Volume 4 No. 6, June 2014 ISSN 2223-4985

International Journal of Information and Communication Technology Research

http://www.esjournals.org

Simulation and Analysis the Performance of PHFs under Sinusoidal and Harmonic Distorted Main AC Source Using Single Common Passive Filter

[1]Morteza Nasiraghdam, [2]Hossein Nasiraghdam, [3]M.Mohammadi
[1]Department of Computer Engineering, College of Engineering, Ahar Branch, Islamic Azad University, Ahar, Iran.
[2]Department of Electrical Engineering, College of Engineering, Ahar Branch, Islamic Azad University, Ahar, Iran
[3]Department of Electrical Engineering, College of Engineering, Borujerd Branch, Islamic Azad University, Borujerd, Iran.

ABSTRACT

Harmonic filtering is the most important method of preventing the harmonics from entering the distribution system and mitigating their adverse effects on electrical equipment. Use of passive harmonic filters (PHF) is currently the method of choice, though much has been written on harmonic current control using advanced techniques such as magnetic flux compensation, harmonic current injection and dc ripple injection. Passive filters are inductance, capacitance, and resistance elements configured and tuned to control harmonics and can be classified into tuned filters and high-pass filters. Installation of such a passive filter in the vicinity of a non-linear load is to provide low-impedance paths for specific harmonic frequencies, thus resulting in absorbing the dominant harmonic currents flowing out of the load. In this research the performance of a single common passive filter (CPF) at the bus is investigated and the most effective method which could lead to improve voltage distortion and to decrease power losses is presented.

Keywords: *Non-linear load, voltage and current harmonics, harmonic compensation, passive filter.*

1. INTRODUCTION

Increases in harmonic distortion will result in additional heating losses, shorter insulation lifetime, higher temperature and insulation stress, reduced power factor, lower productivity, efficiency, capacity and lack of system performance of the plant.

Between the different technical options available to reduce harmonic distortions and improve power quality, due to implementation of shunt capacitors to compensate the load power factor; it seems the passive power filters have proved to be an important method to compensate current and voltage disturbances in power distribution system [2].

The results of related investigations show that the most of voltage and current distortions in distribution networks are arose to harmonics of third, fifth and seventh orders [3] . Due to that, in this case the implantation of three single tuned passive filters could solve this problem and therefore the sitting and sizing of filters is quite simple. However, because of distributed linear and nonlinear loads in distribution system, the passive filter planning is much difficult. In [4] the genetic-algorithm-based design of passive filters for offshore application is presented and discussed. In [5] a new genetic algorithm based approach to design a passive LC filter for a full-bridge rectifier with aim of finding maximum power factor of the ac mains is presented. In [6] the calculation of the R-L-C parameters for a typical passive harmonic filter used in the customers' house is analyzed. Optimum location and sizing of two passive harmonic filters, whose harmonic tuning orders are 5 and 7 in distribution networks using genetic algorithm is analyzed by [7]. Power loss reduction and minimization of total voltage harmonic distortion are considered as objective function in this reference.

2. MATHEMATICAL MODELING OF HARMONICS

As shown in Fig.1 in presence of sinusoidal source voltage due to non-linear load the current which drawn via source is harmonic distorted.

Harmonic distortion is the corruption of the fundamental sine wave at frequencies that are multiples of the fundamental, (e.g., 180 Hz is the third harmonic of a 60 Hz fundamental frequency; 3 X 60 = 180).

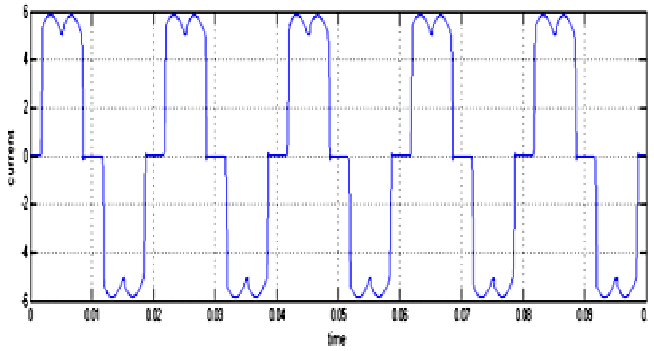


Fig.1.Harmonic distorted current wave

Total harmonic distortion, or THD, based on the IEEE definition, is the summation of all harmonic components of the voltage or current waveform M_i compared against the fundamental component of the voltage or current M_1 [8]:

Volume 4 No. 6, June 2014 ISSN 2223-4985
International Journal of Information and Communication Technology Research

http://www.esjournals.org

$$THD = \frac{\sqrt{\sum_{i=2} M_i^2}}{M_1} \quad (4)$$

The end result is a percentage comparing the harmonic components to the fundamental component of a signal. The higher the percentage, the more distortion that is present on the mains signal.

The rms values of all the harmonics that can be represented as:

$$RMS = \sqrt{\sum_{i=1} M_i^2} = M_1\sqrt{1+THD^2} \quad (5)$$

When the fundamental component of a signal is zero, then the THD will be infinite, so in this condition this parameter does not have a engineering concept, therefore the another definition must be presented for total harmonic distortion. This new definition is DIN and can be defined as a percentage of the rms (used by the Canadian Standards Association and the IEC), and is calculated as follows:

$$DIN = \left[\sqrt{\sum_{i=2} M_i^2} \Big/ \sqrt{\sum_{i=1} M_i^2}\right] \quad (6)$$

The total power factor is called distortion power and results from the harmonic component of the current and voltages as follows [11]:

$$PF = \frac{P}{S} = \frac{\sum_{h=1} V_h I_h \cos\phi_h}{V_{rms} I_{rms}} \quad (7)$$

Where, h is the order of the h^{th} harmonic and $\cos\phi_h$ is the angle between the h^{th} harmonic voltage and the h^{th} harmonic current.

It could be calculated easily as follows [6-7]:

$$PF = \frac{1}{\sqrt{1+THD_I^2}}.DPF \quad (8)$$

Where, THD_I demonstrates the total harmonic distortion of currents and DPF is the displacement power factor and is the cosine the angle of fundamental voltage and current component and assuming that for non-inductive or non-capacitive loads, the value can be considered as 1.

3. PASSIVE HARMONIC FILTER

Precautionary solutions are not generally sufficient to eliminate the harmonics in power system, so we should use harmonic filters to eliminate or to reduce the effects of one or more orders of harmonic components. In a general context, we can refer to harmonic filters as passive and active filters.

Passive filters are inductance, capacitance, and resistance elements configured and tuned to control harmonics and can be classified into tuned filters and high-pass filters [4]. They are connected in parallel with non linear loads such as diode/thyristor rectifiers, ac electric arc furnaces, and so in. Fig.2 and Fig.3 shows circuit configurations of the passive filters on a per phase base. Among them, the combination of two or three single-tuned filters to the 5th, 7th, 11th have been used in a high-power three-phase thyristor rectifiers in a non linear distribution system.

Passive filter is a series combination of an inductance and a capacitance. In reality, in the absence of a physically designed resistor, there will always be a series resistance, which is the intrinsic resistance of the series reactor sometimes used as a means to avoid filter overheating.

All harmonic currents whose frequency coincides with that of the tuned filter will find a low impedance path through the filter.

Passive filter design must take into account expected growth in harmonic current sources or load reconfiguration because it can otherwise be exposed to overloading, which can rapidly develop into extreme overheating and thermal breakdown. The design of a passive filter requires a precise knowledge of the harmonic-producing load and of the power system.

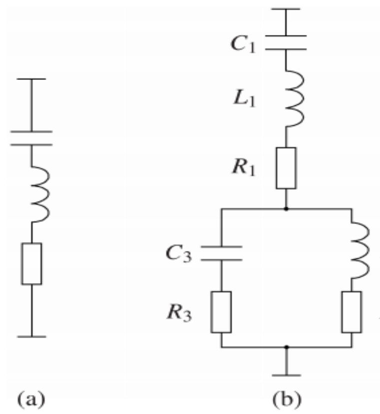
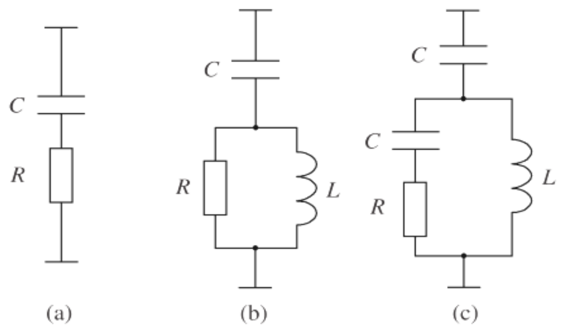


Fig.2 Passive tuned filters: (a) single tuned, and (b) double tuned



International Journal of Information and Communication Technology Research

http://www.esjournals.org

Fig.3.Passive high-pass filters: (a) first-order, (b) second-order and (c) third-order

4. HARMONICS EFFECTS

Waveform distortions can drastically alter the shape of the sinusoid. However, no matter the level of complexity of the fundamental wave, it is actually just a composite of multiple waveforms called harmonics.

This harmonics distorted voltages and currents have these disadvantages [9]:

- Failure, tripping or overheating of capacitors, filters and related equipment.
- Abnormally high noise levels in capacitors, cables, transformers and lightning equipment.
- Overheating of transformers, cables, switchgear, conductors, etc.
- An abnormally high rate of failures of thyristors and converter equipment.
- Frequent failures of capacitors in lighting equipment or tripping of associated low voltage circuit breakers.
- "Nuisance failures" of fuses.
- "Nuisance tripping" of protection relays, in particular sensitive earth fault relays or earth leakage relays.
- Apparent errors in electronic power transducers.
- Apparent inconsistencies in metering equipment.
- Interference with computer equipment.
- An abnormally high cable failure rate or an increase in cable failures.

Once the harmonic sources are clearly defined, they must be interpreted in terms of their effects on the rest of the system and on personnel and equipment external to the power system. Each element of the power system must be examined for its sensitivity to harmonics as a basis for recommendations on the allowable levels. The main effects of voltage and current harmonics within the power system are [10]:

- Amplification of harmonic levels resulting from series and parallel resonances.
- Reduction in the efficiency of the generation, transmission and utilization of electrical energy.
- Ageing of the insulation of electrical plant components with consequent shortening of their useful life.
- Malfunction of system or plant components.

The effects of voltage distortion are:

- Thermal stress
- Load disruption
- Insulation stress

Harmonics increase the equipment losses and thus the thermal stress. The triple harmonics result in the neutral carrying a current which might equal or exceed the phase currents even if the loads are balanced. This dictates the derating or over sizing of neutral wires. Moreover, harmonics caused resonance might damage the equipment. Harmonics further interfere with protective relays, metering devices, control and communication circuits, and customer electronic equipment. Sensitive equipment would experience mal-operation or component failure.

Harmonic currents in the power distribution system can cause [6, 7]:

- Transformer secondary voltage distortion
- Overloaded neutrals and capacitors
- Telephone and communication system noise
- Increased power losses and thermal stress

5. MATLAB/SIMULINK BASED SIMULATION

The simulation model of test system in order to analysis the performance of passive filter under CPF state is presented in Fig.4.

The power system elements, including power source, interconnecting cable, transformer, variable frequency drives (VFDs) as non-linear load which is considered as harmonic source, and passive filter bank, is modeled in MATLAB.

The non-linear load has been modeled with a diode rectifier with a smoothing capacitance of $300\ \mu F$ and an ac drive as equivalent resistance which represents the real power consumed by the load. This equivalent resistance corresponds to a 10.4-kW drive.

The parameters of system including cable impedance, transformer equivalent parameters, passive filter parameters, main source and non-linear load are listed in Table 1.

Table 1- System parameters

Elements	Parameter Value
AC mains	$230V, 50Hz$
Load impedance	$VFD1: R_L = 15\Omega \quad C_L = 300\ \mu F$ $VFD2: R_L = 15\Omega \quad C_L = 300\ \mu F$ $VFD3: R_L = 10\Omega \quad C_L = 300\ \mu F$
Transformer equivalent	$0.15\Omega, \quad 6mH$
Passive filter	$L_5 = 10.34\,mH \quad C_5 = 36.34\ \mu F$ $L_7 = 10.34\,mH \quad C_7 = 18.86\ \mu F$
Cable impedance	$0.6\Omega/km, 0.3mH/Km, 3\mu F/km$

In this study two conditions are considered. At first it is assumed that the main AC source is devoid from voltage harmonics and in second study it is assumed that due to injection of other harmonics current, the main source which feeds the nonlinear load is previously harmonic distorted.

The result of simulation when power source is devoid from voltage harmonics is presented in Table 2. It clearly shows that the application of passive filters reduces the net rms source

Volume 4 No. 6, June 2014 ISSN 2223-4985

International Journal of Information and Communication Technology Research

http://www.esjournals.org

current from 73.3 to 66.6 A for a single common passive filter (CPF) at the bus.

Table 2- simulation result assuming main source is devoid of voltage harmonics

Current/Voltage	RMS value	THD%
Load current	73.29 A	38.13
Source current with CPF	66.64 A	2.11
Voltage at PCC	313.92 V	27.52
Voltage at PCC with CPF	317.24 V	9.35

When power source is distorted with voltage harmonics, the application of passive filters reduces the net rms source current from 82.11 to 72.76 A for a single common passive filter at the bus. This result is listed in Table 3.

Table 3- simulation result assuming main source is distorted with voltage harmonics

Current/Voltage	RMS value	THD%
Load current	82.11	42.72
Source current with CPF	72.76	1.34
Voltage at PCC	312.4	31.09
Voltage at PCC with CPF	340.2	8.57

Fig.5 shows the voltage at PCC without passive filter and Fig.6 presents the source and load current without passive filter.

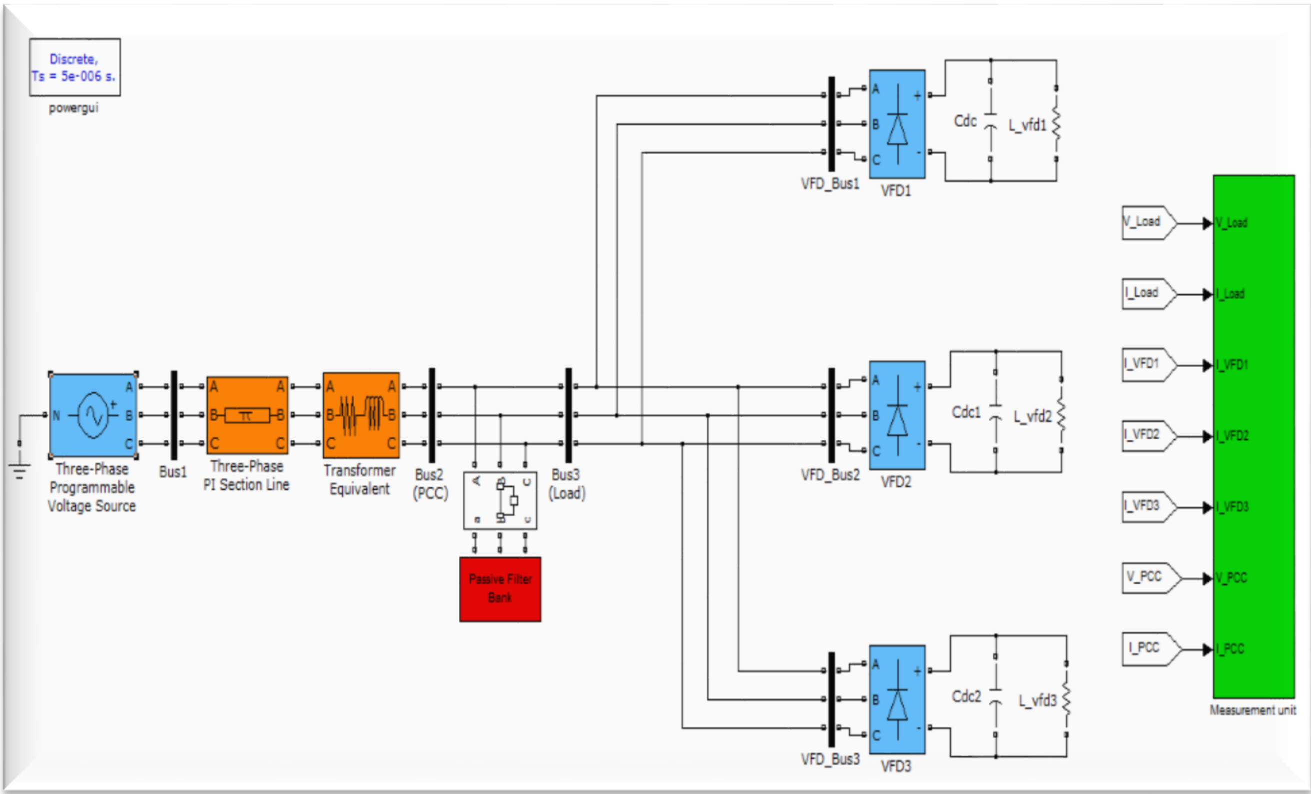


Fig.4. Matlab/Simulink developed model of the test system including of power system and VFD loads for passive filter in CPF state

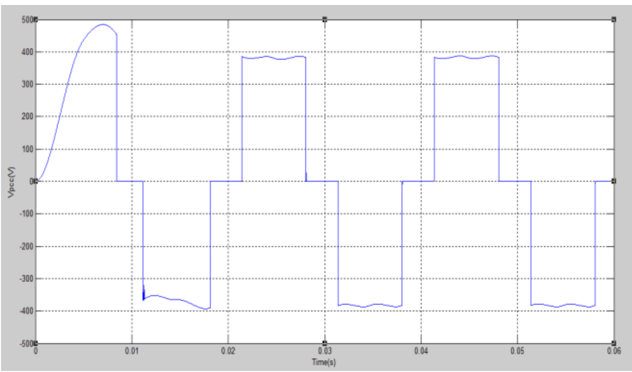


Fig.5.Voltage at PCC without passive filter

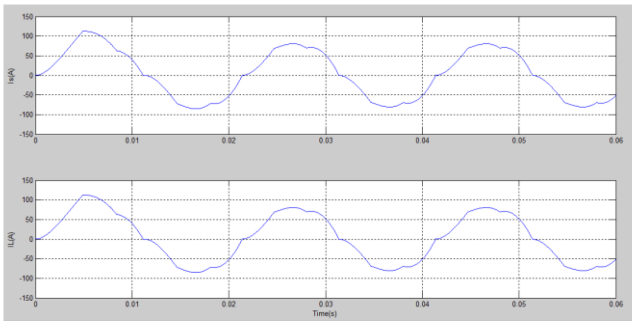


Fig.6. Source and load current without passive filter

Volume 4 No. 6, June 2014 ISSN 2223-4985

International Journal of Information and Communication Technology Research

http://www.esjournals.org

In Figure 7 the non-linear phase a, b, c currents without passive filter is presented.

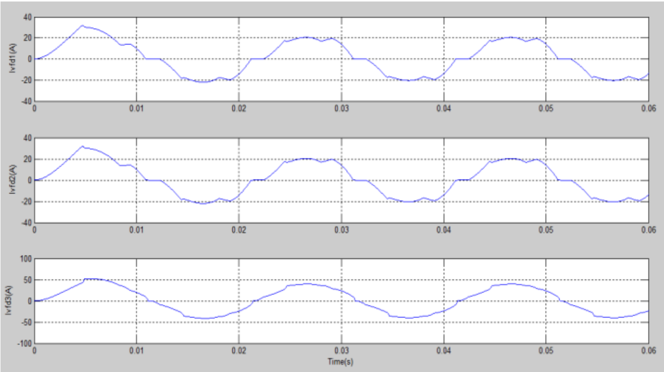


Fig.7. Non-linear phase a, b, c currents without passive filter

Figure 8 shows the voltage at PCC with passive filter under CPF state.

In figure 9 the source and load current with passive filter under CPF state is presented.

Also figure 10 shows the voltage at PCC without passive filter when main source is voltage harmonic distorted.

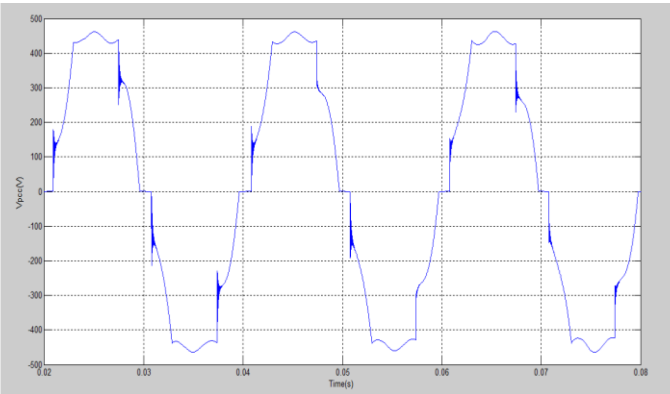


Fig.8.Voltage at PCC with passive filter under CPF state

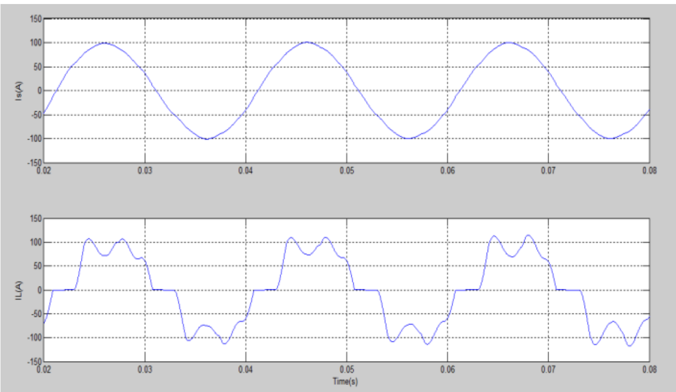


Fig.9. Source and load current with passive filter under CPF state

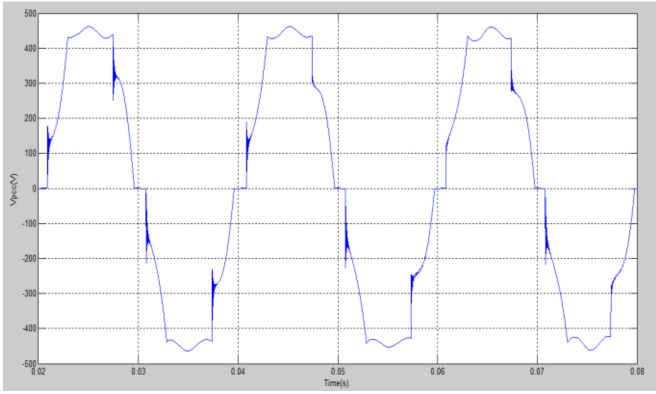


Fig.10.Voltage at PCC without passive filter when main source is voltage harmonic distorted

6. CONCLUSION

Harmonic distortion will result in additional heating losses, shorter insulation lifetime, higher temperature and insulation stress, reduced power factor, lower productivity, efficiency. In this research the performance of a common passive filter for non-linear load is investigated and the most effective method which could lead to improve voltage distortion and to decrease power losses is presented.

REFRENCES

[1] E. F. Fuchs, et al., "Sensitivity of Electrical Appliances to Harmonics and Fractional Harmonics of the Power System's Voltage," Parts I and II, IEEE Trans. on Power Delivery, vol. PWRD-2, no. 2, pp. 437-453, April 1987.

[2] Prachi Godbole, Effect of harmonics on active power flow and apparent power in the power system, IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), PP: 39-43.

[3] Almoataz Youssef Abdelaziz. "Sources and Mitigation of Harmonics in Industrial Electrical Power Systems: State of the Art" The Online Journal on Power and Energy Engineering (OJPEE) 3.4 (2012): 320-332.

[4] I. Daut, H.S. Syafruddin, Rosnazri Ali, M. Samila and H. Haziah, the Effects of Harmonic Components on Transformer Losses of Sinusoidal Source Supplying Non-Linear Loads, American Journal of Applied Sciences 3 (12): 2131-2133,2006.

[5] H.AKAGI, Modern active filters and traditional passive filters, Bulletin of the Polish Academy of Sciences Technical Sciences, Vol.54, No.3, 2006.

International Journal of Information and Communication Technology Research

http://www.esjournals.org

[6] J. L. Afonso, C. Couto, J. S. Martins, "Active Filters with Control Based on the p-q Theory", IEEE Industrial Electronics Society Newsletter, vol. 47, nº 3, Set. 2000, pp. 5-10.

[7] A.Bachry and 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.

[8] Charles.S, G. Bhuvaneswari, Comparison of Three Phase Shunt Active Power Filter Algorithms, International Journal of Computer and Electrical Engineering, Vol. 2, No. 1, February, 2010 ,1793-8163.

[9] João Afonso, Maurício Aredes, Edson Watanabe, Júlio Martins, "Shunt Active Filter for Power Quality Improvement", International Conference UIE 2000- Electricity for a Sustainable Urban Development, Lisboa, Portugal, 1-4 November 2000, pp. 683- 691.

[10] Ninomiya, T. Chun-feng Jin Shoyama, M. Ohmae, "Line-harmonics reduction techniques for consumer electronics and low-power electronic equipment", Industrial Electronics Society, IECON 2000, 26th Annual Confjerence of the IEEE, Print ISBN: 0-7803-6456-2, p766, 2000.