Volume 1, Issue 2, April 2014 ISSN: 2348-8565 (Online)

International Journal of Modern Engineering and Research Technology

Website: http://www.ijmert.org Email: editor.ijmert@gmail.com

Power Quality Improvement through Shunt Active Power Filter

Saba Siraj
M.E. Scholar (Control Systems)
Jabalpur Engineering College,
Jabalpur, (M.P) [India]
Email: sirajsaba06@gmail.com

ABSTRACT

Non-linear loads are increasing day by day due to invention of many electrical and electronic equipment not only in industries but in domestic applications. These loads draw harmonic non-sinusoidal currents and voltages in the connection point with the utility and distribute them through it. The excessive use of power electronics devices in distribution system has evolved the problem of power quality. Deterioration of power quality is also occurring due to Arc Furnaces, Variable Frequency Drives (VFD), Computer power supplies etc. They inject harmonics in the utility supply source. This work presents the effective removal of harmonics from the devices by the use of shunt active power filter and they are useful in maintaining the quality of utility power supply. The proposed topic comprises of an insulated gate bipolar transistor (IGBT), series inductance, phase locked loop (PLL), dc link capacitor. The switching signal generation for filter is from hysteresis current controller techniques. With the all these element shunt active power filter reduce the total harmonic distortion.

In this work, three-phase shunt active power filter to compensate harmonics and reactive power by nonlinear load to improve power quality is implemented for three-phase three wire systems in a substation. The compensation process is based on sensing line currents only, an approach different from conventional methods, which require sensing of harmonics or reactive power components of the load.

Keywords:*—Insulated Gate Bipolar Transistor, Shunt Active Power Filter, Harmonic Removal, Active Power Filter, Phase Lock Loop, Hysteresis Current Controller*

I. INTRODUCTION

Early equipment was designed to withstand disturbances such as lightning, short circuits, and sudden overloads without extra expenditure. Current power electronics (PE) prices would be much higher if the equipment was designed with the same robustness. Pollution has been introduced into power systems by nonlinear loads such as transformers and saturated coils; however, perturbation rate has never reached the present levels. Due to its nonlinear characteristics and fast switching, PE create most of the pollution issues. Most of the pollution issues are created due to the nonlinear characteristics and fast switching of PE. Approximately 10% to 20% of today's energy is processed by PE; the percentage is estimated to reach 50% to 60% by the year 2010, due mainly to the fast growth of PE capability. A race is currently taking place between increasing PE pollution and sensitivity, on the one hand, and the new PE-based corrective devices, which have the ability to attenuate the issues created by PE, on the other hand.

In order to face the problem of harmonics, many solutions have been proposed. These solutions included modifications on the load itself for less harmonic emissions like the case of special structure single phase and three phase rectifier, and PWM rectifiers or the connection on the polluted power grids of other traditional or modern compensation systems.

Most of traditional harmonic reduction solutions include the use of harmonic trapping passive filters based on RLC elements calculated in accordance with the harmonic ranges to be trapped. In addition, these passive filters can be designed to compensate reactive power simultaneously with the desired harmonics. Nevertheless, these solutions are of poor efficiency due to different factors.

- Insufficient fitness for large bands of harmonic frequencies, which implies the use of many filters.
- Possibility of series and parallel resonance with the grid which lead to dangerous amplification of neighboring frequency harmonics.
- Highly dependent on the grid and load parameters and main frequency.
- Bulky equipments.
- Very low flexibility for load variations which implies new filter design for each load variation.

There are two approaches to the mitigation of power quality problems. The first approach is called load conditioning, which ensures that the equipment is made less sensitive to power disturbances, allowing the operation even under significant voltage distortion. The other solution is to install line-conditioning systems that suppress or counteract the power system disturbances. Passive filters have been most commonly used to limit the flow of harmonic currents in distribution systems. They are usually custom designed for the application. However, their performance is limited to a few harmonics, and they can introduce resonance in the power system. Among the different new technical options available to improve power quality, active power filters have proved to be an important and flexible alternative to compensate for current and voltage disturbances in power distribution systems. The idea of active filters is relatively old, but their practical development was made possible with the new improvements in power electronics and microcomputer control strategies as well as with cost reduction in electronic components. Active power filters are becoming a viable alternative to passive filters and are gaining market share speedily as their cost becomes competitive with the passive variety. Through power electronics, the active filter introduces current or voltage components, which cancel the harmonic components of the nonlinear loads or supply lines, respectively. Different active power filters topologies have been introduced and many of them are already available in the market.

II. Shunt Active Power Filter Components Used

Hysteresis Current Controller

The hysteresis band current controller for active power filter can be carried out to generate the switching pattern of the inverter. There are various current control methods proposed form such active power filter configurations, but in terms of quick current controllability and easy implementation hysteresis current control method has the highest rate among other current control methods. Hysteresis band current controller has properties like robustness, excellent dynamics and fastest control with minimum hardware. The two-level PWM-voltage source inverter systems of the hysteresis current controller are utilized independently for each phase. Each current controller directly generates the switching signal of the three phases. In the case of positive input current, if the error current e(t) between the desired reference current iref(t) and the actual source current actual(t) exceeds the upper hysteresis band limit (+h), the upper switch of the inverter arm becomes OFF and the lower switch is become ON as shown in the Fig. below.

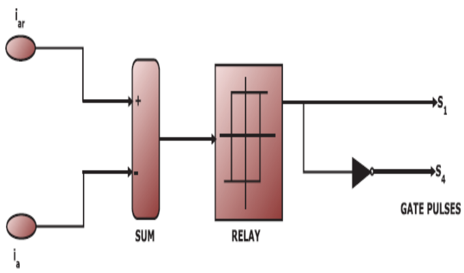

Figure 1: Hysteresis band current controllers
Advantages of Hysteresis PWM:

- Excellent dynamic response
- Low cost and easy implementation.

Disadvantages of Hysteresis PWM:

- Large current ripple in steady-state.
- Variation of switching frequency.
- The modulation process generates sub-harmonic components.

DC Link Capacitor

DC link capacitor serves two main functions:

It maintains a constant DC voltage with small ripples in steady state.

It serves as an energy storage element to supply real power difference between load and source during transients.

In steady state the real power supplied by the source should be equal to the real power demand of the load plus small power to compensate the losses in the active filter. Thus DC link voltage can be maintained at a reference value.

However, when the load condition changes the real power balance between the mains and the load will be disturbed. This real power difference is to be compensated by the DC link capacitor. This changes the DC link voltage away from the reference voltage. In order to keep the satisfactory operation of the active filter, the peak value of the reference current must be adjusted to proportionally change the real power drawn from the source. This real power charged/discharged by the capacitor compensates the real power consumed by the load.

Insulated Gate Bipolar Transistor (IGBT)

The IGBT is basically the hybrid MOS- gated bipolar junction transistor that combines the best attributes of a MOSFET and a BJT. It has lower switching losses and higher switching speed than a BJT and also has the advantage of a high impedance MOS gate drive. The device was commercially introduced in 1983 and has come to dominate the medium power (up to a several hundred of kilowatts), medium frequency(up to 50 KHz). The IGBT combines the simple gate-drive characteristics of the MOSFETs with the high current and low saturation handling capabilities in the order of hundreds of amperes with blocking voltages of 6000V, equating to hundreds of kilowatts.

The IGBT is a fairly recent invention. The first – generation devices of the 1980s and early 1990s were relatively slow in switching, and prone to failure through such modes as latch up (in which the device won't turn off as long as current is flowing) and secondary breakdown (in which a localized hotspot in the device into thermal runaway and burns the device out at high currents). Second-generation device were much improved, and the current third-generation ones are even better, with speed rivaling MOSFETs, and excellent ruggedness and tolerance of overloads.

The extremely high pulse rating of second- and third-generation devices also make them useful for generating large power pulses in areas like particle and plasma physics, where they are starting to supersede older devices like thyratrons and triggered spark gaps.

IGBTs are finding increasing applications such as in medium-power.

Applications such as dc and ac motor drives, power supplies, solid –state relays, and contractors.

III. METHODOLOGY

In this paper two case studies have been studied. In both simulations, it is used simulink and powersys toolboxes of MATLAB software and results have been seen from FFT blocks. The proposed circuit models a standard shunt AHF with IGBT inverter and series inductor on the AC side and DC capacitor energization. In this model balanced three phase three wire system with supply voltage present in the distribution system is presented at the 11kv substation is used. The loads are supplied from 11KV bus through three phase supply using 11KV/440V transformers, having capacity of 66MW.The main objective of Shunt Active Power Filter is to reduced the existing level of harmonic distortion present in the system which are injected by using nonlinear loads are studied. The THDs is recorded using Fast Fourier Transform (FFT) less is less than 1% in the system is studied.

Simulation Model Without Using Shunt Active Power Filter

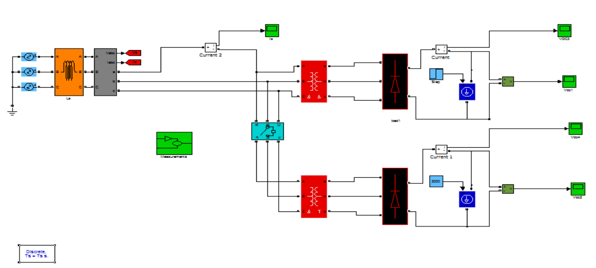

Figure 2: Block of Shunt Active Power Filter

Circuit Description

The circuit models a standard shunt AHF with IGBT inverter and series inductor on the AC side and DC capacitor energization. The load consists of two diode rectifiers which are phase -shifted by 30 degrees. The Delta-Y connected rectifier is connected after 10 cycles to change the load from 6-pulse to 12-pulse.

The AHF uses a PLL to generate a reference sinusoidal source current which is in-phase and has the same RMS gain as the load current. The current error between the load current and the reference current is generated by the IGBT Bridge through hysteresis switching. The AHF aims to inject this current error at the point of common coupling in order to match the source current as closely as possible with the reference current.

Inner Block of Shunt Active Power Filter (SAPF)

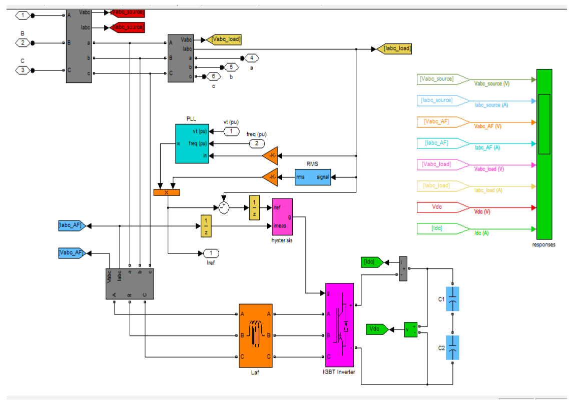

Figure 3: Block of Shunt Active Power Filter

Simulation Model with Using Shunt Active Power Filter

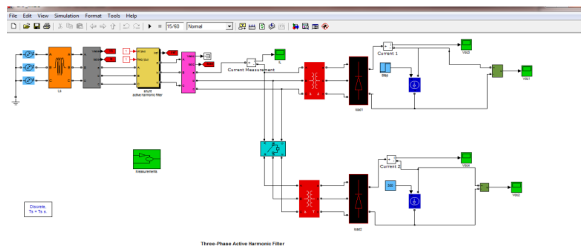

Figure 4: Block of Shunt Active Power Filter

[9] MOHAMED Maghraoui, Validation Techniques Controlling a Parallel Active Filter "," Memory Master in Electrical Engineering, University of Quebec, 2007.

[10] Abdelhamid Hamadi, Improved performance of the active filter: Application of Proportional Integral controller and fuzzy controller "," Memory Master in Electrical Engineering, University of Quebec, 2004.

[11] Schneider Electric Industries SAS, technical guide No 4, DBTP152GUI/ FR, 2008, http://www.schneider-electric.com

[12] Mehmet Tümay M. Uğraş Cuma K. Çağatay Bayındır, Çukurova University, Faculty of Engineering and Architecture, Department of Electrical & Electronics Engineering, Balcalı, Adana, Turkey.

[13] Chakphed Madtharad, Suttichai Premrudeepreechacharn, “Active Power Filter for Three-Phase Four-Wire Electric Systems Using Neural Networks”, Electric Power Systems Research 60 (2002), pp.179-192.

[14] J. Zeng,C. Yu, Q. Qi,Z. Yan, Y. Ni, B. L. Zhang, S. Chen, F. F. Wu, “ A novel hysteresis current control for active power filter with constant frequency”, Electric Power Systems Research (2003), pp.1-8.

[15] M. El Habrouk, M. K. Darwish, M Pehta, “Active Power Filters: A Review”, IEE Proc. Electr. Power Appl. Vol.147, No.5, September 2000, pp. 403-413.

* * * * *

IV. Simulation Results

Results and Discussions

Table: Readings Taken from Simulation

Order of harmonics	**Harmonic components(% of fundamental)**					
	Without Shunt Active Filter			**With Shunt Active Filter**		
	Reference current	**Load current**	**Source current**	**Reference current**	**Load current**	**Source current**
3	16.21	16.54	13.78	18.16	0.01	0.00
5	8.69	8.87	7.19	6.54	0.00	0.01
7	6.02	6.23	4.95	4.50	0.00	0.01
9	4.62	4.93	3.80	3.56	0.00	0.01
11	3.76	4.30	3.08	2.91	7.43	0.00
13	3.17	7.71	2.63	2.44	5.87	0.01
15	2.74	3.63	2.24	2.07	0.01	0.00
17	2.42	1.58	1.98	1.80	0.00	0.00
% THD	**43.17 %**	**43.88 %**	**36.70 %**	**40.00 %**	**9.85 %**	**0.60%**

1. Simulation model without shunt active power filter. Frequency spectrum

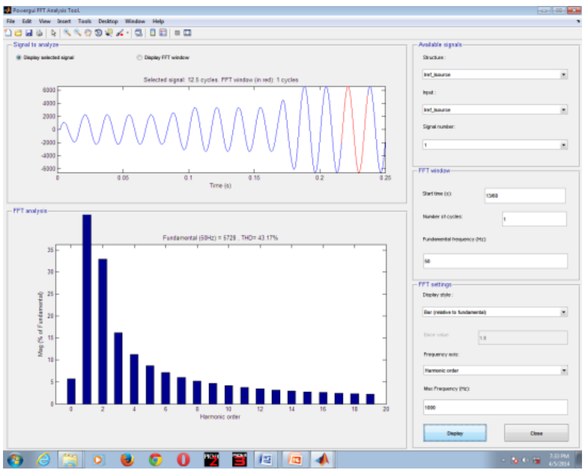

Figure: Graph showing Frequency Spectrum without Shunt Active Power Filter for Reference Current

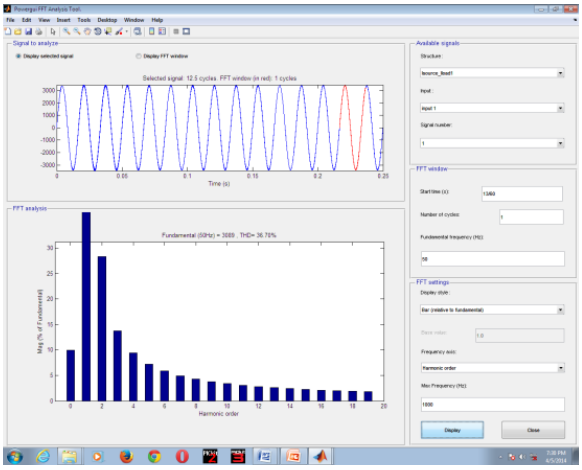

Figure 6: Graph showing Frequency Spectrum without Shunt Active Power Filter for Load Current

2. Simulation model with shunt active power filter:

Without use of any filters the total harmonic distortion is very high. Therefore shunt active power filters were used to improve THD and this make the supply current more sinusoidal. The system consists of shunt active power filter, balanced supply system, nonlinear load.

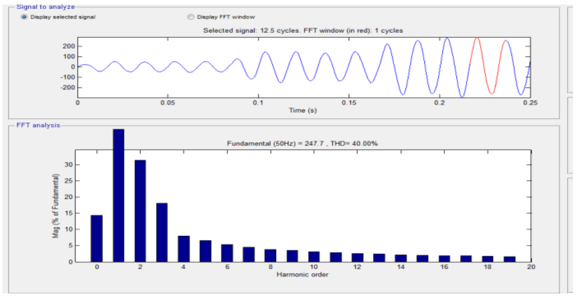

Figure 7: Graph showing Frequency Spectrum with Shunt Active Power Filter for Reference Current

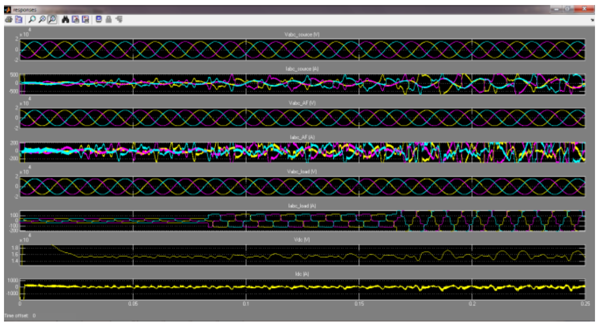

Figure 8: Voltage & current waveform in Shunt active filter responses

FFT waveform of source &load Current with SAPF

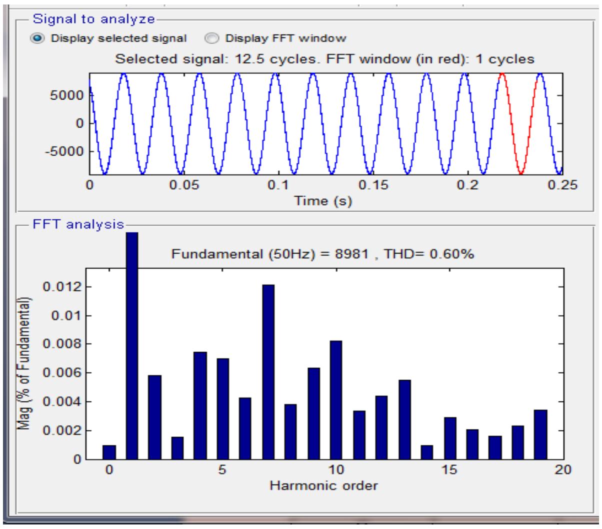

Figure 9: Graph showing Frequency Spectrum with Shunt Active Power Filter for Load Current

V. CONCLUSION

A comparative study using shunt active power filters & without using shunt Active Power Filter are used. When no filter filters were used the total harmonic distortion (THD) was very high 36.70%. But according to IEEE standard THD should be below 5%, therefore active filters were used. On using shunt active filter THD reduced to 0.60%. Hence it is proved that by using active power filter for three phase three wire system is giving better results and supply current is more sinusoidal and less of harmonics.

VI. FUTURE SCOPE

- Experimental investigations can be done on shunt active power filter by developing a prototype model in the laboratory to verify the simulation results for both P-I and hysteresis controllers.
- The extension of work can be done on high level for industrial purpose.
- This process can also analyze using 3ph. & 4 wire for fuzzy and neural networks.

REFERENCES:

[1] IEEE-519, IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems, 1992.

[2] IEC 61000-3-4, Limitations of Emissions of Harmonic Currents Low -voltage Power Supply Systems for Equipment with Rated Current Greater than 16A, 1998.

[3] A. Sahbani, M. Labben-Ben Braiek, M. A.Dami et M. Jemli, Controlling a three phase shunt active fuzzy logic filter"", 3rd International Conference, SETIT, Tunisia, March 27-31, 2005.

[4] Mr. AlaaEddin Alali, "" Contribution to the Study of Assets Clearing Low Voltage Electric Networks "", Thesis PhD from the University Louis Pasteur, Strasbourg I, 2002

[5] Hanan Kourara, "Application of afilter active series to control the tension on a network. Basse Tension," Student Kouara Hanane (born 08February 2006)

[6] Mohd Izhar Bin A Bakar, Active Power Filter with Automatic Control Circuit for Neutral Current Harmonic Minimization Technique"", PhD Thesis, Universiti Sains Malaysia, 2007

[7] François Defay, "Direct Predictive Control of a Three Phase Converter To A Multicell Application Filtering Active "", PhD Thesis, University of Toulouse, 2008.

[8] Keith H. Sueker, Power Electronics Design: A Practitioner's Guide", Newnes, SciTech Publishing, 2005