Power Quality Improvement by Using Active Filter with Hysteresis Band Controller

S. Bharathkumar, S. Satheesh
Department of Electronics and Communication Engineering, Sethu Institute of Technology, Virudhunagar, India

Article Info
Article history:
Received 13 February 2015
Received in revised form
20 February 2015
Accepted 28 February 2015
Available online 6 March 2015

Keywords
Power Quality;
Hybrid Filter;
HB controller;
Total Harmonic Distortion (THD)

Abstract

The power quality (PQ) management is the key issue in electrical power system and industries are facing this issues around the world. The hybrid filter configuration with HBController is more efficient scheme for the improvement of power quality in power system. The main purpose of this work is to reduce the effects of Harmonics in a cost effective by mitigating both voltage and current harmonics generated in anelectrical power system owing to the presence of non linear loads. This paper shows comparative study of a simple filter circuit, circuit with hybrid filter and a circuit with hybrid filter using HBcontroller. The systems are modeled by using SIMULINK in MATLAB and performance is observed. The simulation results reveal that the proposed method of hybrid filter with PI controller is the better solution for improving power quality.

1. Introduction

To develop and maintain the modern economy & society, the economical, social and environmental sustainability are required in the emerging future trends of energy. For the economical and social growth, the prime movers are more important. The electrical energy is main prime mover for this. So the electrical energy is most important elements for thesociety and industry. The quality and reliability of the power supply are more required for the health of electrical power systems [1]-[2].Both electric utilities and consumers of electricity are mostly concerned a to the power quality of electricity. The issue power quality has turn out to be one of the most necessary words in the power industry, since the late 1980s. In the power utility distribution systems, the power quality (PQ) problems are not new, but now a days due to the public awareness these problems are becoming popular. By invention of the advances technology in semiconductor device has fuelled a revolution in power electronics over the last decade and there is direction to the technocrats to continue this trend [2]. With more application of power electronics based appliances in the industry, the harmonics problem arises and which is more serious and dangerous. The power electronics based equipments viz. adjustable speed motor drives, Battery chargers, electronic power supplies, DC motor drives are responsible for the enhancement of issues in power quality [3-4]. According to characteristics of power converters viz. nonlinear, are cause serious problems of poor power factor, current harmonics, non sinusoidal supply voltage, reactive power burden and low system efficiency [5].The nonlinear loads are primary sources of harmonic distortion in any distribution system. From beginning to end, the point of common coupling (PCC), harmonic distorted currents are injected into power a distribution system, which is produces by the nonlinear loads. The harmonics are generated owing to the many problems and affect the electrical equipments connected to the power supply [6]. When the non sinusoidal currents pass through different impedances in power systems then voltage harmonics produces. Due to the propagation of voltage harmonics in power systems, the power system component and devices are affected. The important harmonic source is AC/DC converters and inverters [7]. Hence, due to the serious issues there is need of power quality improvement techniques which can suppress the voltage and current harmonics, improves the power factor and also balance the input supply. A number of circuit configurations of filter are available to limit the distorted harmonic current. The active power filters as well as passive power filters have been implemented to reduce the ailing impacts of harmonics to electric power quality. So this becomes an important trend in operation of distribution system [8]. Passive filters, which act as least impedance path to the tuned harmonic frequencies, were used initially to reduce harmonics. This technique is simple and less expensive. But it has many drawbacks viz. resonance, fixed compensation characteristics, large size, high losses at no load etc. The technology for active power filters configuration have been developed for complete compensation of harmonics distortions. Active filters are very helpful to conquer the drawbacks of passive filter by using the switched mode power (SMPS) converter by eliminating the complete harmonic voltage and current distortion. The harmonic currents and reactive power compensation simultaneously can be suppress by suitable control techniques with the shunt APFs to generate a compensating current in equal and opposite direction so that source current becomes harmonic free. However, the power rating and manufacturing cost of APFs is very high. The hybrid filter configurations play a great roll to avoid the limitations of passive and active filters. The power rating of active converter, using the application of the passive filters with the active filter, is reduced with respect to the pure active filters. This hybrid filter is having the advantages of both active and passive filters. So the hybrid filters are cost effective and become more practical in industry used. The block diagram of a hybrid filter is shown in fig.1 [9]. In this paper the authors discussed a hybrid filter configuration to suppress harmonic current distortion in the source current. This system is

Corresponding Author,
E-mail address:

combination of Series Active Filter (SAF) and Shunt Passive Filter (SPF). Many of the important international standards define power quality as to maintain the pure sinusoidal current waveform in phase with the pure sinusoidal voltage waveform. Therefore, a power quality problem occurs due to any of the voltage, current or frequency deviation from sinusoidal nature occurs. Power quality problems are common in industrial, commercial and utility networks as power electronics appliances are widely used in these fields. The power electronics devices generate harmonics and reactive power.

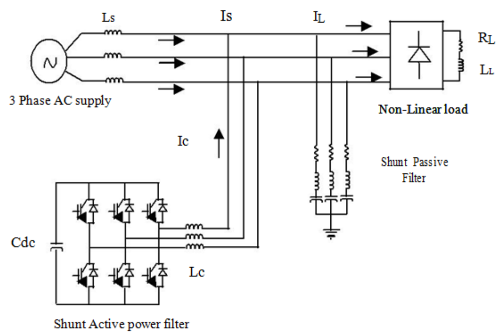

Figure 1. Hybrid Filter Configuration

Therefore it is very important to compensate the dominant harmonics as well as total Harmonic Distortion (THD) below 5% as per specifications of IEEE 519 [10]. Harmonics not only influence the normal work state of electric equipments, but also interfere the communication equipments. At present, passive power filter (PPF), active power filter (APF) and hybrid active power filter (HAPF) are mostly preferred to eliminate the harmonics [11]. Harmonic pollution is not a new phenomenon, issues of harmonic components of voltage and / or current curves occurred early in the industrial use of electricity, the first mention regarding to the use of harmonic analysis as a way of solving a practical electrical engineering problem, was made in 1893 by Steinmetz. Nowadays, in modern industry, about 50% of receivers, an industrial customer are supplied using frequency converters (AC and DC adjustable drives), switching mode power supply (for powering computer systems or process controllers) and electronic ballasts. Due to presence of nonlinear characteristics of the receivers, the resonance phenomena produce in distribution systems. This may increase the harmonic components which lead to the increase in the voltage in different parts of the electricity supply system, overloading of transformers and, in particular capacitor. Also, can causing losses increasing in overhead electric lines, cable, transformers and capacitor banks, leading to acceleration of insulation aging and reduction life [12]. The designing of the filters are primarily required for the best functioning of distribution systems. While designing a filter, the size, the total investment cost and the unacceptable voltage profiles should be corrected as well as the harmonic distortion must be reduced within the permissible value as per IEEE Std. 519 [13]), is keep at a minimum. The cost of an active power filter is expensive enough for practical installation. Actually, the passive filters using series resonant capacitors and inductors with parallel resistors have been widely used as harmonic improvement devices in distribution systems. Recent surveys show that the performance of an active power filter in most of the industrial plants is more or less sensitive to the voltage disturbances. Particularly, voltage sags are the most concerns, and causing the frequent protection tripping, incorrect load operation, interruption of processes and even may shut down the whole industrial plant. [14]. In this paper the Simulink model is developed to reduce the effects of Harmonics in a cost effective and practical way by mitigating both current and voltage harmonics generated in a power system due to the presence of non-linear loads.

A comparative study of a simple circuit, circuit with hybrid filter and a circuit with hybrid filter using P-I Control strategies have been done. The systems are modeled by using MATLAB/SIMULINK software and performance is observed.

2. Hbpwm Current Control

The HBPWM is basically an instantaneous feedback current control method of PWM where the actual current continually tracks the command current within a specified hysteresis band. [3]

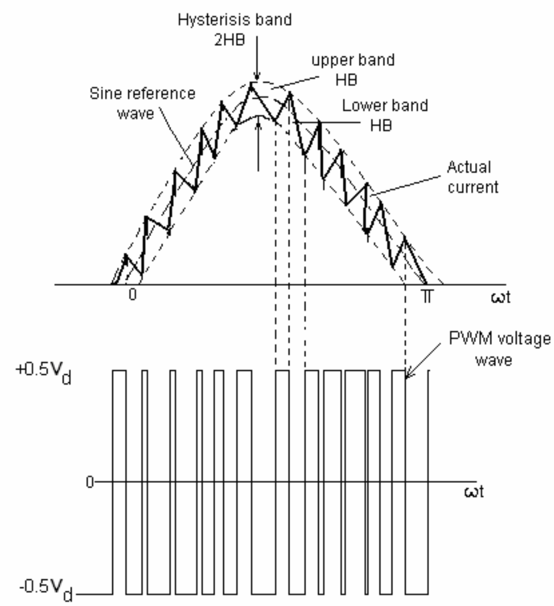

Fig: 1. Principle of Hysteresis Band Current Control

The Fig 1 explains the operation principle of HBPWM for a half bridge inverter. The control circuit generates the sine reference current wave of desired magnitude and frequency, and it is compared with the actual phase current wave. As the current exceeds a prescribed hysteresis band, the upper switch in the half-bridge is turned off and the lower switch is turned on. As a result the output voltage transitions from +0.5Vd to -0.5Vd, and the current starts to decay. As the current crosses the lower band limit, the lower switch is turned off and the upper switch is turned on. The actual current wave is thus forced to track the sine reference wave within the hysteresis band by back- and-forth switching of the upper and lower switches. The inverter then essentially becomes a current source with peak to peak current ripple, which is controlled within the hysteresis band irrespective of Vd fluctuation. The peak-to peak current ripple and the switching frequency are related to the width of the hysteresis band. The HBPWM inverter control method is shown in the Fig 2. The inputs to the HBPWM controller are three phase current errors and the outputs are the switching patterns to the PWM inverter. k in the figure represents the normalization factor and is used for the purpose of scaling the current error input to the HBPWM controller. PS is the pulse separation circuit for the separation of pulses to the IGBTs in the upper and lower leg of the inverter. [4]

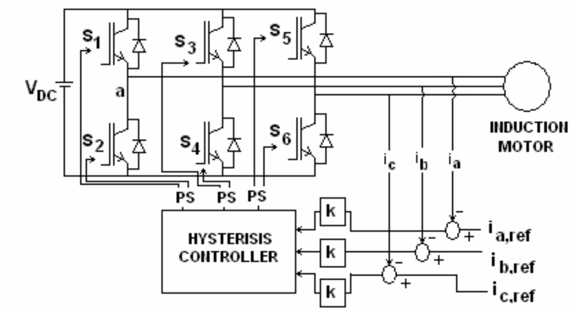

Fig: 2. Conventional HBPWM Inverter Control Method

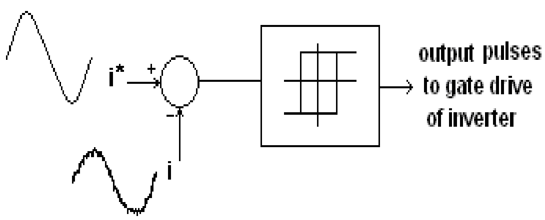

Fig: 3. Control Block Diagram for HBPWM

The main drawback of this method is that the PWM frequency is not constant and, as a result non optimum harmonics will result.

3. Hybrid Filter Design

The designing of hybrid filter is described in [4], which based on compensated load. It involved the passive parameter viz. capacitor, and inductor. LC branches are important for harmonic load current to be removed from the source current. In the case of non-linear loads, it is usually enough to employ one, two or three branches for the main harmonics. By three phase systems it is possible to reduce or eliminate .The harmonic of 3rd order and its multiples by choosing correct connections of the transformers supplying the power to the load. Therefore it is usual to include LC branches tuned for the 5th and 7th harmonic order. For the "n" order of harmonic

There are different schemes to control the compensation voltage. In any balanced three-phase system, a voltage is proportional to the harmonic source current which allowed to changes the impedance by which the performance can be enhance of the shunt compensator and the passive filter. With the current source, the non linear load is modeled.

4. Model Representation

For the smooth operation of any power system, the quality and reliability, of the supply of electricity to the optimum cost is prime requirement. The life of power system can be enhanced, with the installation of power electronics devices with nonlinear loads, and with the application of hybrid filter configuration. To reduce the harmonic distortion, the hybrid filters are one of the most effective configurations.

The three models have been simulated in SIMULINK. The harmonics of source current and voltage are obtained. The three models simulated are:

- System with non linear load without using filter.
- System with non linear load with hybrid filter
- System with non linear load with hybrid filter using HB Controller.

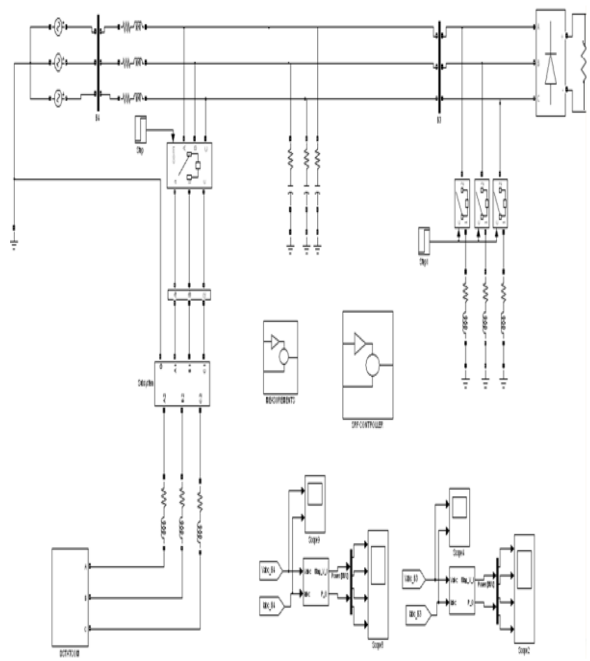

Fig: 4. Schematic diagram of SHPF with Hysteresis Controller

Inductance(L1)	11.24 mH
Capacitor(C1)	0.9 mF
Inductance(L2)	15.6 mH
Capacitor(C2)	0.6 mF
Inductance(L1)	11.24 mH

Table: 1. Comparison of THD in % for Using Schemes

With out filter	29.37%
With HAPF	24.02%
HAPF with hysteresis controller	9.78%

5. Simulation Results and Discussion

In this paper, three schemes are considered. In the first scheme the model is developed without any filter using non linear load which shown in fig.1. After simulation, fig3.shows the waveform of current source without filter.Fig.8 shows THD is 29.37%. In the second scheme the Simulink model is developed using hybrid filter.fig.4 shows the waveform of current source. Fig: 9. shows THD is 24.05%. The third scheme represents the model with hybrid filter controlled by HB Controller which shown in fig. The fig. 5 shows the waveform of current source. Fig.10 shows THD is 9.7%. table 1, the values of parameters of passive filter and. The table2 shows the compression of THD in each case. Fig. 2 Waveform of voltage Source without filter

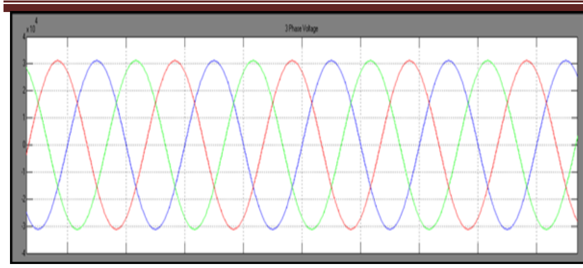

Fig: 5. Wave forms of Supply Voltage (V)

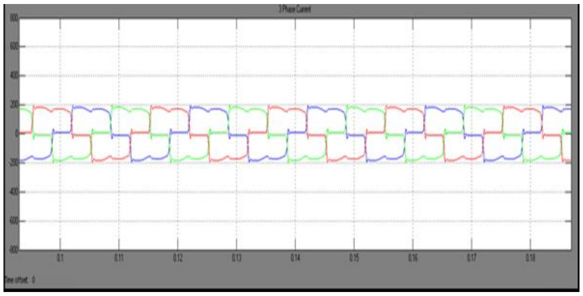

Fig: 6. Waveform of Supply Current (A) without filter

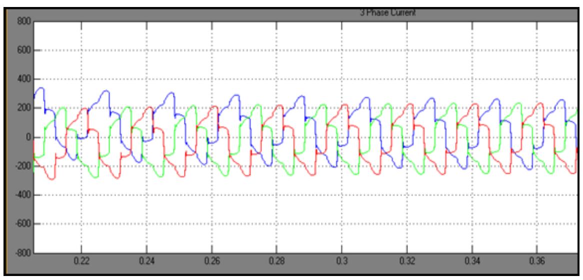

Fig: 7. Waveforms of Supply Current (A) with HAP filter

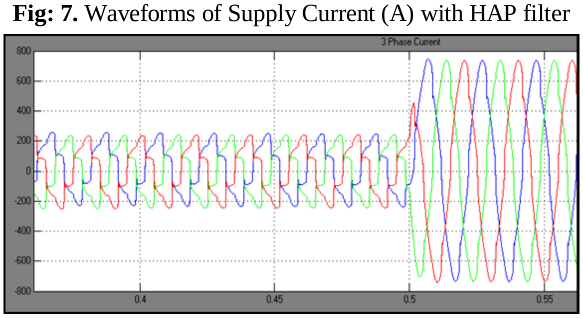

Fig: 8. Wave forms of HAP filter with hysteresis controller

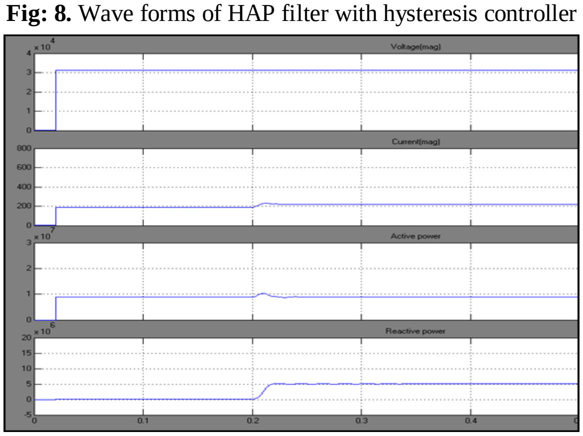

Fig: 9. Wave forms of (v), (A), reactive and real power before compensation

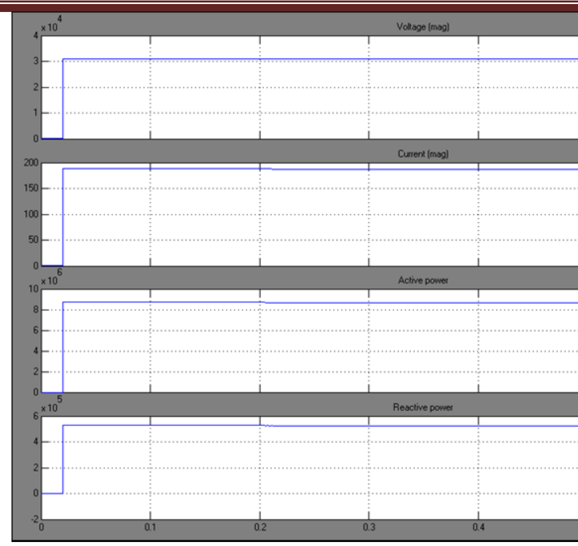

Fig: 10. Waveforms of reactive and real power after compensation

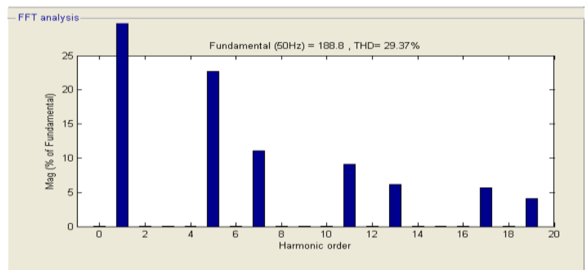

Fig: 11. THD calculation without filter

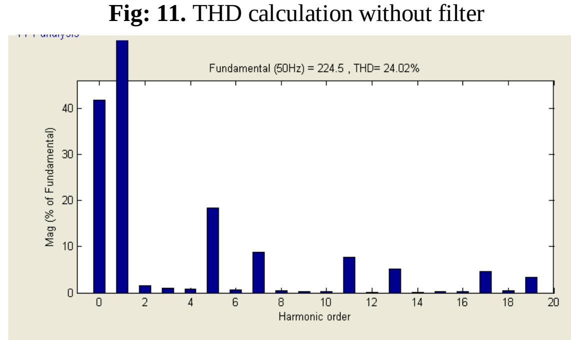

Fig: 12. THD calculation with HAP filter

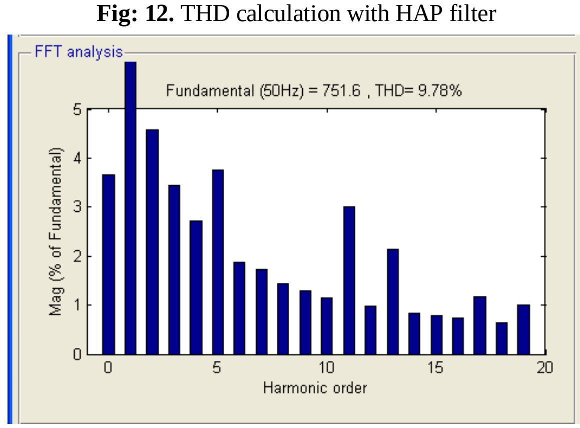

Fig: 13. THD calculation with HAP filter and hysteresis controller

6. Conclusion

This project work presents design of shunt hybrid power filter for a distribution system. The hybrid filter reduces the harmonics as compare to open loop response. This hybrid filter is tested and verified using MATLAB program. A hysteresis controller is implemented for three phase shunt hybrid power filter. The hysteresis controller extracts the reference current from the distorted line current and hence improves the power quality parameters such as harmonic current and reactive power due to nonlinear load. We obtained it from the simulation responses. The shunt hybrid power filter is verified with the simulation results. The performance of the hysteresis controller is verified with the simulation results. Hence we obtained comparative results by using these controllers. The comparative simulation results for non-linear load is presented fig.

References

[1] Aadesh Kumar Arya, Saurabh Chanana and Ashw Smart Grid to Power System Planning and Opera of Int. Conf. on Emerging Trends in Enginee GIMT, Kurukshetra

[2] C. Gao, M. A. Redfern, A Review\ Smart Metering Technologies oInternational conference, Univer (UPEC), Soest, Germany

[3] W. E. Kazibwe, M. H. Sendau Techniques, Van Nostr and Rein

[4] R. C. Dugan, M. F. Mc Granaghan, Power Systems Quality 2nd

[5] Wei-Fu Su, Chin E. Lin, Ching-Li power quality improvement, El, 1998, 165–171

[6] R. Belaidi A. Haddouche, HBased Three-Phase Shunt Acti Harmonics and Reactive Power Energy Procedia, 560, 18

[7] Rashmi S. Phasate, Archana Baw Matrix Converter Using HybridSystem Operation and Energy Ma– 4407, 2011

[8] G. Ahrabian, F. Shahnia, M. for Power Quality Improveme Utilizing Renewable Energies, Industrial Electronics, Montreal, 2006

[9] Laxmi Devi Sahu, Satya Praka Power Filter for Harmonics, International Journal of Power Evol. 2(3), 241-248

[10] Roger C. Dugan, Mark F. Mc Gr. Beaty, Electrical power syEducation, 2012.

[11] Wei Zhaoa, Ruimin Chena, An Control Method used in Shunt Procedia, 16, C, 1

[12] Jarupula Somlal, Efficient HybriImprovement of Power Factor a MATLAB, In proceeding of 10 thon communications, electrical & USA, 195-199, 2011

[13] S Z. Shuai, A. Luo, R. Fan, Injhybrid active power filter, Aupp. 2007, 57–60

[14] Jingrong Yu, Shiqi Ding, Yijunengineering design and optimizapower filter, Electrical Power a48, 2013

[15] H. Akagi, Y. Kanazawa and Instantaneous Reactive Power the IEE-Japan, Part B, 103

[16] R. Belaidi, A. Haddouche, H Based, Three-Phase Shunt Act Harmonics and Reactive Power Energy Procedia, 18, 56w of Voltage Control in Smart Grid and on Distribution Networks, In Proc ofrsities Power Engineering Conference -5, 2011