Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 14 (14): 1612-1617, 2014
ISSN 1812-5654 / DOI: 10.3923/jas.2014.1612.1617

LMS Algorithm Based Fundamental Current Detection for Shunt Hybrid Filter

R. Sriranjani and S. Jayalalitha
School of Electrical and Electronics Engineering, SASTRA University, Thanjavur, Tamil Nadu, India

Abstract: An adaptive control technique is used to extract the fundamental current for the active filter. The Shunt Hybrid Filter (SHF) comprises passive filter (resonant filter) and active filter. The passive filter is tuned to suppress dominant harmonics and the active filter is tuned to reduce harmonics and reactive power of the supply mains. The Least mean Square (LMS) algorithm is used for implementing Hysteresis current control. The dc bus voltage is regulated using Proportional-Integral controller which improves the dynamic characteristics of SHF. The Shunt Hybrid filter with the dc bus voltage control is analysed by the MATLAB simulink and the results are compared.

Key words: Harmonics, reactive power, least mean square, resonant filter, active filter, controller

INTRODUCTION

The growth of the power converters raises the issue of the power quality problems. The major power quality problem is the harmonics which distorts the supply voltage, derating the electrical equipment and there is a mal functioning of the protective devices (Bashi *et al*., 2006). This load also consumes reactive power from the mains. The bank of capacitors is connected to reduce the reactive power (Q) so that power factor is reduced. But there is harmonic amplification caused by the capacitor and the line impedance. The diode rectifier with boost converter improves the power factor (Bashi *et al*., 2005). But the THD does not meet the IEEE standard. The side filter such as passive filter and active filter reduces the harmonics as well as improves power factor (Vahedi, 2012). The Shunt Active Filter (SAF) was used to reduce the supply current harmonics and also minimizes Q. But the active filter cost is high and it is difficult to construct the filter with quick current response (Kouzou *et al*., 2010; Singh and Verma, 2006). Various hybrid filter topology was investigated in the recent years. The hybrid filters are connected to the supply line through a transformer. By removing the transformer, the expenditure of the active filter is reduced to 10% (Mattavelli, 2001). Series hybrid filter carriers the fundamental reactive current (i_q) and the total harmonic current (Sriranjani and Jayalalitha, 2011). But in the Shunt hybrid filter (Rahmani *et al*., 2012) the SAF carries the (i_q) and the other harmonic current. The dominant harmonic current is flowing in tuned passive filter which is

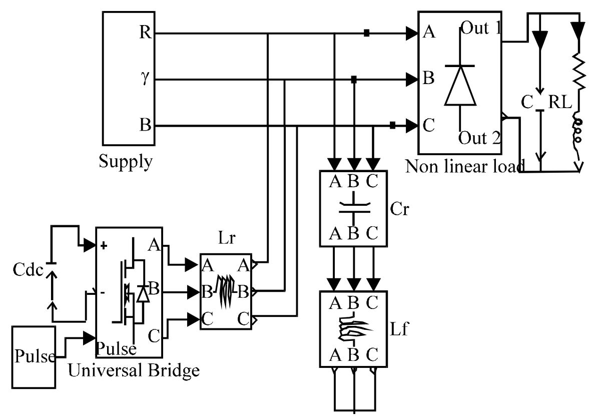

Fig. 1: Schematic representation of shunt hybrid filter

connected to supply as shown in Fig 1. This study presents a SHF without transformer is used to decrease the rating of the SAF (Luo *et al*., 2009).

The control of active filter is done by detecting the harmonics by the theory of instantaneous reactive power or synchronous reference frame (Sriranjani and Jayalalitha, 2012a). This theory needs more computation and also Phase locked loop has many disadvantages. Many control strategy uses harmonic detection methods (Tao *et al*., 2009). In this study, the fundamental current is detected from the supply using Least mean square algorithm which simplifies the control circuit (Sriranjani and Jayalalitha, 2012b). There is no intermediate transformer between the supply line and the active filter. This reduces the cost of the filter design. The inverter losses are minimized by managing the

Corresponding Author: R. Sriranjani, School of Electrical and Electronics Engineering, SASTRA University, Thanjavur, Tamil Nadu, India

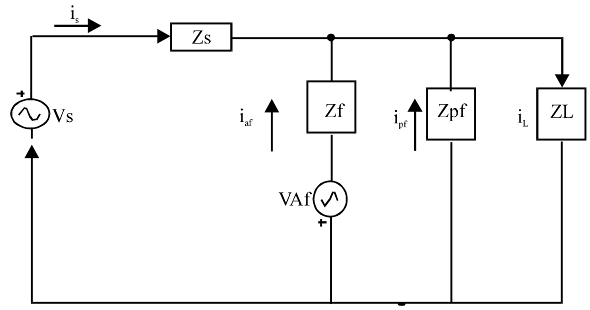

Fig. 2: Shunt hybrid filter equivalent circuit

dc bus voltage using PI. Hysteresis current controller based Shunt hybrid filter is analysed in MATLAB simulink.

MATHEMATICAL MODELLING

Non linear load: The 3φ full bridge rectifier with RL load act as a non linear load which distorts the line current.

Source voltage is given by:

$$V_{in} = V_m \sin(\omega_s t) \quad (1)$$

Due to the diode rectifier load, the supply current contains fundamental component and harmonics component:

$$i_s(t) = \sum_{h=1}^{\infty} I_h \sin(h\omega_s t + \Phi_h) \quad (2)$$

$$i_s(t) = I_1 \sin(\omega_s t + \phi_1) + \sum_{k=2}^{\infty} I_k \sin(h\omega_s t + \Phi_k) \quad (3)$$

Where:

- I_1 = Fundamental current
- I_k-k^{th} = Harmonic current
- V_m = Peak supply voltage
- ω_s = Fundamental frequency at rad/sec
- φ_k = Phase angle between the supply voltage and current of the k^{th} harmonic component

Shunt hybrid filter: The Shunt Hybrid filter contains the passive filter which is tuned for the dominant harmonic frequency of the line current. The SAF provides the reactive power compensation and harmonic compensation. The equivalent circuit of the system is shown in Fig. 2. The switching ripples are reduced by the inductance coupled with the active filter.

The distorted current is given by:

$$i_L(t) = i_f(t) + i_h(t) \quad (4)$$

For harmonic compensation and power factor improvement, the supply current should have the fundamental component and it should be in phase with the supply mains.

Thus the line current is:

$$i_S(t) = I_m \sin(\omega_1 t) = i_f(t) \quad (5)$$

where, I_m is the maximum fundamental component current of the mains and ω_1 is the supply frequency (50 Hz). In this study the resonant filter is tuned for the fifth order harmonic frequency:

$$f_r = \frac{1}{2\Pi\sqrt{L_r C_r}} \quad (6)$$

where, L_r and C_r are the inductor and capacitor of the resonant filter.

The resonant filter current and the active filter current is given by:

$$i_{pf} = I_d = I_{dm} \sin(d\omega_1 t + \phi_d) \quad (7)$$

$$I_{hr} = \sum_{k=2}^{\infty} I_k \sin(k\omega_1 t + \phi_k) \quad (8)$$

$$i_{af} = I_{r1} + I_{hr} \quad (9)$$

where, I_{r1} is the fundamental reactive current component, I_d is the dominant harmonic current, d is the dominant harmonic order and I_{hr} represents the remaining harmonic component of the line current. φ denotes the phase angle between the current and supply voltage. The Z_{pf} is the passive filter tuned for the dominant frequency so that it will inject the i_{pf} to the supply mains. The shunt active filter will inject the I_{hr} and I_{r1} current so that the supply is free from harmonics and reactive power is minimized.

Reference current extraction: With the intention of tuning the active filter, the reference current at the

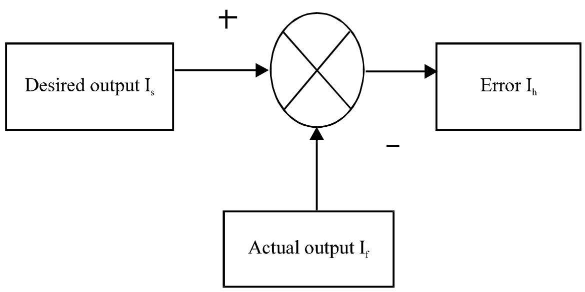

Fig. 3: Adaptive linear combiner

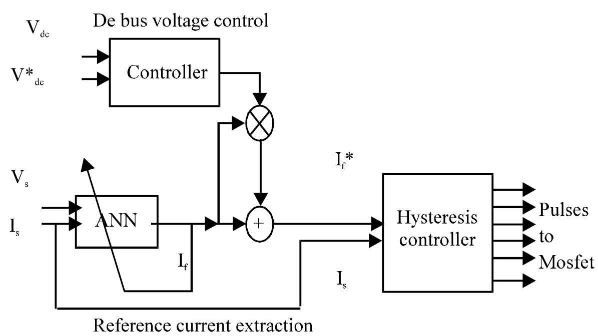

Fig. 4: Block diagram of generation of pulses for Mosfet

fundamental frequency is extracted by the least mean square algorithm from the line current. The distorted line current is filtered out by the adaptive linear combiner shown in Fig. 3. Pulse generation of SAF is shown in Fig. 4. In this proposed control circuit, the fundamental current is detected from the supply current.

The actual output is the fundamental current I_f determined by the LMS algorithm (Bernard and Stearns, 2002).

The harmonic current is:

$$I_h = I_s - I_f \tag{10}$$

The adaptive linear combiner with desired output and error signal is given by:

$$\varepsilon_n = d_n - y_n \tag{11}$$

Where:

$$y_n = w_n^T X_n \tag{12}$$

Weight matrix is updated by:

$$w_{n+1} = w_n + 2\mu\varepsilon_n X_n \tag{13}$$

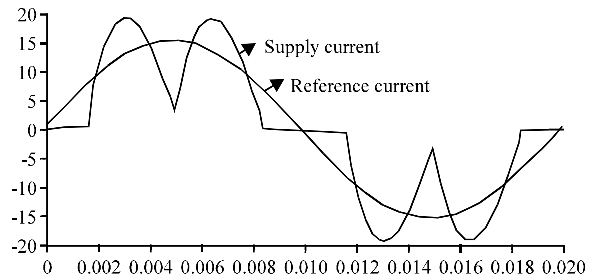

Fig. 5: Comparison of supply current and reference current using hysteresis controller

where, ϵ_n is error signal, d_n is the desired output, y_n is the actual output and μ is gain constant. From Eq. 1, 3, 10 and 12:

$$I_f - w^* V_s \tag{14}$$

So the fundamental current is extracted by updating the weight matrix w_{n+1}.

Inverter dc bus voltage control: The capacitor is charged or discharged due to the switching of the Mosfet. The increasing of the capacitor voltage is limited by PI controller and while switching pattern are formed by considering the reference voltage of the dc bus shown in Fig. 4. This minimizes the losses of the inverter.

$$I_f^* = (K+1)\, I_f \tag{15}$$

where, k is the controller gain and I_f is the fundamental reference current.

Hysteresis current control (HCC): The switching patterns for the each leg is obtained by comparing the instantaneous value of the line current and the fundamental current at supply frequency is shown in Fig. 5. The fixed band HCC is used because of fast response and high accuracy compare to PWM control (Abedi and Vahedi, 2013). The Switching pattern for leg -1, the upper switch is ON when the supply current is more than the reference current within the hysteresis band and the lower switch is ON when the supply current is less than the reference current.

Design of SAF: The ripples of the SAF is filtered by an inductor which is designed by:

$$L = \frac{|V_s| - |V_{dc}|}{\frac{di_L}{dt}/\min} \tag{16}$$

Table 1: Specification shunt hybrid filter

Parameters	Value
Maximum mains voltage	150 V
Load resistor, load inductor, filter capacitor	17 Ω,1 mH, 1 mF
Inverter capacitor, V^*_{dc}	1 mF, 300 V
Inverter inductor	2 mH
Passive filter	4.05 mH, 0.1 mF
KVA rating of active filter	1.3 KVA

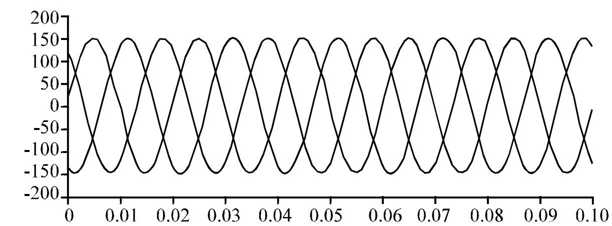

Fig. 6: Supply voltage waveform

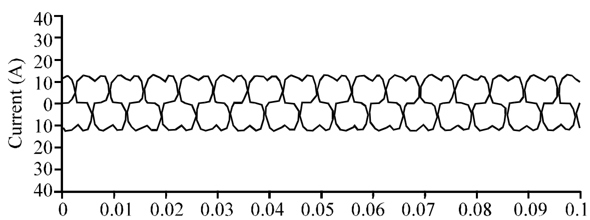

Fig. 7: Supply current waveform without filter

and the active filter capacitor is given by:

$$C_{dc} = \frac{Vs_{max} \Delta I_L T}{V^{*2}_{dc} - V_{dc,\ min}} \tag{17}$$

where, I_L is load current, T is the switching period, V^*_{dc} is the reference active filter dc voltage. V_{dc} is the actual voltage.

MATLAB SIMULATION

Shunt Hybrid filter is simulated in Matlab. Power gui is used to measure THD. Here the full bridge rectifier with RL load is used and power is measured. The passive filter is designed in such way that it will reduce the Fifth order harmonics. Finally the SAF is connected and the power, power factor and harmonics are measured. The rating of the active filter is calculated. Table 1, shows Selection of parameters.

SIMULATION ANALYSIS

Figure 6 and 7 shows supply voltage waveform and the supply current waveform before the connection of SHF. The current waveform is distorted and the power factor is less than 0.95. Figure 8 and 9 shows the passive filter current waveform and active filter current waveform. The passive filter injects the fifth order harmonics to the load and the active filter injects the fundamental reactive current and other harmonic current. The HSAF gives near to unity power factor and reduces the current harmonics which is shown in Fig. 10. When the Hysteresis controlled SHF is connected, the supply is free from harmonics. Figure 11 and 12 shows the frequency spectrum of supply current before and after connection of the filter. The Total harmonic distortion of the line current is trim down from 20.85 to 0.15% and there is an improvement in power factor. The KVA rating of the active filter is 1.3 KVA. Figure 13 shows the dc bus voltage waveform. It finally settled to its reference dc voltage value. When the reference voltage is reduced below the set value (300 V), the harmonics are increased. Thus the shunt hybrid filter

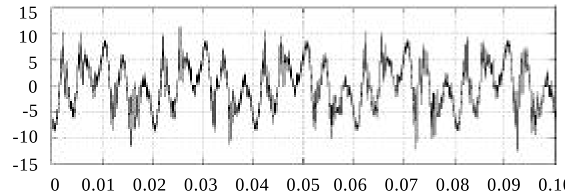

Fig. 8: Active filter current

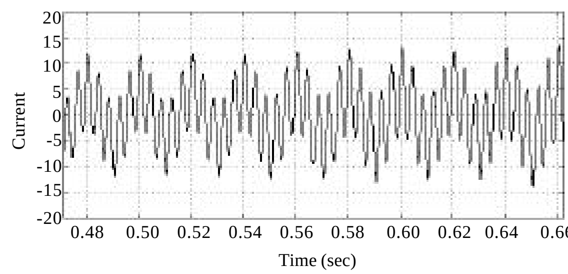

Fig. 9: Fifth order Harmonic current waveform of the passive filter

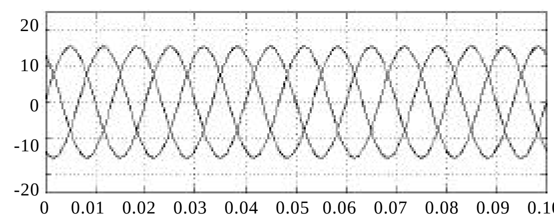

Fig. 10: Suply crrunt waveform after compesation

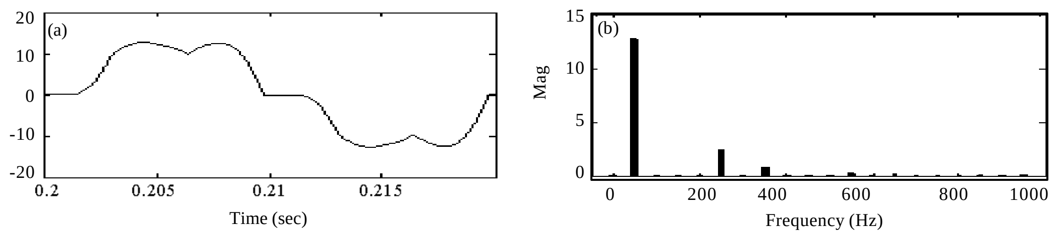

Fig. 11(a-b): Frequency spectrum of the line current without SHF

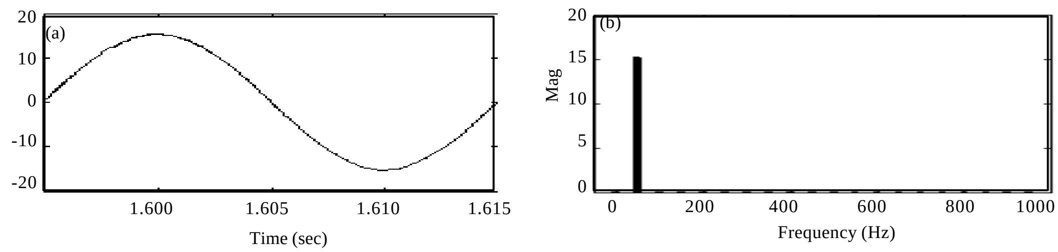

Fig. 12(a-b): Frequency spectrum of the line current with SHF

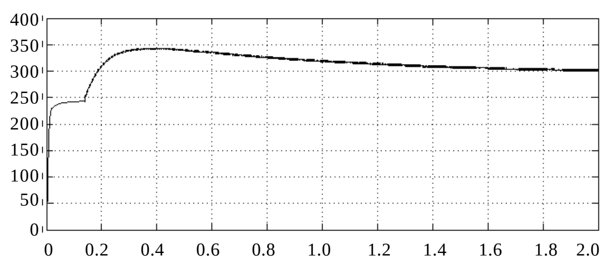

Fig. 13: Dc bus voltage of the active filter

Table 2: Individual harmonics of the supply current

Compensation	5th (%)	7th (%)	11th (%)	THD (%)	Power factor	P (W)	Q (VAR)	S (VA)
Rectifier unit	19.45	6.850	2.300	20.86	0.945	925	247	978
Hybrid filter	0.130	0.019	0.002	0.15	0.990	1100	3	1100

overcomes the drawbacks of the resonant filter and SAF. Table 2 shows the results of power, harmonics and power factor before and after the connection of SHF. The nonlinear load absorbs very high reactive power from the supply line. After the Shunt Hybrid filter is implemented in the supply line, the reactive power is reduced from 272 to 3 VAR. Thus the harmonic and reactive power compensation is done by Shunt Hybrid filter with LMS algorithm.

CONCLUSION

Using Hysteresis controlled Shunt Hybrid filter the reactive power and current harmonics becomes scanty. The Least mean square algorithm is used for extracting the fundamental reference current for hysteresis current control. By balancing the active filter dc voltage using the PI controller reduces the losses of SAF. The proposed filter achieves 0.99 power factor and current harmonics are reduced to less than 5%. The dominant harmonic of the supply current is five. So passive filter is tuned for the fifth order harmonics and SAF balances the reactive power and other harmonics. The burden of the SAF is very much diminished.

REFERENCES

Abedi, S.M. and H. Vahedi, 2013. Simplified calculation of adaptive hysteresis current control to be used in active power filter. Trends Applied Sci. Res., 8: 46-54.

Bashi, S.M., A.U.M. Al-Abulaziz and N.F. Mailah, 2006. Effects of high power electronics converters on PLC signals. J. Applied Sci., 6: 1888-1891.

Bashi, S.M., N. Mariun, S.B. Noor and H.S. Athab, 2005. Three-phase single switch power factor correction circuit with harmonic reduction. J. Applied Sci., 5: 80-84.

Bernard, W. and S.D. Stearns, 2002. Adaptive Signal Processing. Pearson Education, Singapore.

Kouzou, A., M.O. Mahmoudi and M.S. Boucherit, 2010. Apparent power ratio of the shunt active power filter under balanced power system voltages. Asian J. Applied Sci., 3: 363-382.

Luo, A., Z. Shuai, J.Z. Shen, W. Zhu and X. Xu, 2009. Design considerations for maintaining DC-side voltage of hybrid active power filter with injection circuit. IEEE Trans. Power Electronics, 24: 75-84.

Mattavelli, P., 2001. A closed-loop selective harmonic compensation for active filters. IEEE Trans. Ind. Appl., 37: 81-89.

Rahmani, S. A. Hamadi and K. Al-Haddad, 2012. A Lyapunov-function-based control for a three-phase shunt hybrid active filter. IEEE Trans. Ind. Electron., 59: 1418-1429.

Singh, B. and V. Verma, 2006. An indirect current control of hybrid power filter for varying loads. IEEE Trans. Power Delivery, 21: 178-184.

Sriranjani, R. and S. Jayalalitha, 2011. Improvement of the dc bus voltage of shunt active filter using controllers. Proceedings of the IEEE International Conference on Recent Advancements in Electrical, Electronics and Control, Engineering, December 15-17, 2011, Sivakasi, pp: 187-191.

Sriranjani, R. and S. Jayalalitha, 2012a. Comparison of passive active and hybrid filter in front end system. Int. J. Commun. Eng. Appl., 3: 503-506.

Sriranjani, R. and S. Jayalalitha, 2012b. Investigation the performance of various types of filter. World Applied Sci. J., 17: 643-650.

Tao, G., L. Baoshen and Z. Jin, 2009. A high precision selective harmonic compensation scheme for active power filters. Inform. Technol. J., 8: 89-94.

Vahedi, H., 2012. Double band adaptive hysteresis current control employed in active power filter. Trends Applied Sci. Res., 7: 151-159.