

# A REVIEW OF CONTROL STRATEGIES FOR SHUNT ACTIVE POWER FILTER FOR HARMONICS COMPENSATION

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## ABSTRACT

*This paper proposes two different current control based controllers for a shunt active power filter system. A shunt active power filter system has been designed, built to work under balanced; unbalanced and distorted supply conditions to meet IEEE 519 recommended harmonic standards. The shunt active filter is mainly controlled by two different control schemes i.e. constant instantaneous power and sinusoidal current control based controller to act as a harmonic isolator between the supply and load. This paper discusses about both the current controllers.*

**Keywords:** Active power filter (APF), Constant instantaneous power control strategy, Sinusoidal current control strategy, Harmonic compensation, IEEE 519.

## INTRODUCTION

Nonlinear loads produce the harmonics into the power system and these harmonics create a lot of disadvantages in the system. Supply gets distorted and unbalanced when application of unbalanced and nonlinear loads increases. These currents pollute the supply point of the utility. Therefore, it is very important to compensate unbalance, harmonic and reactive component of the load currents. Whereas when supply is unbalanced and distorted, these problems worsen the system.<sup>[13]</sup> By the application of shunt active power filters can eliminate harmonic, reactive and unbalanced currents, improve the power supply performance and the stability of system. Today, the soft computing techniques are used broadly for optimization of the system applied or in control system. Some of them are such as adaptive tabu search<sup>[48]</sup> used for finding the optimized values of the controllers variables,<sup>[412]</sup> optimization of active power filter using GA,<sup>[912]</sup> power loss minimization using particle swarm optimization,<sup>[13]</sup> neural network control <sup>[1418]</sup> applied in both machinery and filter devices.

In this paper, two different control techniques i.e. constant instantaneous power

control strategy (CIPC) and Sinusoidal current control strategy (SCC) have been discussed which are used for reduction of harmonics and others problem created into the supply system due to the nonlinear loads.<sup>[1]</sup> The paper has been organized in the following manner. The APF configuration is discussed in Section I. Section II presents constant instantaneous power control strategy and the Section III discusses about Sinusoidal current control strategy. Section IV concludes the paper.

## SYSTEM DESCRIPTION

The supply system is a threephase system with source frequency of 50 Hz. Figure 1 shows the APF applied for improvement of the power quality under all supply conditions. Shunt APF compensates the harmonic currents in the system <sup>[22,24,25,27,28,30]</sup> and thus improves the power quality. The shunt APF is realized by using one voltage source inverters (VSIs) connected at point of common coupling (PCC) with a common DC link voltage <sup>[2023]</sup>. The loads generally used are three types of nonlinear loads i.e. 6pulse current source Converter Bridge, three phase diode bridge rectifier with inductance of 300mH and three phase diode bridge rectifier with capacitance of 1000uF.

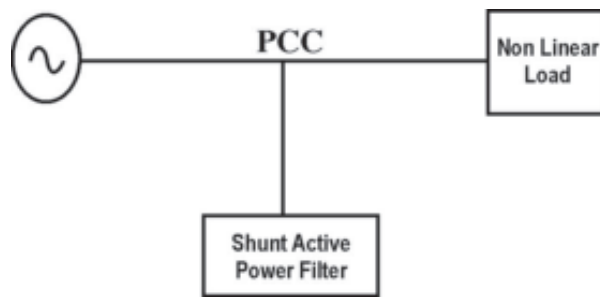


Figure 1: Shunt Active Power filter

### Constant Instantaneous Power Control Strategy

Figure 2 presents the control diagram of the shunt active filter using constant instantaneous power control strategy. We can observed that

four low pass filters have been shown in the control block; in which, three with cut off of 800 Hz has been applied to filter the voltages and one for the power  $p_0$ . Direct application of the phase voltages cannot be used in the control due to instability problem. There may be resonance between source impedance and the small passive filter. Low pass filters have been applied to the system to attenuate the voltage harmonics at the resonance frequency which are higher than 800 Hz.  $p$ ,  $q$ ,  $p_0$ ,  $v_a$  and  $v_b$  are obtained after the calculation from  $\alpha\beta 0$  transformation and send to the  $\alpha\beta$  current reference block, which calculates  $i'_{ca}$  and  $i'_{cb}$ . Finally,  $\alpha\beta 0$  inverse transformation block calculates the current references and applied to the PWM current control i.e. hysteresis band controller.

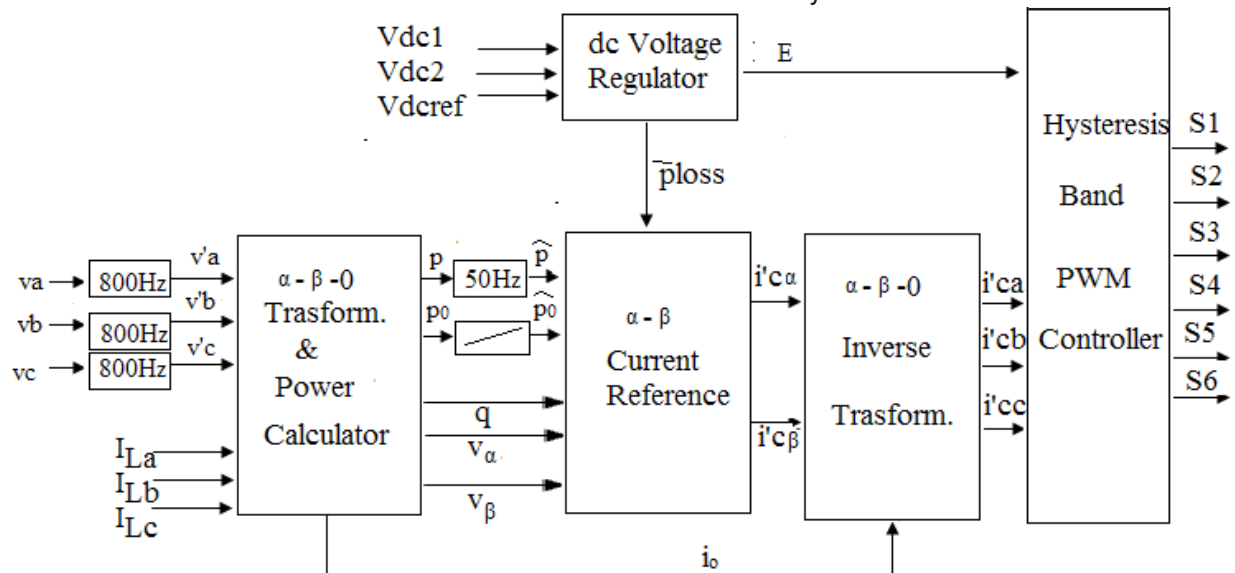


Figure 2: Control block diagram of the shunt active filter using constant instantaneous power control strategy

In a real realization, these lowpass filters may be removed, depending on system parameters such as a switching frequency of the PWM converter and a frequency response of the electronic circuit for voltage measurement.

With this approach, the active filter supplies the whole  $i_0$  to the load. If no zero sequence voltage is present, the zero sequence power  $p_0$  is zero. In this case, the zero sequence current  $i_0$  of the load is completely compensated without the need for energy balance inside the active filter, since  $p_0 = 0$ . This operation takes place only under the supposition that the three phase system is balanced and that the voltage

waveforms are purely sinusoidal. If, on the other hand, this technique is applied to contaminated supplies, the resulting performance is proven to be poor.

The above compensation principle that provides constant source instantaneous power is an extended version of the original control strategy. The control technique does not use any RMS value calculation, even though it uses a low and a highpass filter to separate the powers  $p_0$  and  $\check{p}$ , which influence the dynamic response of the active filter. Figure 3 presents the MATLAB/Simulink Model of Constant Instantaneous Power control strategy.

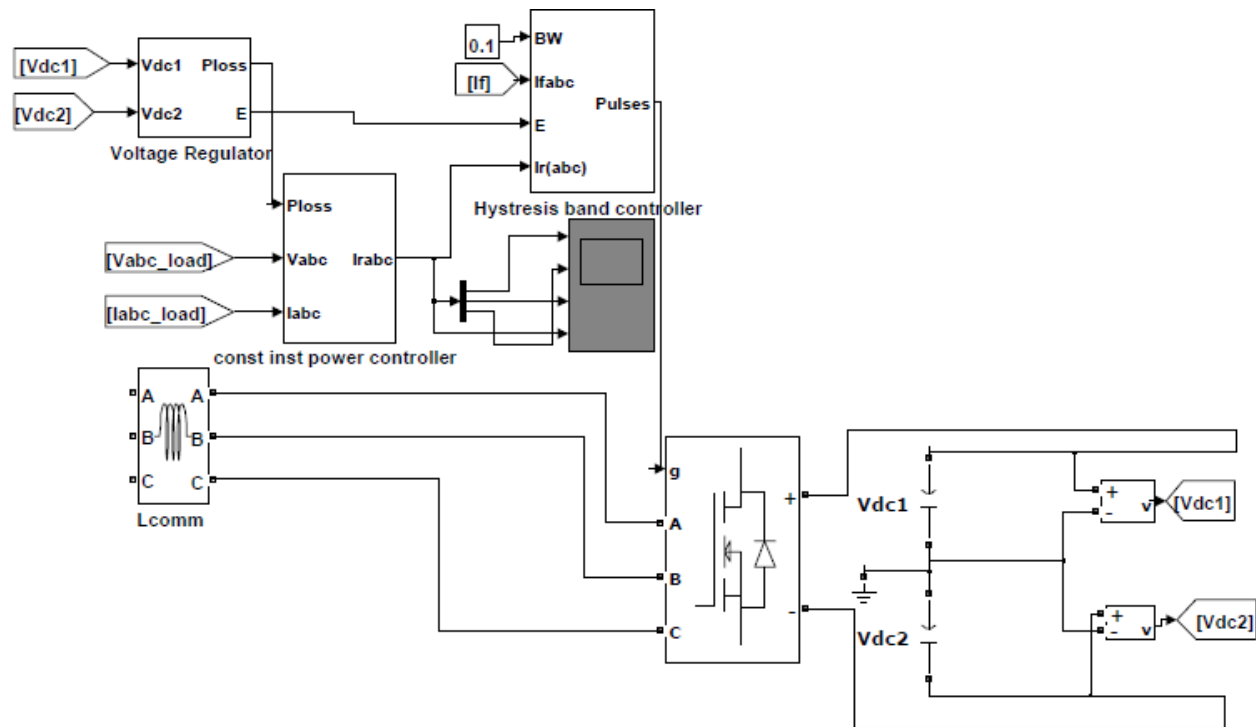


Figure 3: Shunt active filter model using constant instantaneous power control strategy

### SINUSOIDAL CURRENT CONTROL STRATEGY

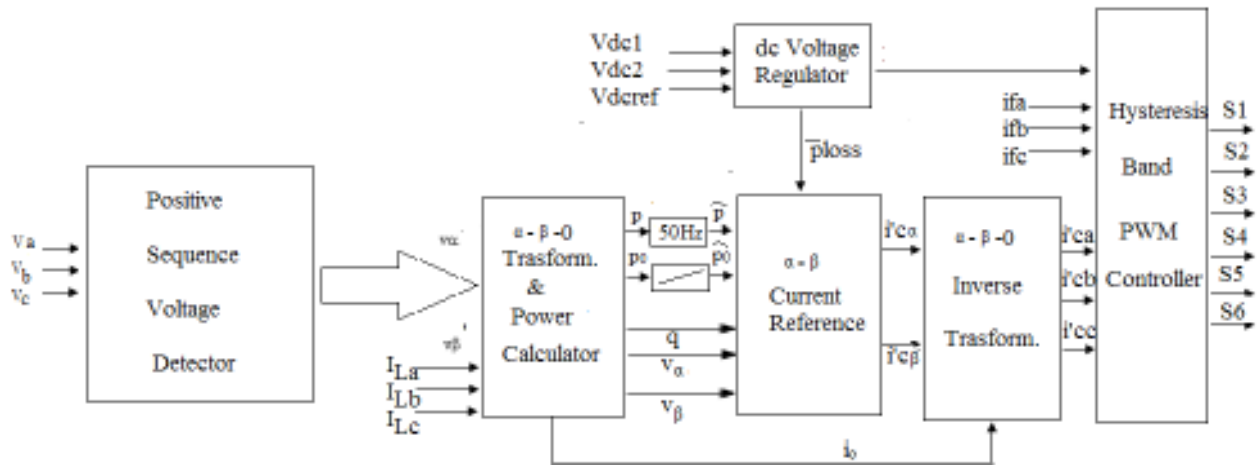
With some modification in constant instantaneous power control strategy, the new strategy can be used under unbalanced conditions too. The new strategy has been named as Sinusoidal current control strategy.

Figure 4 shows the control diagram of shunt active filter using sinusoidal current control strategy which is modified version of constant instantaneous power control strategy and able to compensate load currents under unbalanced conditions too. The modification includes a positive sequence detector which replaced the 800 Hz cutoff frequency lowpass filters and correctly finds the phase angle and frequency of the fundamental positive sequence voltage component and thus shunt active power filter compensates the reactive power of the load. While designing this detector, utmost care should be taken so that shunt active filter produces ac currents orthogonal to the voltage component, otherwise it will produce active power.  $i_{\alpha}, i_{\beta}, p'$  and  $q'$  are obtained after the calculation from  $\alpha-\beta-0$  transformation block and send to the  $\alpha-\beta$  voltage reference block, which calculates  $v_{\alpha}$  and  $v_{\beta}$ . Finally,  $\alpha-\beta-0$  inverse transformation block calculates the  $V_a', V_b'$ , and

$V_c'$ . In place of the filtered voltages used previously, and, are considered as input to the main control circuit of figure 4 Now fundamental negative sequence power, harmonic power, and the fundamental reactive power, are also included in the compensating powers. It should be noted that the controller for supply systems can be treated as a simplification, just considering  $v_0 = i_0 = p_0 = 0$  and the elimination of signal.

The sinusoidal current control strategy makes the active filter to compensate the current of a nonlinear load to guarantee balanced, sinusoidal current drawn from the network, even under an unbalanced and/or distorted system voltage. We know that neutral current is a big problem for aircraft system and this strategy compensates also the neutral current of the load.

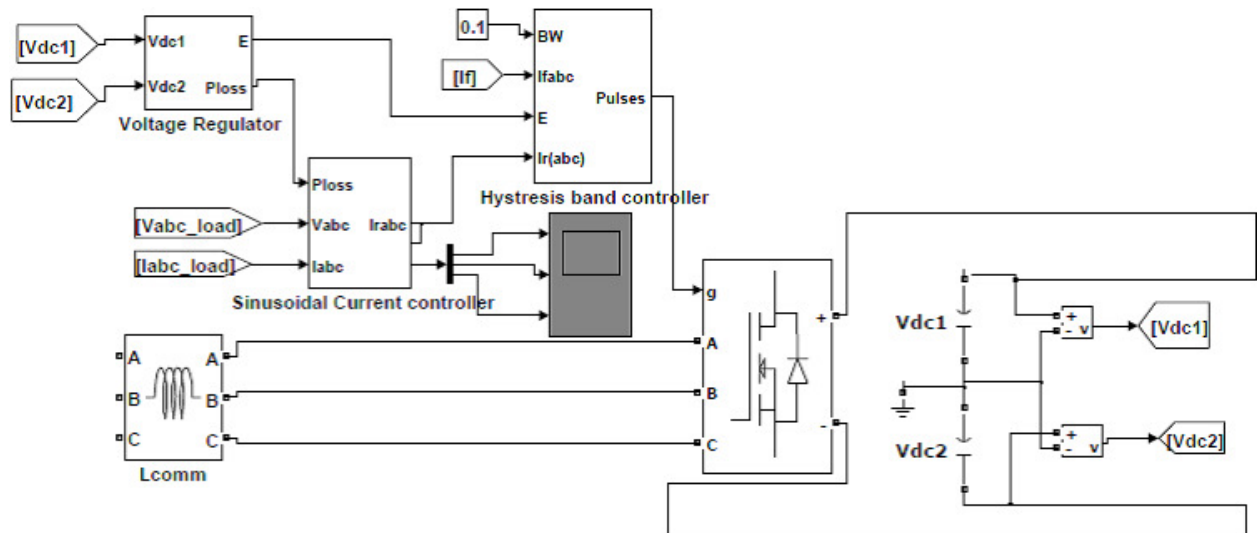
At this point, it is important to remark that the voltage regulator of Fig.5 that generates the signal  $p_{loss}$  has received an additional task besides those listed in the last sections: to correct errors in power compensation. This occurs because the feed forward control circuit is now unable to supervise the zero-sequence power. Since the active filter compensates the whole neutral current of the load in the presence



**Figure 4: Control diagram of the shunt active filter controller using sinusoidal current control strategy**

of zero-sequence voltages, the shunt active filter eventually supplies.  $\Delta \bar{p}$  is replaced simply by  $\bar{p}_{loss}$ . Therefore, if the active filter supplies  $\bar{p}_0$  to the load, this causes dc voltage variations, which are sensed by the PI controller of the dc voltage regulator. Hence, an additional amount of

average real power, numerically equal  $\bar{p}_0$ , is automatically added to the signal plot that is mainly used to provide energy to cover for losses in the power circuit of the shunt active filter. Figure 5 presents the MATLAB/Simulink model of Sinusoidal current control strategy.



**Figure 5: Shunt active filter model using Sinusoidal current control strategy**

## CONCLUSIONS

This paper presented an innovative technology management by critically analyzing about power quality improvement using different control strategies applied in supply system. CIPC and SCC control techniques are discussed in detail, which can be remedy for power quality problems generated in different equipment. This paper will help research workers, users and suppliers of electrical power to gain a guideline about the power quality.

## REFERENCES

1. Mauricio Aredes, Jurgen Hafner, Klemens Heumann, "ThreePhase FourWire Shunt Active Filter Control Strategies," IEEE Transactions on Power Electronics, Vol. 12, No. 2, pp. 311318, March 1997.
2. Koteswara Rao Uyyuru, Mahesh K. Mishra, and Arindam Ghosh, "An OptimizationBased Algorithm for Shunt Active", IEEE Transactions on Power Electronics, Vol. 24, No. 5, pp. 12231232, May 2009.

3. Habi, M. Bouguerra, D. Ouahdi, and H. Megloui, "Using the Schunt Active Power Filter for Compensation of the Distorted and Unbalanced Power System Voltage", World Academy of Science, Engineering and Technology, Vol. 24, pp. 152156, 2006.
4. S.Khalid, Niraj Kumar, V.M.Mishra, "Application of Adaptive tabu Search Algorithm in Sinusoidal Fryze Voltage Control based Hybrid Series Active Power Filter," International Journal of Energy Optimization and Engineering (IJEEO), USA, Volume 3, No 2, pp. 6075, OctDec 2014.
5. Saifullah Khalid, Niraj Kumar, V.M.Mishra, "Performance Evaluation of Adaptive Tabu Search Algorithm Optimized Sinusoidal Fryze Voltage control based Hybrid Series Active Power Filter," International Journal on Electrical Engineering and Informatics (IJEI, Indonesia), Volume 6, No. 3, pp. 511520, September 2014.
6. KN.Areerak, S.V.Bozhko, G.M.Asher, and D.W. P.Thomas, "DQTransformation Approach for Modelling and Stability Analysis of ACDC Power System with Controlled PWM Rectifier and Constant Power Loads", Proceedings of 13th International Power Electronics and Motion Control Conference (EPEPMC 2008), 2008,pp. 20492054.
7. T.Kulworawanichpong, KL.Areerak, KN.Areerak, and S.Sujitjorn, "Harmonic Identification for Active Power Filters Via Adaptive Tabu Search Method", LNCS (Lecture Notes in Computer Science) , SpringerVerlag Heidelberg, Volume 3215, 2004, pp. 687694.
8. D.Puangdownreong, KN.Areerak, A.Srikaew, S.Sujitjorn, and P.Totarong, "System Identification via Adaptive Tabu Search, Proceedings of IEEE International Conference on Industrial Technology (ICIT02), 2002, pp. 915920.
9. Babak Keshavarz Hedayati, Abdolreza Rahmati, "Genetic Algorithm Application in Controlling Performance and Power Dissipation of Active Power Filters", Canadian Journal on Electrical & Electronics Engineering, Vol. 1, No. 1, pp. 1519, February 2010.
10. Saifullah Khalid, Bharti Dwivedi, "Application of AI techniques in implementing Shunt APF in Aircraft Supply System," SOCROPROS Conference (Springer Lecture Notes), IITRoorkee, Dec 2628, 2013, Volume 1, pp. 333341, 2013.
11. Saifullah Khalid, Bharti Dwivedi, "GAFUZZY Application in SAF & Its Comparative Study with Conventional Techniques in 400 Hz Aircraft System," IEEE – CARE 2013, Dec 1618, pp. 15, 2013.
12. M. ElHabrouk and M. K. Darwish, "A New Control Technique for Active Power Filters Using a Combined Genetic Algorithm/Conventional Analysis", IEEE transactions on Industrial Electronics", Vol. 49, No. 1, pp. 5866, February 2002.
13. Radha Thangaraj, Thanga Raj Chelliah, Millie Pant, Ajit Abraham and Crina Grosan, "Optimal gain tuning of PI speed controller in induction motor drives using particle swarm optimization," Logic Journal of IGPL Advance Access, pp.114, July 2010.
14. Avik Bhattacharya, Chandan Chakraborty, "A Shunt Active Power Filter With Enhanced Performance Using ANNBased Predictive and Adaptive Controllers," IEEE Transactions on Industrial Electronics, Vol. 58, No. 2, pp. 421428, February 2011.
15. Saifullah Khalid, Bharti Dwivedi, Dharamveer, "Performance Evaluation of GA Optimized & Fuzzy Logic Control based Shunt Active Power Filter for Constant Frequency Aircraft Power System," IEEE International conference on "Emerging Trends in Communication, Control, Signal Processing and Computing Applications" (C<sup>2</sup>SPCA 2013), pp. 16, 2013.
16. Jiang YouHua, Chen YongWei, "Neural Network Control Techniques of Hybrid Active Power Filter," Proceedings of International Conference on Artificial Intelligence and Computational Intelligence, 2009, pp. 2630.
17. Saifullah Khalid, Bharti Dwivedi, Bhim Singh, " New Optimum ThreePhase Shunt Active Power Filter based on Adaptive Tabu Search and Genetic Algorithm using ANN control in unbalanced and distorted supply conditions," Elekrika : Journal of Electrical Engineering, Vol. 14, Issue 2, pp. 0914, 2012,.
18. R. Dehini, A. Bassou, B. Ferdi, "Artificial Neural Networks Application to Improve Shunt Active Power Filter," International Journal of Computer and Information Engineering, Vol. 3, No. 4, pp. 247254, 2009.
19. Maurício Aredes, Luís. F. C. Monteiro, Jaime M. Miguel, "Control Strategies for Series and Shunt Active Filters," IEEE Bologna Power Tech Conference, June 23th26th, Bologna, Italy, 2003, pp. 101106.
20. Murat Kale, E. Ozdemir, "Harmonic and reactive power compensation with shunt active power filter under nonideal mains voltage", Electric Power Systems Research, Vol. 74, pp. 363–370, 2005.
21. S.Khalid, Bharti Dwivedi, "Power Quality Issues, Problems, Standards & Their Effects in Industry with Corrective Means", International Journal of Advances in Engineering & Technology, Vol. 1, Issue 2, pp.111, May 2011.
22. F. Z.Peng, , H.Akagi, , and A.Nabae, "A New Approach to Harmonic Compensation in Power Systems a Combined System of Shunt Passive

- and Series Active Filters”, IEEE Trans. on Industry Applications, Vol. 6, No. 26, pp. 983990, 1990.
23. B.K.Bose, “Recent Advances in Power Electronics,” IEEE Trans. on Power Electronics, Vol. 7, No.1, pp. 215, Jan.1992.
  24. R. C. Dugan, M. F. McGranaghan, and H. W. Beaty, Electrical Power Systems Quality. New York: McGrawHill, 1996.
  25. S.Khalid, N.Vyas, Application of Power Electronics to Power System, University Science Press, INDIA, 2009.
  26. IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems, IEEE Standard 5191992, 1992.
  27. H. Akagi, E.H. Watanabe and M. Aredes, “Instantaneous Power Theory and Applications to Power Conditioning,” John Wiley & Sons, Inc., New Jersey, 2007.