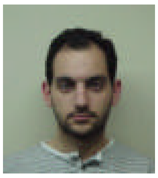

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Fausto Bastos Líbano was born in Porto Alegre, Brazil, on November 7, 1960. He obtained the Electrical Engineering Diploma from the Pontifícia Universidade Católica do Rio Grande do Sul, MSc degree from the Universidade Federal de Santa Catarina and Dr. Ing. degree from Universidad Politécnica de Madrid. Since 1980, he has been with Department of Electrical Engineering of the Pontifícia Universidade Católica do Rio Grande do Sul. His main interest are in Power Electronics, Power Quality and Electrical Drives.