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IMPROVEMENT OF POWER QUALITY USING PQ THEORY BASED SERIES HYBRID ACTIVE POWER FILTER

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***Abstract*— This paper investigate the power quality improvement under unbalanced supply condition. The current drawn is highly non-linear and contain harmonics. Shunt active filter eliminate only the current harmonics, not the voltage harmonics. But he series active filter provide harmonics isolation. SHAPF is suitable for compensation of source voltage, reactive power and reduce source current and voltage harmonics. It also eliminate series and parallel resonance. The control technique for the SHAPF is based on the Generalized Instantaneous Reactive Power Theory. The real and reactive power are converted into voltage component. Then the reference voltage are calculated inorder to compensate the source current and load voltage harmonics. Simulations have been carried out on MATLAB-Simulink Platform and results are presented.**

Keywords—Active and passive filter; instantaneous reactive power theory; Harmonics; MATLAB.

I. INTRODUCTION

Electrical energy is the most efficient form of energy and the modern society is heavily dependent on the electric supply. The life is impossible without the supply of electricity. The quality of the electric power is very important for the efficient functioning of the power system components and the end user equipment. The term power quality became most important in the power sector and both the electric power supply company and the end users are concerned about it. The electric power system is affected by various problems like transients, noise, voltage sag/swell, which leads to the production of harmonics and affect the quality of power delivered to the end user [1]. The harmonics may exist in voltage or current waveforms which are the integral multiples of the fundamental frequency, which does not contribute for the active power delivery. The quality of power is affected when there is any deviation in the voltage, current or frequency.

The main effect of these problems is the production of harmonics. The presence of harmonics deteriorates the quality of power and may damage the end user equipment. These harmonics causes the heating of underground cables, insulation failure, increases the losses, reduces the life-time of the equipment etc. The most effective solution to improve the power quality is the use of filters to reduce harmonics. There are different filter topologies in the literature such as- active, passive, hybrid.

The passive filter is used to compensate the current harmonics. The voltage harmonics are compensated using the Active filter. The Active filter can regulate the voltage at the load but cannot reduce the current harmonics in the system [2-3]. The hybrid filter is the combination of the active filter and passive filter. Among various combination the series APF with a shunt connected passive filter (SHAPF) is widely used. To overcome the problems of both passive and active power filters, Series Hybrid Active Power Filters (SHAPF) have been used and extensively used. It provide the cost effective solution for the nonlinear load compensation. The performance of the SHAPF depend on the proper reference generation algorithm.

A variety of configurations and control strategies are proposed to reduce inverter capacity [4-6]. Many approaches have been published. The instantaneous reactive power theory caused a great impact on harmonic isolation. The instantaneous reactive power theory caused a great impact in reference voltage generation. The instantaneous active and reactive power has average component and oscillating component.

This paper is organized as follows. First, a system configuration is presented in section II. The generalized definition of instantaneous active, reactive and apparent power quantity is presented in section III-A. The control strategy for the Series Active Filter is presented in section III-B. The simulation results are given in section IV. The Simulation study for the compensation of current harmonics, voltage harmonics, reactive power and unbalanced supply voltage is presented.

II. SYSTEM CONFIGURATION

Figure 1 shows the block diagram of SHAPF. It consist of the shunt passive filter and series active filter with a series transformer. This arrangement act as a harmonic isolator, voltage harmonic compensator. The harmonic current is made to sink into the passive filter. The SHAPF eliminate the series and parallel resonance. The setup also reduce the need of the precise tuning of the passive filter. The harmonics are eliminated by the passive filter and only higher order harmonics are eliminated by the series active filter and thus the rating of the active filter needed will be less compared with conventional shunt active filters [7-9].

Series active filter compensate unbalanced voltage and harmonics simultaneously. The arrangement of the series active filter and shunt passive filter reduces the need for precise tuning of the passive filter and eliminates possibility of series and parallel resonance. The ripple filter inductor and capacitor are used to suppress the switching ripples generated because of the high-frequency switching of the PWM inverter. The purpose of the coupling transformers is not only to isolate the PWM inverters from the source it also to match the voltage and current ratings of the PWM inverters with of the power system.

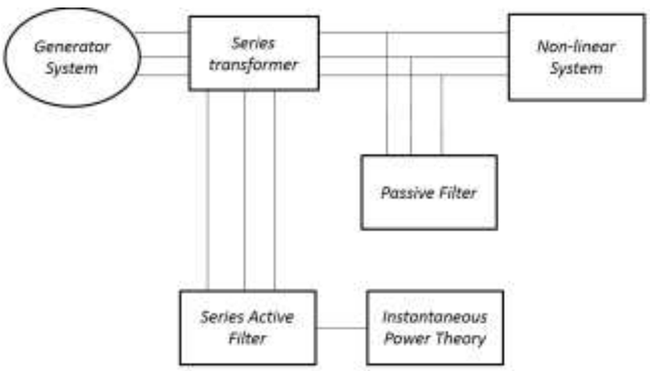

Figure 1 Block Diagram of SHAPF

The turn ratio of the transformer should be high in order to reduce the amplitude of the inverter output and to reduce the voltage induced across the primary winding. Also, the selection of the transformer turns ratio affect the performance of the ripple filter connected at the output of the PWM inverter. The series active filter in the arrangement is controlled as active impedance and is controlled as a harmonic voltage source which offers zero impedance at fundamental frequency and high impedance at all desired harmonic frequencies.

III. CONTROL SCHEME

A. Instantaneous Reactive Power Theory

"The Generalized Theory of the Instantaneous Reactive Power in Three-Phase Circuits", also known as instantaneous power theory or p-q theory. This Theory was given by Akagi, Kanazawa and Nabae in 1983. Control strategy presented in this section is capable of compensating the source current harmonics and it balance in load voltages. It deals with instantaneous power and classified into following two groups. The first one is developed based on abs phase to three orthogonal axes which is known as p-q theory that is based on a-b-c to α-β-0 transformation, and the next is directly on a-b-c phases. The main use of this theory is that it is valid for steady state or transitory operations. It also allow control the active filter in real time. The main advantage of using this technique is the calculation is simple. It require only algebraic calculation.

The p-q theory consists of an algebraic transformation (Clarke transformation) of the three-phase voltages and currents in the a-b-c coordinates to the α-β-0 coordinates, followed by the calculation of the p-q theory instantaneous power components [10-11]. Three phase generic instantaneous line current can be transformed on the α-β-0 axes. On applying the α-β-0 transformation, the zero sequence can be separated and eliminated.

B. Control statergy

Control strategy plays very important role in the performance of the system. The instantaneous 3ϕ load currents and the 3ϕ voltages are sensed and transformed from *a, b, c* coordinates to *α, β, 0* coordinates by using Clark transformation.

The voltage obtained after the Clarke transformation in the *α, β, 0* coordinates is

$$\begin{bmatrix} V_0 \\ V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (1)$$

The current obtained after the Clarke transformation in the *α, β, 0* coordinates is

$$\begin{bmatrix} I_0 \\ I_\alpha \\ I_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} \qquad (2)$$

The real and reactive power obtained from the voltage and current of the *α, β, 0* coordinates is

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \cdot \begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} \qquad (3)$$

Where

Instantaneous Real Power $p=V_\alpha I_\alpha+V_\beta I_\beta$

Instantaneous Imaginary Power $q=V_\alpha I_\beta-V_\beta I_\alpha$

The Instantaneous Real Power and the Instantaneous Imaginary Power has both average and oscillating power. The average power of the real and reactive power are expressed as $\bar{p}$ and $\bar{q}$. The oscillating power of the real and reactive power are expressed as $\tilde{p}$ and $\tilde{q}$. The real and imaginary power can be obtained based on the average and oscillating power is

$$p = \bar{p} + \tilde{p} \qquad (4)$$
$$q = \bar{q} + \tilde{q} \qquad (5)$$

The Zero sequence voltage is eliminated and the α and β coordinates are to be considered. The voltage of the α and β corresponding with the oscillating power of the real power and the reactive power is calculated in (6).

$$\begin{bmatrix} V_\alpha^* \\ V_\beta^* \end{bmatrix} = \frac{1}{I_\alpha^2+I_\beta^2} \begin{bmatrix} I_\alpha & I_\beta \\ I_\beta & I_\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} \\ q \end{bmatrix} \qquad (6)$$

The reference voltage is calculated in order to compensate the harmonic voltage in (7). They are obtained by the inverse Clarke transformation.

$$\begin{bmatrix} V_{ca}^* \\ V_{cb}^* \\ V_{cc}^* \end{bmatrix} = \sqrt{2/3} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ 1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} V_\alpha^* \\ V_\beta^* \end{bmatrix} \qquad (7)$$

The reference voltage is compared with the source voltage and the output is given to the comparator and the output is used to control the controller [6]. The inverter are operated corresponding to the output of the comparator. SHAPF injecting the voltages that follows the reference voltage. It can compensate the source voltage unbalances and supply current harmonics simultaneously. The special features of this approach are: simplicity in separating harmonic voltage component, computational complexity is less compared with existing techniques.

IV. SIMULATION RESULTS

The control algorithm for the SHAPF is developed in the MATLAB/Simulink software environment to check the performance of the control strategy in improving the system behavior. The simulation is carried under three conditions-

- Without Filter
- With Passive Filter
- With Active and Passive Filter

The proposed control strategy is simulated with a non-linear balanced load and the performance of the system is analyzed. The system data is given in Table 1

System Parameter	Value
Voltage	230 V
Source Inductance	10 H
Source Resistance	0.5
Turns Ration of Coupling Transformer	1:1

Table 1 System parameter

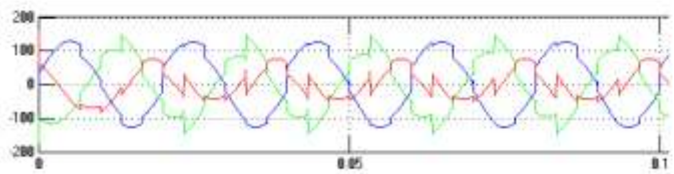

Figure 2 Load voltage without any filter

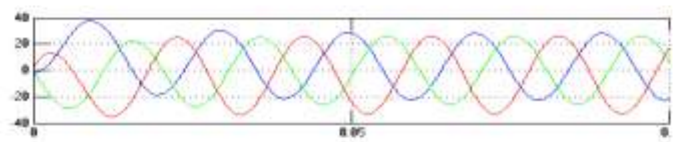

Figure 3 Load current without any filter

The load voltage and load current obtained when the system is in open loop without any filter is shown in the Figure 2 and Figure 3. Load voltage and Load Current obtained consist of more Harmonics which must be eliminated. The harmonics generated is eliminated with the help of filters.

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The FFT Analysis is carried out for the system without any filter. The THD values are calculated and it is 34.64%, which is higher shown in the Figure 4.

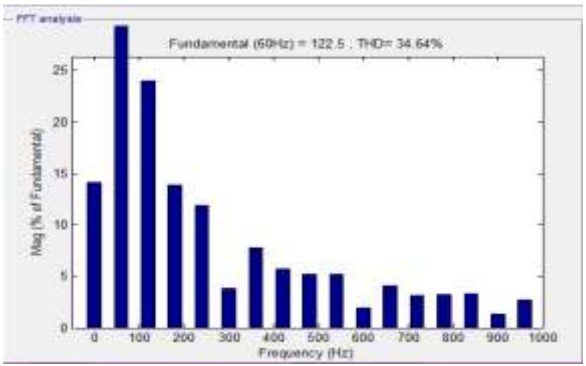

Figure 4 THD Analysis without any filter

The load voltage and load current obtained when the system with passive filter is shown in the Figure 5 and Figure 6.The Load voltage and the load current obtained with passive filter consist of less harmonics.

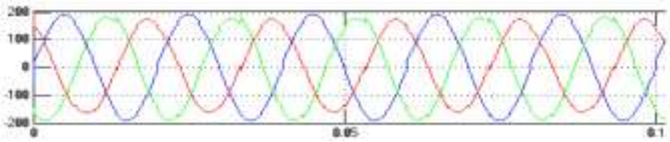

Figure 5 Load voltage with passive filter

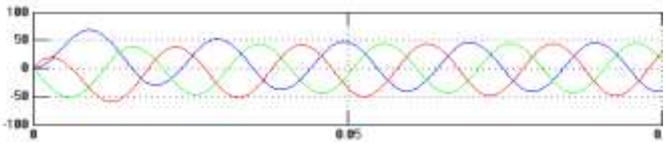

Figure 6 Load current with passive filter

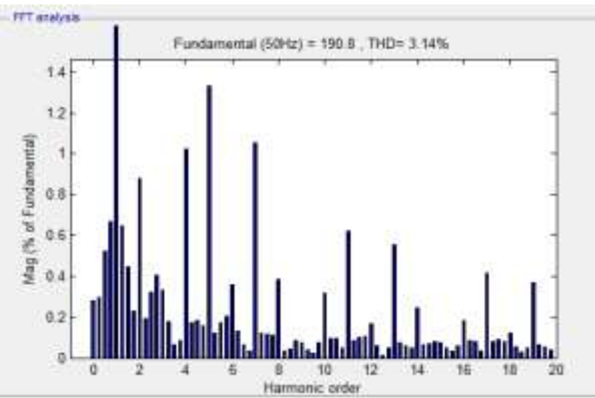

Figure 7 THD Analysis with passive filter

The FFT Analysis is carried out. The THD values are calculated for the system with passive filter and shown in the Figure 7. The value is 3.14%, which is less compared with the system without filter.

The load current and load voltage obtained when the system with both Active and Passive filter is shown in the Figure 8 and Figure 9. The Harmonics content in the load voltage and Load current obtained with the series connected active filter and shunt passive filter is comparatively low than the other.

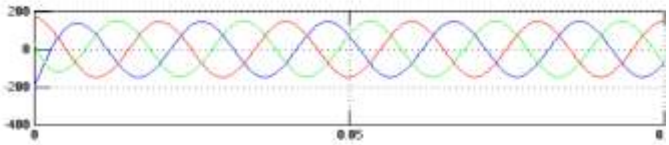

Figure 8 Load voltage with SHAPF

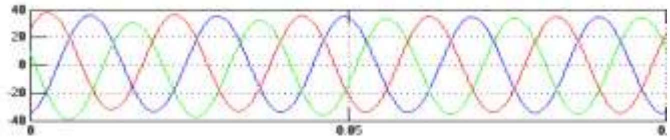

Figure 9 Load current with SHAPF

The FFT Analysis is carried out. The THD values are calculated for the system with SHAPF and shown in the Figure 10. The value is 0.24%, which is lesser compared with passive filter.

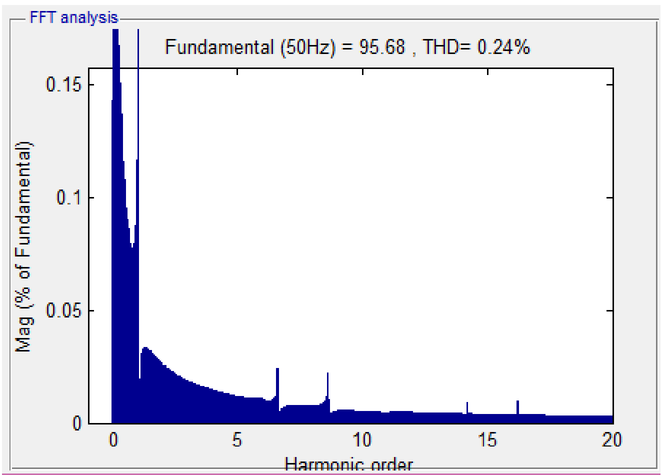

Figure 10 THD Analysis with SHAPF

The Table gives the THD value for the system (a) without filter, (b) With Passive Filter, (c) With Active and Passive Filter. The THD value that are obtained by the RL Load. From the table the THD value for the system with both Active and Passive Filter are very much less compared with the system with no Filter and system with Passive Filter.

System	THD Values in %
Without Filter	34.64
With Passive Filter	3.14
With SHAPF	0.18

Table 2 Comparison of the THD values

The voltage and current harmonics that are produced in the system will be eliminated with the Active and Passive Filter. The Active Filter is connected in series and Passive Filter is connected in parallel to obtain the necessary output.

V. CONCLUSION

The demand for electric power is increasing at an exponential rate and at the same time the quality of power delivered became the most prominent issue in the power sector. Thus, the reduction of harmonics and improving the power factor of the system is of utmost important. In this project a solution to improve the electric power quality by the use of Active Power Filter is discussed. Most of the loads connected to the system are non-linear which the major source of harmonics is in the system. A Hybrid power filter with series connected APF and shunt connected passive filter is used. The simulation is also carried out with unbalanced load and found that the APF improves the system behavior by reducing the harmonics. Therefore, it is concluded that the hybrid filter consisting of series APF and a shunt passive filter is a feasible economic solution for improving the power quality in electric power system.

REFERENCES

[1] W. E. Reid, "Power quality issues-standards and guidelines", *IEEE Translnd. Appl.* , Vol. 32, No.3, pp. 625-632, 1996.

[2] F. Z. Peng and D. J. Adams, “Harmonics sources and filtering approaches,” Proc. Industry Applications conf., vol. 1, Oct.1999.

[3] J. C. Das, “Passive filters-potentialities and limitations,” IEEE Transaction Industry Applications, vol. 40, no. 1, Jan. 2004.

[4] Salmero´n, P.; Litra´n, S.P., “A Control Strategy for Hybrid Power Filter to Compensate Four-Wires Three-Phase Systems”, IEEE Transactions on Power Electronics, July 2010, Volume 25, Issue 7, pp. 1923–1931.

[5] J. Tian, Q. Chen and B. Xie, “Series Hybrid Active Power Filter based on Controllable Harmonic Impedance”, IET Journal of Power Electronics, 2012, Vol. 5, Issue 1, pp. 142-148.

[6] H. Akagi, Y. Kanazawad, and A. Nabae, Instantaneous power theory and application to power conditioning” IEEE Press, Wiley-inter-science, A Jon Wiley & sons, INC., Publication.

[7] R.S.Herreraand, P.Salmern, ‘Instantaneous reactive power theory: A comparative evaluation of different formulations’, IEEE Trans. Power Del., vol. 22, no. 1, pp. 595604, Jan. 2007.

[8] M. F. Shousha, S. A. Zaid and O. A. Mahgoub. “Better Performance for Shunt Active Power Filters” Clean electrical Power (ICCEP), IEEE June 2011

[9] H. Fujita, H. Akagi, “A practical approach to harmonic compensation in power systems series connection of passive and active filters,” IEEE Transactions on Industry Applications, Vol. 27, Nov.-Dec. 1991.

[10] Bhattacharya, S., Cheng, P.-T., Divan, D.M.: ‘Hybrid solutions for improving passive filter performance in high power applications’, IEEE Trans. Ind. Appl., 1997, 33, (3), pp. 732–747

[11] Mulla, M.A., Chudamani, R., Chowdhury, ‘A novel control scheme for series hybrid active power filter for mitigating source voltage unbalance and current harmonics’. Presented at the Seventh Int. Conf. on Industrial and Information Systems (ICIIS-2012) held at Indian Institute of Technology Madras, Chennai, India, 06–09 August 2012

[12] A.Surendar, “A parallel reconfigurable platform for efficient sequence alignment”, African Journal of Biotechnology ISSN 1684-5315, Volume 13(33), 13 August, 2014 pp. 3344-3351, DOI:10.5897/AJB2014.13680.

[13] A.Surendar,“Hardware Based Algorithm for Bioinformatics Application- A Survey”, International Journal of Applied Engineering Research,ISSN 0973-4562, Volume 8, Number 6 (2013), pp. 745-754

[14] A.Surendar,“Evolution of Reconfiguration Based Algorithm For Bioinformatics Application: An Investigation”, International Journal of Life Science Biotechnology and Pharma Research, ISSN 2250-3137 Volume 2, Number 4 (2013), pp. 17-27.