Shunt Active Filters: A Review on Control Techniques

Ankit Raj[1], Abhimanyu Kumar[2] and Chirag Gupta[3]

[1] Department of Electrical & Electronics Engineering,Vedica Institute of Technology, RKDF University, Bhopal, India
[2] Department of Electrical & Electronics Engineering,Vedica Institute of Technology, RKDF University, Bhopal, India
[3] Department of Electrical & Electronics Engineering,Vedica Institute of Technology, RKDF University, Bhopal, India
[1]ankitraj76890@gmail.com, [2]ies.abhi@gmail.com, [3]cgupta.011@gmail.com

* Corresponding Author: Author Name Manuscript Received: Manuscript Accepted:

Abstract: *In this review study, we looked at a variety of power filter approaches for high-power applications that frequently involve complicated digital control circuits and expensive batteries. An analog-based hysteresis current controller and capacitive energy storage are used to create a simple and low-cost active power filter circuit in this study. The filter is designed to be a low-power add-on item that reduces AC harmonic currents generated by existing electronic equipment (such as personal computers), which cause nonlinear loads on the AC mains. The suggested filter is addressed in terms of its operating concept, design requirements, and control method.*

Keywords: *Power Active Filter, Shunt filters, Simulink.*

I. Introduction

The use of power electronics in power conversion has downsides that can include communication interference, heating, solid-state device failure, and resonance. The use of passive and active power filters is one of the techniques used to find solutions (APF). Hybrid filters, which combine the passive filter with the shunt APF, are a more effective technology. They're employed to get rid of both low and high-order harmonics. The passive filter is often designed to remove the majority of load-current harmonics, leaving the APF to tackle the more complicated issues.

Shunt APFs often employ pulse width modulation (PWM) inverter methods to inject the requisite non-sinusoidal current needs of nonlinear loads, however the number of switches in use makes things more complicated. A series active power filter, which employs a simple bridge-diode circuit, a boost circuit, and an inductor, is another option. Because of its heat-producing action, single phase converters create a significant amount of ac ripple voltage at their dc terminal. To achieve continuous functioning, smoothing was required. Increase the number of pulses to reduce this effect. The pulse number can be increased using a three phase ac supply and a proper transformer connection. The output voltage smoothes out as the number of pulses increases. So here we are implementing an extension of single phase hybrid active power filter with three phases HAPF.

II. Shunt Active Power Filter

Due to its efficiency and ease of installation, the shunt topology is more prevalent than the others. In order to counteract the influence of harmonics in the system, the shunt APF injects harmonic current in opposite to the load harmonics, as illustrated in fig. 1. For current reference generation, simulink employs the instantaneous power (p-q) theory.

In the literature, hybrid active filters have been proposed as a less expensive harmonic compensation alternative to solely active filters. Hybrid filters combine passive components to lower the active element's necessary ratings [1-4]. The evolution of hybrid filter topologies has been a logical progression from long-used fully passive tuned filters to simpler passive structures with a single active element. The original tuned structures served as a foundation for these passive buildings. This study examines the various hybrid active filter topologies available and identifies those that are most suited for harmonic reduction while maintaining low active component ratings. The following is the procedure that was followed:

- select suitable models for the load
- determine the desirable attributes of a filter
- generate possible topologies and identify useful filters

This approach uncovers existing and new topologies and establishes a systematic framework for describing active filters.

III. Literature Survey

Chi-Seng Lam; Wai-Hei Choi; Man-Chung Wong; Ying-Duo Han [1] in 2012 presents the reference dc-link voltage is classified into certain levels for selection in order to alleviate the problem of dc voltage fluctuation caused by its reference frequent variation, and hence reducing the fluctuation impact on the compensation performances. Finally, representative simulation and experimental results of a three-phase four-wire center-split LC -HAPF are presented to verify the validity and effectiveness of the proposed adaptive dc-link voltage-controlled LC-HAPF in dynamic reactive power compensation.

Bhattacharya, A.; Chakraborty, C.; Bhattacharya, S.[2] in 2012 proposed a combination of low- and high-frequency hybrid active power filter (APF) to operate in parallel for better performance. The individual hybrid APF is a series combination of L-C filter with the corresponding voltage source inverter. The dc links of both the inverters are connected in parallel, and the voltage of the dc link is maintained by the low-frequency inverter (LFI). The low- and high-frequency inverters eliminate lower order and higher order harmonics, respectively. In addition, it is possible to design the LFI such that it can also compensate the reactive power of the load. The individual L-C filter of the hybrid topology is designed to take care of specific order of harmonics that are predominant in the load. A combination of feedforward and feedback controller is designed for the proposed conditioner.

Mulla, M.A.; Patel, P.; Chudamani, R.; Chowdhury, A.[3] in 2012 done research on power quality problems have received increasing attentions in recent years due to proliferation of nonlinear and sensitive loads as well as unpredictable and unavoidable system faults. Power quality problems mainly include current harmonics, reactive power, supply unbalance, sag, swell etc. Series Hybrid Active Power Filters (SHAPF) has been the main topic of interest for researchers working in the area of active power filters (APF). SHAPF provides cost-effective solution as compared to standalone active filters and are preferred to compensate both voltage and current type harmonics. This paper present simplified control strategy for SHAPF with added functionality of compensating voltage sag, swell and unbalance. Mathematical formulation of reference generation scheme with simulation verification of SHAPF model is tested for compensation of voltage sag, swell, unbalance and harmonics is presented.

Wai-Hei Choi; Chi-Seng Lam; Man-Chung Wong; Ying-Duo Han, [4] in 2013 investigated different dc-link voltage control strategies in a three-phase four-wire LC coupling hybrid active power filter (LC -HAPF) for reactive power compensation. By using direct current (current reference) pulse width modulation (PWM) control method, to achieve dc-link voltage self-charging function during LC -HAPF start-up process, the dc-link voltage control signal feedback as reactive current component is more effective than the traditional method as an active current component.

Y Hoon, M. Radzi, M. Zainuri [5] in 2019 discusses and analyzes various types of existing phase synchronization techniques which have been applied to manage operation of SAPF; in terms of features, working principle, implementation and performance. The analysis provided can potentially serve as a guideline and provision of information on selecting the most suitable technique for synchronizing SAPF with the connected power system.

P. Mahapatra and C. Gupta [6] in 2020 presented a hysteresis pulse width modulation study for a inductor-capacitor (LC)-coupling hybrid active power filter. As the coupling LC impedance yields a non-linear inverter [7] – [9] current slope, this can affect the controllability of using the conventional hysteresis control method and generate unexpected trigger signals to the switching devices. This results in deteriorating the system operating , performances. The design criteria of hysteresis band and sampling time can then be derived. Single-phase simulation and experimental results are given to verify the hysteresis control study of HAPF compared with active power filter [10].

IV. Proposed Methodology

The new hybrid APF is made up of two types of filters: a basic LC passive filter and a PAPF for eliminating both high and low order harmonic components. In the block diagram of Fig. 2, the PAPF is used to inject equal but opposing current into the system to minimise the distortion current to a sinusoidal form, in phase and time with the voltage supply, as shown in Fig. 1. In order to simplify the compensation circuit and decrease switching stress, the new suggested PAPF design only uses a single active power switch (IGBT).
The SCCL (fig.1) is used to monitor the supply current waveform and apply current compensation techniques to rectify it. If the supply current is distorted, the SCCL will respond by sending a switching signal to the IGBT, which will inject current compensation from the PAPF circuit to the mains to compensate for the distorted supply current. Because the system only has one power switch, unipolar switching is recommended. To create the injected current into the system, the compensating circuit employs a boost and PWM approach.

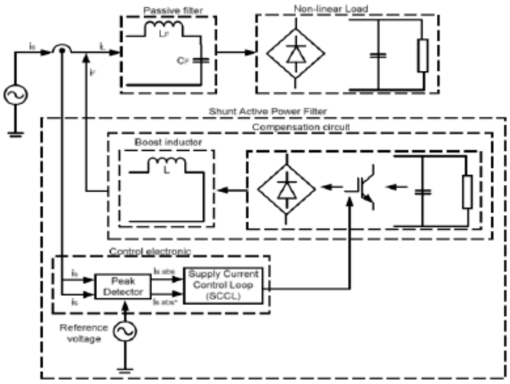

Figure 1: The Proposed Hybrid APF Arrangement

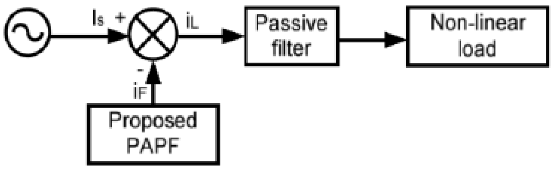

Figure 2: Functional Block Diagram of Hybrid APF

Switching control is achieved by active PWM, also known as active current wave shaping. This method compares the error signal to the carrier signal in real time to verify that the error stays inside the carrier peaks at all times. In order to provide the appropriate PWM control, the active PWM compares the corrected signal with the carrier signal. The comparator output (PWM sequence) is greater when the sinusoidal signal is larger or equal in magnitude to the carrier signal. The error is controlled using the proportional integral (PI) control technique.

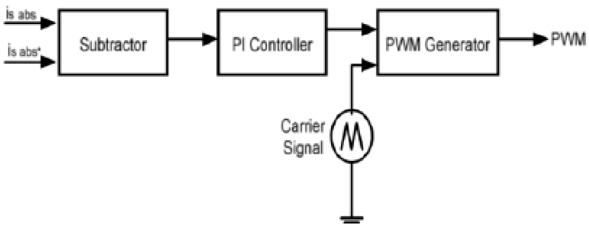

Figure 3: Control Components of PAPF

The PAPF works by injecting the needed current into the system, as shown in Figure 4. Diode D5 is reversed biassed when the switch is switched on (Figure 4(a)). As a result, the system's output stage is isolated. The boost inductor receives energy from the input, which causes the current in the inductor to grow linearly with ramp behaviour. The inductor's stored energy can be used to compensate. As illustrated in the comparable circuit of Fig. 4, diode D5 is forward biassed when the switch is switched off (b). A shift in the current has occurred. Because the inductor can't change its polarity instantly, the voltage in the inductor switches polarity to keep the current steady. In this stage, the current will flow through the inductor, diode D5 and the compensating load.

V. Conclusion and Future Scope

The provided mathematical tool presents a generic method for calculating instantaneous power based on a formal specification, regardless of the power system's reference frame or phase number. The reference currents for APF control may now be estimated geometrically using this new formulation. This is done by calculating the shape deviations (distance changes) in each component of the proposed power tensor. Furthermore, the simulation that was investigated may be used to construct an active power filter.

References

[1] Chi-Seng Lam; Wai-Hei Choi; Man-Chung Wong; Ying-Duo Han, "Adaptive DC-Link Voltage-Controlled Hybrid Active Power Filters for Reactive Power Compensation," *Power Electronics, IEEE Transactions on* , vol.27, no.4, pp.1758,1772, April 2012.

[2] Bhattacharya, A.; Chakraborty, C.; Bhattacharya, S., "Parallel-Connected Shunt Hybrid Active Power Filters Operating at Different Switching Frequencies for Improved Performance," *Industrial Electronics, IEEE Transactions on* , vol.59, no.11, pp.4007,4019, Nov. 2012.

[3] Mulla, M.A.; Patel, P.; Chudamani, R.; Chowdhury, A., "A simplified control strategy for Series Hybrid Active Power Filter that compensat voltage sag, swell, unbalance and harmonics," *Power Electronics (IICPE), 2012 IEEE 5th India International Conference on* , vol., no., pp.1,6, 6-8 Dec. 2012.

[4] Wai-Hei Choi; Chi-Seng Lam; Man-Chung Wong; Ying-Duo Han, "Analysis of DC-Link Voltage Controls in Three-Phase Four-Wire Hybrid Active Power Filters," *Power Electronics, IEEE Transactions on* , vol.28, no.5, pp.2180,2191, May 2013.

[5] Y Hoon, M. Radzi, M. Zainuri, “Shunt Active Power Filter: A Review on Phase Synchronization Control Techniques,” MPDI, energies journal, 2019.

[6] P. Mahapatra and C. Gupta, “Study of Optimization in Economical Parameters for Hybrid Renewable Energy System,” Res. J. Eng. Technol. …, no. 2581, pp. 39–46, 2020, [Online]. Available: http://www.rjetm.in/RJETM/Vol03_Issue02/Study of Optimization in Economical Parameters for Hybrid Renewable Energy System.pdf.

[7] A. Hridaya and C. Gupta, “Hybrid Optimization Technique Used for Economic Operation of Microgrid System,” Academia.Edu, vol. 5, no. 5, pp. 5–10, 2015, [Online]. Available: http://www.academia.edu/download/43298136/Aditya_pape_1.pdf.

[8] D. Kumar and C. Gupta, “Multilevel Current-Source Inverter Grid-Connected Analytical Control Approach III . Comparative Performance Evaluation of the CSI Based PV System with the VSI Based PV,” Res. J. Eng. Technol. Med. Sci., vol. 2, no. 2, pp. 51–54, 2020.

[9] A Hridaya; C Gupta, “AN OPTIMIZATION TECHNIQUE USED FOR ANALYSIS OF A HYBRID SYSTEM ECONOMICS,” Int. J. Curr. Trends Eng. Technol., vol. 1, no. 6, pp. 136–143, 2015, [Online].

[10] K. Jagwani, “Contemporary Technological Solutions towards fulfilment of Social Needs A Design Analysis of Energy Saving Through Regenerative Braking in Diesel Locomotive with Super-capacitors,” pp. 94–99, 2018.