International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Harmonic Elimination for Power Quality and Compensation in Single Phase Distribution

A.N. Mudiraj[1], V.P. Dhote[2]

[1] Electrical Engineering Department, Government College of engineering, Aurangabad, India

[2] Assistant Professor, Electrical Engineering Department, Government College of engineering, Aurangabad, India

Abstract: ***Harmonics are generated in the single phase circuit due to use of semiconductor devices like fluorescent lamps, computers, mobile chargers, TV and automatic devices. Harmonics impacts on power system badly. This leads to heating of equipment and decrease in life of the equipment. Active power filter for single phase distribution network developed to control l these harmonics. This also improves power factor of the system. The developed active filter consists of a MOSFET inverter, PI controller, and hysteresis controller. Current is injected at point of common coupling through inductor. This made source current sinusoidal and in phase with source voltage. The validity of the proposed model is confirmed by simulation in mat lab software. THD from 30% dropped down to almost 2%. The developed active filter can offer reduction in power loss and improve power quality. This leads to saving in consumption of electrical energy.***

Keywords: Active power filter, PI controller, Hysteresis controller, harmonic distortion

1. Introduction

Harmonics are produced due to non-linear, digital loads such as computer, communication device, fluorescent lamps, and automation device. Use of these devices increased now days. Harmonics are nothing but complex alternating waveforms which are nothing but sum of alternating waveforms with frequencies which integer multiple of fundamental frequency. Even though these devices are economical, flexible and energy efficient they degrade power quality by creating harmonic currents and consuming excessive reactive power. The above causes low power factor, flickers, excessive neutral current, resonance and malfunctioning of microelectronics based applications. Although they produce insignificant amount of harmonic currents individually, the collective effect of large number of such loads can be substantial.

These devices require dc power for their operation so these have rectifier for AC-DC power conversion, which generates harmonic current and consume reactive power. The circuit is shown in fig1 used before the load. For maintaining dc power constant these draw current near peak of mains voltage when dc voltage of capacitor decreases. The load current distorts source current and so on source voltage despite of applied voltage being sinusoidal after some time it may get distorted and affect other connected appliances.

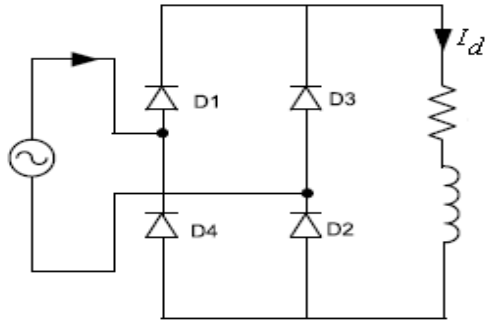

Figure 1: Rectifier circuit for non linear load

Harmonics generated can be removed by passive filters with different topology but it is not much effective due to different harmonics. Tuning is difficult and can lead to resonance. So task can be done with single phase active power filter effectively [1]-[2]. There are two methods to generate the compensating current in active power filter, the source voltage detection method and the load current detection method [3]. The load current detection method generates compensating current from load current but phase delay of harmonics components brings about performance degradation of active power filter. Voltage source active filter used in this paper in shunt topology in this paper as shown in **Fig 3** the filter generates current at the point of connection to cancel harmonic contents in AC system, and correct power factor. So the AC distribution system only carries the active fundamental component of load current which is in phase with source voltage. The source voltage detection method [4]-[5] generates compensating current and makes source current sinusoidal and in phase with source voltage. The developed control system [6] generates the reference waveform for source current with low processing time.

The proposed design of single-phase active power filter investigated as many digital loads are used in office and home. Source voltage detection method which is considered here requires one current sensor and two voltage sensors. Operations of proposed system are verified through computer simulation with mat lab software and results are encouraging.

2. Necessity of Filter

Harmonics generated due to nonlinear load affects in operation of device; reduces life of device; increases heating in conductors; malfunction of devices. Passive filters do not depend on type of external power source which consists of L and C combination with R does not serve the purpose of elimination and improvement in reduction of losses

effectively as tuning is required and can introduce resonance in circuit.

Active filter overcomes drawback of passive filter by injecting current as and when it is required, supplies required reactive power to the load and improves power factor also with reduction of harmonics. Different topologies like shunt, series and hybrid are available with different theories but shunt active filter most used and popular.

3. Single Phase Active Power Filter

The single phase active power filter recommended for single phase distribution network where load such as computer and automation devices used. It improves power quality, reduction of harmonics and improves power factor. These types of loads consist of in build rectifier to convert ac power to dc power as shown in fig 1.Capacitor draws current from source for maintaining its output voltage constant at the peak of source voltage and making source current non sinusoidal as shown in fig 2

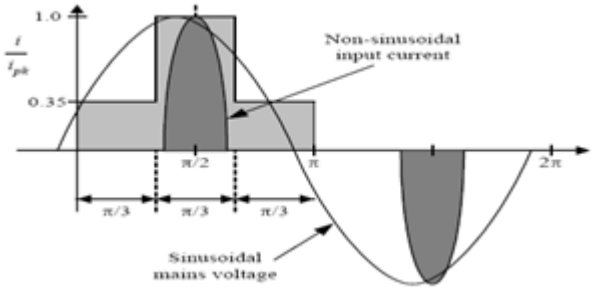

Figure 2: Generation of Harmonic current

The harmonic spectra of input source current shown in figure using fast Fourier analysis transformation. Magnitudes of 3rd, 5th, 7th and 9th harmonics are generally found to be 68%, 28%, 9% and 7% respectively to that of the fundamental component. Lower order harmonics levels are very high with respect to higher orders. Generally THD is measure for harmonics present. Total Harmonic Distortion should be within limit. It is necessary to eliminate the lower order harmonics due to their high magnitudes with the help of active power filter. Also THD value can be decreased with help of Active Power Filter up to 2% from 30% as shown in FFT analysis

$$THD = \sum_{n=2}^{n=\infty} (y_n^n)^{1/2} \Big/ (y_1^2)^{1/2} \text{ X } 100$$

Operating principle of active power filters are shown in the figure in which current is injected in the circuit for providing reactive power which required to nonlinear loads in between the load and source and makes the source current sinusoidal and also in phase with source voltage results in almost unity power factor. The lower order harmonics are removed with this and power quality is maintained.

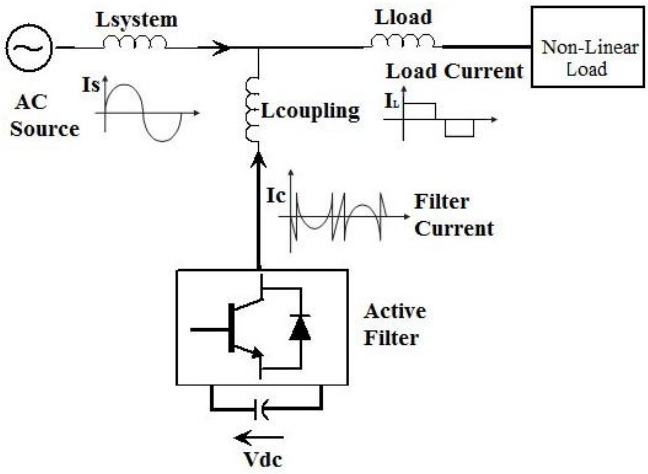

Figure 3: Active Filter Working Principle

3.1 Proposed Active Filter

In proposed circuit five sensors are used for measurement of source voltage, source current, load voltage, load current and capacitor voltage. In this circuit simple control system is used. Single phase circuit generally has low power ratings so installation of active power filter near load is preferred. As its single phase active filter so model considered is economical , low cost , reliable and stable so that improvement in power quality is concern in single phase distribution network. In single phase shunt active power filter there is voltage supply source, full bridge rectifier delivers dc current to non linear load represented with resistor and inductor, voltage source inverter using MOSFET and dc link capacitor. This is connected at the point of coupling through AC reactor. There is injection of current in the circuit at the point of coupling whenever required for maintaining source current sinusoidal and in phase with source voltage. Inductor is connected between so as to avoid inrush of current and for avoiding damage of the MOSFET Bridge.

Controller used has voltage sensors for sensing capacitor voltage which is compared with dc ref. and difference is sent to pi (propagation integrator) which depicts the power required for maintaining dc link voltage and power required against switching losses. Load current and load voltage is sensed and used for calculating actual active power required for the load. This actual power required is subtracted from source power side and extra alternating power which is responsible for harmonics is eliminated by comparing source current with reference current. Hysteresis controller or triangular wave carrier used for comparing and generating error which is used for generation of gate pulses for MOSFET.

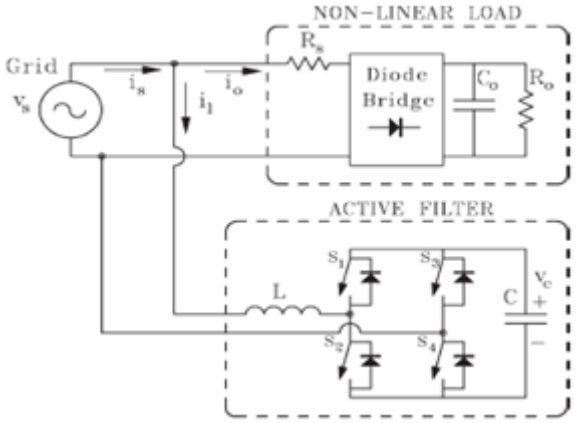

Figure 4: Proposed Active Filter

3.2 Controller Design

Controller is main element of the active power filter which enables operation of active filter and makes the source current sinusoidal and in phase with source voltage. The required reactive power is supplied to non linear load by the filter and it also eliminates the harmonics presents in the circuit and the result is shown by mat-lab simulation.

DC capacitor voltage across non-linear load has to be maintained constant so little power required to maintain it. DC link volt is compared with ref. DC link and difference is processed through PI controller. The control signal coming from PI controller for regulating DC capacitor voltage is given by

$$P_{dc} = K_p(V_{dcref} - V_{dc}) + K_i (V_{dcref} - V_{dc})d_t$$

Here Kp and Ki are proportional and integral gains. Time required for maintaining the voltage can be set by K_P and K_I.. For generation of reference current the method used is synchronous detection with idea that active power required for the load is nothing but fundamental components of current and voltage. Reference current is generated by filtering alternative power from active power. Mat lab simulation in this paper is done with hysteresis current controller to generate pulses for the switching pattern of the inverter. Hysteresis type controller available used due to its robustness, quick response and ease of implementation and fast operations. In this method transistor is switched when current error exceeds the given hysteresis band. Accuracy is depend on the hysteresis band and the current follow reference current generated.

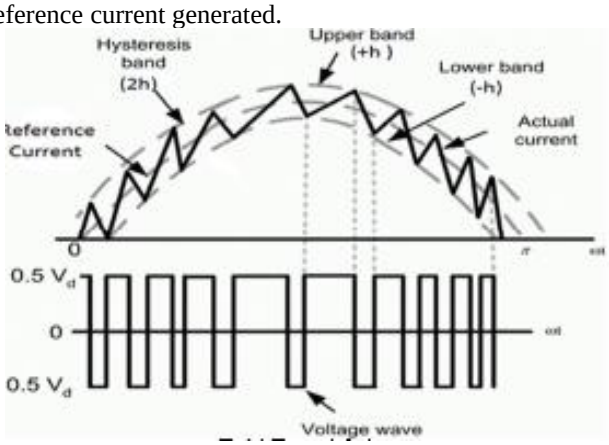

Figure 5: Principle of Hysteresis controller

Controller which is implemented in mat lab is shown in the following figure. Gating signals are generated with the help of Boolean and not gates and current is injected in the circuit through the inductor for meeting harmonic components and reactive power of load.

4. Mat lab Simulations

The various results of above shunt type single phase active filter system are tested with the help of MATLAB simulations with different parameters considered and some of that are mentioned here in the below table 1.The above model run for 0.1 second without active filter in the circuit and after that the active filter is connected in the circuit with the help of breaker. When active filter is connected in the circuit first capacitor is charged at inverter side which is seen by rush of source current

Table 1

Sr No	Parameter	Ratings
1	Source voltage	230 V rms
2	Source impedance	1 mH
3	R-L load	10 ohm, 50 mH
4	Filter impedance	5 mH
5	DC link capacitor	4700 uF
6	DC link Ref voltage	400 V
7	Sampling frequency	1 e^{-4}
8	DC link PI controller	K_P=15,K_I=20
9	Hysteresis current controller	Hysteresis band=0.1

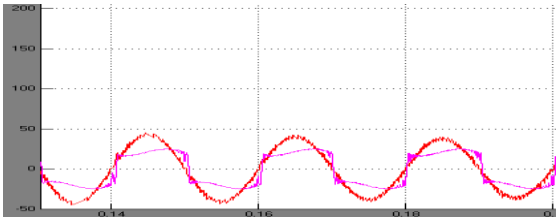

Figure 6: Source current and Load current

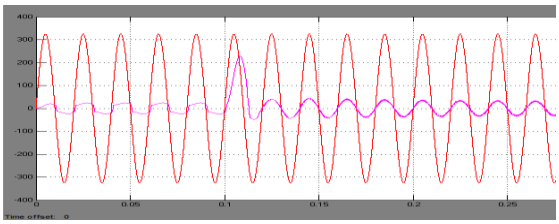

Figure 7: Source voltage and Source current

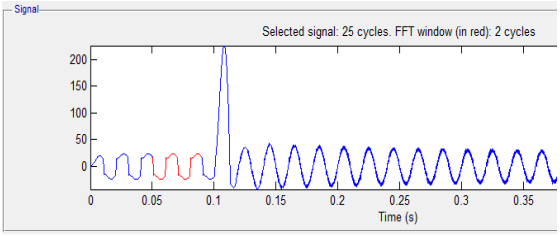

Figure 8: Selected signal FFT window (red) 2cycles

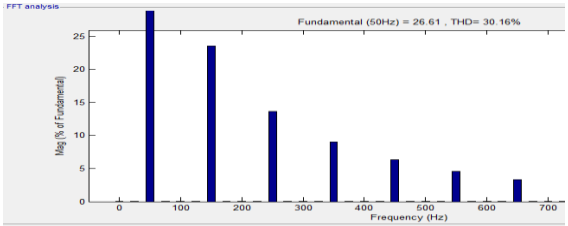

Figure 9: THD of source current before use of active filter

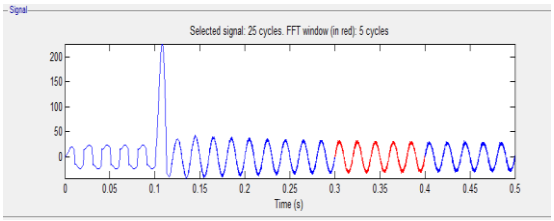

Figure 10: Selected signal FFT window (red) 5cycles

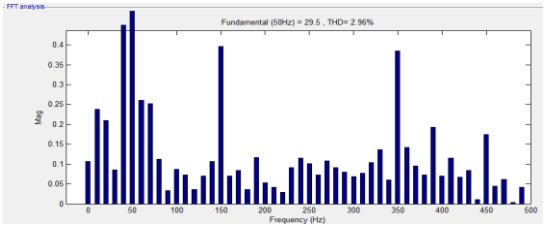

Figure 11: THD with active power filter

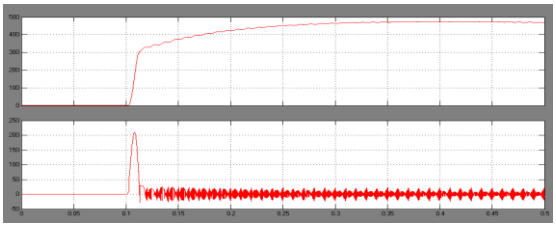

Figure 12: Capacitor voltage and Capacitor current

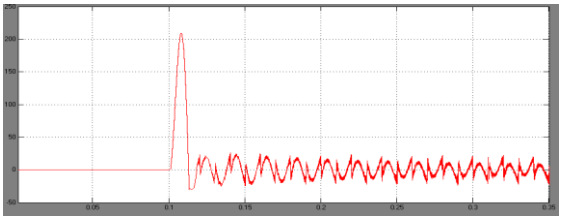

Figure 13: Filter current

5. Conclusion

Single phase non linear load such as computers, office automation used at office and home , which draws current having harmonic contents more than 30% of THD values can be bought down up to 2% by single phase shunt type active filter effectively.

Also the power factor of the circuit can be raised near unity with the help of this shunt active power filter using PI controller and hysteresis current controlling techniques. Thus reactive power required at the load is sent by active power filter. Due to APF source voltage and source current got in phase with each other.

Above results are verified with mat-lab simulations and can be used for further developments while assembling model with available components which would be a economical solution using analog components.

References

[1] H. Akagi, Y. Kananzawa and A. Nabae, "Generalized Theory of Instantaneous Reactive Power in Three phase circuit" *Int. conf. power electronics, Tokyo, 1983,* pp 1375-1386

[2] L.Malesani, L.Rossetto, and P Tenti, "Active power and harmonics compensation", *IEEE power electron.spec.conf.rec.*, pp.321-330,1986

[3] H. Jou, J. Wu and H.chu, "New Single Phase Active Power Filter", *IEE proceeding Electric Power Application, vol. 141, no. 3,* pp. 129-134, May 1994.

[4] C. Y. Hsu and H.Y. Wu, "A new single phase active filter with reduced energy storage", *IEE proc. On electric power application, vol. 143, No. 1,* pp25-30, January 1996

[5] J.C.Wu and H. L. Jou, "Simplified control method for single phase active filter", *IEE proc. On electric power application, vol. 143, No. 3,*pp 219-234, May 1996

[6] F. Harashima, H. Inaba and K. Tsubio, "A closed loop control system for the reduction of reactive power required by electronic converters", *IEEE Trans., IECI-23,(2),*pp 162-166, 1976.

[7] Hye-Yeon Lee, Myong-Bo Shim, Ji-Heon Lee and Byung-Moon Han (2009), " Single phase active power filter design Using EMTP Simulation", *IPST2009, Kyoto, Japan* june 3-6, 2009

[8] L. Gyugyi and E.C. strycula, "Active AC Power Filters", IEEE-1AS annual meeting record, 1976,pp. 529-535.

[9] NPTEL Notes

[10] Grady, W. Mack, and Surya Santoso, "Understanding power system harmonics", *IEEE.Power Engineering Review* 21.11 (2001): 8-11.

Author Profile

Abhay Mudiraj completed the B.E. degree in Electrical Engineering from Government college of Engineering, Aurangabad in 1991. During 1994-1996, he worked in Maharashtra State Electricity Board (MSEB), for quality control.