A REVIEW OF STATE OF ART TECHNIQUES IN ACTIVE POWER FILTERS AND REACTIVE POWER COMPENSATION

S.Khalid, Lecturer Amity University, U.P.
Bharti Dwivedi, Professor I.E.T, Lucknow
N.Agrawal, Lecturer Amity University, U.P.
N.Kumar , Lecturer BBDNITM, Lucknow

ABSTRACT

This paper presents a review of the state of the art techniques in active power filters and reactive power compensation. The presentation and subdivision of these techniques is discussed in detail with their merits and demerits. Latest research work in the field of controlling techniques has also been given. This is important for design engineers and researchers in Power Quality to enable them to select the correct system for their specific applications.

INTRODUCTION

Since the sudden increase in number of small nonlinear loads, such as computers, T.V. sets, etc., the issue of power quality became very important to the power electronics industry. It is well recognized that impending supply quality legislation will soon demand that even the existing levels of harmonic pollution and reactive powers be reduced in distribution networks. The solution for many installations will be to install global power system conditioners (active filters and reactive power compensators) at the points of common coupling. Hence the study of active power system conditioner solutions is becoming extremely popular [4].

This review paper critically classifies the available active power system conditioning techniques according to their suitability from the point of view of the power circuit and control techniques. This leads ultimately to the provision of the main guidelines for choosing

The appropriate power system conditioner required for power system application [18].

The various researches done in this field are discussed under the following heads:

1. Compensated System Parameters
   - (a) Reactive Power
   - (b) Harmonics
   - (c) Balancing
2. Power circuit configuration and connections
3. Control and Reference estimation Techniques

1. Compensated System Parameters:

I. Pulse Width Modulated (PWM) static VAR compensator:

To overcome the problems associated with thyristor switched capacitor and thyristor controlled inductor static var compensators, PWM static var compensator using self commutated switches have been proposed in the literatures. Different converter topologies have been reported, viz.

a) PWM Inverter Configurations
b) Multi bridge Inverter Configurations

A) Pulse Width Modulated (PWM) inverter configurations:

Based on PWM inverter two reactive VAR compensation configuration are used

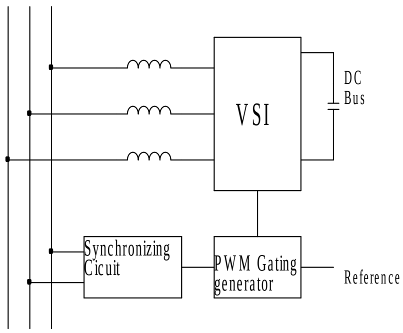
- Voltage Source PWM Inverter
- Current Source PWM

Voltage Source PWM (VS-PWM) inverter:

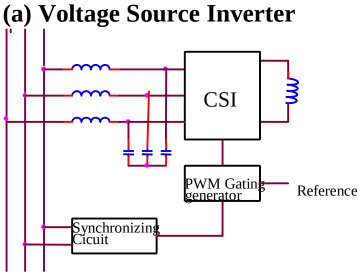
Fig. 1 (a) shows the schematic diagram of the VS-PWM Inverter based static var compensator. The energy storing elements is the dc link capacitor. Here, the VAR is supplied by controlling the output voltage of the inverter. If the output voltage is greater then the supply voltage, it supplies vars to meet the reactive demand of the load, and if the output voltage is less then the supply voltage it absorb the reactive power [2, 3, 22].

Current Source PWM (CS-PWM) inverter:

Fig. 1 (b) shows the schematic diagram of the CS-PWM Inverter based Static var compensator. The energy storing element is inductor, which provides the reactive current to produce reactive power. The CS-PWM inverter is operated as dc/ac converter with inductor as its load on the converter. By controlling the current magnitude, reactive power can be supplied or absorbed by the load.



(a) Voltage Source Inverter



(b) Current Source Inverter

Fig. 1 Schematic Diagram of PWM Inverter

PWM Inverter based static VAR compensator can supply both inductive and capacitive VARS dynamically Inverter [2, 3, 7, 23]. Limitations of the PWM Inverter scheme are:

- More complex in terms of control.
- The PWM inverter injects low order switching frequency harmonics into the utility.
- The ratings of PWM inverter based VAR compensators are limited, due to limited power ratings of fully controlled semiconductor switches.

B) Multi bridge inverter configurations:

Fig. 2 shows the basic configurations of the multi bridge VAR compensator. In this scheme, PWM inverters are connected in series to raise the capacity and voltage rating of VAR compensator. The PWM inverters are connected to the utility through a transformer. The transformer primary windings are series connected star and the secondary windings are parallel connected. Since, the lowest order harmonics are multiplied with the no of stages, therefore the lowest order harmonics number is shifted upwards. The scheme has the disadvantage of complex control, bulky input transformer and requires large no. of controlled power semiconductor devices.

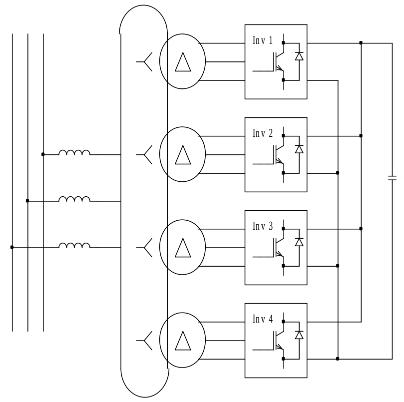


Fig. 2 Multi Bridge Inverter Configuration

parallel or auxiliary converter is operated in the controlled current mode to eliminate the remaining higher order harmonics generated by the main converter [22, 23].

II. Harmonic compensation:

Nowadays, this is the most important parameter requiring compensation in power system. It incorporates both voltages and current harmonics. The harmonic in the power system may result from reactive power compensation devices which them self generate considerable amount of harmonics [2].

Compensating voltage harmonics is not widely addressed because usually power supplies have low impedance. The terminal voltages at the PCC is normally maintain with in the standard limits for voltage sag and total harmonics distortion. This problem is usually important for harmonics-voltage sensitive devices, which required the supply to be purely sinusoidal, such as power system protection devices [11, 28]

The problem relating to current harmonics is much more important in low and medium power applications and is covered in various publications. The compensation of current harmonics reduces to a great extent the amount of distortion in the voltage at the point of common coupling since the compensations of voltage and current harmonics are interrelated [6].

Multiple compensation can be used to improve the effectiveness of compensators. Harmonic current and reactive power are the best candidates in order to maintain the supply current voltage. In this case, only one compensator is major advantage from the point of view of flexibility but reduces the power capabilities of the compensator.

Moreover, the compensation of harmonics in both voltages and current can be implemented in conjunction with reactive power compensation. The circuit in this case would require the presence of series and shunt compensator leading to better compensation characteristics in the power system.

The imposition of the harmonics standards will soon oblige factories and establishment to control the amount of harmonics they inject into the power system.

III. Balancing of Unbalanced Three phase systems.

This problem exists mainly in low and medium voltage distribution systems where the currents and consequently the voltage imbalance and the voltages in the three phases are not balanced and are not spaced in time by 120^0 apart [13].

The degree of system imbalance depends on the amount of voltage imbalance and the magnitude of supply impedance. The remedy to this problem is to either reduce the reactive component of the supply impedance or to add to each phase the corresponding amount of instantaneous voltage to force it to follow the sinusoidal reference waveform.

The magnitudes of currents to be supplied to the grid depend entirely on the amount of imbalance in the system, which mostly occurs in low voltage distribution system for residential loads. The compensator under consideration would sometimes be forced to supply the rated value of current, which limits its power handing capabilities.

2. Power circuit configuration and connections

In the last twenty years, the applications of power system conditioners have widely grown and resulted in a plethora of circuits that manipulate system variables differently. The circuits are grouped into two main subdivisions namely, harmonics generating circuit, which constitute the conventional techniques for reactive power compensation. The other group includes modern (non harmonic generating) circuits, which can be used to serve as both active power filters and reactive power compensators.

(i) Harmonic generating circuits:

This category of circuit serves only the purpose of reactive power compensation. This conventional type is more in use in industry despite the fact that it generates a considerable amount of harmonics, which infiltrate the power system and cause the voltages and current waveforms to be distorted [1, 33, 34].

(ii) Non Harmonic generating circuits:

The different modules of active filters come under this subheading. Various types of active filters have been proposed in many technical literatures [11, 17, 26, 27, 28]. The term active filter is a generic one which applies to a group of power electronic circuits incorporating power semiconductor devices for switching function and passive components as inductor and capacitor as energy storage elements. They are used for achieving one or more desired functions amongst controlling current/ voltage harmonics, reactive power compensation (for near unity p.f of the system and for load balancing of unbalanced three phase systems. They are active DC filters and active AC filters. Active DC filters are primarily used in HVDC systems. Active filters that are used to compensate these voltage harmonics are called harmonic dc filters. Active AC filters are discussed below:

Active AC filters:

This class of active filters is classified as given below:

1) Shunt Active Power Filters
2) Series Active Power Filters
3) Combination of Series-Shunt Active Power Filters
4) Hybrid Active Power Filters

1) Shunt active power filters:

This class of filters constitutes the most important and widely used filter configuration in industrial processes. The concept of the shunt active power filter is based on harmonic cancellation by the act of injecting equal but opposite harmonic currents into the supply line by means of solid-state converter circuits as shown in Fig. 3. Normally these filters are connected in parallel with the load, and carry only a fraction of the fundamental load current. Furthermore, they can be designed to provide compensation for all of the system non-linearities at the point of common coupling (PCC) under distorted and non-distorted supply [11, 17].

These filters have disadvantage of injection of switching frequency harmonics in the system and hence these filters are limited to low-medium power range only.

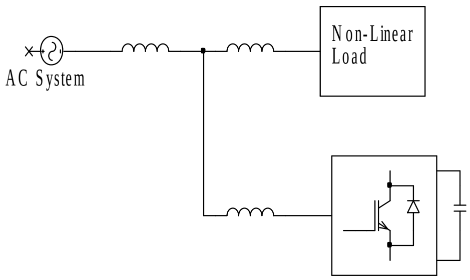


Fig.3 Line Diagram of Shunt Active Filter

2) Series active power filters:

The active power filter in this configuration produces a PWM voltage waveform, which is added/subtracted, on the instantaneous basis, to force the supply voltage to maintain a pure sinusoidal voltage waveform across the load. The line diagram of power circuit configuration is shown in Fig. 4. The inverter configuration accompanying such a system is a voltage fed-inverter without any current control loops. Series active filters are less common industrially than the shunt active filters. This is due to the fact that the series filter is required to handle full load current that increases its current ratings considerably compared with shunt filters and hence is the major disadvantage of this topology. It is used mainly for eliminating voltage harmonics and for balancing unbalanced three phase load circuits [11,17].

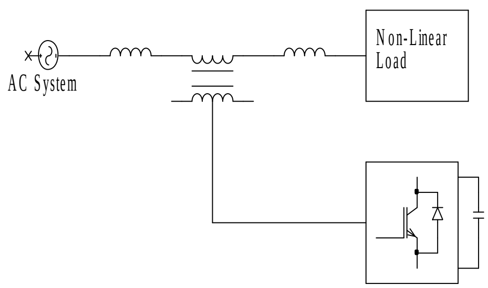


Fig.4 Line Diagram of Series Active Filter

3) Combination of series-shunt active power filters:

Fig. 5 shows the line diagram of the combination of the shunt active and series active filter. The major functions of the series filter are to provide voltage harmonic isolation between the supply side and the load side, voltage regulation, voltage flicker and/or imbalance compensation at the point of common coupling (PCC). The main functions of the shunt active filter is to act as harmonic sink, however this may also be used to provide reactive power compensation and dc link voltage regulation between the filters. This combination is generally known as "Unified Power Flow Controller (UPFC)" or "Unified Power Quality Conditioner (UPQC)".

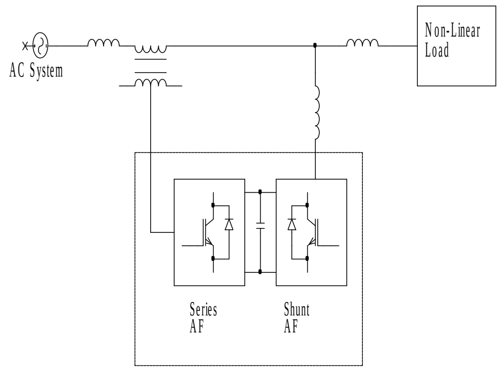


Fig. 5 Line Diagram of Combination of Shunt Active Filter and Series Active Filter

The main disadvantage of this combination is the complex control circuit; this is due to the dependency of switching of the shunt and series active filter [28].

4) Hybrid Active Power Filters:

A kind of hybrid filter is shown in Figure 6. It is a combination of an active series and shunt passive filter. This is quite prominent because the solid-state devices used in the active series part can be reduced in size and cost (about 5% of the load size) and a major part of the hybrid filter is made of the passive shunt L-C filter used to eliminate lower order harmonics. It has the capability of reducing voltage and current harmonics at a reasonable cost. There are many other types of hybrid filters, which offer the advantages of the individual types included in them [26], [27].

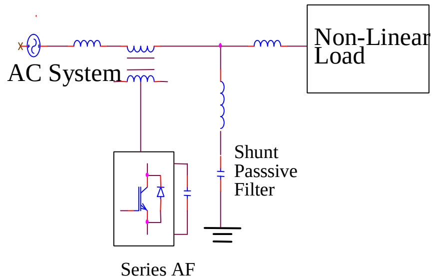


Figure 6 Line Diagram of Series Active and Shunt Passive Hybrid Filter

2. Control and Reference estimation Techniques:

The schematic block diagram used for control of active filters is as given below in Fig. 7.

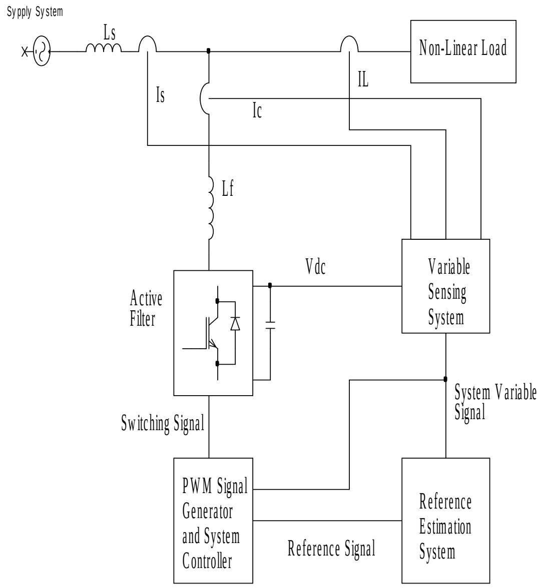


Fig 7 Block Diagram Used For Control of Active Filters

Here all the variables i.e Source current, load current, filter current and the voltage across the dc link capacitor are sensed.

The sensed signals are sent to the reference estimation block when certain calculations are done on the diff signals to generate the reference current that is to be drawn from the supply.

This reference signal is compared with its corresponding sensed signal and provided to the PWM signal generator and the system controller block to generate the desired firing pulses for the active filter switches.

The different control strategies used in active filters:

(I) Optimization techniques:

The optimisation procedure is mainly suitable for switched capacitor and lattice filter circuits. The key to controlling these filters is to determine the appropriate switching function for the switches. The main task of the controller is to minimise a predetermined number of individual load current harmonics; in addition to the minimisation of THD. A time delay exists between the detection of a change in the harmonic current and the application of the new set of switching angles obtained from the optimisation procedure. This technique is mainly suitable for constant or slowly varying loads [2, 7].

(II) Constant Capacitor voltage technique:

This technique is utilized for both single and three phase inverter configurations with a capacitor in the dc link. It relies on the fact that if the output voltage of the active filter (V_f) is kept constant, then The active power flowing in the active filter is zero. Thus in the active filter a reactive power flows that cancels the reactive power generated by the non-linear load. Often this logic is used in the outer loop which consists of a comparison of active filter instantaneous capacitor voltage and a fixed reference voltage. The error generated is multiplied by a sine wave(unit amplitude and in phase with the supply voltage) which provides the in phase of current with the supply voltage required to cater to the switching losses in the capacitor. This along with the load current reference obtained from the inner loop is send to the current controller to generate the firing pulse [14].

The inner loop in this case consists of a current comparison to obtain the fundamental component of load current. There are two methods for sensing in this case:

i) Sensing the load current
ii) Sensing the source current

The current controller is implemented by using either:

(i) PI based triangularization of error control:

The triangular wave method is a very simple technique to implement but the main disadvantages of this technique are very high switching losses and high frequency distortion. The high losses are the result of fast switching rates. A switching action is done either two times or four times for each period of the high frequency carrier [5, 9, 11, 19]

.

(ii) Hysteresis band control:

It has also a very fast response times, but they incur fewer switching losses than do triangular wave based methods [2, 5]. Rather than using a high frequency carrier wave to control the switching rate, switching occurs only when the error leaves the specified band. Very good results have been shown using these results [12, 15].

(iii) Sliding Mode control:

This also provides good results but has a very complex logic which is difficult to implement [35].

(iv) Other Techniques:

Other control techniques simply include small changes to the aforementioned techniques providing simply newer or better performance over their predecssors. These techniques may include the state of art adaptive, predictive and sliding mode controllers, which are normally difficult to implement without of DSPs These techniques can be implemented either in time or frequency domain [7, 10, 24, 35].

Reference estimation techniques:

Estimation of the reference signals for compensation is most essential part of active filter control [5]. The techniques used to generate compensation commands are based on synthesis and calculation of reference signal.

Estimation of reference current/voltage based on synthesis:

This technique uses the analogue signal filter to determine the harmonics contained in supply current or voltage. The technique is preferred because of its simplicity and easy implementation, using analogue devices. However, it suffers from a serious drawback, of considerable phase and magnitude errors, introduced by the filter [18].

Estimation of reference current/voltage based on calculation:

Harmonics calculation techniques are usually adopted to overcome the main drawback of the synthesis technique. Most conventional methods of calculation can be classified either as time-domain or frequency-domain and other modern techniques based on expert system.

Time domain techniques:

Control methods of active filters in time domain are based on deriving instantaneous compensating commands in the form of voltage or current signals from distorted harmonic-polluted voltage or current signals [5]. Several techniques are reported in the time domain, which are referred to as instantaneous reactive power theory [16, 22], synchronous reference frame theory [11], and flux based controller [13], etc.

Instantaneous Reactive Power Theory:

This technique is suitable for three phase systems only. The instantaneous load power is calculated and separated into a DC and an oscillating component over a fixed interval of time. The reference signals are then calculated by distributing the total current equally to each of the three phases, under the assumption of balance three phase system and purely sinusoidal waveform. Under distorted supply the performance of this technique is known to be poor [16, 22].

Synchronous Reference Frame Theory:

This technique uses park's transformation to transform the three-phase system from a stationary reference frame to synchronously rotating d-q-0 sequence components. These can be analyzed since the fundamental frequency component is transformed into DC quantities. The active and reactive components of the system are represented by the direct and quadrature components, respectively. The system is stable since the controller deals mainly with DC quantities. This method is also applicable only to three-phase systems [11].

Flux based controller:

This technique is similar to the synchronous reference frame theory, in applying Park's transformation to transfer the system into synchronously rotating d-q-0 sequence frames of reference. However, it applies the transformation on the flux linkage of the filter inductance, which is then controlled using the output voltages and current in separate integral loops [13].

Frequency domain techniques:

Frequency domain techniques are based on the fourier analysis of the distorted voltage or current signals to extract compensating commands. Different methods are reported [5].

Conventional fourier and FFT method:

Using Fast Fourier Transform, the harmonic current can be reconstructed by eliminating the fundamental component from the transformed current signal and then the inverse transform is applied to obtain a time-domain signal [5]. The main disadvantage of this method is the accompanying time delay. This technique needs to take samples of at least one complete cycle to generate the Fourier coefficient and is therefore suitable for slowly varying load conditions.

Sine-multiplication techniques:

This method relies on the process of multiplying the current signal by a reference sine wave of the fundamental frequency and from the resulting signal, high order harmonics are eliminated using a simple low pass filter [8].

Other algorithms:

There are numerous other optimisation and estimation techniques and all the utilities and libraries for estimation can be used to perform this task. However some new methods arise, such as the neural network and the adaptive estimation, DSP, genetic algorithm, fuzzy logic techniques, which are quite accurate and have, must better response [29, 30, 31, 32, 34].

CONCLUSION

The paper presented a brief and critical evaluation of each of the subdivision techniques supported with list of references. This paper will help research workers, users and suppliers of electrical power to gain an overview and an inspiration for further research on the subject of active filters and reactive power compensation.

REFERENCES

[1] B.K.Bose, "Recent Advances in Power Electronics," *IEEE Trans. on Power Electronics*, Vol. 7, No.1, pp. 2-15, Jan.1992.

[2] Kishore Chatterjee, B.G. Fernandes, Gopal K. Dubey, "An instantaneous Reactive Volt-Ampere compesation and harmonic suppressor system," *IEEE Trans. on Power Electronics*, Vol. 14, No. 2, pp. 381-391, March 1999.

[3] Hirofumi Akagi, "Trends in active power line conditioners," *IEEE Trans. on power Electronics*, Vol. 9, No.3, pp.263-268, May 1994.

[4] T.J.E. Miller, "Reactive Power Control in Electric System", *John Wiley & Sons, 1984.*

[5] W.M.Grady, M.J. Samotyj, A.H. Noyola, "Survey of Active Power Line Conditioning Methodologies," *IEEE Trans. on Power Delievery*, Vol. 5, No. 3, pp. 1536-1542, July 1990.

[6] Luis A.Moran, Juan W.Dixon, and Rogel R. Wallace, "A three-phase active power filter operating with fixed switching frequency for reactive power and current harmonic compensation," *IEEE Trans. on industrial electronics*, Vol. 42, No. 4, pp. 402-408, August 1995.

[7] Richard M. Duke, Simon D. Round, "The steady-state performance of a controlled current active filter," *IEEE Trans. on Power Electronics*, Vol. 8, No. 3, pp.140-146, April 1993.

[8] H.L.Jou, J.C. Wu, H.Y. Chu, "New Single-phase active power filter," *IEE Proceedings Electr. Power Application,* Vol.141, No. 3, pp. 129-134, May 1994.

[9] Bhim Singh, Kamal Al-Haddad, Ambrish Chandra, "A review of active filters for power quality improvement," *IEEE Trans. on industrial electronics*, Vol.46, No. 5, pp. 960-971, October 1999.

[10] David A. Torrey, Adel M. A. M. Al-Zamel, "Single-Phase active power filters for multiple non-linear loads," *IEEE Trans. on Power Electronics*, Vol. 10, No. 3, pp. 263-271, May 1995.

[11] Luis A. Moran, Juan W. Dixon, Jose R. Espinoza, Rogel R. Wallace, "Using active power filters to improve power quality," *An internet search on www.google.com* .

[12] Bimal K. Bose, "An adaptive Hysteresis-band current control technique of a voltage fed PWM inverter for machine drive system," *IEEE Trans. on industrial electronics*, Vol. 37, No. 5, pp. 402-408, October 1990.

[13] Mauricio Aredes, Jurgen Hafner, Klemens Heumann, "Three-Phase Four-Wire shunt active filter control strategies," *IEEE Trans. on power electronic*s, Vol. 12, No. 2, pp. 311-318, March 1997.

[14] Haroon I. Yunus, Richard M. Bass, "Comparison of VSI and CSI topologies for single-phase active power filters," School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0250(404)-894-0560, pp. 1892-1897, *1997 IEEE.*

[15] Hiroumi Akagi, Akira Nabae, Satoshi Atoh, " Control strategy of active power filters using multiple voltage-source PWM converters," *IEEE Trans. on Industry Applications, V*ol. IA-22, No.3, pp. 460-465, May/June 1986.

[16] Takeshi Furuhasi, Shigeru Okuma, Yoshiki Uchikawa, "A study on the theory instantaneous Reactive Power," *IEEE Trans. on Indusrial Electronic*s,Vol. 37, No.1, pp. 86-90, Feb 1990.

[17] C. G. Terbobri, M.F. Saidon, M. S. Khanniche, "Trends of Real Time Controlled Active Power Filters," Power Electronics and variable Speed Drives, 18-19 september 2000, *Conference publication No. 475 (c) IEE 2000*, pp. 410-415.

[18] M. El. Habrouk, M. K. Darwish, P. Mehta, "A survey of active power filters and reactive power compesation techniques," Power electronics and variable speed drives, 18-19 September 2000, *conference Publication No. 475 (c) IEE 2000*, pp. 7- 12.

[19] Luis Moran, Phoivos D. Ziogas, Geza Joos, "A solid-state high-performance reactive-power compensator," *IEEE Trans. on industry applications*, Vol. 29, No. 5, pp. 969-977, september 1993.

[20] Guy-Ha Choe, Min-Ho Park, "Analysis and control of active power filter with optimized injection," *IEEE Trans. on Power Electronics*, Vol. 4, No. 4, pp. 427-433, October 1989.

[21] Leobardo Cortes B., Sergio Horta M*, Abraham Claudio S., Victor M., Cardenas G., "Single-Phase active power filter and harmonic compensation," Centro Nacional de investigacion y Desarrollo Technologico interior internado Palmira s/n, Cuernavaca, Mor., Mexico, *Instituto Technologico y de Estodios Superiores de Monterrey, Campus Ciudad de Mexico Calle del Puente 222, Esquina Periferico Sur, C.P. D.F. Mexico, pp. 184-187, CIEP 1998.

[22] M.E. Ortuzar, R.E., Carmi, J.W.Dixon and Luis Moran, "Voltage-Source Active Power filter based on multilevel converter and ultracapacitor DC link," *IEEE Trans. on Industrial Electronics*, Vol. 53, No. 2, pp. 477-485, April 2006.

[23] E.Baaei, S.H.Hossein and G. B. Gharehpetian, "A new topology for multilevel current source converters," *ECTI Trans. on electrical eng., electronics and communication*, Vol. 4, No. 1, pp. 2-11, Feb 2006.

[24] Nassar Mendalek*, Kmal Al-Haddad*, Louis A. Dessaint*, Farhat Fnaiech+, "Nonlinear control strategy applied to shunt active power filter," *Department of electrical engineering, 1100, rue Norte-Dame Quest, Montreal, Quebec H3C1K3, Canada, +Department of electrical engineering 5 Av, Taha Hussein, 1008 Tunis, Tunisia, pp. 1877-1882, *2001 IEEE*.

[25] Chengyong Zhao, Gengyin Li, Zhiye Chen Guangakai Li, "Design and realization of new Hybrid Power filter system used in single-phase circuit," IECON'2001: The 27th *Annual Conference of IEEE Industrial Electronics Society*, pp. 1067-1071.

[26] Luigi Malesani, Leopoldo rossetto, Paolo Tenti, "Active power filter with hybrid energy storage," *IEEE Trans. on Power Electronics*, Vol.6, No.3, pp. 392-397, July 1991.

[27] Gu Jianju, Xu Dianguo, Liu Hankui, Gong Maozhong, "Unified Power quality conditioner (UPQC):the principal, control and Application," Dept. of Electrical Engineering, Harbin Institute of Technology, China, pp. 80-85, *PCC-Osaka 2002*.

[28] X.Tang, Y.Wang, X.Zhang, W.Si , Y.Tao, Z.Wang, "An overall optimization strategy for novel hybrid parallel active power filters based on genetic algorithm,"Applied power electronics conference and exposition, 2006, APEC'06, *an internet search on www.google.com.*

[29] M.Farrokhi, S.Jamali and S.A.Mousavi, "Fuzzy logic based indirect current control of the shunt active power filter," Iran University of science and technology, *an internet search on www.google.com* .

[30] M. Rukonuzzaman, Mutsuo Nakaoka, "Adaptive neural network based harmonic current compensation in active power filter," *Power Electronics System and Control* Laboratory, Yamaguchi University, Ube 755-8611, Yamaguchi, Japan, pp. 2281-2286, 2001 *IEEE.*

[31] N. Pecharanin, H. Mitsui, M. Sonc, "Harmonic detection by using neural network," Department of Electrical Engineering Musashi institute of Tecnology, 1-28-1 Tamazutsumi, Setagaya-Ku, Tokyo 158 Japan.

[32] Czarnecki L., Hsu. S., "Thyristor controlled susceptances for balancing compensators operated under non-sinusoidal conditions", *IEE-Electrical power applications*, Vol. 141, No. 4, pp. 177-185, Jan. 1994.

[33] Blazszczak. G., "Static VAR compensator with fully controlled reactors," *IEE-Electrical power applications*, Vol. 141, No. 5, pp. 264- 268, 1994.

[34] P.J.Randewijk and H.T.Mouton, "Using VHDL-AMS for electrical, electromechanical, power electronic and DSP-Algorithm simulations," University

of Stellembosch, Dept. of electrical and electronic engineering, Stellembosch, South Africa, *an internet search on www.google.com* .

[35] Claudia Hernandez, Nimrod Vazquez, Victor Cardenas*, “Sliding mode control for a single phase active Filter,” Instituto Technologico de Celaya Depto. Sistemas e informatica, Av. Tecnologico y A. G. Cubas s/n Apdo. postal 57 C.P. 38010, Celaya, Gto., *CENIDET, Depto. de Electronica, interior iternado palmira s/n, Col. Palmira Apdo. Postal 5-164 Cuernavaca, Mor. C.P. 62490, pp. 171-176, CIEP 1998.