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Filters for Power Quality Improvement – A Survey

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ABSTRACT

In recent years, there is an abrupt growth of the non linear loads, which leads to a number of issues like harmonics, voltage sag, voltage swell, flicker, voltage imbalance etc., which affects the quality of the power supplied. Because of these issues the performance and the lifetime of the utilities are very much affected. In order to overcome this issues power filters were developed. In this paper, a survey on the power filters is done that are used to improve the power quality of a power system. Here initially an introduction to the power quality and the need of filters were discussed. The filters are broadly classified as passive, active and hybrid filters. Later these filters are sub classified based on its characteristics and applications. Finally its merits and demerits were listed, which leads to further improvement of the filters.

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INTRODUCTION

Power Quality (PQ) issues were considered only in the past few years ago. Earlier this problem was only considered by the power engineers. Recently only the community deals about the PQ problems because of their awareness and the standard power stations maintain. Even in the industries only the recent generation people are trained in these power quality areas. There are various PQ issues related in power system. Some of the power quality issues are reactive power balance, voltage imbalance, harmonics, transients and interruption. Of these issues the harmonic issues play a major role in the PQ.

Harmonics generally refer to something that co-exists. In electrical terminology harmonics can be defined as components that are present with fundamental waveform of voltage or current and that are integral multiples of fundamental frequency. Harmonics cause certain undesirable effects in the operation of a load and affect its performance badly. Harmonics are generally caused due to non-linear loads which inject harmonic currents in the AC system and increase overall reactive power demanded by the equivalent load. This harmonics is known to distort the ideal sinusoidal voltage or current, increase the losses; cause sags in system voltage and may cause overheating of the equipments due to integral multiple frequency currents. This increase in power electronic based non-linear loads may cumulatively lead to a state of harmonic pollution that affects the operation of power system. Modern day digital electronics and control equipments require high degree of precision for perfect operation and thus they cannot yield expected results with a system affected by harmonics. Thus we are in a situation to ponder over on how to mitigate or eliminate these harmonics for the better operation of power system. For this harmonic filters are of great use. Their basic concept is the filtering of unwanted frequency components from supply waveform either by LC tuning to create resonance or current compensation using custom power devices or both in case of hybrid mode of filters.

An overview of harmonic filters:

When linear loads are connected to the supply the waveforms are linear. Whereas non linear loads are connected harmonic appears on electric voltage or current. The harmonics are integer multiples of system frequency. This leads to various power quality problems like heating of the devices, mis–triggering of the drives, pulsating output in the motors, etc., A harmonic filter are used to eliminate the harmonics. There are three basic types of harmonics filters given below.

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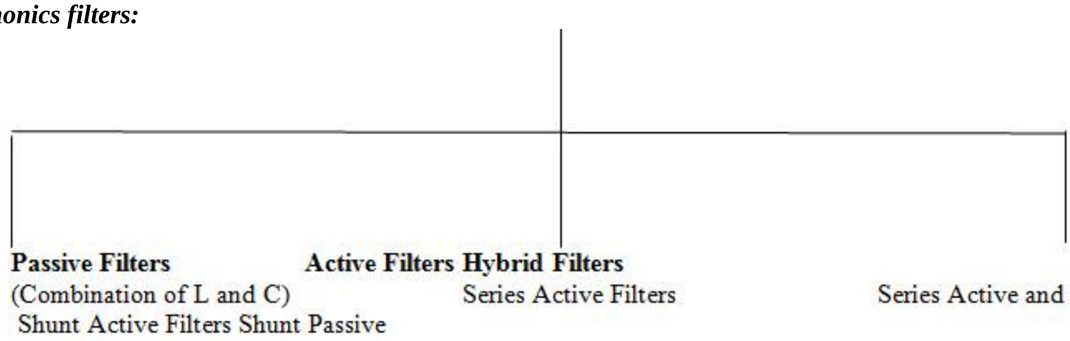
Harmonics filters:



A lot of work, surveying and analysis were done so as to design a suitable filter for power systems and for a wide variety of applications. Primitively used filters were of PPF type. Then the advent of technology paved way for the development of active power filters and hybrid power filters.

Passive power filters (ppf):

PPF is a type of filter, which consists of only passive components. It consists of linear elements like resistors, capacitors and inductors. They are also called as LC filters, which produce series resonance or parallel resonance that forms a major drawback of this type of filter. Another drawback of PPF is the cost which increases as the voltage rating of the inductor and capacitor increases. For this type of filters external power source is not required, which becomes major advantage of PPF over active power filters. An additional advantage of this filter is the stability over wide range. They offer very high or low impedance at tuning frequency and capacitive impedance below tuned frequency and inductive impedance above tuned frequency. Extensive work was done with respect to PPF. A sample figure of the PPF is shown in figure 1.

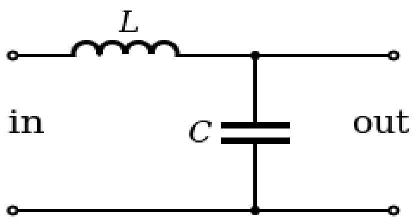


Fig. 1: An example of PPF

Zubair Ahmed Memon et. al., presented a paper that describes the necessity for mitigation of harmonics and design of two passive filters for harmonic reduction using MATLAB / Simulink. The filter design is mainly aimed to reduce current harmonics produced by non-linear loads in industries. It is observed from the simulation results that after installation of filters, current harmonics are reduced and power factor of the system is improved (Zubair Ahmed Memon et.al., 2012). But one demerit of passive filter is they are based on lumped LC components that are tuned to a single frequency and obviously particular order of harmonics thus there is a need of large number of tuned filters in order to eliminate a larger portion of harmonics.

Active power filters (apf):

APF is a type of filter that uses either current or voltage source as its major component. They compensate voltage or current harmonics by injecting the negative of the harmonic signal measured injected signals fed are of same magnitude but in phase opposition with the measured harmonic signals. Of these two voltage source based APF is more advantages. In the last three decades there is vast development in APF and based on these developments the filter is further subdivided into seven categories as follows.

Category I – Overview of power quality concepts and improvement
Category II – Mathematical analysis and extraction of components
Category III – Based on soft computing techniques
Category IV – Design methodologies of special topologies
Category V – Applications to Real time systems
Category VI – Comparative study of filters
Category VII – Based on control techniques

The number of publications in each category is shown in table 1.

Table 1: Number of Publications in each category .

Category	Number of Publications
I	16
II	06
III	03
IV	05
V	04
VI	04
VII	07

The other way of classification of APF is series APF, shunt APF and hybrid APF. Of these first classification is more explanation. The advantage of the APF is the cost, which is less when compared to that PPF for high voltage transmission circuit. A sample figure of the APF is shown in Figure 2.

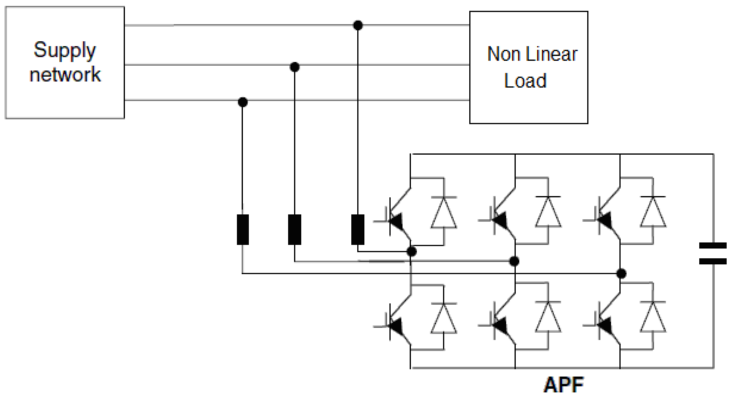


Fig. 2: An example of APF.

Category I – Overview of power quality concepts and improvement:

This section describes reference papers with basic concepts, APF techniques and how they are used for power quality improvement with discussions about various topologies used so far.

The discussion about topologies and control schemes of various APF classifying them as series and shunt active filters was done by Luis. A. Moran et. al., The compensation characteristics and operational principles are of each of them are discussed and proved with their respective control schemes by simulation as well as by experimentation (Morán L et.al., 1999). Very little information is given about the reactive power requirement and switching losses involved in the operation of active filters.

H. Akagi expresses his views where he enumerates the multifunction of active power filters namely reactive power compensation, harmonic compensation, flicker compensation and voltage regulation. Instances around the world where active filters have been successfully installed were also provided. The paper clearly states the evolution of active from mere harmonic compensation devices to harmonic isolation and even damping out harmonics in the entire power system due to the expansion of state- of- art power electronic technology (Akagi H, 1996). But if the passive filters are not connected, the series active power filter can compensate only voltage regulation, and voltage unbalance. Also passive filters are known to create resonance. This should be looked into with serious concern.

Bhim singh et. al., presented a comprehensive review of active filter topologies control strategies, selection of components, other related economic and technical considerations, providing a broad perspective on the status of APF technology, with a list of research publications. Selections of suitable active filter topology for certain applications were also discussed (Bhim Singh et. al., 1999). They suggested that advantages of active filters over passive when it comes to dynamic compensation but very little was mentioned about the switching losses involved in VSI's and the high cost of installation of power conditioners and the complexity of their operation.

João L. Afonso et. al., discussed the effects of harmonics on power systems and briefly described some important methods to analyze electrical circuits with non-sinusoidal waveforms. Of these the p-q theory - was used to implement the control algorithm of a shunt active filter. The filter designed, can compensate for harmonic currents, power factor and load unbalance. Both simulation and experimental results are presented (Joao L. Afonso et. al., 2001). From the experimental results it can be inferred that active filters alone can't contribute in a most effective way to harmonic filtering and there is a need for passive filters to be used in conjunction with them.

Murat Kale and Engin O¨ zdemir presented a new control algorithm to compensate harmonic and reactive power of a 3-phase thyristor bridge rectifier under non-ideal mains voltage conditions. Driving signals are produced with reference signals via a hysteresis band current controller. MATLAB / Simulink power system toolbox is used to simulate the proposed system. The proposed method's performance is compared with conventional instantaneous power (p–q) theory and better performance is observed (Murat Kale, 2005). However unsymmetrical distorted voltage system is the most severe condition and the systems performance is not guaranteed under such conditions.

Adaptive shunt filter design using the concept of artificial neural networks was proposed by L. H. Tey et. al., who also proposed in the same paper a self charging technique to regulate the dc capacitor voltage at the desired level with the use of a PI controller. The filter so designed was found to give good performance in terms of harmonic mitigation and this was verified quantitatively with simulation results (Tey L H et. al., 2005). The author doesn't give experimental results which leave a question mark on the implementation feasibility of the system.

P. Salmerón and S. P. Litrán proposed a control algorithm for a three-phase hybrid power filter using series active power filter. The control is based on the vectorial theory dual formulation of instantaneous reactive power, so that the voltage waveform injected by the active filter is able to compensate the reactive power and the load current harmonics and to balance asymmetrical loads (Salmerón P et. al., 2010).

Kamala Kant Mishra and Rajesh Gupta discussed the enhanced power quality problems even at the lowest voltage level in distribution system. a new control strategy for series active filter has been proposed for improvement of power quality problems in single phase system. the non linear load variation ranging from Voltage Source type Harmonic Load (VSHL) dominant to Current Source type Harmonic Load (CSHL) dominant has been taken up for study (Kamala Kant Mishra and Rajesh Gupta, 2011).

The various topologies of shunt series and hybrid filters are analyzed in their paper by Saheb Hussain et. al., along with the compensation techniques and control strategies for each of the topologies and the advantages of active filters are established (Saheb Hussain MD et. al., 2011).

The interest in power quality is explained by G.Ravindra et. al., in the context of a number of much wider developments in power engineering: deregulation of the electricity industry, increased customer-demands, and the integration of renewable energy sources. Voltage dips and harmonic distortion are taken into account. Shunt, hybrid and series active power filters are described showing their compensation characteristics and principles of operation (Ravindra G et. al., 2012).

T. Kavitaha and K.Ratnaraju discussed the various power quality issues the system is subjected to when it is affected by fault conditions. The system performance during fault can be improved by using suitable topology of a shunt active power filter. The principles of operation of both series and shunt active power filters are discussed. The paper fails to throw sufficient light on the cost effectiveness/economics of the active filters and why hybrid filters are used many a times in place of active filters (Kavitaha T et. al., 2011).

Kanchan Chaturvedi et. al., presented the study & analysis of various active techniques used for suppression of harmonics. The discussion performed in this paper includes the various filter topologies and control techniques and may be used for system designer for adopting the best filter according to operating conditions and requirements (Kanchan Chaturvedi et. al., 2012).

S. Kavaskar et. al., discussed the inability of passive filters which do not provide any solution for unbalance and variable reactive power compensation. APF is used to compensate harmonics and reactive current drawn by nonlinear and linear loads. The system is examined with and without APF to minimize the voltage sag and harmonic distortion. The Fast Fourier Transform (FFT) analysis is done to find the total harmonic distortion. The proposed scheme has a fast response and is able to maintain bar sinusoidal source current for harmonic compensation (Kavaskar S et. al., 2013).

Sandeep G J S M and S K Rasoolahemmed in their paper the importance of active filters in power quality improvement and the various topologies of APF that are commonly used and the countries that have successfully installed APFs in their power systems. Economical approach for the selection of filters for the improvement of power quality is also discussed. But main drawbacks are its large cost and control complexity because of the large number of solid-state devices involved (Sandeep G J S M et. al., 2013).

Metkari Archana Subhash and S.H.Pawar discussed a Series active and passive shunt filter. The control strategy based on vectorial theory of instantaneous reactive power, so that the voltage waveform injected by the active filter is able to compensate the reactive power. Besides that the paper also describes the various power quality problems and their causes. Though active filters are advantageous in many ways their implementation involves computational complexity unlike passive filters due to reference current computation methods and control complications (Metkari Archana Subhash and S.H.Pawar, 2013)

Bhakti I. Chaughule et. al., presented a review an active power filter that commonly used to mitigate harmonics. The paper starts with a brief overview of harmonic problems and their impacts on power quality, how the active power filter can mitigate these problems. The simulation is done using MATLAB software. The paper gives a general overview of active power filters but does not give a clear idea of what are the various real time applications in which active filters are employed which can be useful in selecting the right topology for the right application (Bhakti I et. al., 2013).

In this category the following problem identifications are done.

- Reactive power requirement and switching losses involved can be calculated.
- Stability range is less which can be increased.
- Dynamic compensation involved in VSI's can be considered.
- The role of filter in the most severe condition is not guaranteed.
- Complexity of the large number of solid-state devices involved.

Category II – Mathematical analysis and extraction of components:

This classification is based on what method is discussed in detail by the authors for the extraction of reference components and their subsequent manipulation along with filtering techniques.

M.Tarafdar Haque who gave new definitions for instantaneous real and reactive power quantities to be used in control circuit. Generation of reference compensating current of single-phase active filter is based on canceling the alternating component of p(t) for, harmonic compensation and q(t) for reactive power compensation. The simulation results are proved experimentally (Tarafdar Haque M, 2002). P-Q theory is discussed in detail but it would have been better if the author had included the performance wise comparison of this theory with other methods to prove or disprove the superiority of this theory.

Makoto Saitou et. al., suggested a novel d-q transformation based control strategy for a single phase active filter. The suggestion is to use Hilbert transform, by which the instantaneous single phase voltage and current are converted into complex vectors (analytic signals) on an instantaneous basis. Since the fundamental components of voltages and currents are converted into dc components on the d-q coordinate both in the steady and transient states, the harmonics of voltages and currents can be obtained precisely through the low-pass filer installed on the d-q coordinate (Makoto Saitou et. al., 2003). The method was but intended to suppress voltage fluctuations on dc bus and it was not suggested whether it would come in handy for a generalized harmonic filter implementation.

S. Golestan et. al., brought forward a novel method in the synchronous reference frame to extract the reference compensating current for single-phase shunt active power filters. This method was found by no way inferior to the other reference current generation methods but was rather advantageous in many respects. The effectiveness of the method was proved both mathematically and through simulation results (S. Golestan et. al., 2011). But in this method for simplicity, only first order LPFs are considered and implemented as a block.

Emílio F. Couto et. al., discussed the application of p-q theory to the design of a shunt active power filter. The shunt active power filter allows compensating harmonic currents, reactive power, unbalanced loads, and zero-sequence currents, presenting a good dynamic and steady-state performance observed through simulation results using MATLAB. The simulations are carried out for different loads, both linear and non-linear and the performance is evaluated (Emílio F. Couto et. al., 2003).

Lucian Asiminoaei et. al., presented their views on commonly used theories. Then, the work here proposes a simulation setup that decouples the harmonic reference generator from the active filter model and its controller. The conclusions are collected and a comparison is given at the end, which is useful in deciding the future hardware setup implementation. It is inferred that choice of numerical filtering is the key to good accuracies (Lucian Asiminoaei et. al., 2005).

H. Kouara et. al., proposed a three phase four wire active power filter to eliminate harmonic currents both in the phases and in the neutral conductor of unbalanced three-phase four wire electrical distribution systems, feeding three single non-linear loads. Here pq theory is suggested using two improvements: a multi-variable filter having the advantage of extracting harmonic voltages directly from the axis and the second consists on the use of Fuzzy Logic Controller (FLC) to extract current harmonics components (H. Kouara et. al., 2012).

In this class the two problem were identified they are

- Voltage fluctuations should be suppressed
- Higher order filters can be designed

Category III – Based on soft computing techniques:

This section enumerates and briefs about various soft computing techniques like fuzzy logic, neural networks and artificial intelligence and how they can be incorporated in the design of filters.

Ramadan El Shatshat et. al., introduced soft computing techniques into APF design. The proposed control system processes the distorted line current signal and forces the converter to inject the proper compensating current and also regulates the dc components in the converter topologies. A new control scheme for a modular single-phase active power filter based on the current source converter (CSC) topology is proposed which utilizes two adaptive linear neurons (ADALINE) to process the signals obtained from the power-line. The first one extracts the harmonic components of the distorted line current signal and the second one estimate the fundamental component of the line voltage signal. The outputs of the two are used to construct the modulating signals of a number of CSC modules, each dedicated to eliminate a specific order harmonic. The activation of the filter module(s) is based on the decision-making rules in accordance levels set by the IEEE 519-1992 standard. The high speed, accuracy, efficiency and flexibility offered by the proposed controller, combined with the fast response and low dc energy storage requirement are its main advantages. Digital simulation of the controller is done using Electro Magnetic Transients including DC (EMTDC) (Ramadan El Shatshat et. al., 2004). The technique was implemented for a current source controller which cannot operate in all four quadrants. Thus the same ADALINE network can't be globalized and used for a VSI.

S. S. Mortazavi et. al., takes into account the randomness in the variation of non-linear loads which pose a serious threat to power quality in the system. Classic filters may not have satisfactory performance in such fast varying conditions. This paper presents an auto tuned active power filter for harmonic minimization and reactive power compensation. FLC is used to tune Proportional Integral (PI) controller coefficients and make it robust under random load variation (S. S. Mortazavi et. al., 2008). It must be noted that improper design of fuzzy sets may lead to maloperation and thus they need an expert. Thus a fuzzy system is not easy to implement and is hard to universalize a fuzzy system.

R.Dehini et. al., combine both the strategies for extracting the three-phase reference currents for APFs and DC link voltage control method. The Artificial Neural Network (ANN) learning capabilities to adaptively choose the power system ensure suitable transit of powers to supply the inverter. The study is done using simulation with the MATLAB Simulink Power System Toolbox. The simulation study results of the new Shunt Active Power Filter (SAPF) identification technique compared to other similar methods are found quite satisfactory (R.Dehini et. al., 2010).

Category IV – Design methodologies of special topologies:

Some special design methodologies for active filters and associated topologies are dealt with in this section.

O. Ucak et. al., proposed system consists of a small rated voltage source APF. Besides these, they proposed that no additional switching filter is required for the current ripples in their model which is seen as an advantage as it reduces the voltage level and also the no of filter units actually needed (O. Ucak et. al., 2007). The author suggests that the rating of active filter used for large power applications is a consideration and in order to reduce the same, they have to be used as hybrid filters. This reduces the standalone capability of active filters.

Husev Oleksandr designed a transformerless boost AC/DC converter with the front–end active filter. Constant output voltage, which considerably exceeds the amplitude of the input AC voltage, upon the absence of the consumption of the reactive power from the grid was achieved by such combination. The overload ability of the converter is a special point to note here (Husev Oleksandr, 2011). Transformerless schemes have limitations in the amplitude of the output voltage, and also to the high-frequency components of the input current. It should also be noted that the stability problem not examined in detail in this work.

George Adam et. al., presented the analysis and simulation using MATLAB Simulink of a three-phase four wire neutral clamped active power filter (APF) compensating the harmonics and reactive power created by nonlinear balanced and unbalanced low power loads in steady state and in transients (George Adam et. al., 2011). Only the elimination of current harmonics is discussed and extension to voltage harmonics is described as a future scope.

A. Ajami and E. Salary discussed the operation of APF based on asymmetric cascaded multilevel converter to compensate current harmonics, unbalance currents and reactive power in power distribution systems (Ajami A and E. Salari, 2011).

S.S. Darly et. al., constructed Field Programmable Gate Array (FPGA) based series active filter by adding a bi-directional switch to the conventional bridge topology. This paper proposes a fully digitized hardware design scheme of a space vector pulse width modulation verified and implemented on a single chip FPGA, for series active filter. This is also implemented in Digital Signal Processor (DSP) as FPGA. The superiority of FPGA based solution of industrial drives is established (S.S. Darly et. al., 2011). The paper enumerates the detection methods other than active filters but does not give a comparative reasoning of why the methods proposed are advantageous to APFs.

Here high rating of active filters can be studied and stability aspects of transformerless schemes can be done as future improvement of this category.

Category V – Applications to Real time systems:

Any filter once designed is applied to real time systems already in operation and their performance is evaluated. Some of such applications of filters to real time systems are discussed in this section along with their topologies and design considerations.

I. Zamora et. al., carried out the simulation of an active power filter topology using MATLAB / Simulink. Reduction of harmonics, mainly voltage harmonics was observed after the implementation of active power filters i.e., a reduction in Total Harmonic Distortion (THD) of the system was achieved. As a real time scenario, two examples one of a cement plant and the other a steel plant were taken for analysis by the author (I. Zamora et. al., 2003). The results were proved by simulation using MATLAB/Simulink and very little was discussed about the practical feasibility of installing such a filter. This discussion was required as it was based on real time systems.

U. Kuperman et. al., presented in the paper the modeling and control of a 50kW electric vehicle battery fast charger power factor correction stage, developed at Gamatronic Electronic Industries Ltd., which included an APF. The APF is operated using all-analog control circuitry according to the predetermined grid interfacing behavior. The input stage creates an uncontrolled DC bus while complying with the grid codes by keeping the THD and power factor within the permissible limits while the output stage is modeled as a constant power load (U. Kuperman et. al., 2011). Since the input stage includes a diode rectifier, firing angle variation can't be achieved at the rectification stage.

V. Bindu et. al., proposed a Injection based Hybrid Active Power Filter (IHAPF). This paper concluded that the stability of the IHAPF based on detection supply current is superior to that of others. To minimize the capacity of IHAPF, an adaptive fuzzy dividing frequency-control method is proposed by analyzing the bode diagram, which consists of two control units: a generalized integrator control unit and fuzzy adjustor unit. Compared to other IHAPF control methods, the adaptive fuzzy dividing frequency control shows the advantages of shorter response time and higher control precision. It is implemented in an IHAPF with a 100-kVA APF installed in a copper mill in Northern China (V. Bindu et. al., 2012).

Y. Kusuma Latha et. al., presented the case study of harmonics mitigation in a cement plant. Impacts of harmonic distortions due to adjustable speed electric drives in Anjani Portland cement Ltd., Jaggayapet, Nolgonda (Dist), Andhra Pradesh, India is investigated. Harmonic measurements at various motor drives with the help of Fluke 434 PQ analyzer have been done to determine where a significant amount of harmonic currents or voltages are presented. From these measurements and subsequent calculations, the impact of harmonics is analyzed. In this paper, an APF has been developed for minimization of the harmonics, which is implemented in MATLAB / Simulink based on real time measurement of harmonic data. The implementation details of the designed filter had it been given, would have given an idea of how power conditioning is done in real time (Y. Kusuma Latha et. al., 2012). Modeling of power conditioning equipment can be done as future scope of improvement.

Category VI – Comparative study of filters:

Various topologies of active passive and hybrid filters are discussed and based on studies carried out and a comparison of performance of those filters is done so as to find the most suited filter for a particular application.

H. Akagi published in the bulletin of Polish Academy of Sciences a comparison of APFs with the conventional PPFs. APFs are found to be advantageous in several ways like flexibility, usability for various operations like reactive power compensation, mitigation of voltage imbalance, cheaper cost and several other factors. In this paper, pure active filters for power conditioning, and specific hybrid active filters for harmonic filtering of three-phase diode rectifiers (Akagi H, 2006). The view of the author is that active filters can contribute only to power conditioning and only when combined with passive filters can they provide harmonic filtering also.

Linash P. Kunjumuhammed, and Mahesh K. Mishra just like Akagi, presented a comparative study of various control algorithms for APF. Different type of approaches, both direct and indirect methods was discussed in this paper. The performance of these algorithms was analyzed giving importance to the transient performance of the filter (Linash P. Kunjumuhammed, and Mahesh K. Mishra, 2006).

María Isabel et. al., compared the strategies for extracting the three-phase reference currents for shunt active power filters, evaluating their performance under different conditions with the new IEEE Standard 1459. Under balanced and sinusoidal voltages, harmonic cancellation and reactive power compensation can be attained through all methods. However, it was observed when the under distorted and/or unbalanced conditions, the compensation capabilities are not up to the mark, with some unable to yield an adequate solution (María Isabel et. al., 2007).

Charles.S and Bhuvaneswari.G presented a comparison of three of the three phase SAPF algorithms implemented for a non – linear load namely an induction motor. The algorithms are all time domain based. It is proved that the algorithms are effective inspite of the complex nature of the time domain based current detection method (Charles S and Bhuvaneswari G, 2010).

Category VII – Based on control techniques:

Control methodologies for current control in active filters are discussed in this section which includes papers on a few of very important and widely used current control techniques in practice.

Johann Petit Suárez et. al., proposed a comparative study of various current control schemes based on dead beat control, delta modulation and PI controllers. The objective of the design is to minimize the instantaneous error and the root mean square error between the current of the active power filter and its reference and the best controller is applied in a setup designed for mitigating harmonics (Johann Petit Suárez et. al., 2010). Though dead beat control is found to be effective, delta modulation is implemented for simplicity. Hence there is lack of sufficient experimental proof for the effectiveness of dead beat based control.

A review of converter topologies and control strategies is presented by Ahmet Teke et. al., which identifies APF is one of the Custom Power (CP) devices and can mitigate harmonics, reactive power and unbalanced load currents originating from load side. This study also helps the researchers to select the optimum control strategies and power circuit configuration (Ahmet Teke et. al., 2011).

Vikash Anand and Srivastava S.K. did the simulation and performance investigation of Series APF using hysteresis current control method which employs a simple method for the reference compensation voltage based on p-q theory. Classic filters may not have satisfactory performance in fast varying conditions. But auto tuned APF give better result for harmonic minimization, reactive power compensation and power factor improvement. The active filter does not use any parallel passive filter and interfacing capacitor and thus its effective contribution to harmonics elimination is questionable (Vikash Anand and Srivastava S.K, 2012).

Seven level control of SAPF was proposed by Jayakrishna et. al., i.e., nothing but Hybrid Cascaded Seven-Level Inverter (HCSLI) used to compensate reactive power, improve the power factor and to suppress the THD due to linear load and non-linear loads. In this paper, d-q reference frame theory for reference current computation, Constant Switching Frequency Multicarrier Sub-Harmonic Pulse Width Modulation (CSFMSHPWM) technique for controlling the switches of HCSLI, and FLC is used for regulating dc side capacitor voltage (Jayakrishna et. al., 2011).

Current control by ramp comparison, hysteresis current control and adaptive hysteresis (band) current control using Simulink power system toolbox was dealt with by Dipti A Tamboli et. al., using instantaneous reference frame theory for reference current compensation. Other control concepts like synchronous detection, sliding window, Fourier analysis etc., known as group harmonics identification methods were discussed which used a special scheme for current control known as Modified Least Compensation (MLC) current control method. There are some drawbacks of using Fourier analysis i.e. loss of information during transformation from time to frequency domain which is not dealt with in detail, in this paper (Dipti A. Tamboli and D. R. Patil, 2012).

Thanatchai Kulworawanichpong et. al., proposed MLC current control method. The effectiveness of the method is verified by comparison studies among the d-q axis, the synchronous detection, and the sliding-window Fourier analysis methods, respectively which are known as group-harmonic identification methods. From this comparative analysis, the superiority of the MLC method is established with experimental as well as simulation results (Thanatchai Kulworawanichpong et. al., 2004).

Bhupinder Singh et. al., presented in their paper an overview of SAPF and their usage in PQ improvement. Two control techniques are proposed to determine the reference current for the three phase three wire SAPF in order to improve the power quality using PI controller. The first one is based on the instantaneous real and reactive power (p-q) method and second one is the instantaneous active and reactive current (I_d-I_q) method. The author explains about shunt active filters but doesn't elaborate on why he preferred shunt over series active filter and the application of hybrid filters to the same problem (Bhupinder Singh et. al., 2013). Analysis of time to frequency transformation and effect of shunt active filter over series active filter can be studied.

Hybrid power filters (hpf):

There are independent advantages separately for the passive and active filters. If they are combined then the overall performance of the system can be improved. The HPF is combination of both APF and PPF with suitable control methodologies incorporated for better performance. A sample figure of the HPF is shown in Figure 3.

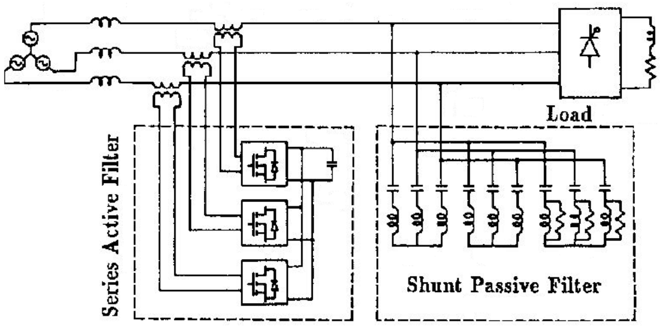


Fig. 3: An example of HPF

HPFs are found to be more advantageous than the other two types because they combine the advantages of both active and passive filters in order to eliminate the others demerits. They are further sub classified as follows.

Category I – Overview of power quality concepts
Category II – Based on soft computing techniques
Category III – Applications to Real time systems
Category IV – Based on control techniques
The number of publications in each category is shown in table 2.

Table 2: Number of Publications in each category .

Category	Number of Publications
I	07
II	04
III	02
IV	01

Category I –Overview of power quality concepts:

An overview of various topologies concepts and implementation of HPFs for power quality improvement is discussed in this section.

G. Bhuvaneswari and Manjula G. Nair suggested that APFs can be cost-effective for use in practical systems with the insertion of a few passive elements in shunt or series configuration. The resulting HPFs can be designed so as to reduce the burden of their active counterparts. The simulation and the experimental results of the shunt active filter, along with the estimated value of reduction in rating, show that the hybrid shunt filtering system is quite effective in compensating for the harmonics and reactive power, in addition to being cost-effective. This paper suggests that passive filters are implemented along with active filters for their performance improvement but there is a lack of idea as to how to mitigate the inherent disadvantages of passive filters (Bhuvaneswari G and Manjula G.Nair, 2007).

R. D. Patidar and S. P. Singh proposed a combination of single three-tuned PPF and APF is proposed for reducing the rating of active filter. In the proposed technique the three-tuned passive filter which is an equivalent of three single-tuned filters is tuned to compensate 3rd, 5th and 7th order harmonics while the APF compensates all remaining harmonic components which are not compensated by PPF. The effectiveness of the proposed algorithm is demonstrated by its simulation in MATLAB / Simulink and was found to possess better performance for harmonic compensation, low power loss, less space requirement (R. D. Patidar and S. P. Singh, 2008).

Nor Farahaida Abdul Rahman et. al., proposed a method, in which the active power filter is injecting equal but opposite current to mitigate the distortion current shape the supply current to a sinusoidal form and in phase with the supply voltage. In this work, the single-switch parallel active power filter is used to reduce switching stress, losses and also the cost. The performance of this topology in conjunction with a simple passive filter in a hybrid arrangement using two components; a parallel active power filter and a passive filter for removing both high order and low order harmonics is observed (Nor Farahaida Abdul Rahman et. al., 2009).

T. Mahalekshmi, in this paper claimed that the current harmonic can be compensated by using the SAPF, PPF and the combination of both. The system has the function of voltage stability, and harmonic suppression. The reference current can be calculated by d-q transformation and an improved generalized integrator control is proposed to improve the performance (Mahalekshmi T, 2010).

Rashmi S. Phasate et. al., proposed a hybrid filter to minimize the power quality impact of matrix converters. Matrix converters inject significant harmonics and nonstandard frequency components into power systems. A hybrid filter constructed of a shunt active filter and distributed passive filters used for power quality improvement. The proposed approach has been tested and validated on the matrix converter using MATLAB / Simulink. Matrix converters are used to convert AC to AC without a DC link which may be an advantage but switching losses involved in matrix converters and ways to mitigate them are not discussed in detail (Rashmi S. Phasate et. al., 2011).

Thirumoorthi P and Yadaiah N proposed a technique PPF is tuned to compensate 3rd and 5th order harmonics and APF compensates all remaining harmonic components which are not compensated by PPF. A half bridge inverter with DC bus capacitor is used as APF. It has only two power switches. The APF control is based on DC side voltage control. The effectiveness of the proposed algorithm is demonstrated by its simulation in Power Simulation (PSIM) software. The simulation results show that the designed HPF compensates the harmonic currents produced by loads and the power factor, making the current at the source side to become sinusoidal and in phase with the system voltage (Thirumoorthi P and Yadaiah N, 2012).

Mehdi Asadi and Ali Reza Jalilan formulated a hybrid APF design comprising a b-shape C-type hybrid APF and an active electromagnetic filter. The design consists of a three-phase Zig-Zag transformer and a half-bridge single-phase inverter connected in parallel with the b-shape C-type hybrid active power filter and the loads. The b-shape C-type hybrid APF consists of a double tuned parallel PPF and a half-bridge three-phase inverter. The steady state compensation and the resonance-damping characteristics of the proposed topology are analyzed in this paper. The hybrid APF is simulated and the simulation results are provided to validate effectiveness of the topology and the design considerations. The paper throws very little light on the transient response of a filter which is an important characteristic which will be useful to decide the rating in case of large systems which are prone to transient disturbances (Mehdi Asadi and Ali Reza Jalilan, 2012). Switching losses involved in matrix converters and transient responses of filter over transient disturbances can be analyzed.

Category II – Fuzzy based control of HPF:

Application of soft computing techniques to the design of HPF by various authors is discussed in this section. Nagaraju Devarashetti et. al., proposed that the stability of the IHAPF based on spotting supply current is exceptional to that of others. To minimize the capacity of IHAPF, an adaptive fuzzy dividing frequency control method is used, which consists of two control units: a generalized integrator control unit and fuzzy adjustor unit. It exhibits clear promise in decreasing harmonics and increasing the power factor with a comparatively low capacity APF (Nagaraju Devarashetti et. al., 2011).

N. Bett et. al., proposed a combination of a shunt C-type high-pass filter in parallel with an APF controlled by a neuro-fuzzy controller. The C-type will help to reduce component rating for APF and suppress the overall filter resonance while active filter compensate for the low order harmonics. A three phase converter supplying highly inductive load has been chosen as a typical non-linear load for which a shunt HPF comprising of a shunt C-type high pass PPF and a SAPF is employed to improve the PQ at the source end. The neural network has to be trained with patterns or values which involves the use of different algorithms. Each algorithm may impact the performance of the system in terms of computational time and convergence. Thus for the same rating of systems used two different algorithms can yield two different results (N. Bett et. al., 2012).

Sakshi Bangia et. al., dealt with the implementation of fuzzy logic based Shunt Hybrid Active Power Filter (SHAPF) with non-linear load to minimize the source current harmonics and provide reactive power compensation. A shunt connected three phase single tuned LC filter for 5^{th} harmonic frequency with rectifier load acts as PPF. The active filtering system is based on synchronous reference frame. The proposed fuzzy logic based control strategy improves active filter operation and reduces the selective harmonic contents. Design of a fuzzy based algorithm needs expert guidance and is a complex process (Sakshi Bangia et. al., 2013).

G.Nageswara Rao et. al., dealt with a hybrid active power filter with injection circuit (IHAPF). This paper concluded that the stability of the IHAPF based on detection supply current is superior to that of others. To minimize the capacity of IHAPF, an adaptive fuzzy dividing frequency-control method is proposed. The generalized integrator is used for dividing frequency integral control, while fuzzy arithmetic is used for adjusting proportional-integral coefficients. The precision of fuzzy based system is purely based on the knowledge of the domain expert who designs the system. Thus there is a variation in performance when the same logic is being implemented by different people and thus we can’t say that there will be a significant reduction in THD if the system is designed by inexperienced persons (G.Nageswara Rao et. al., 2010).

Category III – Applications to Real time systems:

HPFs are incorporated for power quality improvement in various real time systems which are discussed below.

Răzvan–Daniel Albu and Daniel Albu suggested that hybrid APFs inherit the efficiency of passive filters and the improved performance of APFs, and thus provide improved approach for harmonic compensation. This paper presents a single-phase hybrid APF connected to a photovoltaic array. The uniqueness of the scheme is the fact that it improves the filtering performance of the conventional shunt active power filter, as well as simultaneously supplies the power from the photovoltaic array to the load. The compensation current reference estimation is based on the extension instantaneous reactive-power theorem. A PV based system needs converters for grid interfacing. These converters inject harmonics in the system. The paper considers only the harmonics caused by load and not that which is caused by converter switching operations (Răzvan–Daniel Albu and Daniel Albu, 2009).

T. Nageswara Prasad et. al., discussed the advantages of using HPFs to mitigate harmonics. A seven level cascaded multilevel is used in the present work to mitigate the harmonics using HPF is proposed. The simulation results of the same are presented in this paper for a distribution system of voltage 11kV. HPFs are essential in maintaining harmonic levels in power system as defined by international standards like IEEE-519-1992, IEC-61000 (T. Nageswara Prasad et. al., 2012).

Category IV – Based on control methodologies:

The current control methodology of a hybrid filter based on certain theory of formulation as a special case is given as follows.

S. P. Litrán et. al., proposed a new control method for series active shunt passive filter. The new control strategy is based on the dual formulation of the vectorial theory of electric power, so that the signal injected by the active filter is able to compensate he reactive power and the harmonics of the load current. To verify the developed theoretical analysis using MATLAB, the control strategy was verified by means of an experiment also. There is a problem in tuning the capacitor and inductor of the passive filter (fixed compensation) as per the changes in the firing angle of the VSC (S. P. Litrán et. al., 2008).

Conclusion:

In this paper a widespread review of papers based on filters were discussed, which will help the future engineers to work in this area. The role of filters is increasing nowadays because the use of power electronics based utility devices is increasing rapidly these days. Initially in this paper the impact of non linear loads and the importance of various filters used in power system are discussed, with their advantages and disadvantages. Here how the harmonics are reduced and the quality of power improved by various researchers was also discussed. Based on these information future improvement were suggested.

REFERENCES

Ahmet Teke, Lutfu Saribulut, M. Emin Meral and Mehmet Tumay, 2011. Active Power Filter: Review of Converter Topologies and Control Strategies. Gazi University Journal of Science, 24(2): 283–289.

Ajami, A. and E. Salari, 2011. Active Power Filter based on Cascaded Transformer Multilevel Inverter. International Journal of Advanced Engineering Sciences and Technologies (IJAEST), 7(2): 313–318.

Akagi, H., 1996. New Trends in Active Filters for Power Conditioning. IEEE Transactions on Industrial Applications, 32(6): 1312–1322.

Akagi, H., 2006. Modern active filters and traditional passive filters. Bulletin of the Polish Academy of Sciences, Technical Sciences, 54(3): 255–269.

Bett, N., J.N. Nderu and P.K. Hinga, 2012. Neuro–Fuzzy Control Technique in Hybrid Power Filter for Power Quality Improvement in a Three–Phase Three–Wire Power System. Innovative Systems Design and Engineering, 3: 41–50.

Bhakti, I. Chaughule, Amit L. Nehete and Rupali Shinde, 2013. Reduction In Harmonic Distortion of the System using Active Power Filter in MATLAB/Simulink. International Journal of Computational Engineering Research, 3(6): 59–64.

Bhim Singh, Kamal Al–Haddad and Ambrish Chandra, 1999. A Review of Active Filters for Power Quality Improvement. IEEE Transactions on Industrial Electronics, 46(5): 960–970.

Bhupinder Singh, Ashish Sharma, Hardeep Singh, 2013. An Introduction of Shunt Active Power Filter (SAPF) to Improve Power Quality. International Journal of Enhanced Research in Science Technology and Engineering, 2(3): 1–6.

Bhuvaneswari, G. and G. Manjula Nair, 2007. Three–Phase Hybrid Shunt Filters for Power Quality Improvement. Journal of Power Electronics, 7(3): 257–264.

Bindu, V., I. SaiRam and K.K. Vasishta Kumar, 2012. Hybrid Active Power Filter using Fuzzy Dividing Frequency Control Method. International Journal of Advances in Engineering and Technology, 2(1): 426–432.

Charles, S., 2009. Power Quality Enhancement in Variable Frequency Drive using Hybrid Filters– An Shunt Passive and Series Active Combination. International Journal of Recent Trends in Engineering, 2(5): 227–231.

Charles, S. and G. Bhuvaneswari, 2010. Comparison of Three Phase Shunt Active Power Filter Algorithms. IJCEE 2010, 2(1): 175–180, ISSN: 1793–8163.

Darly, SS., P. Vanaja Ranjan and Dr. B. Justus Rabi, 2011. FPGA Based Series Active Filter For Power Quality Enhancement. International Electrical Engineering Journal (IEEJ), 1(1): 506–513.

Dipti, A. Tamboli and D.R. Patil, 2012. Active Power Filter with advanced Current Controller Technique for Power Quality Improvement. International Conference on Electronics and Communication Engineering, Bangalore, pp: 147–154.

Dipti, A. Tamboli and D.R. Patil, 2012. An Advanced Current Controller Technique Based Active Power Filter for Power Quality Improvement. International Conference on Electronics and Communication Engineering, Bangalore, pp: 55–60.

Emílio Couto, F., S. Júlio Martins and L. João Afonso, 2003. Simulation Results of a Shunt Active Power Filter with Control Based on P–Q Theory. ICREPQ’03, International Conference On Renewable Energies And Power Quality, Vigo, pp: 1–6.

George Adam, G. Alina Stan (Baciu) and Gheorghe Livinţ, 2011. A MATLAB–Simulink Approach to Shunt Active Power Filters”, Department of Electrical Engineering Technical University of Iasi, 700050, Iasi, Romania, ECMS, pp: 1–6.

Golestan, S., M. Monfared and J.M. Guerrero, 2011. A Novel Method for Extraction of the Reference Compensating Current for Single–Phase Shunt Active Power Filters. International Conference on Electrical Engineering and Informatics (ICEEI), pp: 1–5.

Husev Oleksandr, 2011. Transformerless Boost AC/DC Converter with the Front–end Active Filter. Student Forum of the 7th International Conference–Workshop Compatibility and Power Electronics CPE 2011, Tallinn, pp:77–81.

Jayakrishna, G., P. Sujatha and K.S.R. Anjaneyulu, 2011. Seven Level Control of Shunt Active Power Filter for Power Quality Enhancement. International Journal of Engineering Science and Technology (IJEST), 3(9): 7037–7046.

Joao, L. Afonso, H.J. Ribeiro da Silva and S. Julio Martins, 2001. Active Filters for Power Quality Improvement.IEEE Porto PowerTech, 10–13 Sept. 2001, Porto, Portugal, pp: 1–8.

Johann Petit Suárez, Hortensia Amarís and Guillermo Roble, 2010. Current Control Schemes for Three–Phase Four Wire Shunt Active Power Filters: A Comparative study", Rev. Fac. Ing. Univ. Antioquia, (52): 206 –214.

Kamala Kant Mishra and Rajesh Gupta, 2011. Load compensation for single phase system using series active filter. International Journal of Engineering, Science and Technology, 3(3): 83–93.

Kanchan Chaturvedi, Dr. Amita Mahor, Anurag Dhar Dwivedi, 2012. Active Power Filter Techniques for Harmonics Suppression in Non Linear Loads. International Journal of Scientific Engineering and Technology, 1(2): 123–127.

Kavaskar, S., M. Rajmal Joshi, S. Paneer Selvam, P. Kalaimani, A. Kalaimani, R. Bharat kumar and K. Narashkumar, 2013. Compensation of Power Quality Problems Using Active Power Filter International Journal of Engineering Science Invention, 2(3): 25–30.

Kavitaha, T. and K. Ratnaraju, 2011. Novel method for Power Quality Improvement using Active Power Filter. International Journal of Computer Trends and Technology, pp: 491 – 496,

Kouara, H., H. Laib and A. Chaghi, 2012. A New Method to Extract Reference Currents for Shunt Active Power Filter in Three Phase Four Wire Systems. International Journal of Advanced Science and Technology, 46: 165–174.

Kuperman, U. Levy, J. Goren, A. Zafranski and A. Savernin, 2011. Modeling and Control of the PFC Stage for a 50KW EV Fast Battery Charger. Conference Proceedings of the World Congress on Engineering 2011, II: 1–5.

Kusuma Latha, Y. Ch. Sai Babu and Y.P. Obulesu, 2012. Harmonics Mitigation of Industrial Motor Drives with Active Power Filters in Cement Plant–A Case Study. International Journal of Power Electronics and Drive System (IJPEDS), 2(1): 1–8.

Linash, P. Kunjumuhammed and K. Mahesh Mishra, 2006. Comparison of Single Phase Shunt Active Power Filter Algorithms", IEEE Power India Conference, pp: 1–8.

Litrán, SP., P. Salmerón, R.S. Herrera and J.R. Vázquez, 2008. New Control Strategy to Improve Power Quality Using A Hybrid Power Filter. International Conference On Renewable Energy And Power Quality (ICREPQ'08), pp: 1–6.

Lucian Asiminoaei, Frede Blaabjerg and Steffan Hansen, 2005. Evaluation of Harmonic Detection Methods for Active Power Filter Applications. Twentieth Annual IEEE Applied Power Electronics Conference and Exposition, Vol.1. Electrical Engineering/Electronics, Computer, Communications and Information Technology Association, pp: 635–641.

Mahalekshmi, T., 2010. Current Harmonic Compensation and Power Factor Improvement by Hybrid Shunt Active Power Filter. International Journal of Computer Applications, 4(3): 9–13.

Makoto Saitou, Nobuyuki Matsui and Toshihisa Shimizu, 2003. A Control Strategy of Single–phase Active Filter using a Novel d–q Transformation, IAS Annual Meeting (IEEE Industry Applications Society), 2: 1222–1227.

María Isabel Milanés Montero, Enrique Romero Cadaval and Fermín Barrero González, 2007. Comparison of Control Strategies for Shunt Active Power Filters in Three–Phase Four–Wire Systems. IEEE Transactions on Power Electronics, 22(1): 229–236.

Mehdi Asadi and Ali Reza Jalilan, 2012. A Hybrid Active Power Filter Comprising an Active Electromagnetic Filter. PRZEGLĄD ELEKTROTECHNICZNY (Electrical Review), pp: 205–212.

Metkari Archana Subhash and S.H. Pawar, 2013. Improvement of Power Quality by Using Active Filter based on Vectorial Power Theory Control Strategy on the MATLAB–Simulink Platform. IOSR Journal of Electronics and Communication Engineering (IOSR–JECE), 4: 37–40.

Morán, L., J. Dixon, J. Espinoza and R. Wallace, 1999. Using Active Power Filters to Improve Power Quality.5th Brasilian Power Electronics Conference, COBE P'99, pp: 1–11.

Mortazavi, SS., R. Kianinezhad and A. Ghasemi, 2008. Auto Tuned Robust Active Power Filter for Power Quality Improvement under Fast Load Variation. Third International Conference on Electric Utility Deregulation and Restructuring and Power Technologies, pp: 1–6.

Murat Kale, Engin O¨ zdemir, 2005. Harmonic and reactive power compensation with shunt active power filter under non–ideal mains voltage. Electric Power System Research, 1: 363–370.

Nagaraju Devarashetti, Y. Rajasekhar Reddy and P.V. Kishore, 2011. Design and simulation of Hybrid Active Power Filter using the Adaptive Fuzzy Dividing Frequency–Control Method. International Journal of Scientific and Engineering Research, 2(12): 1–9.

Nageswara Prasad, T., V. Chandra Jagan Mohan and V.C. Veera Reddy, 2012. Harmonic Reduction in Hybrid Filters for Power Quality Improvement in Distribution Systems. Journal of Theoretical and Applied Information Technology, 35(1): 44–55.

Nageswara Rao, G., K. Chandra Sekhar and P. Sangameswara Raju, 2010. Design and Implementation of Hybrid Active Power Filter. International Journal of Computer Applications, 8(10): 10–15.

Nor Farahaida Abdul Rahman, Mustafar Kamal and Ahmad Shukri Abu Hasim, 2009. Single–Phase Hybrid Active Power Filter using Single Switch Parallel Active Filter and Simple Passive Filter. The Eighth International Conference on Power Electronics and Drive Systems, pp: 40–45.

Patidar, RD. and S.P. Singh, 2008. A Single–Phase Hybrid Filter to Improve Power Quality. XXXII National Systems Conference, pp: 83–88.

Rachid.Dehini, Abdesselam Bassou and Brahim Ferdi, 2010. Artificial Neural Networks Application to Improve Shunt Active Power Filter. Special issue of the Proceeding of the 4th International Conference on Electrical Engineering (CIGE4) organized at the University of BECHAR on, (3–4): 1058–1065.

Ramadan, El Shatshat, M.M.A. Salama and Mehrdad Kazerani, 2004. Artificial Intelligent Controller for Current Source Converter–Based Modular Active Power Filters. IEEE Transactions on Power Delivery, 19(3): 1314–1320.

Rashmi, S. Phasate and Archana Bawankar, 2011. Power Quality Improvement in Matrix Converter using Hybrid Filter. International Journal of Power System Operation and Energy Management, 2(1-2): 9–13.

Ravindra, G., P. Ramesh and Dr.T. Devaraju, 2012. Enhancement of Power Quality using Active Power Filters. International Journal of Scientific and Research Publications, 2(5): 1–4.

Răzvan Daniel Albu and Daniel Albu, 2009. Hybrid Active Power Filter Connected to a Photovoltaic Array. Journal of Electrical and Electronics Engineering, 2(1): 109–112.

Saheb Hussain, MD., K. Satyanarayana and B.K.V. Prasad, 2011. Power Quality Improvement by Using Active Power Filters. International Journal of Engineering Science and Advanced Technology, 1(1): 1–7.

Sakshi Bangia, PR Sharma and Maneesha Garg, 2013. Simulation of Fuzzy Logic based Shunt Hybrid Active Filter for Power Quality Improvement. I.J. Intelligent Systems and Applications, pp: 96–104.

Salmerón, P and S.P. Litrán, 2010. Improvement of the Electric Power Quality using Series Active and Shunt Passive Filters. IEEE Transactions on Power Delivery, 25(2): 1–10.

Sandeep, GJSM. and SK. Rasoolahemmed, 2013. Importance of Active Filters for Improvement of Power Quality. International Journal of Engineering Trends and Technology (IJETT), 4(4): 1164–1171.

Tarafdar Haque, M., 2002. Single–Phase PQ Theory for Active Filters. IEEE Proceedings Region 10 Conference on Computers, Communications, Control and Power Engineering, 3: 1941–1944.

Tey, LH., P.L. So and Y.C. Chu, 2005. Improvement of Power Quality using Adaptive Shunt Active Filter. IEEE Transactions on Power Delivery, 20(2): 1558–1568.

Thanatchai Kulworawanichpong, Kongpol Areerak and Sarawut Sujitjorn, 2004. Active Power Filter Design by a Simple Heuristic Search. Knowledge–Based Intelligent Information and Engineering Systems, 8th International Conference, KES 2004, Wellington, New Zealand, Part III, Volume 3215 of Lecture Notes in Computer Science, Springer, pp: 695–701.

Thirumoorthi, P. and N. Yadaiah, 2012. Mitigation of Harmonic Current through Hybrid Power Filter in Single Phase Rectifier. ACEEE Int. J. on Electrical and Power Engineering, 3(1): 62–68.

Ucak, O., I. Kocabas and A. Terciyanli, 2007. Design and Implementation of a Shunt Active Power Filter with Reduced DC Link Voltage. TUBITAK– Space Technologies Research Institute, Power Electronics Group, METU Campus, TR 06531, Ankara, Turkey, pp: 1–5.

Vikash Anand and S.K. Srivastava, 2012. Simulation and Performance Investigation of Series Active Power Filter Using Hysteresis Current Control Method. International Journal of Engineering Research and Applications (IJERA) ISSN: 2248–9622, 2(4): 1073–1080.

Zamora, I., A.J. Mazon, P. Eguia, I. Albizu, K.J. Sagastabeitia and E. Fernández, 2003. Simulation by MATLAB/Simulink of active filters for reducing THD created by Industrial Systems. Power Tech Conference Proceedings, IEEE Bologna, 3: 1–8.

Zubair Ahmed Memon, Mohammad Aslam Uquaili, And Mukhtiar Ali Unar, 2012. Harmonics Mitigation of Industrial Power System using Passive Filters. Mehran University Research Journal of Engineering and Technology, 31(2): 355–360.