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Hybrid Active Power Filter Topologies for Power Quality Improvement: A Review

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Abstract – *This paper deals with different topologies of hybrid active power filters (HAPF) along with their different control strategies. The use of active power filter and passive filter in the hybrid active power filter technology aids in elimination of harmonics and improvement of power quality where the system consists of non-linear loads. For the detailed analysis of hybrid active power filter to enhance the quality of power more than twelve research papers have been reviewed. The comprehensive study of converter topologies and various control strategies of hybrid active power filter (HAPF) is introduced in this paper.*

***Key Words*: Hybrid active power filter (HAPF), harmonics, Power quality, Active Power Filters, Instantaneous Reactive Power Theory (IRPT).**

1. INTRODUCTION

Non linear loads have degraded the quality of power and has also increased the concern for issues related to power quality. For enhancement of power quality implementation of active filtering has always given satisfactory results. In ac networks the compensation of harmonics and reactive power, elimination of voltage harmonics can be accomplished utilizing active filters.

By utilizing active filters discretely or in integration as per the necessity and control strategy favorably selected wide range of objectives can be attained. [1]

With expanding power capacity cost of active power filters (APF) increases in spite of beneficial compensation. Therefore, the combination of active and passive filter together called HAPF (Hybrid Active Power Filter) is developed to overcome the demerits of conventional filters. [2]

Main aim in the development of HAPF(Hybrid active power) is to utilize passive filter to mitigate the cost and rating of active power filter which is effective in furnishing requirement of reactive power and filtering non-linear loads dominant harmonics. [3]

2. POWER QUALITY PROBLEMS

The power quality problem which affect the supply system predominantly is harmonics. The harmonics as per IEEE dictionary states as “a sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency.”[4]. Problems on power system such as communication interference, solid –device malfunction and heating can result in harmonics.

Magnitude of the waveform distortion and sensitivity of equipment describes the problem severity caused by harmonics. [5]

Other power quality problems may be transient like voltage fluctuations, frequency variations etc.

Steady state problem like waveform distortion, unbalanced voltages etc.

Non sinusoidal current on interaction with the distribution system impedance distortion in voltage occurs which greatly affects system on the distribution side. [8].

3. CLASSIFICATION OF HYBRID ACTIVE POWER FILTER

The hybrid active power filter configuration is given in fig 1. The detailed desciption of the topologies is as follows:-

3.1 Series Active Power Filter with Shunt Connected Passive Filter

In this topology it can be seen that the combination has active filter connected in series with passive filter in shunt. Series active filter by providing high impedance path to current harmonics and by reducing the nonlinear load distortions makes the high frequency current to flow

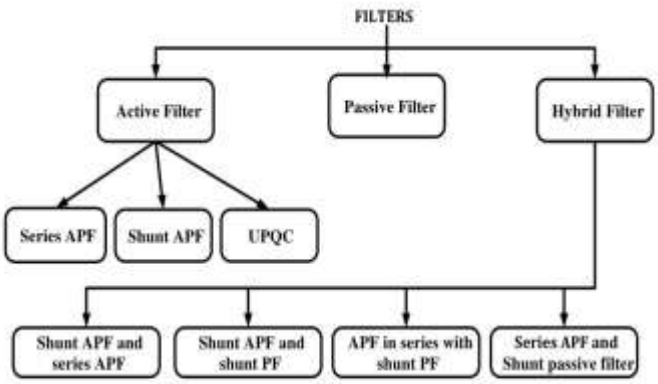

Fig -1: Classification of Hybrid Active Power Filter

through the shunt connected passive filter .It protects the system from harmonics, voltage sag and swell. [6] Because of the resistive behavior of this topology the risk of overloading is minimized due to harmonics [7].

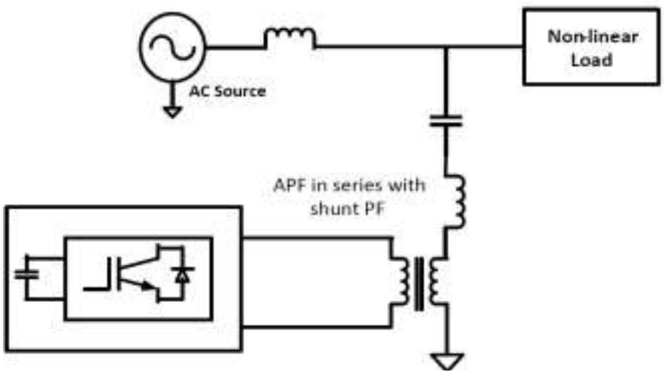

Fig -2: Active filter in series with passive filter in shunt

3.2 SHUNT ACTIVE POWER FILTER WITH SHUNT PASSIVE BASED HYBRID FILTER

This filter topology is a combination of active power filter connected in shunt and passive filter also connected in shunt [8-10].

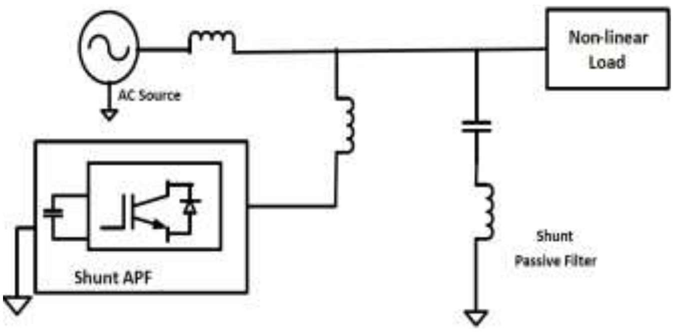

Fig -3: Active filter connected in shunt with passive filter connected in shunt

The active filter is capable in reducing the dominant harmonics which cannot be suppressed by passive filters .The supply current harmonics can be eliminated by the shunt active filter in which the harmonic current gets injected by the inverter.

The active filter which has the ability to reduce the dominant harmonics also aids in compensating the reactive power .The shunt connected passive filter helps in compensating the lower order harmonics .Resonance is merely negligible across the passive component and the power system with this topology. [11]

3.3 ACTIVE SERIES AND PASSIVE SHUNT BASED HYBRID FILTER

This topology contains the active filter connected in series with the passive filter connected in shunt.

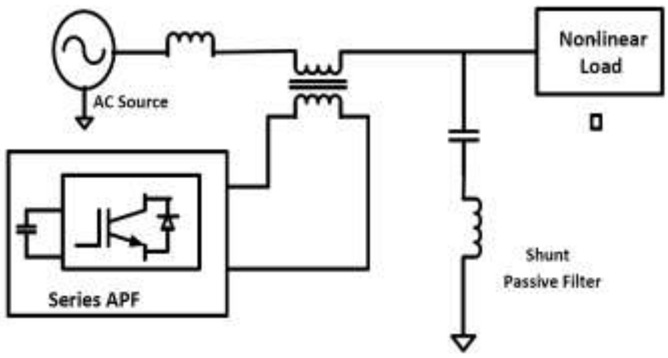

Fig -4: Active filter connected in series with shunt connected passive filter

The hybrid filter depicts a resistive behavior which reduces the risk of overload caused by the current harmonics. [12]. The following topology is very cost effective solution which aids in mitigating the drawbacks of active and passive filter both. By connecting the passive filter in shunt the ratings of the active filter is reduced. The active filter aids in improving the filtering characteristics and passive filter reduces the harmonics component which makes this topology to operate effectively. The harmonics of the firm connected load can be compensated effectively with this topology.

3.4 ACTIVE SERIES AND ACTIVE SHUNT BASED HYBRID FILTER

This hybrid filter topology is also known as the universal active filter (APF).This topology consists of two voltage source converters (VSCs) out of which one is connected in shunt across the point of common coupling and the other is connected in series across the load at consumer end . For eliminating the voltage harmonics produced at point of common coupling(PCC) and nonlinear loads current harmonics can be suppressed by this topology of hybrid filter .[13]

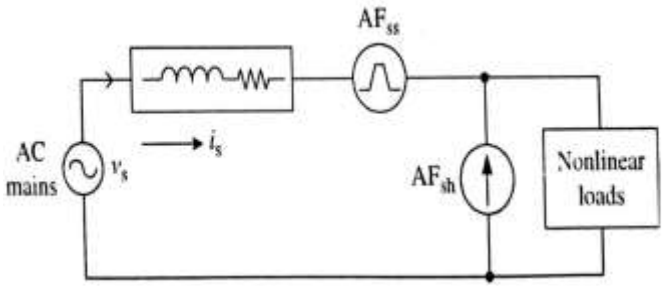

Fig -5: Active filter connected in series with active filter connected in shunt

4. CONTROL STRATEGIES OF HYBRID FILTER

4.1 CONTROL OF HYBRID FILTER USING INSTANTANEOUS REACTIVE THEORY

For conventional active filter instantaneous reactive power theory (IRPT) is accepted .The conversion of three phase voltage a-b-c into α-β-0 orthogonal coordinates can be given as [14]

$$\begin{pmatrix} v_{s0} \\ v_{s\alpha} \\ v_{s\beta} \end{pmatrix} = \sqrt{\frac{2}{3}} \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{pmatrix}$$

Similarly, conversion of three phase currents (i_{sa}, i_{sb}, i_{sc}) into α-β-0 orthogonal coordinates $(i_{s0}, i_{s\alpha}, i_{s\beta})$ can be given as [14].

$$\begin{pmatrix} i_{s0} \\ i_{s\alpha} \\ i_{s\beta} \end{pmatrix} = \sqrt{\frac{2}{3}} \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{pmatrix}$$

The instantaneous active power p_s and the instantaneous reactive power q_s can be calculated as follows :-

$$\begin{pmatrix} p_s \\ q_s \end{pmatrix} = \begin{pmatrix} v_{s\alpha} & v_{s\beta} \\ v_{s\beta} & -v_{s\alpha} \end{pmatrix} \begin{pmatrix} i_{s\alpha} \\ i_{s\beta} \end{pmatrix}$$

This control strategy determines the harmonic distortion by calculating the stationary coordinates. This control algorithm improves the compensation of harmonics by passive filter with the aid of active filter and also improves the load power factor. [14]

4.2 INDIRECT CURRENT CONTROL ALGORITHM OF HYBRID FILTER

This control algorithm with reduced number of sensors as compared to instantaneous reactive power theory uses indirect controlling of three phase supply currents. The fundamental positive sequence component is obtained by transforming (i_{sa}, i_{sb}, i_{sc}) into d-q reference frame by synchronous reference frame (SRF). [16]

$$\begin{pmatrix} i_{s\alpha} \\ i_{s\beta} \end{pmatrix} = \sqrt{\frac{2}{3}} \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{pmatrix}$$

$$\begin{pmatrix} i_{sd} \\ i_{sq} \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} i_{s\alpha} \\ i_{s\beta} \end{pmatrix}$$

Synchronous reference frame converts the transformed coordinates into a-b-c coordinates in order to obtain the fundamental components of current which can be given as:-

$$\begin{pmatrix} i_{s1a} \\ i_{s1b} \\ i_{s1c} \end{pmatrix} = \sqrt{\frac{2}{3}} \begin{pmatrix} 1 & 0 \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} i_{s\alpha} \\ i_{s\beta} \end{pmatrix}$$

The reference signal can be given as:-

$$\begin{pmatrix} i_{sa}^* \\ i_{sb}^* \\ i_{sc}^* \end{pmatrix} = \begin{pmatrix} i_{s1a} \\ i_{s1b} \\ i_{s1c} \end{pmatrix} + K_1 \begin{pmatrix} i_{s1a} \\ i_{s1b} \\ i_{s1c} \end{pmatrix}$$

The control scheme can be shown as follows:-

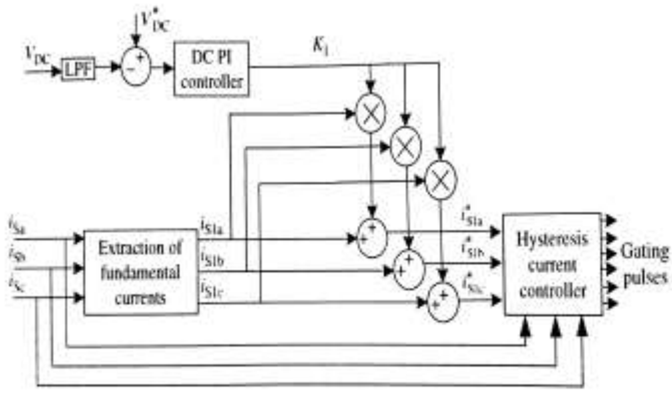

Fig -6: Indirect current control algorithm of hybrid active filter configuration

For varying load conditions this control strategy is suitable. Because of the simplicity of this scheme as compared to instantaneous reactive power theory this aids in damping the resonance caused by the capacitances of passive filter and is also capable of providing dc bus of the active filter which is self-supported through power transfer from ac line at fundamental frequency.

5. CONCLUSION

The literature survey done on hybrid active power filters (HAPF) provide a general perception about the various topologies and control strategies of the hybrid active filter. The control strategies aids for intensifying the utilization of HAPF comprehensively for the compensation of harmonics. The incorporation of active filter along with passive filter mitigates the drawbacks of active filter which at times gets their rating increased up to 80% of load which further increase the cost of system by making it more cost effective and hence reducing its rating and also improves the compensation properties of passive filter. A large number of hybrid active power filter topologies are available which can be used for harmonics compensation along with required control strategies. With the advancement of filters the quality of power have improved to great extent yet more study is require to maintain near perfect quality of power as intricacy and susceptivity of loads is increasing in power networks .

REFERENCES

[1] Bhim Singh, Kamal Al-Haddad, “A Review of Active Filters for Power Quality Improvement”, IEEE Transactions on Industrial Electronics, VOL. 46, NO. 5, October 1999.

[2] Govindaraj. V , Priya M , “Review Of Hybrid Active Power Filter Topologies And Controllers For Enhancement Of Power Quality”, International Journal Of Pure And Applied Mathematics Volume 118 No. 11 2018, 29-37.

[3] An Luo, Ci Tang, Zhi Kang Shuai, “A Novel Three-Phase Hybrid Active Power Filter With a Series Resonance Circuit Tuned at the Fundamental Frequency” , IEEE Transactions On Industrial Electronics, Vol. 56, NO. 7, JULY 2009.

[4] Joseph s. subjak,” Harmonics - Causes, Effects, Measurements, and Analysis: An Update”, IEEE Transactions On Industry Applications, Vol. 26. No. 6. November December 1990

[5] Ankita P. Bagde, Rupali B. Ambatkar, Rupali G. Bhure, Prof. Bhushan S. Rakhonde, “Power Quality Improvement By Series Active Power Filter- A Review”, International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 01 | Jan -2017.

[6] P. Salmerón and S. P. Litrán, “Improvement of the Electric Power Quality Using Series Active and Shunt Passive Filters” , IEEE Transactions On Power Delivery, Vol. 25, No. 2, April 2010.

[7] B. Singh, V. Verma, A. Chandra and K. Al-Haddad, “Hybrid filters for power quality improvement”, IEE Proc.-Gener. Transm. Distrib., Vol. 152, No. 3, May 2005.

[8] K. Dharageshwari, C. Nayanatara, “Power Quality Improvement Using Hybrid Filters for the Integration of Hybrid Distributed Generations to the Grid”, International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064, Volume 4 Issue 2, February 2015.

[9] Vijeta V.Barathe, Sanjay S. Dhamse, “Power Quality Enhancement by Using Hybrid Filter: A Review”, International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE) Vol 4, Issue 3, March 2018.

[10] Victor Fabián Corasaniti, Maria Beatriz Barbieri, Patricia Liliana Arnera, María Inés Valla, “Hybrid Active Filter for Reactive and Harmonics Compensation in a Distribution Network”, IEEE Transactions On Industrial Electronics, Vol. 56, No. 3, March 2009.

[11] Abhishek Agrawal, Prof. Pramod Agarwal , “Comparison of Various Configurations of Hybrid Active Filter With Three Different Control Strategies”, International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 3 Issue 5, May – 2014.

[12] Bhim Singh, Vishal Verma, “ An Indirect Current Control of Hybrid Power Filter for Varying Loads”, IEEE Transactions on Power Delivery, Vol. 21, No. 1, January 2006.

[13] S. Rahmani, K. Al-Haddad, H. Y. Kanaan ,”A comparative study of shunt hybrid and shunt active power filters for single-phase applications: Simulation and experimental validation,” Mathematics and Computers in Simulation, Volume 71, Issues 4–6, June 2006, Pages 345–359

[14] P. Salmerón and S. P. Litrán, “Improvement of the Electric Power Quality Using Series Active and Shunt Passive Filters” , IEEE Transactions On Power Delivery, Vol. 25, No. 2, April 2010.

[15] C N srivatsav, Dr. Pramod Agarwal, Chendika Venkata Avinash, “ types of hybrid power filter and their comparative performance analysis with distorted source voltage using MATLAB”, IEEE International Conference on Advances in Energy Conversion Technologies (ICAECT),2014

[16] H.Fujita, H. Akagi, “A Practical Approach to Harmonic Compensation in Power Systems-Series Connection of Passive and Active Filters, “Industry Applications, IEEE Transactions on , Volume: 27 , Issue: 6 ,Page(s): 1020 – 1025, Nov/Dec 1991.