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Research Article

Economical Model for Power Quality Monitoring and Compensation in Single Phase Distribution Network

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Abstract

One of the major load on power system is domestic type and it consists of devices which are made up of semiconductors like computers, mobile chargers, TV and automatic devices. The excessive use of power electronic based residential loads has resulted in significant harmonic distortion in voltage and current in single phase distribution systems. Harmonics developed due to this has very bad impact on power system. This paper deals with Active power filter shunt type for single phase distribution network to control harmonics generated also it improves power factor of the system. The developed active filter consists of a MOSFET inverter and simple controller using analog circuit for cost reduction. Current is injected at point of common coupling to obtain an input current in sinusoidal waveforms. The validity of the proposed model is confirmed by simulation in mat lab results. The input current total harmonic distortion of around 3% obtained and circuit tested for various loads. The developed active filter can offer reduction in power loss and improve power quality.

Keywords: *Active power filter, PI controller, Hysteresis controller, source voltage detection, harmonic distortion, voltage source inverter.*

1. Introduction

Power quality issues are most concern nowadays. Non-linear and digital loads such as computer, communication device, fluorescent lamps, and automation device use increased. These produces large amount of harmonics in power distribution systems due to non-sinusoidal currents consumed by non-linear loads. 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 can cause 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 have rectifier for AC-DC power conversion, which generates harmonic current and consume reactive power. These draw current near peak of mains voltage despite of applied voltage being sinusoidal. Harmonics generated can be removed by passive filters with different topology but it can be done with single phase active power filter (H. Akagi *et al*,1983)-(L.Malesani *et al*,1986).

There are two methods to generate the compensating current in active power filter, the source voltage detection method and the load current detection method (H. Jou *et al*, 1994). 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 (C. Y. Hsu *et al*,1996)-(J.C. Wu, *et al*,1996) generates compensating current and makes source current sinusoidal and in phase with source voltage. The developed control system (F. Harashima, *et al*, 1976) generates the reference waveform for source current with low processing time.

The proposed low cost design of single-phase active power filter investigated as many digital loads used at office and home. Cost reduction is considered due to installations at home and office for single phase distribution network. The active power filter designed using MOSFET/IGBT for inverter and analog controller with operational amplifiers. Source voltage detection method requires one current sensor and two voltage sensors. Operations of proposed system are verified through computers simulation with mat lab software.

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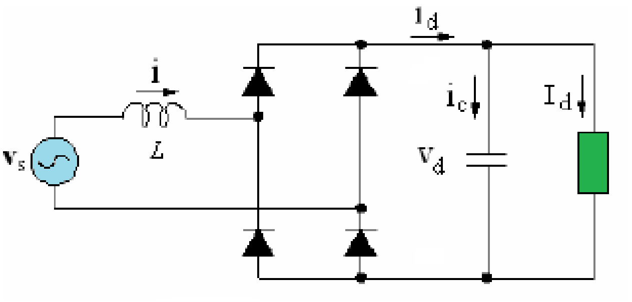

Fig. 1 Rectifier circuit for digital load

2. Necessity of active 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.

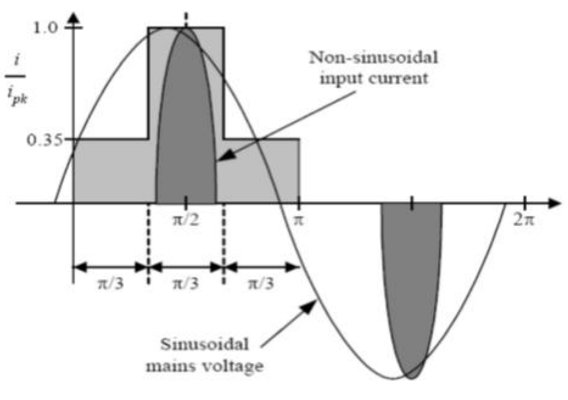

Fig.2 Generation of harmonic current

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 3% from 30% as shown in FFT analysis.

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.

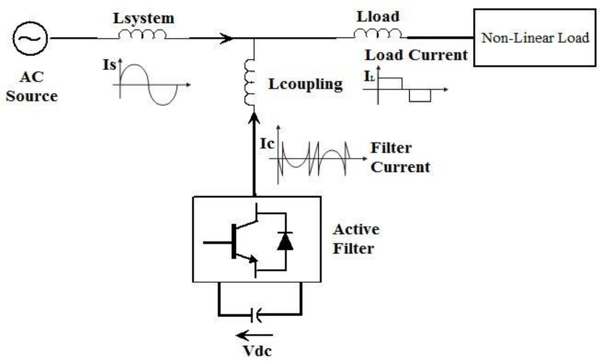

Fig. 3 Principle of operation of active filter

4. 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.

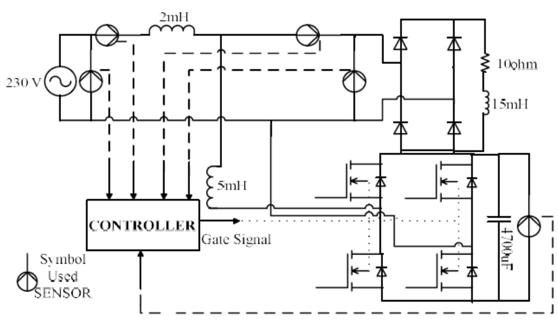

Fig. 4 Single phase active filter connection diagram

Figure 4 shows configuration of single phase shunt active power filter in which 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.

Controller used has voltage sensors for sensing capacitor voltage which is compared with dc ref. and difference is sent to pi (propagation integrator) which is used for generation of reference current and magnitude of ref current is decided with help of output of propagation integral. Source voltage sensed with voltage sensor is sent to sine wave generator for generation of ref. sinusoidal current wave form of phase in phase with source voltage and magnitude calculated with pi control. This reference current is compared with source current and error signal is generated. This error signal is then amplified for getting strength with error amplifier. The reference voltage for inverter is generated. PWM and triangular wave carrier used for generation of gate pulses for MOSFET.

5. Controller design and mathematical modeling

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.

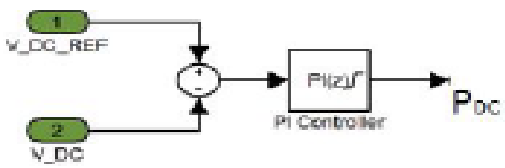

Fig. 5 PI controller for DC

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 out of many 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 band and accuracy is depend on the hysteresis band and the current follow reference current generated .

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.

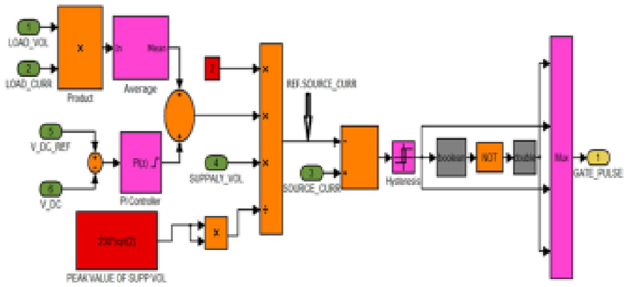

Fig. 6 Operational block diagram

7. 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 Results of above shunt type single phase active filter system are tested with the help of MATLAB simulations

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

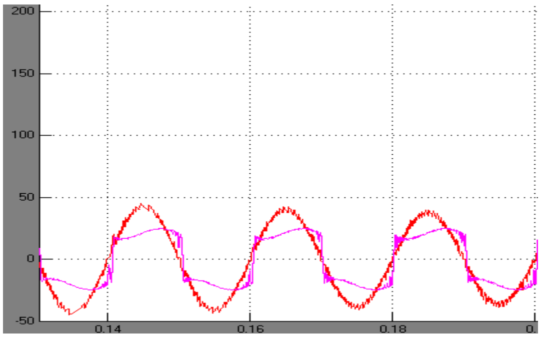

Fig. 7 Source current and load current zoomed version

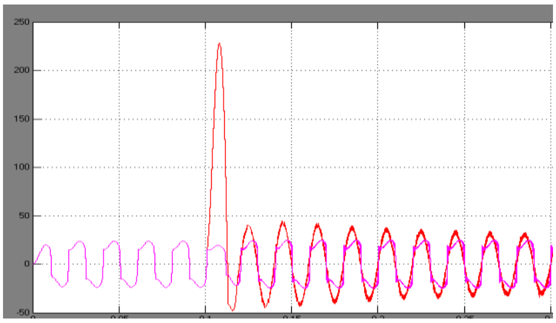

Fig. 8 Supply current and load current

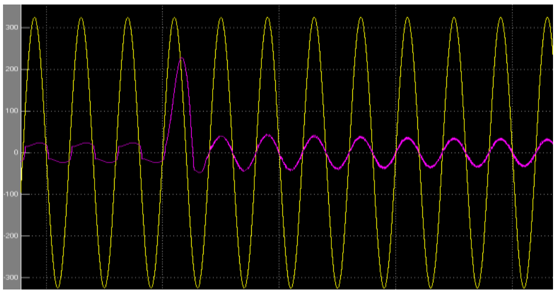

Fig. 9 Source voltage and source current

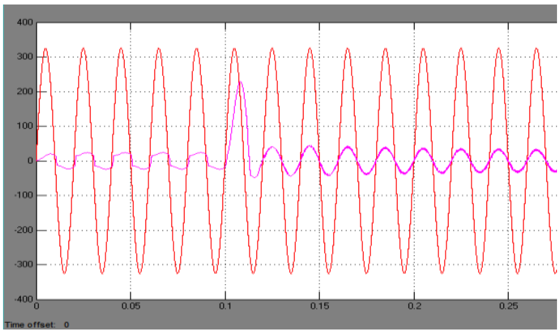

Fig. 10 Source voltage and source current

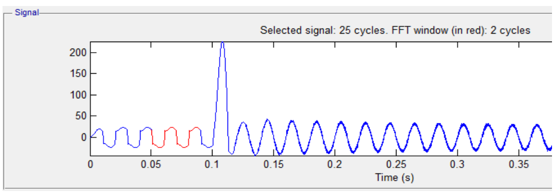

Fig. 11 Selected signal. FFT window (in red): 02 cycles

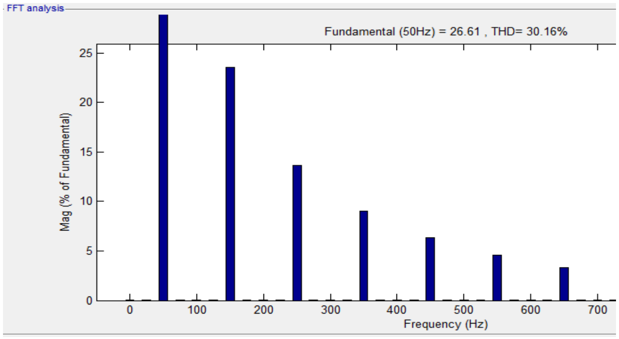

Fig. 12THD of source current before use of active filter

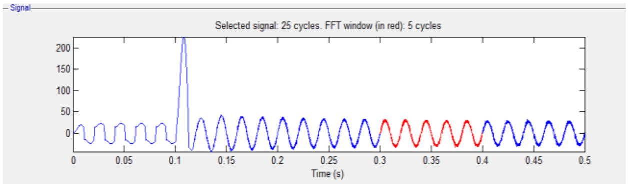

Fig.13 Selected signal. FFT window (in red): 5 cycles

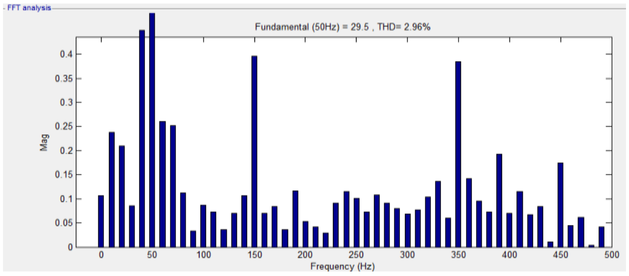

Fig. 14THD of source current after use of active filter THD value becomes 2.96%

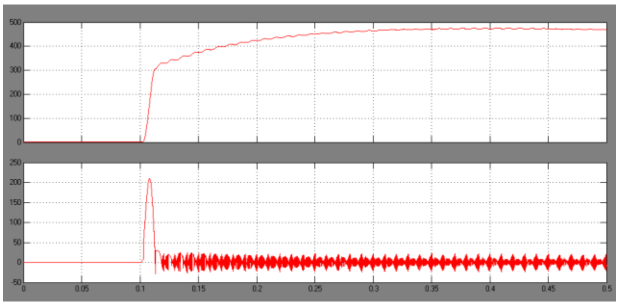

Fig. 15 Capacitor voltage and capacitor current

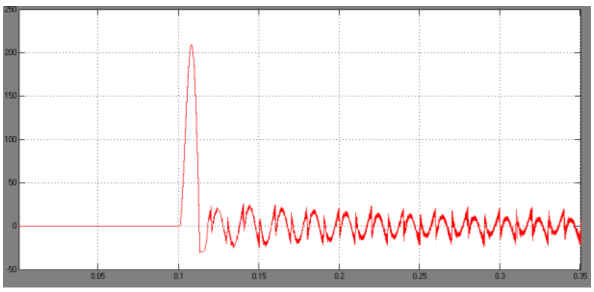

Fig. 16 Filter current

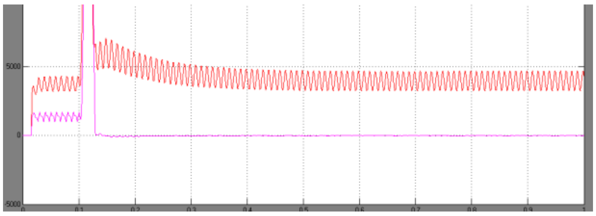

Fig. 17 Active and reactive power

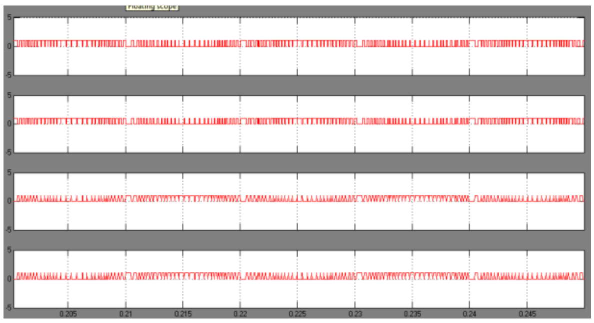

Fig. 18 PWM

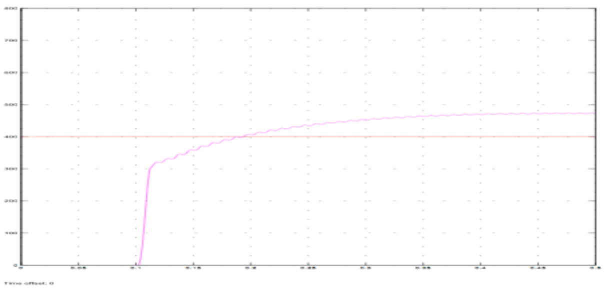

Fig. 19 Capacitor charging current

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 brought down up to 3% 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 an economical solution using analog components.

References

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

L.Malesani, L.Rossetto, and P Tenti (1986), Active power and harmonics compensation, IEEE power electron.spec.conf.rec.,pp.321-330

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

C. Y. Hsu and H.Y. Wu (January 1996), A new single phase active filter with reduced energy storage, IEE proc. On electric power application, vol. 143, No. 1,pp 25-30,

J.C. Wu and H. L. Jou (May 1996),Simplified control method for single phase active filter, IEE proc. On electric power application, vol. 143, No. 3,pp219-234

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

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.

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

NPTEL Notes

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