



Simulation of Shunt Active Power Filter Connected to a Photovoltaic Array for Compensating Current Harmonics in Single Phase System

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ABSTRACT: With the increasing of nonlinear loads in household application which may cause power quality issues at distribution end. In this paper, an analysis and simulation of a PV interactive shunt power active filter (SPAF) in single phase circuit. This system is used to eliminate harmonics generated by a nonlinear load. In the day-time with intensive sunlight, the PV interactive Shunt Active Filter system brings all its functions into operation. At night and during no sunlight periods, the power required by the loads is received from the distribution system while the inverter system only provides reactive power and filter harmonic currents. For the Shunt Active Filter reference current computation. We used the instantaneous real and reactive current (I_p - I_q) algorithm and for gating signal generation we apply the hysteresis current control technique. The Simulation results (using MATLAB/SIMULINK) are presented and discussed. They show the effectiveness of the photovoltaic compensation system, the sinusoidal form of the current and the effectiveness of the reactive power compensation. The proposed solution has achieved a low THD (Total Harmonic Distortion), demonstrating the effectiveness of the presented method.

KEYWORDS: pv cell, Shunt active power filter, current harmonics, Nonlinear load, reactive power.

I.INTRODUCTION

Harmonic currents are present in modern electrical distribution system caused from non-linear loads such as adjustable speed drives, electronic blast lightning, power supply of computer, fax machine and more of telecom equipment used in modern offices. The wide spread and growing demand of these loads greatly increased and the flow of harmonic currents on facilitated distribution system and has created a number of problems. These problems included over heated transformers, motors, conductors and neutral wire; nuisance breaker trips; voltage distortion, which can causes sensitive electronic equipment to malfunction or fail.

The need to generate pollution-free energy has starts considerable effort toward renewable energy (RE) system. RE sources such as wind, sunlight, and biomass offer the promise of clean and abundant energy. Among the RE sources, solar energy, is an attractive one. This useful energy is supplied in the form of DC power from photovoltaic (PV) arrays bathed in sunlight and converted into more convenient AC power through an inverter system. The photovoltaic arrays interactive shunt active power filter system can supply real power from the photovoltaic arrays to loads, and support reactive and harmonic power simultaneously to use its almost installation capacity. This technology has many excellent features and it causes little environmental burden, it is of a modular type technology that can be easily expanded, and it is applicable almost everywhere. This paper presents an analysis and simulation of a PV interactive Shunt Active Power Filter topology that achieves simultaneously harmonic current damping and reactive power compensation. Also, the inverter is always used to act as an active power filter to compensate the nonlinear load harmonics and reactive power. In the day-time with intensive sunlight, the PV interactive shunt active power filter system brings all its functions into operation. At night and during no sunlight periods, the power required by the load is received from the distribution system while the inverter system only provides reactive power compensation and filter harmonic currents.

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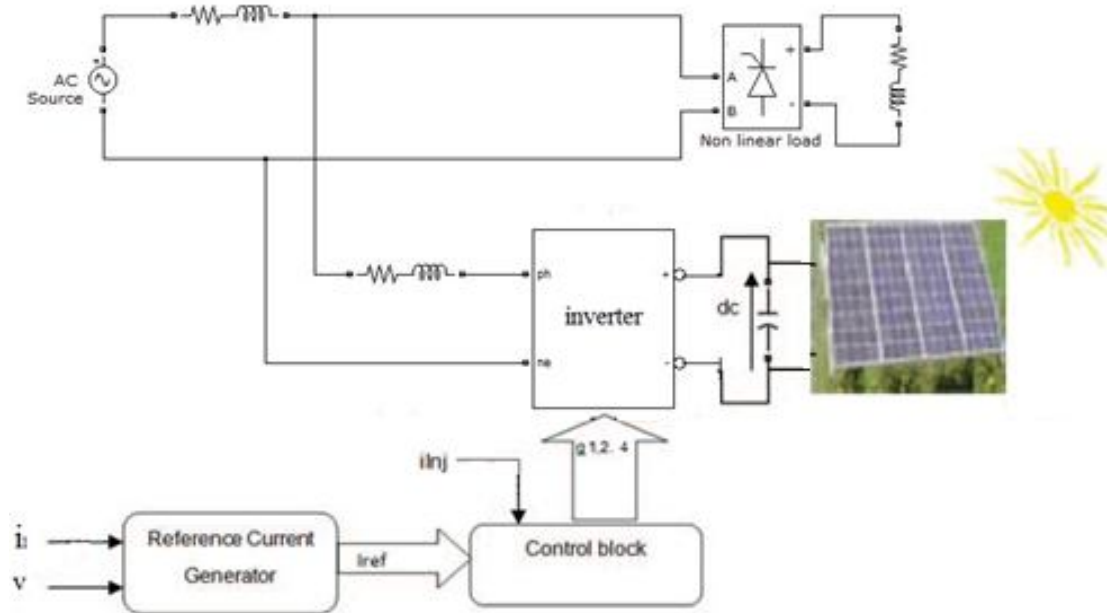


Fig.1 Configurations of photovoltaic interactive Shunt Active Filter system

The harmonics mitigation methods are line reactor, k-factor transformer, isolated transformer, tuned filter and active filter. Among active filter is the best method to mitigate the current harmonics. Because it can achieve harmonic distortion levels below 5% THD-I or less. Active filters can be used to reduce harmonic distortion levels below IEEE 519 -1992 standard guidelines .The shunt active power filter (SAPF) is a device that is connected in parallel to the power system. The performance of a shunt active power filter depends on many factors. Among them, the reference generation is the most important. The method to generate the reference template is responsible for the reference of currents that must be followed by an inverter current to produce the desired compensation currents that will mitigate harmonic currents generated by non-linear loads. Harmonic detection method will calculate the reference compensating currents. In this paper the instantaneous real and reactive current method ($I_p - I_q$) is used to generated the reference compensating current.From this reference compensating current the actual compensating current are generated with the help of hysteresis current controlled voltage source inverter.Hysteresis current controlled inverter will inject the compensating current into the power system. These compensating currents, will cancel the harmonics generated by nonlinear load.

II. PV MODEL

A solar cell is basically a p-n junction fabricated in a thin wafer of semiconductor. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater than the band-gap energy of the semiconductor creates some electron-hole pairs proportional to the incident irradiation. To find the model of the photovoltaic generator, we must start by identifying the electrical equivalent circuit to that source. Many mathematical models have been developed to represent their highly nonlinear characteristics resulting from that of semiconductor junctions that are the major constituents of PVmodules. There are several models of photovoltaic generators which have a certain number of parameters involved in the calculation of voltage and current output. In this study, we will present the model of single diodes (Fig.2) taking into account the internal shunt and series resistances of the PV cell.

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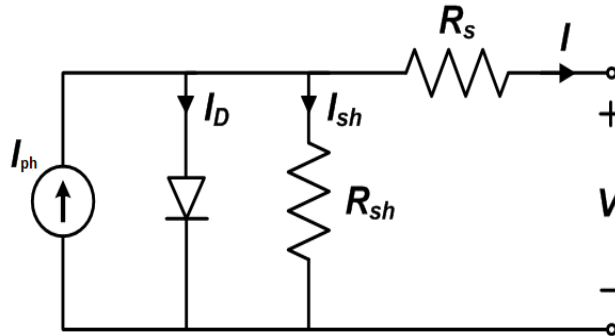


Fig. 2 Model of a photovoltaic cell

The current source I_{ph} represents the cell photocurrent. R_{sh} and R_s are the intrinsic shunt and series resistances of the cell, respectively. Usually the value of R_{sh} is very large and that of R_s is very small, hence they may be neglected to simplify the analysis. PV cells are grouped in larger units called PV modules which are further interconnected in a parallel-series configuration to form PV arrays.

The photovoltaic panel can be modelled mathematically as given in equations (1)- (4)

Module photo-current:

$$I_{ph} = [I_{Scr} + K_i(T-298)] * \lambda / 1000 \quad (1)$$

Module reverse saturation current :

$$I_{rs} = I_{Scr} / [\exp(QV_{OC} / N_s kAT) - 1] \quad (2)$$

The module saturation current I_0 varies with the cell temperature, which is given by

$$I_0 = I_{rs} [T/T_r]^3 \exp \left[\frac{qE_{gp}}{Bk} \left\{ \frac{1}{T_r} - \frac{1}{T} \right\} \right] \quad (3)$$

The current output of PV module is

$$I_{PV} = N_p * I_{ph} - N_p * I_0 \left[\exp \left\{ \frac{q(V_{PV} + I_{PV} R_s)}{N_s A k T} \right\} - 1 \right] \quad (4)$$

Where V_{pv} and I_{pv} represent the output voltage and current of the PV, I_{ph} is the photocurrent; I_0 are diode saturation current; q is coulomb constant ($1.602 \times 10^{-19}C$); T_r is the reference temperature is 298 K; k is Boltzman's constant ($1.381 \times 10^{-23} J/K$); T is cell temperature (K); N_s are P-N junction ideality factor; R_{sh} and R_s are the intrinsic shunt and series resistance of the cell respectively; N_s is the number of cells connected in series is 36 ; N_p is the number of cells connected in parallel is 1

III. DETECTION METHOD BASED ON THE INSTANTANEOUS REAL AND REACTIVE CURRENT METHOD

The instantaneous reactive power theory is used to detect the harmonics here. The source voltage $V(t) = V \sin \omega t$, where V is the peak value of voltage.



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The load distortion current consisting by fundamental and harmonic components is expressed by Fourier series

$$i_s = i_\alpha = \sum_{n=1}^{\infty} I_n \sin(n\omega t + \varphi_n) \quad (5)$$

The distortion current is delayed by $\pi/2$ to get the other current component i_β .

$$i_\beta = \sum_{n=1}^{\infty} I_n \sin[n(\omega t - \pi/2) + \varphi_n] \quad (6)$$

i_α and i_β are divided into three components, viz., active, reactive and harmonic current as follows:

$$\begin{aligned} i_\alpha &= I_1 \cos \varphi_1 \sin \omega t + I_1 \sin \varphi_1 \cos \omega t + \sum_{n=2}^{\infty} I_n \sin(n\omega t + \varphi_n) \\ &= I_p \sin \omega t + I_q \cos \omega t + \sum_{n=2}^{\infty} I_n \sin(n\omega t + \varphi_n) \\ &= i_{ap}(t) + i_{aq}(t) + i_{ah}(t) \end{aligned} \quad (7)$$

$$\begin{aligned} i_\beta &= I_1 \cos \varphi_1 \sin(\omega t - \frac{\pi}{2}) + I_1 \sin \varphi_1 \cos(\omega t - \frac{\pi}{2}) + \sum_{n=2}^{\infty} I_n \sin(n(\omega t - \frac{\pi}{2}) + \varphi_n) \\ &= I_p \sin(\omega t - \frac{\pi}{2}) + I_q \cos(\omega t - \frac{\pi}{2}) + \sum_{n=2}^{\infty} I_n \sin[(n\omega t - \frac{\pi}{2}) + \varphi_n] \\ &= i_{\beta p}(t) + i_{\beta q}(t) + i_{\beta h}(t) \end{aligned} \quad (8)$$

Where the fundamental active and reactive current is

$$i_p(t) = I_p \sin \omega t, \quad i_q(t) = I_q \cos \omega t \quad (9)$$

Where I_p and I_q are their peak values

$$I_p = I_1 \cos \varphi_1, \quad I_q = I_1 \sin \varphi_1 \quad (10)$$

According to instantaneous reactive power theory we can make the following calculations:

$$\begin{bmatrix} i_p \\ i_q \end{bmatrix} = \begin{bmatrix} \sin \omega t & -\cos \omega t \\ -\cos \omega t & -\sin \omega t \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (11)$$

From the above expression, we can deduce,

$$i_p = i_\alpha \sin \omega t - i_\beta \cos \omega t = (I_p + \text{harmonics})$$

$$i_q = -i_\alpha \cos \omega t - i_\beta \sin \omega t = -(I_q + \text{harmonics})$$

The harmonics are filtered by low pass filter (LPF). Then the direct active component I_p and the direct reactive component $-I_q$ are obtained.

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} \sin \omega t & -\cos \omega t \\ -\cos \omega t & -\sin \omega t \end{bmatrix} \begin{bmatrix} i_p \\ -i_q \end{bmatrix} \quad (12)$$

$$i_\alpha = i_f = I_1 \cos \varphi_1 \sin \omega t + I_1 \sin \varphi_1 \cos \omega t \quad (13)$$

The fundamental component is subtracted from actual current to get harmonic current. The result of the original distortion current $i_{s(t)}$ subtracting the fundamental current $i_{f(t)}$ is the sum of harmonics $i_{h(t)}$

$$i_{h(t)} = i_{s(t)} - i_{f(t)} \quad (14)$$

To obtain $i_{q(t)}$ the peak value I_q of direct reactive current multiplies the cosine signal of the supply voltage's phase, namely $I_q(t) = I_q \cos \omega t$ which we expect. The result of the original distortion current $i_{s(t)}$ subtracting the fundamental current $i_{f(t)}$ is the sum of harmonics $i_{h(t)}$, $i_{h(t)} = i_{s(t)} - i_{f(t)}$

The result of the reactive component $i_{q(t)}$ plus the harmonic component $i_{h(t)}$ is the important variable $i_{c(t)} = i_{h(t)} + i_{q(t)}$

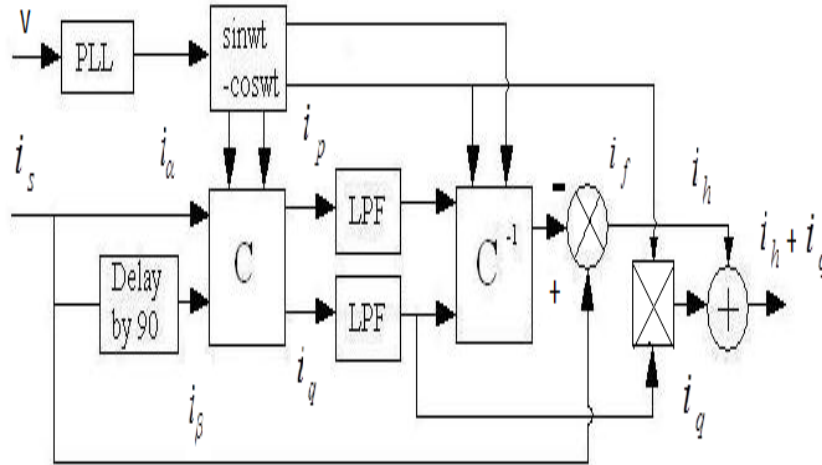


Fig.3 Calculation process the harmonic component and reactive component

III.HYSTERESIS CURRENT CONTROLLER

Hysteresis current control method of generating the switching signal for the inverter switches in order to control the inverter output current. It is adopted in shunt active filter due to best among other current control methods, easy implementation and quick current controllability. It is basically a fed back current control method, where the actual current continuously tracks the reference current in the hysteresis band .the actual current with in this hysteresis band. The reference and actual current is compared with respect to hysteresis band which decides switching pulse of voltage source inverter.

As the current crosses a set hysteresis band, the upper switch in the half-bridge is turned off and the lower switch is turned on. As the current exceeds the lower band limit, the upper switch is turned on and the lower switch is turned off.

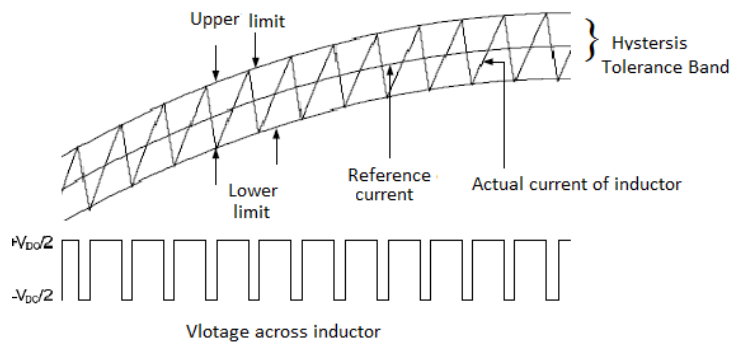


Fig 4.Hysteresis Band and Generation of Pulses

Fig 4.The switching frequency depends on how fast the current changes from upper limit to lower limit and vice versa. This, in turn depend on voltage v_d and load inductance

IV.SIMULATION RESULTS

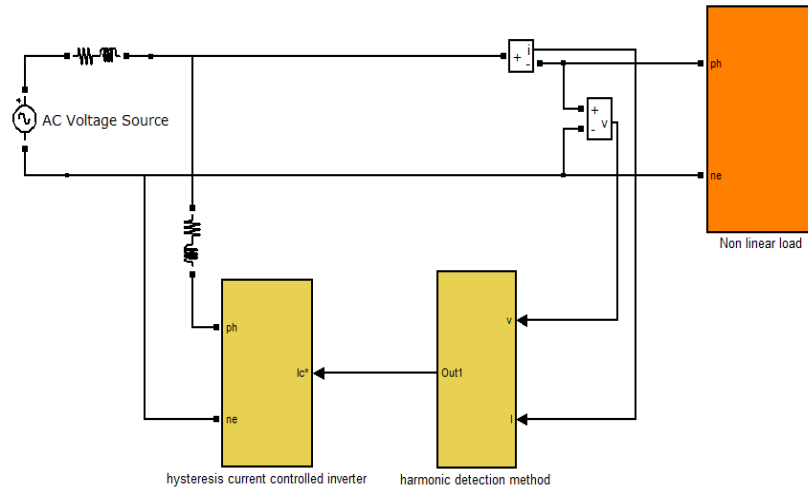


Fig.5 MATLAB/SIMULINK model of PV interactive SAPF

Fig.5 The proposed model for a PV interactive shunt active power filter using harmonic detection method with hysteresis current controller has been successfully modelled and tested using MATLAB/SIMULINK toolbox

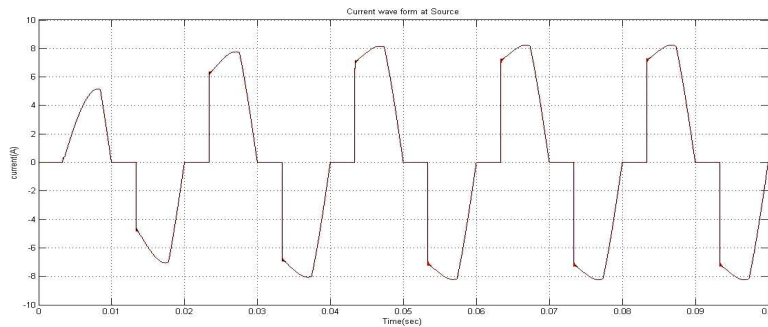


Fig. 6 Distorted current at source without compensation

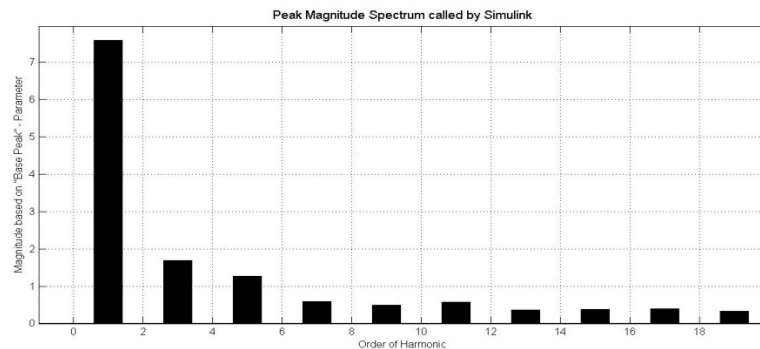


Fig.7 FFT analysis for above fig 6 distorted current

Fig. 6 shows the distorted load currents of nonlinear load. Harmonic currents are injected into power system by nonlinear load. Because of harmonics source current will be distorted. For distorted current THD is 33%

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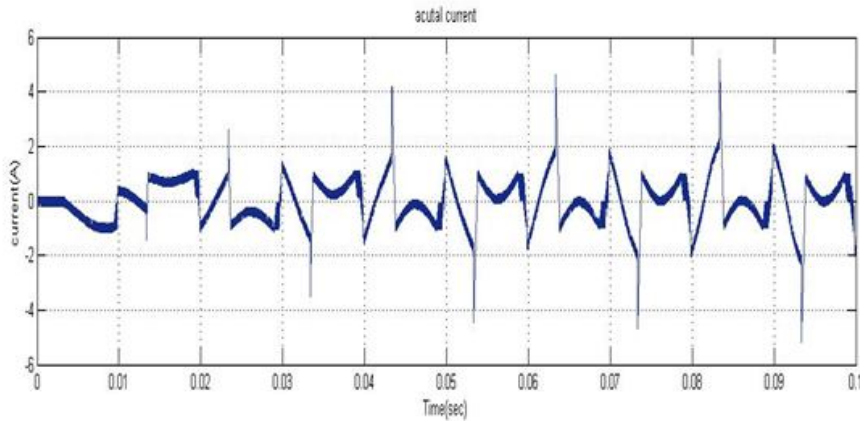


Fig. 8 compensating currents injected by the active power filter

Fig 8 the compensating currents injected by the shunt active power filter at the point of common coupling.

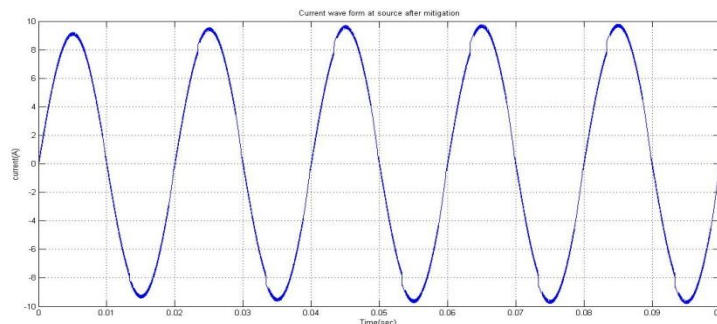


Fig .9 Current at source after compensation

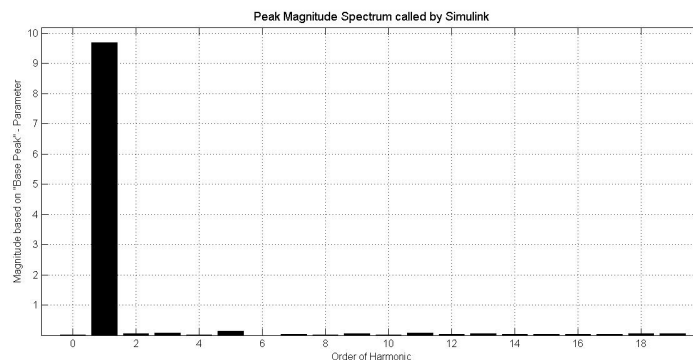


Fig .10 FFT analyses for above fig 9 distorted current

Fig. 9 shows the supply or source currents after compensation current supplied by shunt active power filter. Compensating currents are injected into power system by SAPF. AS a result THD is reduced 33% to 2.1%.reactive power will decreased and power factor will improve.

V. CONCLUSION

An PV interactive shunt active power filter is designed and the circuit is connected in parallel as it reduces the harmonic injection into the power system network due to nonlinear load. In this paper a current control strategy is



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presented for SAPF in single phase circuit. The proposed control algorithm is capable of reducing the harmonics in the limits of IEEE 519. After compensation, the source current is sinusoidal. It compensates harmonics present in the power system and the percentage of current THD values is reduced and reactive power will decreased and power factor will be improve.

REFERENCES

- [1]. Lei Xiao, GuoChunlin, XuYongha “Study on Harmonic and Reactive Current Detection in Single-Phase Circuit” International Conference on Measuring Technology and Mechatronics Automation IEEE may 2009.
- [2].JinweiHe,YunWei Li and FredeBlaabjerg “Active Harmonic Filtering Using Current-Controlled, Grid-Connected Dg Units With Closed-Loop Power Control” IEEE Transactions On Power Electronics, Vol. 29, No. 2, February 2014.
- [3].Hirofumi Akagi, Yoshihirakanazawa and AkiraNabae“ Instantaneous Reactive Power Compensators Comprising Switching Devices Without Energy Storage Components”, IEEE transactions on industry applications, vol. Ia-20, no. 3, may/june 1984.
- [4]. Undeland and Riobbins Wiley India edition “Power Electronics: Converters, Application and Design”, Mohan.