VOL. 10, NO. 12, JULY 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

POWER FACTOR IMPROVEMENT AND HARMONIC COMPENSATION USING ANN BASED SHUNT HYBRID FILTER FOR ACTIVE LOAD

R.Sriranjani and S. Jayalalitha
Department of Electrical and Electronics Engineering, SEEE, SASTRA University, Thanjavur, Tamilnadu, India
E-Mail: mathusri@eee.sastra.edu

ABSTRACT

In this paper, the power factor improvement and harmonics compensation for active load is acquired by the Shunt Hybrid filter (SHF). Dominant harmonic current are infused by the passive filter and the hysteresis controlled shunt active filter infuses the fundamental reactive current and other than dominant harmonic currents. Supply current detection method for controlling the active filter using Artificial Neural Network (ANN), updates the weight by least mean square (LMS) algorithm which determines the reference signal for the hysteresis controller. By trial and error, the learning rate is fixed. The dynamic response of the shunt active filter for active load is studied using MATLABSimulink and the results are verified.

Keywords: active filter, active load, least mean square algorithm, MATLAB, simulink, passive filter.

1. INTRODUCTION

The Harmonic pollution load (HPL) is more dominating in today's scenario. The main HPL is diode rectifier, thyristor rectifier and self commutated rectifier unit. The self commutated rectifier is controlled by PWM technique and space vector modulation [1],[2]. This load disrupts the other linear load activities, protective devices and rises the temperature of the transformer thus life time decreases [3],[4]. Many active filters (AF) are designed to overcome the problem raised by the HPL [5],[6]. But the cost of the filter is high because both the reactive current and harmonic current is flowing through the AF [7]. So, high rated Power devices are used in AF for harmonic compensation. In order to lessen the cost of AF, Hybrid filter (HF) was implemented for harmonic compensation and reactive power compensation [7],[8]. Many types of HF are investigated in various literatures [8]. One such type is Shunt hybrid filter. The passive filter will compensate the dominant harmonic frequency current. So the AF rating becomes scanty [9]. The AF is controlled by many techniques where the reference signal may be a harmonic current, line current or load current. The synchronous reference frame theory (SRF) and p-q (PQ) theory is used for generating reference signal [10]-[12]. The reference current is processed in any one of the technique such as PWM controller, Hysteresis controller, and sliding mode controller. In this paper Hysteresis controlled SAF is used for their simplicity in control of the hysteresis band and also the reference current is generated through the unsupervised learning process. The weight is updated by the LMS. Conventional method (SRF, p-q) involves many transformations but the new control algorithm need not any transformation and it is simple to update the weight. Using Kalman filter, the reference generation also takes much more computation time [13]. The supply current detection method is employed where the measurement parameters are the line current, supply voltage and active filter dc bus voltage. Care must be taken that the reference current should have fundamental component and there must not be a phase difference between the supply voltage and the reference current,when the HF is connected to the supply mains. The passive filter alone compensates the reactive power and harmonics but it provides fixed compensation. As the load is dynamic one, the passive filter could not provide compensation for variable load condition. So the active filter is connected which provides reactive power and harmonic compensation for dynamic load. In this paper the harmonics and reactive power are analyzed for 3Φ diode bridge rectifier with Variable RL load using Matlabsimulink. The passive and active filters are designed in Matlabsimulink to study the performance of the polluted supply. In this paper two RL loads are connected and passive filter, active filter and hybrid filter are connected and the performance of the filters is studied.

2. FILTER CONFIGURATION

a) Passive filter

The LC series combination of passive filter is tuned for the dominant harmonics of the load current. Harmonics are measured for the diode bridge rectifier with passive filter is connected to the AC mains. LC is calculated from the equation

$$f_p = \frac{1}{2\Pi\sqrt{L_p C_p}} \qquad (1)$$

Where fp= resonant frequency, Lp passive filter inductance, Cp= Passive filter capacitance

The Passive filter is designed to mitigate harmonics and diminution in reactive power for the maximum load condition. Three phase diode bridge rectifier injects fifth harmonic component as the dominant harmonic component, the passive filter is tuned for 250Hz for the fundamental frequency of 50 Hz.

b) Active filter

The SAF comprising 3Φ three wire voltage source inverter connected with the supply mains, as the current source inverter needs large dc link inductor results in poor dynamic response [13].For the maximum load condition the passive filter will mitigate the harmonics and reactive power. The necessary compensation is achieved by designing the active filter to compensate all the harmonicstheequivalent circuit of the overall system is shown in Figure-1. The AF capacitor and inductor are designed by [8].

$$L_{af} = \frac{|V_s| - |V_{af}|}{\frac{di_s}{dt}} \tag{2}$$

$$C_{af} = \frac{Vs_{max} \Delta I_s T_s}{{V^*_{af}}^2 - V_{af}} \tag{3}$$

$I_s$is supply current, T is the switching period, V^*_{af} is the reference active filter dc voltage. V_{af} is the actual dc bus voltage of SAF.

c) Shunt Hybrid filter

The equivalent circuit is shown in Figure-1. The supply current is measured and the passive filter is tuned for the fifth order harmonic frequency and the active filter injects the harmonics current other than fifth order and the fundamental reactive current.

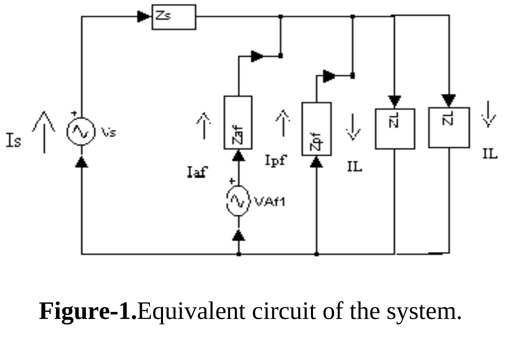

Figure-1. Equivalent circuit of the system.

So the line current is free from harmonics and power factor is near to unity. Here two different loads are connected to analyze the passive filter. When load is suddenly injected the passive filter is not able to lessen the reactive power and harmonics. Now active filter is connected after some delay, the performance of the filter is studied by measuring the THD, Power factor and reactive power for all load condition.

d) ANN technique

The least mean square algorithm is adopted for updating the weight. The block diagram shows the adaptive filtering of the supply current to generate the reference signal for the hysteresis controller [13]-[15]. The weight is calculated by the following equations,
The fundamental component is

$$I_{fund} = I_{sup} - I_{har} \tag{4}$$

The harmonic component is

$$I_{har} = I_{sup} - I_{fund} \tag{5}$$

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

$$\varepsilon_m = d_m - y_m \tag{6}$$

The output is given by,

$$y_m = {w_m}^T X_m \tag{7}$$

The weight matrix is updated by,

$$w_{m+1} = w_m + 2\mu\varepsilon_m X_m \tag{8}$$

The fundamental component is obtained by

$$I_{fund} = w_m * V_{sup} \tag{9}$$

e) Active filter dc bus voltage control

The dc voltage of the active filter is controlled by discrete PI controller where the losses of the inverter are reduced. Because of the use of passive filter the reference dc voltage of the active filter is kept as low as possible nearly 170V [9].

$$I^*_{ref} = (k+1) I_{fund} \tag{10}$$

Where k is the PI gain and I_{fund} is the fundamental line current in phase with the line voltage.

3. SWITCHING STATE

The switching pulse of the Power MOSFET is obtained from the hysteresis controller if the (I^*_{ref} -h_{band}) >I_{supply} S1 is ON, the (I^*_{ref} +h_{band}) <I_{supply} S4 is ON[11]. The remaining four switches are turned on in the similar pattern

4. SIMULATION RESULTS

The system is modeled in MATLABSimulink. Table-1 shows the specification of the system parameters. The load1 (L1) is connected at 0 sec and passive filter compensate the harmonics which is shown in Figure-2. At 0.16 sec the load2 (L2) is connected, the passive filter compensates the harmonics but it injects more reactive power to the supply mains which is shown in Table-2. In order to overcome the above problem the SAF is connected to the supply mains, the waveform shows the reduction of THD and supply current in phase with the supply voltage. Tables2 and 3 show the performance of the nonlinear load and Filter.

Table-1. The system specifications.

Parameter	Value
Source voltage (max.)	150 V
Load 1	17Ω,5mH,
Load 2	10Ω,5mH,
Inverter capacitor,V^*_{dc}	1mF, 220V
Inverter inductor	4mH
Passive filter	4.03mH, 100μF
Active filter	0.9KVA

The passive filter compensates fifth order harmonics and active filter compensates reactive power and remaining harmonics which is shown in Figure-3. The least mean square algorithm gives good dynamic response of the supply current as shown in Figure-4. The learning rate is 1e-4[28]. When the learning rate is increased the system takes more time to reach steady state. The line current follows the reference signal and phase angle is 0°, so the power factor is improved and the frequency spectrum of the PF current andSAF current, when load 2 is connected to the nonlinearload is shown in Figure-5. The SAF injects reactive current, 7th harmonic current and 11th harmonic current and passive filter injects 5th harmonic current. The filters compensate the harmonics and reactive power. So supply is free from harmonics and power is near to unity.

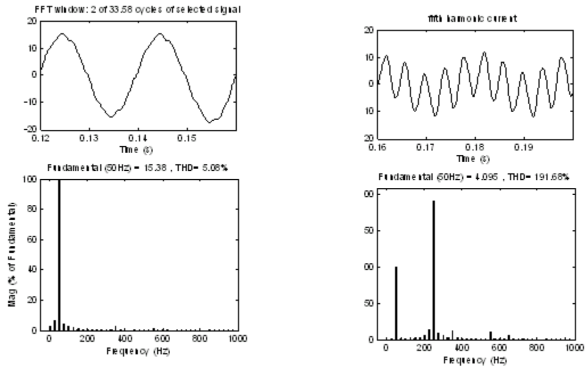

Figure-2. Frequency spectrum of supply current and passive filter current for 0.9 kW.

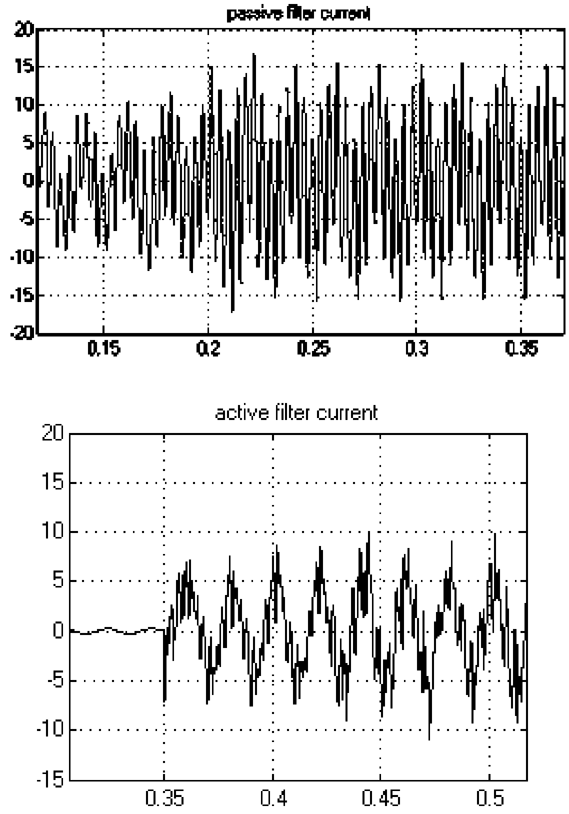

Figure-3. Passive filter current waveform and active filter current for 0.9 kW.

The THD level is minimized for the load2. Table-2 and Table-3 shows the harmonic analysis and power analysis. The reactive power is very much reduced that is from 246 VAR to 17 VAR. The frequency spectrum of line current and AF dc voltage reaches 230V which is shown in Figure-6 and the reference voltage fix on the reactive power compensation and when the reference voltage of the active filter dc bus is 50V then the reactive power is 246VAR. It is not changed when the AF is connected and only there is an improvement in power factor. If the reference voltage is increased to 180V, then reactive power is decreased to 17VAR, but the supply current is increased from 19A to 21A.

So the active power is also increased from 2000W to 2200W and the apparent power is increased from 2042VA to 2200VA. Design of active filter inductance plays an important role that the THD is reduced by properly choosing the value of inductance. The PI controller is used to limit the losses of the AF and the dc voltage is nearly constant and also the dc ripple is minimum. The KVA rating of the SHF is reduced compared to SAF.

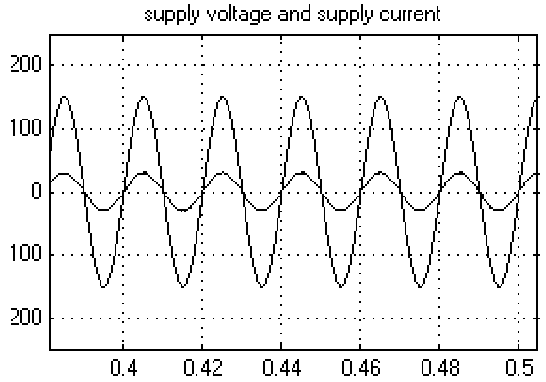

Figure-4. Passive filter current waveform and active filter current for 0.9 kW.

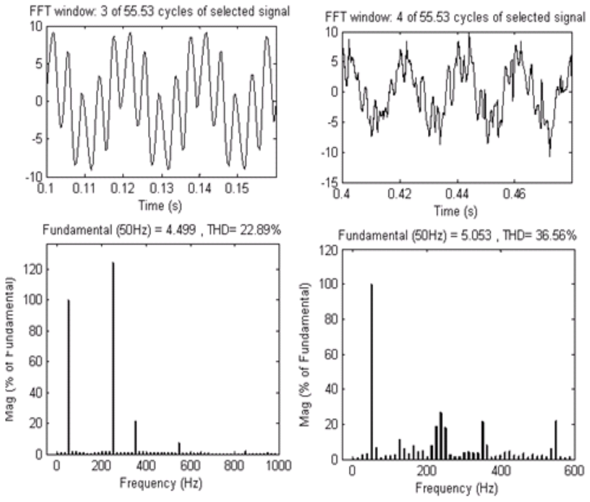

Figure-5. Frequency spectrum of passive current and active filter current for 1.9 kW.

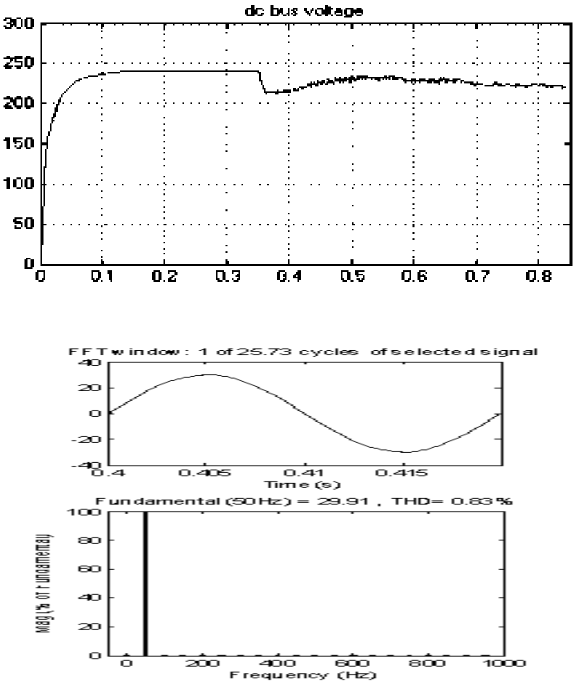

Figure-6.AF dc voltage waveformand frequency spectrum of line current for dynamic load.

Table-2.FFT analysis.

Compensation	Power factor	P (W)	Q (VAR)	S (VA)
Load1(L1)	0.9497	950.9	243.5	1001
Load2(L2+L1)	0.94	1899	603	1992
Passive filter(L1)	0.9903	1004	-147	1015
Passive filter(L2+L1)	0.9926	2000	246	2015
Hybrid filter(L1)	0.9999	1009	-6.7	1010
Hybrid filter(L2+L1)	0.9999	2200	17.06	2200

Table-3. Power analysis.

Compensation	5th%	7th%	11th%	THD%
Load1(L1)	18.74	6.38	2.16	20.05
Load2(L2+L1)	10.95	5.42	1.88	12.46
Passive filter(L1)	1.57	3.16	2.09	5.08
Passive filter(L2+L1)	0.17	0.94	1.17	1.17
Hybrid filter	0.02	0.1	0.8	0.83

5. CONCLUSIONS

The adaptive control of shunt Hybrid filter for active load has good transient and steady state response. The reference current generated for SAF using LMS reduces the time of computation compare to conventional SRF and pq technique. The transformation carried out in SRF and pq are completely ignored in LMS algorithm. For dynamic load condition, the filter responds immediately without any delay. Thus the filter compensates the reactive power and harmonics with very simple control algorithm.

REFERENCES

[1] R. Bensraj. S. P. Natarajan and V. Padmathilagam. 2010. Multicarrier trapezoidal PWM strategies based on Control Freedom Degree for MSMI. ARPN Journal of Engineering and Applied Sciences. 5(5): 32-41.

[2] K. Vinoth Kumar, Prawin Angel Michael, Joseph P. John and Dr. S. Suresh Kumar. 2010. Simulation and Comparison of SPWM and SVPWM Control for three phase inverter. ARPN Journal of Engineering and Applied Sciences. 5(7): 61-74.

[3] Y. Liu and G. T. Heydt.2005. Power System Even Harmonics and Power Quality Indices. Electric Power Components and Systems. 33(8): 833-844.

[4] A. Sowaied and M. Taleb.1996. Assessment of Power Converter Harmonics. Electric Machines and Power Systems. 24(2):147-157.

[5] Husam M. Beides and G. T. Heydt.1992. Power System Harmonics Estimation and Monitoring. Electric Machines and Power Systems.20(2): 93-102.

[6] HamzaTedjini, YoucefMeslem, Mustapha Rahli and BrahimBerbaoui. 2010. Shunt Active Filter in Damping Harmonics Propagation. Advances in Electrical and Computer Engineering. 10(3): 108-113.

[7] V. Rajini and P. Saranya. 2011. Two harmonic elimination in current source inverter Fed Drives - A Unified Approach .ARPN Journal of Engineering and Applied Sciences. 6(10): 76-86.

[8] R.Sriranjani and S.Jayalalitha. 2011. Improvement of the dc bus voltage of shunt active filter using controllers. International conference on recent advancements in Electrical. Electronics and control, Engineering (ICONRAEeCE’2011). 187-191

[9] R.Sriranjani and S.Jayalalitha. 2012. Comparison of passive active and hybrid filter in front end system. International journal of communication engineering application. 3(3): 503- 506.

[10] R.Sriranjani and S.Jayalalitha. 2012. Investigation the performance of various types of filter. World Appiled Science Journal. 17(5): 643-650.

[11] Salem Rahmani, AbdelhamidHamadi, and Kamal Al-Haddad. 2012. A Lyapunov-Function-Based Control for a Three-Phase Shunt Hybrid Active Filter. IEEE Transactions on Industrial Electronics. 59(3): 1418-1429.

[12] JoãoAfonso, Carlos Couto and Júlio Martins. 2000. Active Filters with Control Based on the p-q Theory. IEEE Industrial Electronics Society Newsletter.47(3): 5-10.

[13] RakheePanigrahi, Prafulla Chandra Panda and BidyadharSubudhi. 2014. A Robust Extended Complex Kalman Filter and Sliding-mode Control Based Shunt Active Power Filter. Electric Power Components and Systems. 42(5):520-532.

[14] R.Sriranjani, M.Geetha and S.Jayalalitha. 2013. Harmonics and Reactive Power Compensation Using Shunt Hybrid Filter. Research Journal of Applied Sciences, Engineering and Technology. 5(1):123-128.

[15] R.Venkatesh, S. Dinesh Kumar, R. Sriranjani, and S. Jayalalitha. 2014. Performance analysis of harmonic reduction by shunt active power filters using different control techniques. Journal of Theoretical and Applied Information Technology. 63(1):226-232.