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A REVIEW ON ACTIVE POWER FILTER FOR POWER QUALITY IMPROVEMENT

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Abstract - The quality of electric power plays an important role on supply side as well as user side. The quality of electric power is polluted by using non-linear electronics load. As the use of electronics devices increases day by day for the fast and reliable operation and for the automation are the main sources of harmonics in the power system. Traditionally Passive filters are used for improve the power quality. The inadequate performance of the conventional passive filter techniques to reduce harmonics problems has affirm to introduce active filters. The active filters have many functions like isolation, filtering, damping., load balancing and reactive power compensation. the paper explores a brief review on SAPF for 1-phase,3-phase 3 wire, 3-phase 4 wire and control techniques along with new correction and practical aspects for future research in the area of SAPF.

Keywords- Shunt Active Power Filter, Power Quality, Control Techniques, THD;

I. INTRODUCTION

For the last three decades the demand for electrical energy has been increasing exponentially due to the growth in power electronics industries at high rate. As the power electronics equipments like uninterruptable power supplies (UPS), switched mode power supplies (SMPS) energy saving lamps, arc-furnaces, advanced speed drives (ASDs), and the electrical appliances etc are produced at a large scale are ultimately considered as non-linear load. This boom in the use of non-linear load leads the distortion in current and voltage waveform at the PCC and becomes one of the major issues of power quality [1-4].Conventionally, due to the low cost, simple and robust design of the passive filters, these are used to mitigates the harmonics related problems in electrical system. There are various topologies of passive filter which have been tried and verified for years with improved efficiency in terms of different factors [5-6]. They canmitigate the harmonic contents by providing low-impedance path to the harmonic frequencies and reactive power demand is also compensated by them [7-8]. But passive filters are large in size and rigid as they can only compensate those harmonic frequencies for which they are tunedand they alsosuffer from resonance due to this, the use of such filters are limited to certain typesof loads only. The variation in frequency also effect the compensation characteristic of the passive filter [9]. The switch mode power converter based active power filter (APF)overcomes the problems occurs with passive filter and cancels the harmonics contents in the current produced by the non-linear load by injecting the compensating current in the system.Damping andisolationof harmonics between the power systemand non-linear load as well as between source impedanceand passive filter are provided by APF respectively [10]. The principle of operation of APF is largely dependent on the controller and many different controllers has been suggested in papers [11].APF is divided in shunt and series APF, to solve the voltage related problems series APF are preferred whereas for current harmonics, neutral current compensation andfor compensation of reactive power to make the unity power factor, Shunt APF is preferred which protects loads from these disturbances and reduce the THD (Total Harmonic Distortion) wellbelow 5% recommended by the IEEEstandards (THD<5%) [12]

This paper explores the comprehensive review on shunt APF. In this paper different Section describes the Circuit configuration of Shunt APF,Classification of shunt APF, Control strategies, different PWM techniques andpractical aspectsalong with future scope in the implementation of shunt Active Power filters followed by conclusions.

II. Circuit Configurations of Shunt Active Power Filter

The power quality problems due to non-linear load is a major problem for suppliers and consumers. In past these difficulties have been fixed by use of passive filters but due to many disadvantages like resonance, rigid, fixed, large in size etc, researcher looking for new solutions to overcome these disadvantages. Active power filter based on CSI and VSI with self-supporting inductor and capacitors are connected to PCC.Figure 1 shows basic configuration of SAPF connected to the line in parallel with a non-linear load. Where i_s is the source current, i_l is load current, i_c is the compensating current and i_c* is the compensating current to the filter. The topology three-phase, three-wire system and has a particular characteristic that is the absence of neutral conductor. The absence of neutral conductor signifies that the power flow due to zero-sequence current in the system is zero. One of the significant characteristics of SAPF is to provide harmonic damping throughout the power line to avoid harmonic propagation and results in a better power factor and reactive power compensation. The current compensation and harmonic mitigation and reactive power compensation would be done using different control algorithms [13]. The inductor which is used for the interfacing the filter to PCC improves the wave shape by reducing the ripples in the line. By using proper tuning of controllers, the performance of SAPF can be improved.

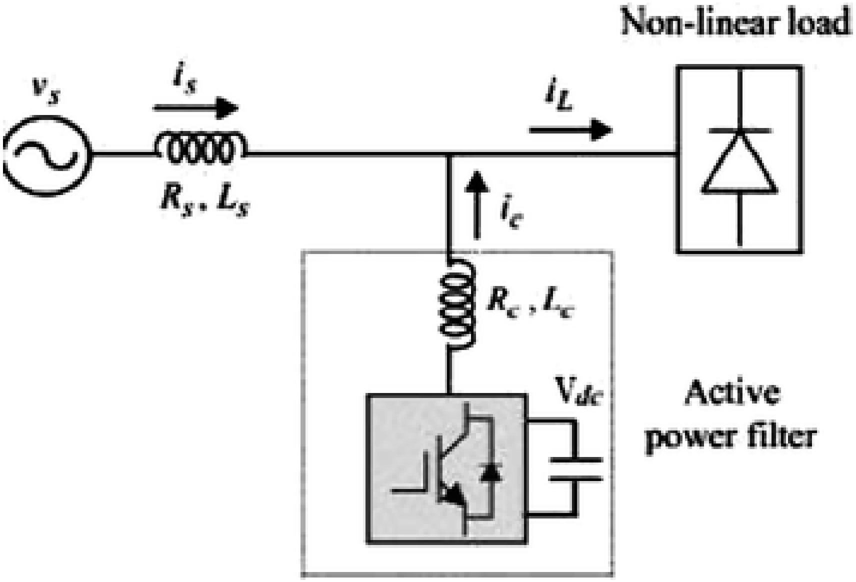


Fig. 1Single-line diagram of Shunt APF

III. TOPOLOGY BASED CLASSIFICATION

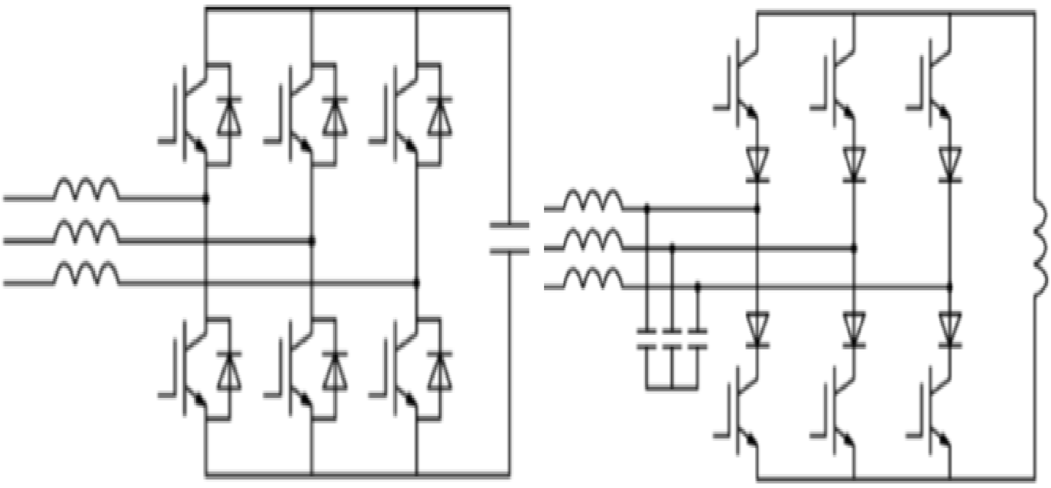
Active power filter (APF) has become a reality and is widely used in industrial and commercial applications and are classified in different categories-

- circuit configuration (Type of inverter)
- type of source
- advanced inverter configuration

A. Circuit Configuration (Type of Inverter)

APFs are basically composed of (i). Current source converter (CSC) and (ii). Voltage source converter (VSC) connected in shunt at the PCC to the grid. [14-15] The Current source converter consist of an inductor at dc side and the voltage source converter consist of a capacitor on dc side as a storing element to maintain the power across the converter through DC link. Both the converters are similar in circuit for use across the loads but are different in their characteristics. CSC having some disadvantage like higher cost, lower in efficiency and large in physical size as compared to VSC as in the sense of capacitor and inductor.

Since IGBT module-based voltage source converter is more flexible because a freewheeling diode is connected antiparallel to it i.e. IGBT does not required to provide reverse blocking capability and hence reduction in switching losses while it is complicated in fabrication and device design in CSC. The VSC is lighter in weight as compared to CSC[16-18]. The basic circuit diagram of voltage source converter and Current source converter are shown in figure 2(a) & (b) respectively.



(a) (b)

Fig 2. Circuit diagram (a)voltage source converter (b) Current source converter

B. Classification based on type of power source

Generally, loads in the household applications are considered as single phase and the industry loads are considered as three phase loads in the electrical power system and these loads are supplied by the two wire or three wire sources which are either single phase or three phase sources. For improve the quality of power the APF also divided on the bases of power supply system. Some of the problems like current harmonics and the reactive power demand are common in both 1-phase and 3-phase and the unbalancing of the voltage and higher neutral current problems occurs in 3-phase system are compensated by using 3-phase 4 wire configuration of APF which are H-bridge model, split capacitor and extra fourth leg inverter configurations. [19]

In 3-phase 4 wire system the neutral current is $\sqrt{3}$ times of the phase current which is compensated by using four leg inverter, two capacitor split type topology. Requirement of additional control loop in 2 capacitor split configuration makes it less effective. [20-22] The four-leg topology has more effective than 2 capacitor type because extra switches compensates the neutral current. [23-25]. In controllability of 3-leg bridge inverter is improved because each phase is controlled by conjugation of other two phases.

C.Advanced configuration-basedClassification

Various types of advanced topology based on inverter configuration are explores by the researchers.

The advanced topology means (IB-FB-APF), multi-level inverters like 9-level, 27-level inverter and 49-level inverter topology, Inter-leaved buck full bridge inverters are used in SAPF to mitigates the harmonics and for improvement of power quality. Since these multilevel topologies is complex in structure and complicated due to large algorithms are used, but having advantageous due to good capability of compensation along with reduction in switching losses and advantages to reduce dV/dt losses. Various types of topologies like H-bridge, diode clamped, modular multilevel and flying capacitors topologies are described in literature.[25-26]. For medium and large power derives the temperature rise in IGBT switches and (EMI) electromagnetic interfaces can be overcome by using interleaved buck full bridge inverter based APF. [27-28]. The classification of different types of Shunt Active Power Filter are shown in figure 3.

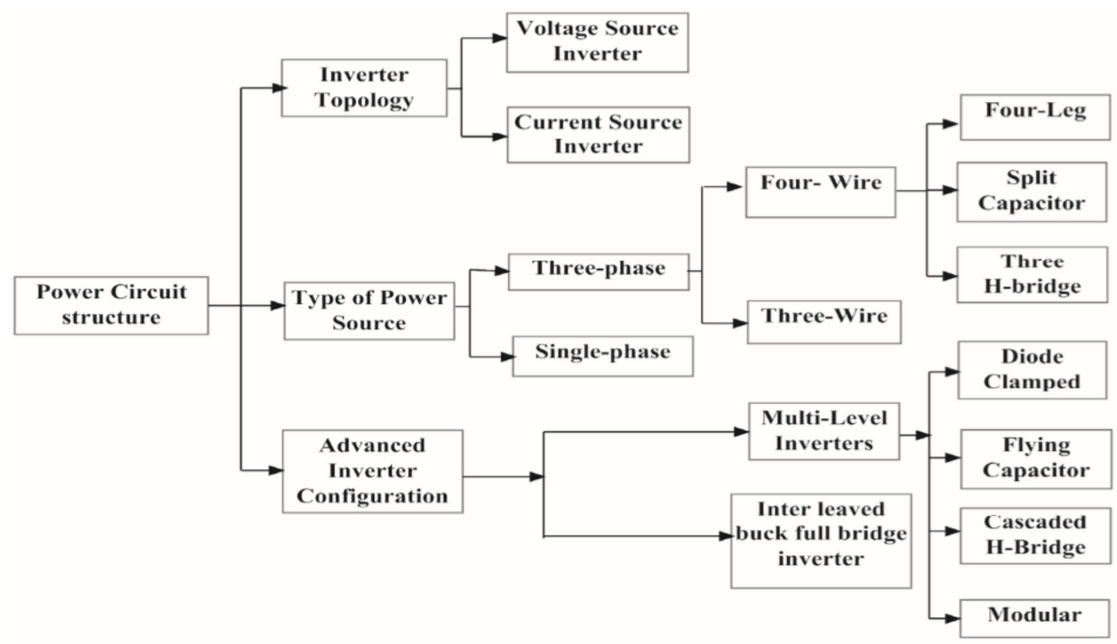


Fig. 3 Classification of shunt Active Power Filter

IV. CONTROL TECHNIQUES BASE CLASSIFICATION

There are many techniques used for controlling the power filters. Though passive power filter is not based on any controlling technique but it does filtering action due to its inherent characteristic. The filter parameters are selected in such way that it allows only harmonic frequency to pass through it. However, active power filterhas to follow controlling techniques for the power converters.The prime objective of the control algorithm is to generate reference current for the calculation of compensating current. The control algorithms are also divided into time-domain and frequency-domain [29].

A. Frequency-domain techniques

The filter like Kalman filter, fast Fourier transform (FFT) analysis and wavelet transform base techniques are the frequency domain techniques. For the extraction of the harmonic component from the polluted system FFT analysis is used for the Shunt Active power filter. This technique consumes more time for the calculation of harmonic content [30]. The Kalman filter used to calculate the time varying harmonic content because it requires state variable model and is used for real time applications. [14]. The Wavelet transform technique convert all the parameters in frequency domain from time domain parameters and all calculation is done in frequency domain.

B. Control techniques in time-domain

The controller based on time domain methods are easy and simple forimplementation in the real-time applications. The IRPT (instantaneous reactive power theory) or PQ theory is widely used due to simple in mathematical equations for calculation of the reference signals ,Power balance theory (BPT) [31],Synchronous reference frame (SRF) theory, also known as d–q theory[32], Singe-phase PQ theory, Singe-phase DQ theory, I cos φ control algorithm[14], Adaptive detecting control algorithm, also known as adaptive interference cancelling theory, unit template technique [33] etc are the time domain techniques.

The p-q Theory defines instantaneous power in time-domain and is applied in a three-phase system. It transforms abc to αβ0 coordinates to define power. It uses Clarke transformation which consists of real matrix and transforms currents and voltages into αβ0 stationary reference frame. The advantage of this transformation is to eliminate zero-sequence components from abc-phase components. The active and reactive powers are calculated instantaneously i.e. there is no any time delay [31]. The UVT based or PI controller-based techniques reduces the Burdon on processor and can effectively correct the power factor along with reactive power compensation. [33]. For the implementation of BPT algorithm the three phase voltages are sensed and are easily implemented. The SRF theory and the P-Q theory are similar in operation. The PLL block is used to compensate the unbalanced voltages and this technique is useful in voltage-based disturbances [32].

The PLL block is tuned by selection of proper values of Kp, Kd.The I-Cosφ control algorithm ensure the unit power factor at the zero-crossing point of the phase and load currents [14]. Under the highly distorted supply voltage and unbalanced load the PLL circuit doesn't works effectively and gives poor synchronisation between current and voltages. The DC link based pq theory is used for both 1-phase or 3-phase due to its simple calculations and easy to implementation [34].

C. PWM Control Techniques

The PWM converter synthesizes compensating current by processing power (active and reactive) responsibly. The active filter controller determines instantaneous compensating current references by signal processing. The PWM should have high switching frequency (10 kHz) to produce accurate compensating current. There are various types of PWM techniques are presented like- deadbeat controller, single band hysteresis current controller (SBHCC), sinusoidal PWM (SPWM) and double hysteresis current controller (DHCC), sliding mode, space vector PWM (SVM), and etc [35-36]. In SPWM technique, for generation of the switching order the reference signal is compared with triangular signal [35]. In SVC due to high calculation the response is slow but the SBHCC is faster than SVC and robust and more accurate [36-37]. Deadbeat control technique requires much calculation time which is the main drawback for this technique because APF requires fast switching speed and fast operation [38]. In DHCC, there are two different bands are presented for upper and lower switches based on these bands the compensating signal are produces. The switching losses in the DHCC is less than the SBHCC due to lower frequency of operation [39].

V. PRACTICAL CHALLENGES AND IMPLEMENTATION

With the fast progress of the advanced digital signal processors like OPAL-RT, FPGA, dSPACE 1104, 1102 and TMS 320F28335 the development of the shunt Active Power Filter has become more simple, flexible and robust in controlling which has also reduced the computational period of the composite control Algorithm [18,40]. The OPAL-RT can be utilised for developing prototype model and for the testing of the control algorithms with the real time situationas it is a real-time simulator and hardware testing loop controller device. But due to its higher cost it is not used commonly and its use is only limited to sophisticated laboratories.

Due to the increase in the sensitive load like medical equipments, defence equipments, laboratories etc there is a large requirement of power conditioning equipments like shunt APFs. Researchers are focussing on the development of the shunt APFs with higher capacity by using multi-level Inverter topologies. But with the increase in the number of levels the complexity of the circuit increases and thus the problems in controlling and stabilizing the voltage at the DC-Link increases which is now a trending topic of research.

Also, the common problem of the shoot-through in the inverter compels to implement either a new switching technique or to develop a novel inverter topology [41]. The more and more use of the renewable energy sources (RES) and their grid synchronisation play a pivotal role for the development of power electronic based converter which has led to many ongoing researches.

VI. CONCLUSSIONS

The effectiveness of the active power filter in the harmonic reduction as well as isolation, reactive power compensation, power factor improvement and other power quality related issues are discussed in this paper. The paper also focuses on the different control algorithms and PWM technique for the APF. Due to higher efficiency and better filtering performance and flexibility than passive filters the APF is most growing technique for power quality related problems. As the different, fast and efficient processors are available in market for development of the APF makes the future scope for the researchers in this field are discoursed in this paper.

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