VOL. 12, NO. 21, NOVEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

HARMONIC REDUCTION USING HYBRID POWER FILTER FORTHREE PHASE FOUR WIRE SYSTEM

Mohit Singh Ahlawat, R. Balasubramanian and K. Parkavi Kathirvelu
Department of Electrical Engineering, Sastra University, India
E-Mail: mohitsahlawat@gmail.com

ABSTRACT

In this paper a hybrid filter which is a combination of series active filter and shunt passive filter is designed to mitigate the harmonics present the distribution system feeding unbalanced load. The control scheme is established on the PQ theory which is also knows as instantaneous theory. The control strategy is applied to eliminate the harmonics present in the load current of balanced and the unbalanced loads. The conventional PI controller has been implemented in the voltage and current loop of active power filter. In this topology, the passive filter compensation performance has been improved by series active filter. The proposed control strategy with the designed hybrid power filter is simulated in MATLAB simulink software and the results are presented.

Keywords: active power filter (APF), all pass filter (ALPF), hybrid power filter (HPF).

1. INTRODUCTION

The demand for processed electric power is increasing every year in industries in order to reduce the maintenance cost of mechanical equipment, reduction of the power consumption and production cost. The processed power can be obtained by using the power converters which contain power electronic switches. These converters causes power quality problems particularly harmonics in the distribution system. The solution to overcome these harmonic problems in the distribution system is to filter out these harmonics from the supply end. There are many filter topologies present in the literature to mitigate harmonics, which are passive filter, active filter and hybrid filter [1]. Passive filters have been implemented for the absorption of the harmonics; however it has limitations like resonance and tuning problems [2]. Accordingly, active filters are used for harmonic mitigation to overcome the drawbacks of passive filters. Active filters requires current transformer and its component of higher rating. The active power filter can be connected in series or in parallel with the load. The active power filter has better compensation properties than passive filter but they require high power rating converters. To overcome the drawback of an active and passive filters hybrid power filter were proposed in the literature. The hybrid

Power filters are the combination of both active power filter and passive power filters and it inherits the advantage of both passive and active power filters.

There are various hybrid power filter topology proposed in the literature. In this work a series connected active power filter with shunt connected passive filtertopology has been

Used [3], [4]. In this topology the control strategy is not much complex and it is effective in reducing both current and voltage harmonics. In this paper proposed control strategy has been implemented to a three phase four wire system and simulation results were presented.

2. SYSTEM CONFIGURATION

Figure-1 shows 3phase 4 wire distribution system feeding nonlinear and unbalanced loads. The nonlinear unbalanced load considered in this work consists of three single phase uncontrolled rectifiers with RL load. The passive filter and active power filter is connected in parallel and in series with the supply system. The active power filter is 3phase Voltage source converter consists of six IGBT switches and terminated with dc link capacitor [5], [6]. DC link side of the APF two 2200μF capacitors are connected to maintain the dc link.

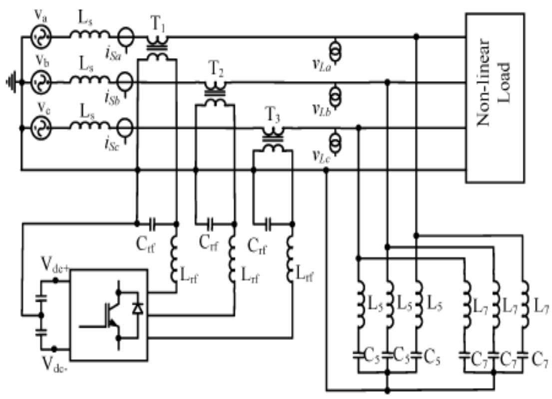

Figure-1. Parallel passive and series APF filter topology.

3. CONTROL SCHEME

3.1Reference compensation voltage generation

Electrical power with balanced and sinusoidal voltages has to be produced by the electrical power producers. The load is considered as an ideal, which should be linear, resistive and balanced. It refers that the source current are collinear with the system voltage and will have a unity power factor.

$$v = iR_e \quad (1)$$

ARPN Journal of Engineering and Applied Sciences

Here, v is the voltage vector, i is supply current and R_e is equivalent resistance.

The voltage vectors and current vector in three phase system can be defined by

$$v=[v_a v_b v_c]^T \qquad i=[i_a i_b i_c]^T \tag{2}$$

Ideal load should have balanced and sinusoidal current vector which can be obtained from the equation (2) further it can be defined by the instantaneous reactive power theory and the expression is given by

$$\begin{pmatrix} i^0 \\ i^+ \\ i^- \end{pmatrix} = \frac{1}{3}\begin{pmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{pmatrix}\begin{pmatrix} i_a \\ i_b \\ i_c \end{pmatrix} \tag{3}$$

the ideal source current vector is obtainedby applying inverse transformation and the value is as follows and it is free from harmonics and balanced

$$i_1^+ = \begin{pmatrix} i^0 \\ i^+ \\ i^- \end{pmatrix} = \frac{1}{3}\begin{pmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{pmatrix}\begin{pmatrix} i_a \\ i_b \\ i_c \end{pmatrix} \tag{4}$$

Active power supplied through source is given by

$$P_S = I_1^{+2} R_e \tag{5}$$

Here I_1^{+2} is the positive sequence fundamental component of current [7] and it is as follows

$$I_1^{+2} = \frac{1}{T}\int_0^T \left(i_1^{+T} i_1^+\right) dt \tag{6}$$

The difference between the instantaneous value of real power needed by the load and power supplied by the source is

$$p_C = p_L - p_S \tag{7}$$

In ideal condition p_C should be zero hence, equation (7) takes the form

$$0 = \frac{1}{T}\int p_L dt - I_1^{+2} R_e \tag{8}$$

The equivalent resistance is calculated from the above equation as

$$R_e = \frac{1/T\int p_L dt}{I_1^{+2}} = \frac{P_L}{I_1^{+2}} \tag{9}$$

Where, P_L is the load power. Active power filter voltage injected at Pcc is calculated as follows:

$$v_{PCC} = \frac{P_L}{I_1^{+2}} i \tag{10}$$

Here i is current vector of the source. The reference voltage signal for power filter is given by

$$v_C^* = v_{PCC} - v_L = \frac{P_L}{I_1^{+2}} i - v_L \tag{11}$$

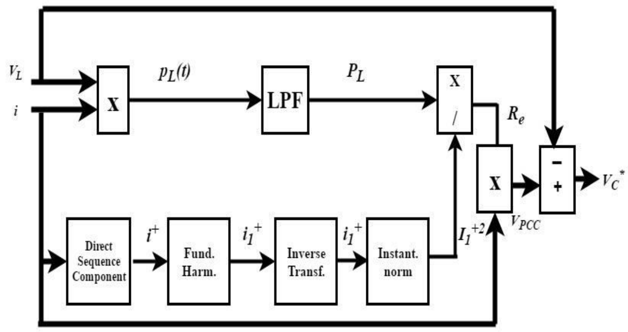

Figure-2. Reference compensation voltage generation.

The reference compensating voltage is calculated by the control scheme shown in the Figure-2 and it has been simulated in MATLAB Simulink software. In order to obtain direct sequence component in the control scheme. The source current vector and voltage vector are the input signals for Direct sequence component calculation subsystem in the main control scheme is shown in Figure-3. The product of voltage vector and current vector gives the instantaneous real power and average real power is obtained with LPF. The Simulink blocks are used to implement the LPFs, it is second order model with the cut off frequency set as 100Hz and damping factor as 0.707.

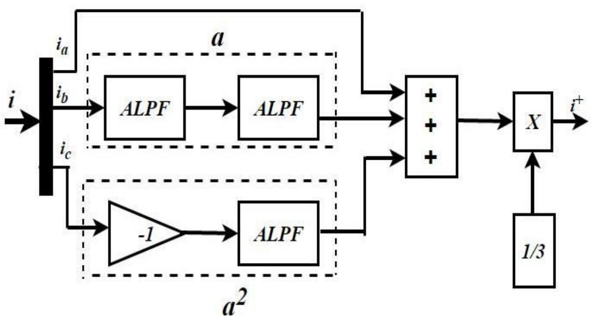

Figure-3. Direct sequence component generation.

VOL. 12, NO. 21, NOVEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

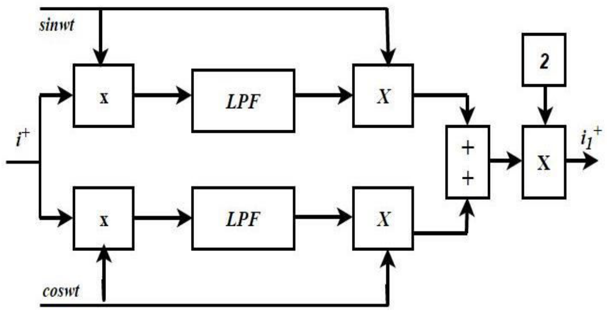

Figure-4. Fundamental component calculation.

For calculating the current positive sequence component "Direct Sequence" component block is formed where instantaneous reactive power transformation is applied

$$i^+ = \frac{1}{3}\left(i_a + \quad ai_b + \quad a^2 i_c \quad\right) \tag{12}$$

Here, a operator value is defines as $a = e^{j2\Pi/3}$ (13)

The delay introduced by the filter is $60°$ at the fundamental frequency, a operator is attained connecting two all pass filter.

All pass filteris used and executed by the simulink block and function is described as

$$F(s) = \frac{s - 181.4}{s + 181.4} \tag{14}$$

In order to attain the fundamental component of the current in the main control scheme the current has to be multiplied with cos*wt* and sin*wt* where, *w* is the fundamental frequency and the results are passed through LPFs and they are multiplied again with the cos*wt* and sin*wt* and then multiplied by 2. Calculation of Fundamental component subsystem in the main control scheme is shown by the Figure-4.

The component of direct sequence fundamental is obtained by inverse instantaneous transformation. Figure-5 shows the inverse transformation. It is given by

$$i_{1a}^+ = \left(i_{1a}^+ \quad i_{1b}^+ \quad i_{1c}^+ \quad\right)^T = \left(i_{1a}^+ \quad a^2 i_{1a}^+ \quad ai_{1a}^+ \quad\right)^T \tag{15}$$

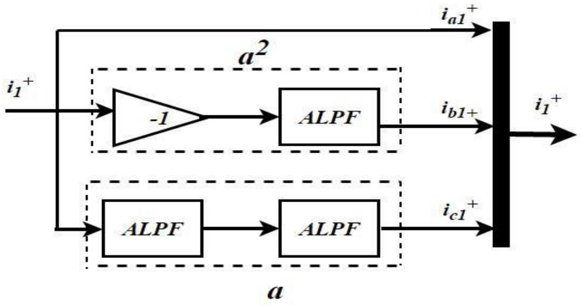

Figure-5. Inverse transformation.

The equivalent resistance has been calculated by division of the average load power with square of the positive sequence component of the current. The outcome is the equivalent resistance obtained above is multiplied by the reference voltage to obtain the source current vector is obtained.

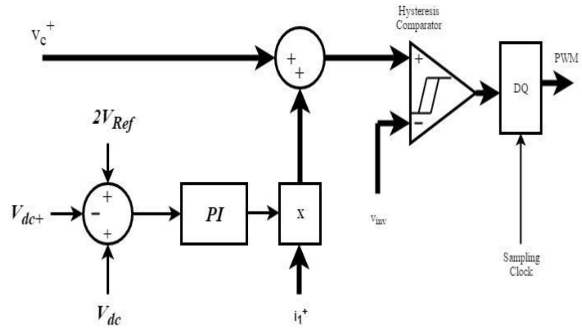

Figure-6. PWM generator scheme control and DC link.

Capacitor voltages are unbalanced by the losses in the inverter hence a control scheme to maintain the capacitor voltage is implemented. The control scheme employs the closed loop proportional integral controller [8]. Figure-6 shows the PWM generator and the control scheme loop. V_{Ref} is the reference voltage and V_{dc} is measured voltage. The input to the PI controller is the difference of the reference voltage and the dc link voltage. The product of current direct sequence component and controller output is added to the v^*_c and reference voltage is corrected. The hysteresis band control is developed to have a fast response and comparison of the inverter voltage. In this method IGBT is switched on and off when the errors vary from fixed magnitude, IGBTs are used to develop the inverter.

Hysteretic control refers to a technique where the output is allowed to vary within an already defined error band called hysteresis bands. The high and low switching of comparator switches are determined by the bands. The output of comparator switches states when the triangular wave reaches either of the hysteresis bands. The main advantage of this control scheme is its ability to respond rapidly to load and line transients.

5. SIMULATION RESULTS

The entire system with the control strategy has been simulated using MATLAB SIMULINK software. The 3 phase system is supplied by the sinusoidal balanced three phase 230V supply and 50Hz frequency having the source resistance of 1.8Ωand 2.8mH inductance. 3phase VSC consists of 6 IGBT terminated with the DC link capacitor. A passive power filter of small rating is used for elimination of the ripples and 5th and 7thorder harmonics. The nonlinear load is used which consists of three single phase uncontrolled rectifiers with a resistor and inductance connected in parallel.

The Table shows the system parameters used for simulation.

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-1. System parameters.

Component	Values
Source	L_s = 2.8mH ; R_s=1.8Ω
Passive filter	L_5 =13.5mH L_7= 6.75mH C_5 =30μf C_7 = 30μf
Load Phase A Phase B Phase C	 L = 5.5mH R = 8.3Ω L = 5.5mH R = 12.5Ω L = 5.5mH R = 16.5Ω

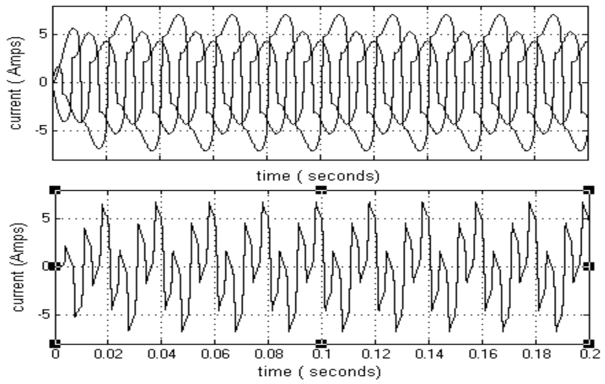

Figure-7. Source current and neutral current without compensating.

When passive power filter is connected the source current of phase a, phase b, phase c are shown in Figure-8. The rms values remains similar to the last case where there is no compensating filter connected but THD values are increased because of the increase of the third harmonics. Values are shown in table II, whereas the lower order harmonics 5^{th} and $7^{th}$are reduced.

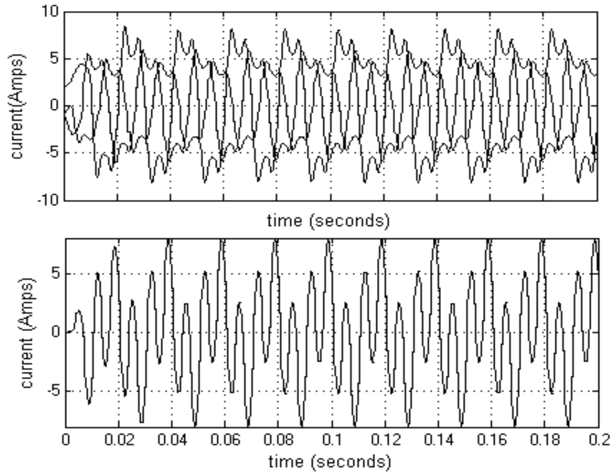

Figure-8. Source current and neutral current with passive filter compensation.

Figure-9shows the current values when the active power filter along with passive power filter is connected. The source current is balance and sinusoidal which is the aim of the project. The THD values are decreased and shown in the Table-3.

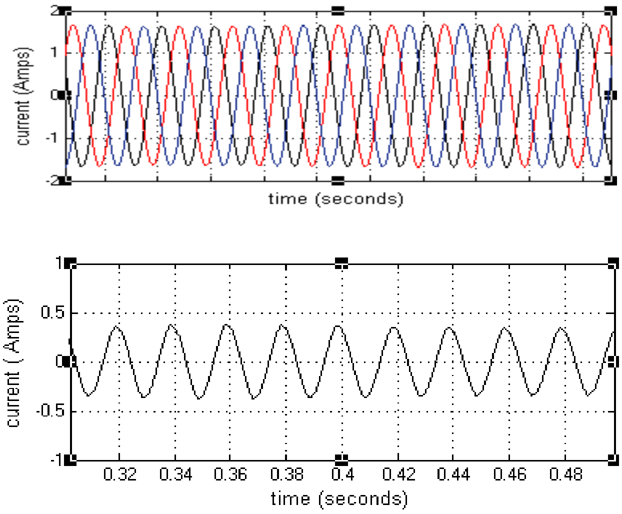

Figure-9. Source current and neutral current after passive filter and active filter compensation.

The results are summarized in Tables 2, 3, 4. In this paper we have proposed a 5^{th} and 7^{th} order tuned passive power filter. There can be problem of the resonance which can be eliminated with the use of active power filter. As Table 1, 2, 3 shows that this problem can be avoided by using active power filter. When the active power filter is offline and LC passive filter is kept online this problem appears.

Table-2. Measured values before compensation.

Phase	V/I	THD (%)	Fundamental
Phase A	V	11.7	94.8
	I	33.7	7.9
Phase B	V	9.3	97.1
	I	27.6	5.5
Phase C	V	7.1	97.3
	I	24.5	4.3

Table-3. Measured values after compensation with passive filter.

Phase	V/I	THD (%)	Fundamental
Phase A	V	10.7	95.8
	I	33.7	7.8
Phase B	V	7.3	97.1
	I	30.28	5.6
	I	27	4.8

Table-4. Measured values after compensation with active filter and passive filter.

Phase	THD%	Fundamental
PHASE A	2.1	4.6
PHASE B	2.3	4.9
PHASE B	2.1	4.7

6. CONCLUSIONS

In this work, the performance improvement of hybrid filter to reduce harmonics in unbalanced system is analysed. Hybrid power filter, which is a combination of series active power filter and shunt connected passive power filter is employed. Simulation results of the proposed control strategy show that the proposed hybrid power filter effectively compensates the harmonics present in the distribution system. The result shows that the performance of Hybrid filter compensation of harmonics is better than the performance of passive power filter or active power filter connected alone. The THD values comparatively decreased from 11.7% to 2.1%. The performance of Active Power filter shows that the series APF enhance the shunt connected passive filter compensation characteristics in addition to improve the system performance. The simulation is carried out with condition of unbalanced load and it is found that hybrid power filter improves the performance of the system by eliminating the harmonics.

REFERENCES

[1] F. Z. Peng and D. J. Adams. 1999. Harmonics sources and filtering approaches. In Proc. Ind. Appl. Conf. 1: 448-455.

[2] H. Akagi. 2005. Active harmonic filters. Proc. IEEE. 93(12): 2128-2141.

[3] J. C. Das. 2004. Passive filters-potentialities and limitations. IEEE Trans. Ind. Appl. 40(1): 232-241.

[4] P. Lohia, M. K. Mishra, K. Karthikeyan and K. Vasudevan. 2008. A minimally switched control algorithm for three-phase four-leg VSI topology to compensate unbalanced and nonlinear load. IEEE Trans. Power Electron. 23(4): 1935-1944.

[5] B. S. Chen and G. Joos. 2008. Direct power control of active filters with averaged switching frequency regulation. IEEE Trans. Power Electron. 23(6): 2729-2737.

[6] F. Z. Peng, H. Akagi, and A. Nabae. 1988. A novel harmonic power filter. In: Proc. IEEE/PESC, Apr. pp. 1151-1159.

[7] G. Superti-Furga and G. Todeschini. 2008. Discussion on instantaneous p-q strategies for control of active filters. IEEE Trans. Power Electron. 23(4): 1945-1955.

[8] Y. S. Kim, J. S. Kim and S. H. Ko. 2004. Three-phase three-wire series active power filter, which compensates for harmonics and reactive power. IEE Proc. Electr. Power Appl. 151(3): 276-282.