# Utilizing Combination of Series Active Filter and Traditional Passive Filters for Balanced Nonlinear Load Harmonic Compensation

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**ABSTRACT**

*The configuration of a series active power filter (APF) and a parallel passive filter (PPF) has proven to be an efficient system for nonlinear load compensation.*
*In this paper, a fuzzy based control strategy for hybrid series active filter is proposed and it is applied by considering a balanced and resistive load as ideal load.*
*Thus, the strategy obtains the reference voltage is obtained to achieving ideal behavior for the set of hybrid filer-load. The validity of the presented approach in harmonic mitigation is verified via simulation results of the proposed test system.*

## 1. Introduction

The harmonic distortion has been a problem that has been present since the electric engineering origin. Nevertheless, it has gone more important in the last decades, due to the electronic loads proliferation because they behave, in general, as non-linear loads, [1].

Always the current harmonics produced, by any load, will cause voltage distortions at the load terminals hence, the loads absorb distorted currents causing heat lost exceeds in most cases 30% of the consumed power.

Active Power Filter (APF) has become the main research direction of load compensation as its filtering characteristic is not affected by system parameters.

Active power filters have several advantages over passive ones: compensation is automatic, there is no risk of resonances, unity power factor (or any other desired value) can be achieved permanently and without disturbing the electrical network, they can compensate for phase unbalance, and excellent performance can be achieved. They can also be combined with passive filters (which may be already installed) in hybrid topologies, in order to diminish its rated power [2].

The series APF is especially appropriate to eliminate the voltage harmonic caused by the named voltage source harmonic loads. They are, among others, the frequency converters, commutated power sources or UPSs. Nevertheless, its correct performance is fixed by the control approach adopted to establish the reference harmonic voltage. Three kinds of compensation strategies have been mainly used.

Originally, the first one proposed a reference voltage proportional to the source current harmonics. Later, another strategy has been proposed where the filter voltage is equal to the load voltage harmonic with the opposite sign. Recently, another strategy has been proposed, combination of the both previous. Since the practical point of view, the last one evolves the advantages of the other two and it overcomes their disadvantages, [3-4].

To obtain efficient SHAPF performance, it is important to choose proper reference generation algorithm and an appropriate current or voltage control strategy. The publication of the instantaneous reactive power theory caused a great impact in reference generation. Many approaches have been published since then [5–6]. But all of these definitions are computational intensive and do not provide simple expression of instantaneous power quantity. In year 2004, X. Dai [7-10] introduced generalized instantaneous power theory which gives a direct and simple expression for instantaneous power quantities.

This work is focused on the analysis of the fuzzy based control strategies of the series three-phase active filters.

The advantages of fuzzy logic controllers over the conventional PI controller are that they do not need an accurate mathematical model; they can work with imprecise inputs, can handle nonlinearity, and may be more robust than the conventional PI controller. Based on this description, an analysis of the compensation strategies earlier referred has been carried out.

## 2. Hybrid Series Active Power Filters

Fig.1 shows a three-phase circuit with a voltage source that feeds a balanced nonlinear load and a series hybrid filter. The source impedance is constituted by a resistance RS and an inductance LS. The active power filter is connected in series with the source through a coupling transformer. The passive filter is connected in parallel with the load. It consists of two LC branches tuned to 5th and 7th current harmonics.
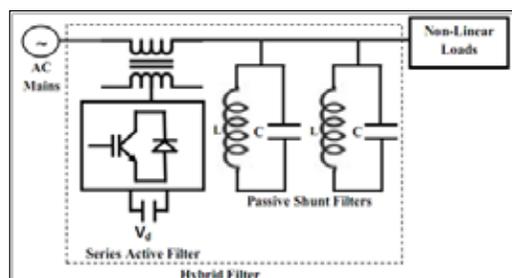


Fig.1 basic configuration of hybrid filter

## 3. Fuzzy Logic controller

As shown in Fig.2 the fuzzy control algorithm is implemented to control the load phase voltage based on processing of the voltage error e(t) and its variation Δe (t) in order to improve the dynamic of SAF.
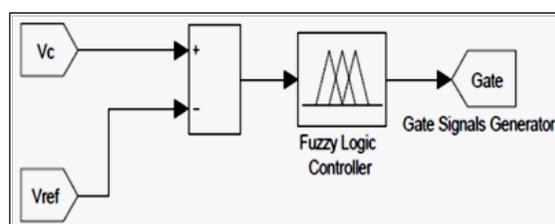


Fig.2. Fuzzy controller structure block diagram

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The main advantages of fuzzy control are its linguistic description, independence of mathematical model, robustness, and its universal approximation [11].

As shown in Fig.3 the fuzzy logic controller is consisting of four stages: fuzzification, knowledge base, inference mechanism and defuzzification.
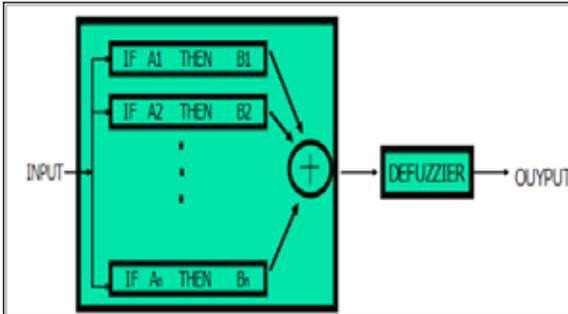


**Fig.3 the basic scheme of fuzzy logic controller**

The knowledge base is composed of a data base and rule base and is designed to obtain good dynamic response under uncertainty in process parameters and external disturbances.

As shown in Fig.4 the data base consisting of input and output membership functions provides information for the appropriate fuzzicztion operations, the inference mechanism and defuzzification. The inference mechanism uses a collection of linguistic rules to convert the input conditions into a fuzzified output. Finally, defuzzification is used to convert the fuzzy outputs into control signals.
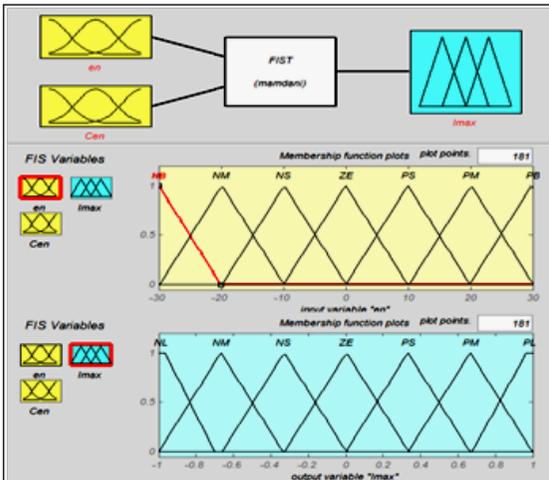


**Fig.4 the GUI interface of fuzzy logic controller setting in MATLAB**

In designing of a fuzzy control system, the formulation of its rule set plays a key role in improvement of the system performance. These rules are listed in Table 1.

**Table 1.Fuzzy rule set used in fuzzy controller of series active filter**

| e(n) | Ce(n) | | | | | | |
|------|-------|------|------|------|------|------|------|
|      | NB    | NM   | NS   | ZE   | PS   | PM   | PB   |
| NB   | NB    | NB   | NB   | NB   | NM   | NS   | ZE   |
| NM   | NB    | NB   | NB   | NM   | NS   | ZE   | PS   |
| NS   | NB    | NB   | NM   | NS   | ZE   | PS   | PM   |
| ZE   | NB    | NM   | NS   | ZE   | PS   | PM   | PB   |
| PS   | NM    | NS   | ZE   | PS   | PM   | PB   | PB   |
| PM   | NS    | ZE   | PS   | PM   | PB   | PB   | PB   |
| PB   | ZE    | PS   | PM   | PB   | PB   | PB   | PB   |

## 4. Simulation and Results:

In this section the simulated test system to investigate the performance of series active filter for harmonic compensating due to connection of balanced non linear load at demand side of system in MATLAB-SIMULINK software is presented.

The power circuit is a three-phase system supplied by a sinusoidal balanced three phase source with a source inductance of 5.56 mH and a source resistance of 4.16 ohm. The inverter consists of an IGBT bridge. On the dc side, two 100-V dc sources are connected. An LC filter has been included to eliminate the high frequency components at the output of the inverter. The passive filter is constituted by two LC branches tuned to the fifth and seventh harmonics. Each element value is listed as Table 2.

**Table 2.he test system parameters**

|                 | Parameters value                               |
|-----------------|------------------------------------------------|
| Source          | Ls=5.8 mH, Rs=3.6 Ω                            |
| Passive filters | L5=13.5 mH , C5=30 µF<br>L5=7.5 mH , C5=30 µF  |
| Ripple filters  | Lr=13.5 mH, Cr=50 µF                           |

In this case, the nonlinear load consists of an uncontrolled three-phase rectifier with an inductance of 45 mH and a 32 resistor connected in series on the dc side.

Figs.5-6 shows the SIMULINK diagram of test system in presence of balanced non linear load for without and with connection of hybrid filter to system respectively.
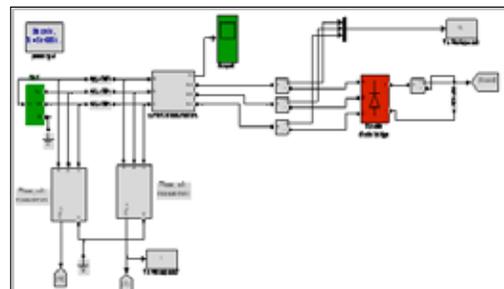


**Fig.5. Simulated test system without hybrid filters with balanced nonlinear load**
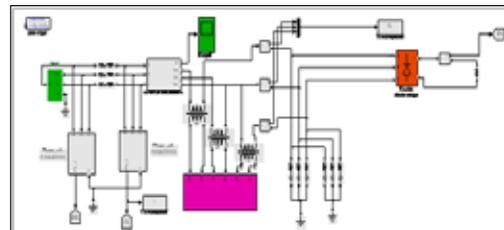


**Fig.6. Simulated test system with hybrid filters with balanced nonlinear load**

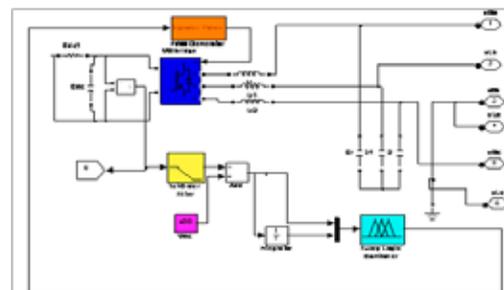The implantation of fuzzy controller to proposed hybrid filter is presented in Fig.7.



**Fig.7.The implementation of fuzzy controller to proposed hybrid filter**

Due to considering the balanced load in this study only the source currents of a phase 'a' current wave form with and without filters as shown in below Figs.8-9 respectively.
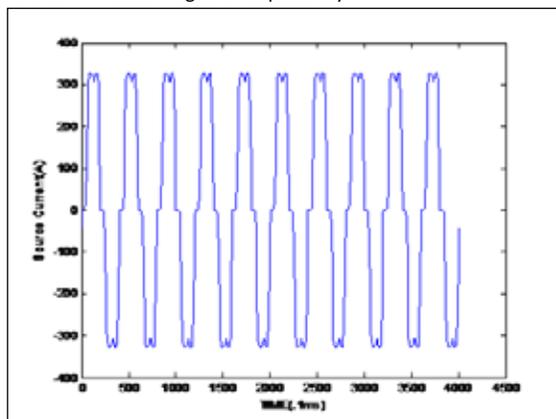


**Fig.8.The source current of phase 'a' of balanced nonlinear load without any compensation**
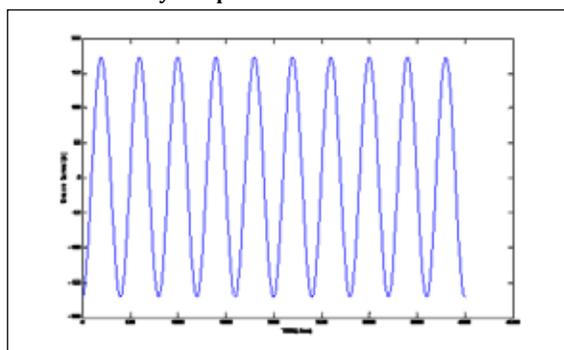


**Fig.9.The source current phase 'a' of balanced nonlinear load after compensation**

As shown in Fig.8 the source current of system without any harmonic compensation includes a series of harmonic frequencies which leads to distortion of current wave. Under this condition, if a liner load at any point of system, would be connected to power system the voltage at PCC will be distorted and will be non sinusoidal wave.

To better understand of harmonic spectrum contains of source current without before connection of proposed filter to system, the FFT analysis of source current wave is presented in Fig.10.
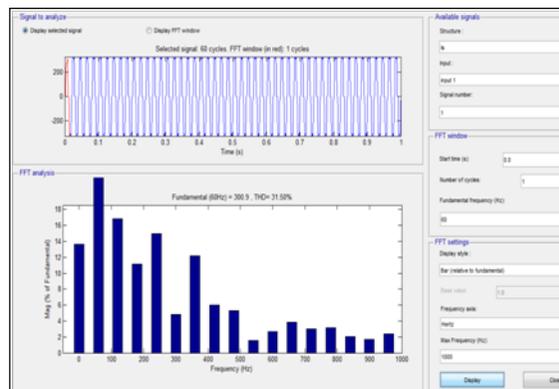


**Fig.10.FFT analysis of source current without any harmonic compensation**

## 5. Conclusion

In this research the power quality improvement through harmonic compensation using combination of a series active filter and a traditional passive filter is presented and analyzed.

The considered passive filter in this research is consists of two passive LC filters, one for 5th harmonic filtering and another for 7th harmonic order.

Due to deficiency in operation of passive filters, a series active filter also connected to system at PCC which nonlinear load is connected to system as parallel to passive filter.

The proposed harmonic compensation approach has been simulated using MATLAB/SIMULINK and results showed the validity of research.

The simulation results indicated that using harmonic compensation by a hybrid configuration based of series active filter and passive filter the harmonic frequencies of source current decreases so that the FFT analysis of source current wave after harmonic compensation verified this matter.

**REFERENCE**    [1] R. Magureanu, S. Ambrosii, D. Creanga, C. Staicu, V. Radut, "Unity power factor rectifiers and active power filters for industrial applications", Proceedings – National Conference on Electrical Drives, Galati, 2002. | [2] V. B. Sriram, S. Sen Gupta and A. Patra, "Indirect current control of a single-phase voltage-sourced boost-type bridge converter operated in the rectifier mode", IEEE Trans. Power Electron., vol.18, no. 5, pp. 1130-1137, Sep. 2003. | [3] M. Basu, S. P. Das and G. K. Dubey, "Parallel converter scheme for high-power active power filters", IEE Proc. Electr. Power Appl., vol. 151, no. 4, pp. 460-466, July 2004. | [4] Y. S. Kim, J. S. Kim and S. H. Ko, "Three-Phase Three-Wire Series Active Power Filter, which Compensates for Harmonics and Reactive Power", IEE proc. Electr. Power Appl., vol. 151, no. 3, May 2004, pp. 276-282. | [5] S. P. Litrán, P. Salmerón, J. R. Vázquez and R. S.Herrera, "Different control strategies applied to series active filters", in Proc. ICREPQ, May 2007. | [6] M. João Sepúlveda, João L. Afonso and Júlio S. Martins, "A Series Active Filter Controlled by Personal Computer", International Conference on Renewable Energy and Power Quality (ICREPQ'03), Vigo, Spain, 9-12 April 2003. | [7] J. Jerzy and F. Ralph, "Voltage waveshape improvement by means of hybrid active power filter", in Proc. IEEE ICHPS VI, Bologna, Italy, Sept. 21–23, 1994, pp. 250–255. | [8] Y.Sato, T.Kawase, M.Akiyama, and T.Kataoka, A control strategy for general- purpose active filters based on voltage detection, IEEE Trans. Ind. Appl., vol. 36, no.5, pp.1405–1412, Sep-Oct.2000. | [9] S. S. Mortazavi, M. Razaz, & E. Khavari., "Power quality improvement using a fuzzy logic Control of a series active filter", Journal of Theoretical and Applied Information Technology systems, pp. 55-63 | [10] Lin, B. R. & Yang, T. Y., "Three-level voltage-source inverter for shunt active filter", IEEE Proceedings Electric Power Applications, Vol. 151, No. 6, pp. 744 - 751, November, 2004. | [11] S. Saad, L. Zellouma, Fuzzy logic controller for three-level shunt active filter compensating harmonics and reactive power, Elesevier, Electric Power Systems Research79(2009)1337–1341. | |