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

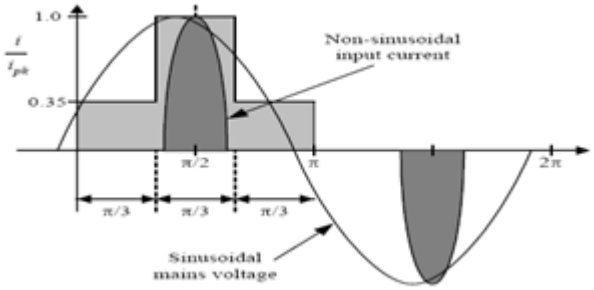

Figure 2: Generation of Harmonic current

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.

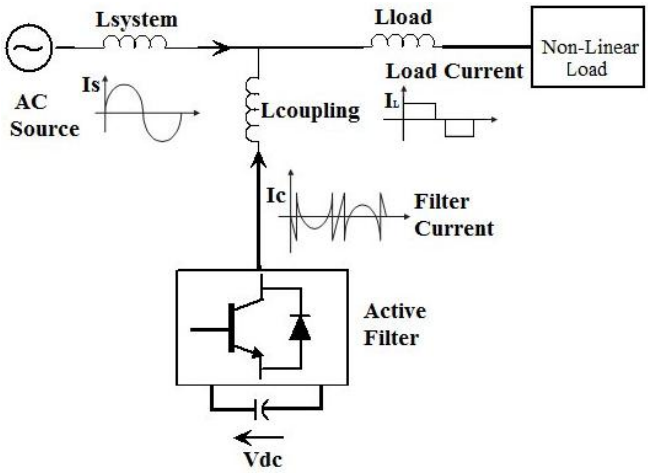

Figure 3: Active Filter Working Principle

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.

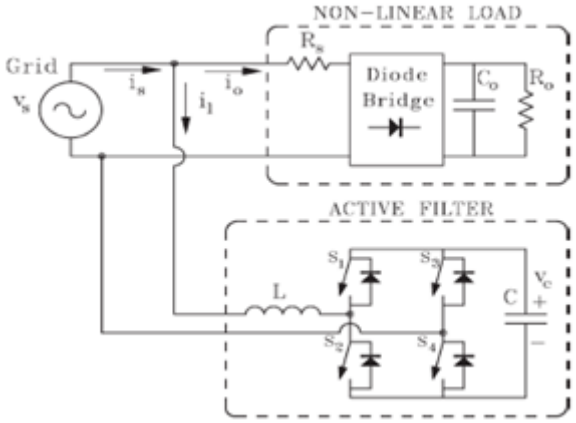

Figure 4: Proposed Active Filter

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.

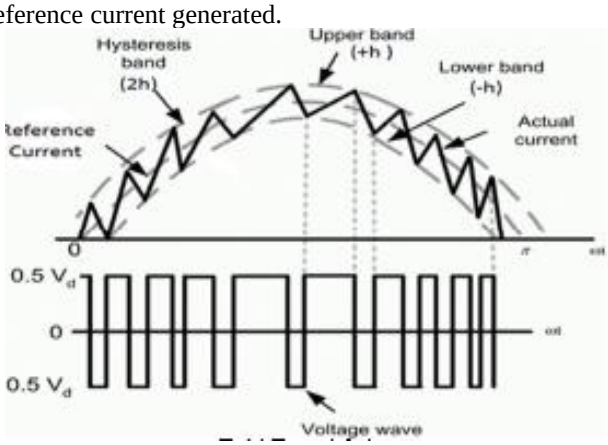

Figure 5: Principle of Hysteresis controller

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

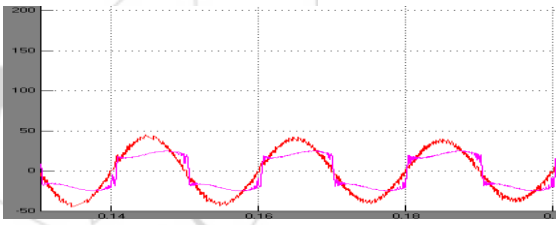

Figure 6: Source current and Load current

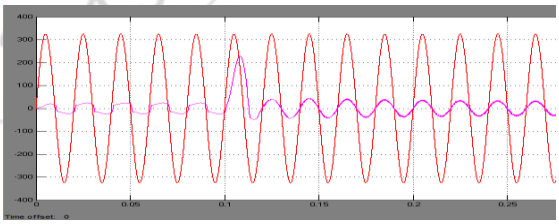

Figure 7: Source voltage and Source current

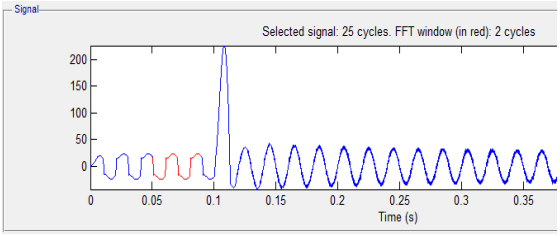

Figure 8: Selected signal FFT window (red) 2cycles

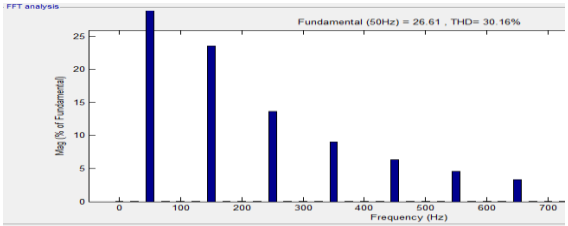

Figure 9: THD of source current before use of active filter

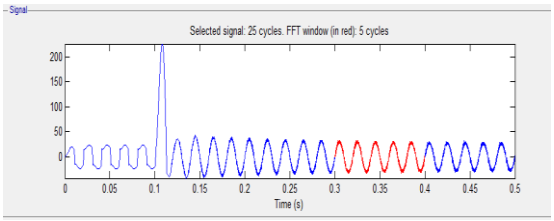

Figure 10: Selected signal FFT window (red) 5cycles

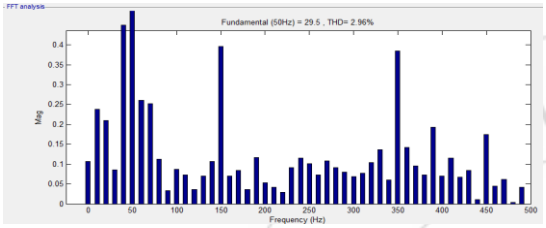

Figure 11: THD with active power filter

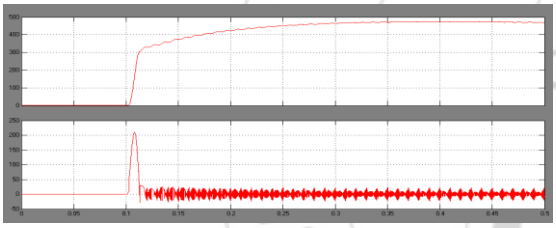

Figure 12: Capacitor voltage and Capacitor current

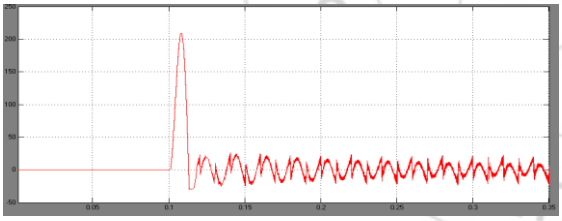

Figure 13: Filter current

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.

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