Harmonic mitigation using single phase active power filter controlled by hysteresis current controller

Jyoti Singh[1] Dr. Girraj Prasad Rathor[2]

Research Scholar, Department of Electrical and Electronics TIT &SCIENCE BHOPAL(MP)

Associate Professor Department of Electrical and Electronics TIT &SCIENCE BHOPAL(MP)

Abstract

In this paper a single-phase active power filter is connected to a single-phase grid with non-linear load. The single-phase active power filter mitigates the harmonics generated by the non-linear load connected at PCC. The harmonics generated by the non-linear load are redirected to active power filter direction so as to avoid injection into the source damaging it. The novel single phase active power filter has half bridge connected to share capacitors. The two power electronic devices of the active power filter are controlled by parabolic PWM with feedback from the source voltage and load current for compensation of harmonics in source current. The parabolic PWM is compared to hysteresis controller with reduction in source current harmonics with the use of hysteresis controller. The circuit of both the controllers with active power filter connected to single phase grid is modelled in MATLAB Simulink environment with graphs generated with respect to time.

Key words: Keywords-shunt active power filter, parabolic PWM, harmonics mitigation power quality; power factor improvement

1.INTRODUCTION

Filters are the networks that possess the property of differentiating between the signals of various frequencies and passing the signals of specific frequency only while the signals of the other frequencies not belonging to this range are suppressed or attenuated.

The frequencies that are allowed to pass through the filters are termed as pass band and the frequencies that are totally suppressed or attenuated are termed as stop band or attenuation band. The frequency that separates the stop band and pass band is termed as cut-off frequency [2].

Filters are classified on the basis of working characteristics, application field, relation between arm impedances, frequency characteristics etc.

On the basis of its application field the filters are classified as follows:

- Passive filters
- Active filters
- Hybrid filters

These are further classified as shunt or series passive/active filters.

1.2INTRODUCTION TO ELECTRICAL POWER QUALITY

Electric power quality can be described as the degree to which the voltage, frequency and waveform of a power supply system match to established specifications. A good power quality can be stated as a steady supply voltage that remains within the prescribed range, a steady ac frequency that is close to the rated value and smooth voltage curve waveform preferably a sinusoidal wave. In other words, it can also be stated as the compatibility between output of an electric outlet and the plugged-in load. In absence of proper power, an electrical device tends to malfunction, prematurely fail or not at all operate. While "power quality" is a suitable term but actually it is the quality of the voltage rather than power or electric current that is actually described by it[4].

The power quality may be expressed as a set of values of parameters, such as:

- Continuity of service irrespective of voltage sag/swell
- Voltage magnitude variations
- Transient currents and voltages
- Harmonics in the waveforms

Compatibility is the major term associated with power quality and the problems associated with it usually have two solutions: i.e., either to clean up the power or to make the equipment stronger. The CBEMA curve, gives the characteristics of tolerance of data-processing equipment to voltage variations, and also gives the duration and magnitude of voltage variations that can be tolerated. (CBEMA Curve: Ideally, an AC voltage is supplied in form of a sinusoidal waveform having an amplitude and frequency given by national standards or system specifications with an impedance of zero ohms at all frequencies.)

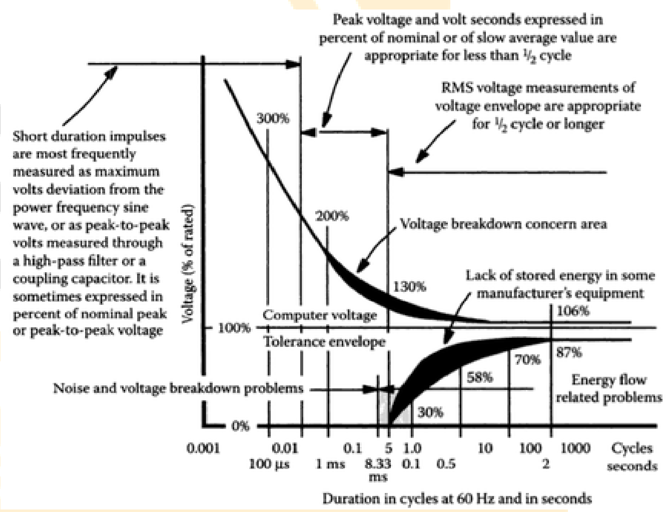

Fig. 1 CBEMA Curve

1.3 POWER QUALITY DEVIATIONS

It is impossible to find an ideal power source in real life and generally power quality can deviate in the below mentioned ways:

a) Voltage

- Variations in the values of peak or RMS voltage (voltage sag/swell)

- Flickering: rapid visible changes of light level that leads to random or repetitive voltage variations.
- Spikes, impulse or surges: brief and abrupt increases in voltage
- Under voltage: when the nominal voltage drops below 90% for more than 1 minute.
- Overvoltage: occurs when the nominal voltage rises above 110% for more than 1 minute.

b) Frequency

- frequency variations
- Non zero low-frequency impedance
- Nonzero high-frequency impedance
- Harmonics at lower frequencies
- Inter harmonics at higher frequencies

c) Waveform

- Usually, oscillations of voltage and current follow a sine or cosine function form, however due to imperfections in the generators or loads there occurs variations.
- In general, generators cause voltage distortions and loads causes current distortions, that are more rapid than the nominal frequency, and are termed as harmonics.
- The distortion of the ideal waveform due to harmonics is termed as total harmonic distortion (THD).
- These waveform distortions can cause vibrations, buzzing, losses and overheating.

All the above said power quality deviations, has some cause and effect on the entire system like some problems are the result of shared infrastructure. A fault on the network may result in a dip that may affect some customers. The fault level decides the number of customers affected. Similarly, a problem(harmonics) on one customer point may lead to a transient that affects all the other customers on the same subsystem and may propagate onto the network as well.

2.METHODLOGY

The proposed Shunt Active Power Filter is for single phase systems. Fig.2 shows the circuit configuration and The SAPF is placed parallel to the non-linear load. A half-bridge voltage source inverter is employed with two neutral clamped capacitors as DC-bus. The inverter will inject the compensation current in the power system through an R-L branch. Load current sensor and PCC voltage will be sensed and fed to the controller section along with the voltages from two DC-bus capacitors. Output of one controller is fed to another. Hence, it is understood that the system can be unstable if any one of the controllers becomes unstable.

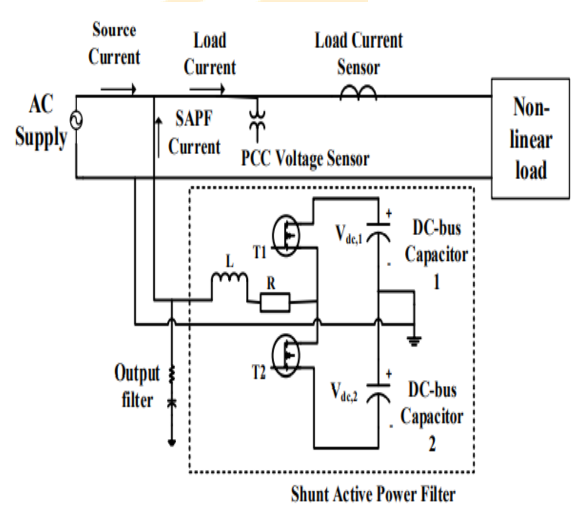

Figure 2 Power circuit of single-phase SA

2.1 Hysteresis Current Controller

The hysteresis band current controller is used to generate pulses for the switching pattern of the inverter. There are numerous current control methods, but quick current controllability and easy implementation make hysteresis current control method much more superior than other current control methods. Some of the better properties possessed by hysteresis band current controllers are robustness, excellent dynamics and fastest control with minimum. This method switches the transistor when the current error fed to it exceeds the fixed band. Smaller the band width better is the accuracy. If current becomes more than the upper limit of the hysteresis band (+h), the switch in the upper part of the inverter arm becomes turned off and the switch in the lower arm becomes turned on. Hence, the current starts decreasing. While decreasing if the current falls below the lower limit of the hysteresis band (-h), the lower switch of the inverter arm becomes turned off and the upper switch becomes turned on. Consequently, the current gets back into the hysteresis band. So, the actual current is forced to follow the reference current within the hysteresis band. Operating principle of hysteresis current controller is depicted in the Fig.3 Variable switching frequency is the disadvantages of this method.[8]

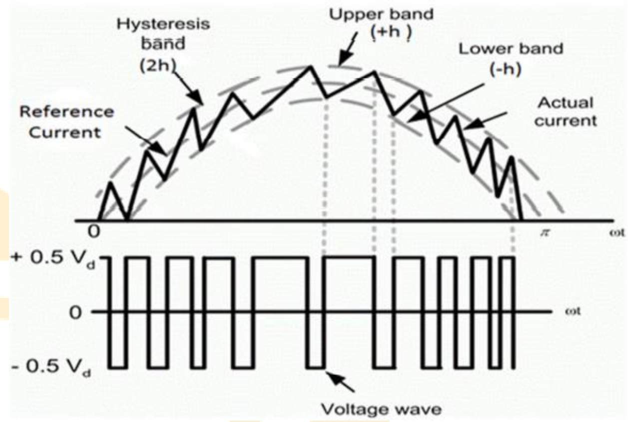

Fig.3 Hysteresis band

3.RESULT ANALYSIS & DISCUSSION

Figure 4 showcases the proposed model of single-phase grid connected shunt active power filter along with half bridge voltage source inverter containing two MOSFET switches T_1 and T_2. The two clamped capacitors, C1 and C2 on the other leg, acts as a DC bus as well as helps in current compensation.

Figure 5 showcases the parabolic PWM controller that undertakes the current control of the SAPF along with source voltage feedback connected to PLL for synchronization of pulses to grid voltage. It provides fast dynamic response and constant source current. Figure 6

showcases a Hysteresis PWM controller of SAPF. Unlike parabolic PWM controller, this is holds simple construction and dynamic response and the MOSFET switches are operated alternatively with the help of NOT gate.

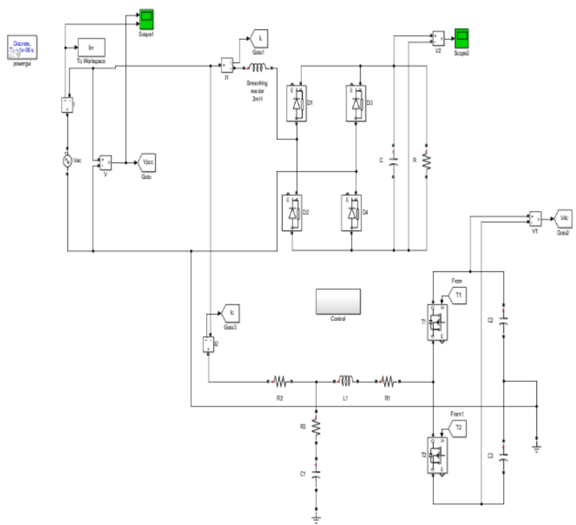

Fig.4 Proposed test system with single phase active power filter

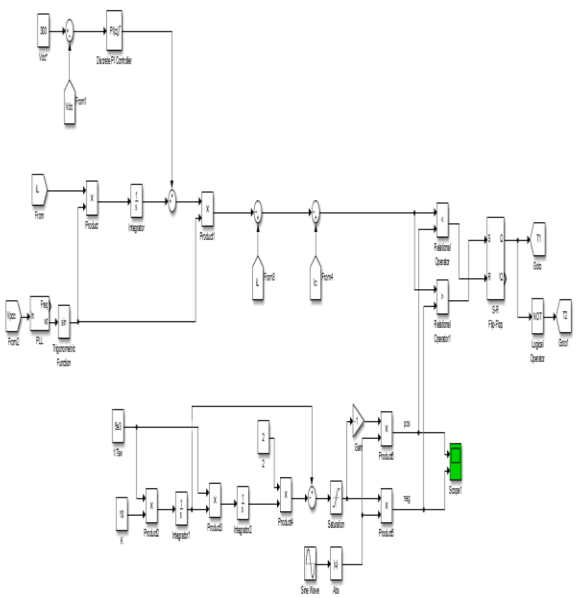

Fig.5 Parabolic PWM controller of single-phase active power filter

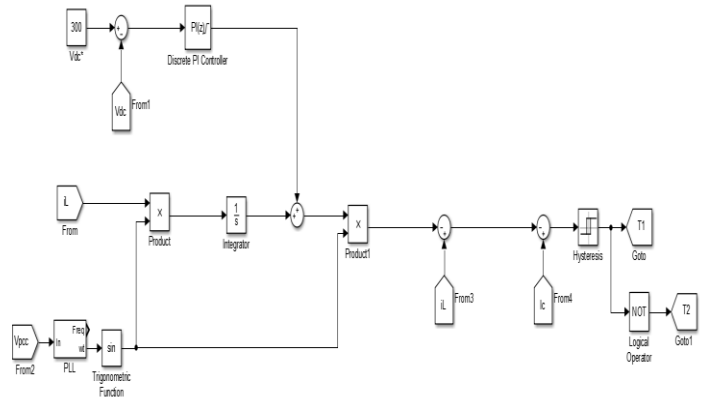

Fig.6 Hysteresis PWM controller

The figure 7 and figure 8 showcases the measured source voltage and current before the connection of active power filter.

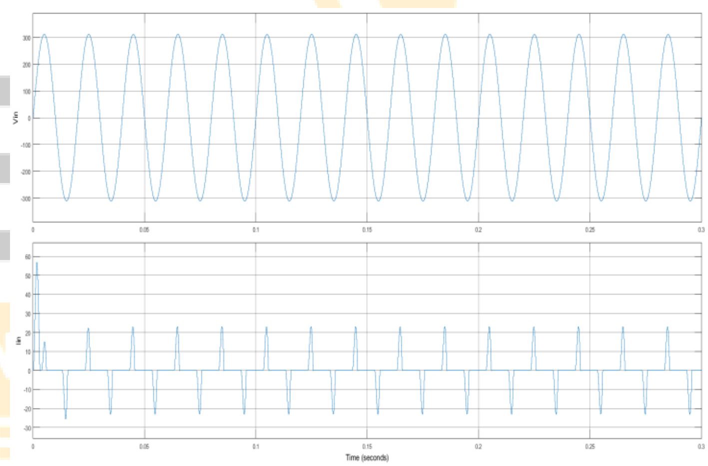

Fig.7 Source voltage and current (without active power filter)

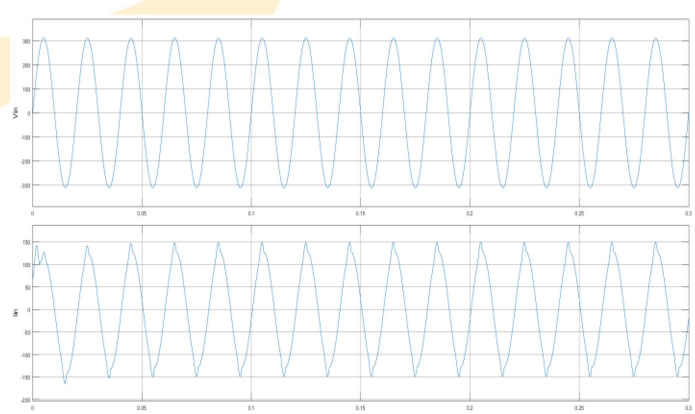

Fig.8 Source voltage and current (with active power filter)

The FFT analysis of the source current is done by determining the THD. The figure 9 depicts the THD in the absence of SAPF which accounts for about 140.46%. The same THD is about 6.24% in presence of a SAPF with parabolic PWM controller as shown in figure 10 Figure 11 depicts the THD for same set of values for a hysteresis PWM controlled SAPF and it value is about 3.98%.

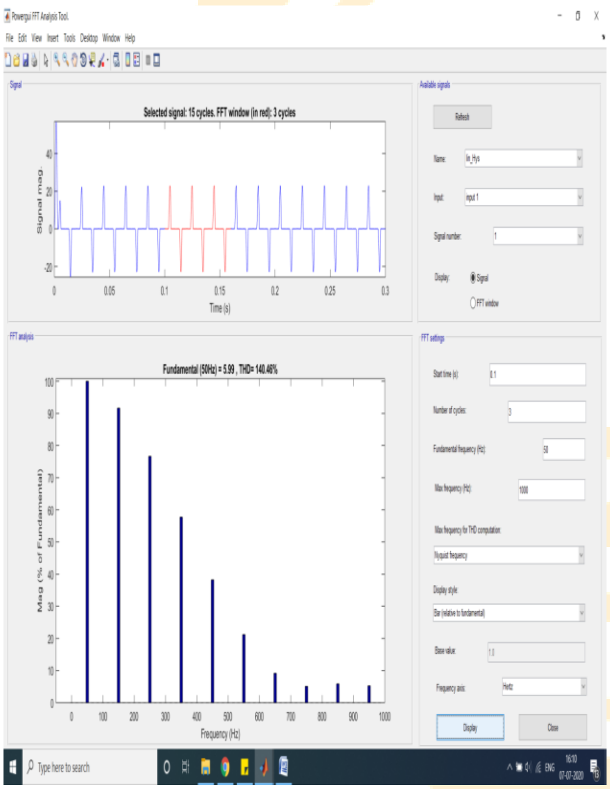

Fig.9 FFT analysis of source current before connecting active power filter

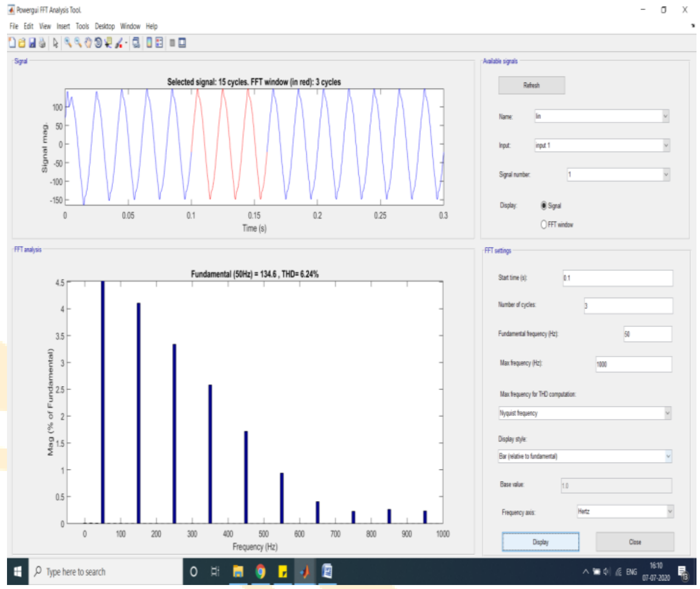

Fig.10 FFT analysis of source current with parabolic PWM active power filter

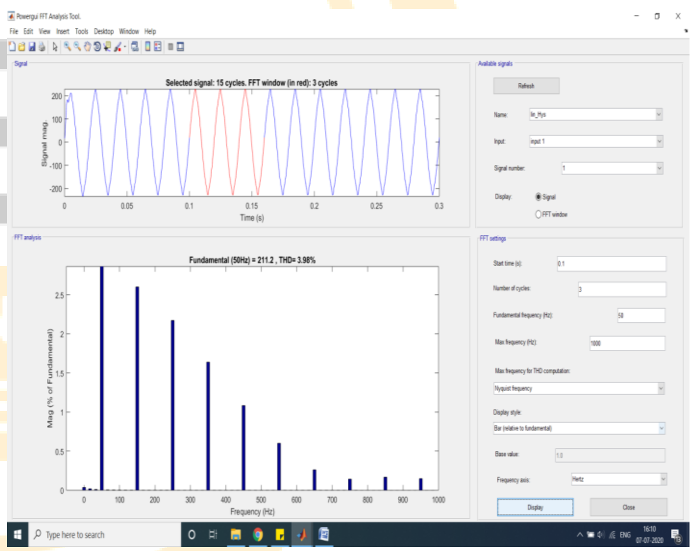

Fig. 11 FFT analysis of source current with Hysteresis PWM active power filter

4. CONCLUSION

From the above FFT analysis results and comparisons of the same we can conclude that the source current THD is about 140% in the absence of SAPF. The same when connected with a parabolic PWM controlled SAPF the THD is reduced to 6.24%. This value is further reduced to about 3.98% when connected with a hysteresis PWM controlled SAPF. The SAPF connected at the PCC mitigates the harmonics produced by the nonlinear loads thereby protecting the overall system from damages. The FFT analysis tool is used from 'Power GUI' block of the Simulink environment in MATLAB software.

5. REFERENCES

[1] B. Singh, K. Al-Haddad and A. Chandra, "A review of active filters for power quality improvement," in IEEE Transactions on Industrial Electronics, vol. 46, no. 5, pp. 960-971, Oct. 1999.

[2] T. C. Green and J. H. Marks, "Control techniques for active power filters," in IEE Proceedings - Electric Power Applications, vol. 152, no. 2, pp. 369-381, 4 March 2005

[3] Zhaoyang Yan and Guiping Zhu, "Voltage ripple across the capacitor in DC side of shunt APF," 2012 IEEE International Conference on Power System Technology (POWERCON), Auckland, 2012, pp. 1-6.

[4] T. Thomas, K. Haddad, G. Joos and A. Jaafari, "Design and performance of active power filters," in IEEE Industry Applications Magazine, vol. 4, no. 5, pp. 38-46, Sept.-Oct. 1998.

[5] H. -. Kuo, S. -. Yeh and J. -. Hwang, "Novel analytical model for design and implementation of three-phase active power filter controller," in IEE Proceedings - Electric Power Applications, vol. 148, no. 4, pp. 369-383, July 2001.

[6] N. Mendalek, K. Al-Haddad, F. Fnaiech and L. A. Dessaint, "Nonlinear control technique to enhance dynamic performance of a shunt active power filter," in IEE Proceedings - Electric Power Applications, vol. 150, no. 4, pp. 373-379, 8 July 2003.

[7] Hoon, Y., Mohd Radzi, M.A., Hassan, M.K., Mailah, N.F., "Control Algorithms of Shunt Active Power Filter for Harmonics Mitigation: A Review", Energies, 10, 2038, 2017.

[8] H. -. Jou, J. -. Wu and H. -. Chu, "New single-phase active power filter," in IEE Proceedings - Electric Power Applications, vol. 141, no. 3, pp. 129-134, May 1994.

[9] Wang, G., and Li, Y.W., "Parabolic PWM for Current Control of Voltage-Source Converters (VSCs)", IEEE Trans. Ind. Appl., vol. 57, no. 10, pp. 3491-3496, 2010.

[10] Y. Singh, I. Hussain, B. Singh, and S. Mishra "Single-Phase Single-Stage Grid Tied Solar PV System with Active Power Filtering Using Power Balance Theory" Received: 9 March 2017 / Accepted: 7 March 2018 the Institution of Engineers (India) 2018.