

Transformer Less Inverter with Leakage Current and Harmonic Suppression for Grid Connected PV Systems

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ABSTRACT: Because of the growing demands and the need for increased energy, in society forces the government to take necessary actions for increasing the power generation by using the renewable energy as the major source of power generation. Due to the improvement in the technology because of the increased efficiency of solar panels, the photovoltaic solar based energy generation is becoming popular in the present century. But the usage of the Converters with transformers includes several stage of power conversion which are quite complex therefore Transformerless concept is usually preferred. This results in the generation of the ground leakage current between the PV system and the load due to the absence of the galvanic isolation. The presence of this leakage current results in the grid current distortions, safety hazards and loss of power quality. Because of the presence of non – linear and unbalanced load in the distribution system also inject harmonics in to the system which results in the additional loss in the power quality of the system. Therefore the main purpose of this paper is to reduce the current harmonics produced due to presence nonlinear loads and also to anticipate the ground leakage current in the PV panels, before being fed to the filter. The elimination of the ground leakage current is possible by using space vector pulse width modulation techniques together by controlling CM voltage. The Neutral Point Clamped (NPC) inverter which also been used as an shunt active filter is used for suppressing the harmonics. The suppression of harmonics uses the Instantaneous Reactive Power Theory together with the modulation technique for anticipating the ground leakage current in the input PV side. Here the Active Power Filter is connected parallel to the phases in order to suppress the harmonics. The NPC inverter which is connected parallel to the phases generates a compensating harmonic voltage. Thus the harmonics and the filter current injected into the phases will cancel out each other without disturbing the fundamental part. Hence the load current harmonics are reduced along with decreased leakage current.

KEYWORDS: Common Mode(CM) leakage current; Photo Voltaic(PV) system; Neutral Point Clamped(NPC) inverter; Shunt Active Power Filter(SAPF); Total Harmonic Distortion(THD); Space Vector Pulse Width Modulation(SVPWM).

I. INTRODUCTION

The Photo Voltaic (PV) power supplied to the utility grid is gaining more and more development, while the world's power demand is increasing. Not many PV systems have so far been placed into the grid due to the relatively high cost, compared with more traditional energy sources such as oil, gas, coal, nuclear, hydro, and wind[2]-[4]. In several situations, the PV inverters are used to feed the DC power into the utility grid. It is necessary for the PV inverter to be of high efficiency, because of the relatively higher price of the solar PV panels [5]. Small size of inverter with reduced cost and the three phase system is now gaining advantage especially when the inverters are installed indoor and used for low power applications. In the early days utilizing traditional grid-connected PV inverters, either a line frequency or a high-frequency transformer is utilized, which provides a galvanic isolation between the grid and the PV panels. This results in decrease in efficiency, increase in size, weight and cost because of the use of the isolation transformer. Removing the usage of the isolation transformer can be an effective solution to increase the efficiency and reduce the size and cost. However, when the transformer is omitted, the Common Mode (CM) ground leakage current may appear on the parasitic capacitor between the PV panels and the ground [7], [8]. Usually the ground leakage current is imposed on the line

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current; which results in higher harmonic in inverters without the transformer. In the transformer less grid-connected circuit which includes the capacitance between PV and the ground, the L-C filters, the MCSI inverter, and the impedance (Z) of the required utility grid. The voltage magnitude of the capacitance depends on given dc PV source and the surrounding environmental conditions. Here the solar PV panels ground capacitance is very high ranging from nanofarads (nF) up to microfarads (μF) [9], [10]. This is because PV panel structure resembles a huge capacitor, in which one electrode is the PV cells and the other one is the ground frame (see Fig. 1).

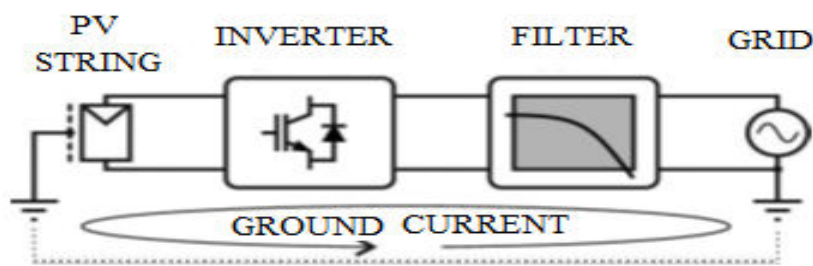


Fig.1.Path of the ground leakage current in Transformerless PV inverter connected to grid

Due to this the ground current is generated which reaches a higher value and it is becoming an important issue in transformerless inverter and it should be anticipated. Due to the CM ground leakage current it results in reduced the power conversion efficiency, increase the grid current distortion, deteriorate the electric magnetic compatibility (EMC), and above, this it give rise to the safety threats. Usually existing solar inverter are using VSI topology, which requires large value of capacitance to reduce the ground leakage current and also they suffers due to the problems of Maximum Power Point Tracking(MPPT). Also the CSI because of the use of small value of the DC capacitance and DC inductor together the reduced dc ripple voltage have added additional advantage. Sometimes in CSI due to the generation of the Common Mode (CM) voltage which induces higher leakage current. For the purpose of human safety and the EMI compatibility the Common Mode (CM) ground leakage current should be less than 300 mA and the complete PV system must be disconnected in 0.3 s as per DIN VDE 012-1-6 standards for PV applications connected to the grid. Thus, the fluctuations in the potential between the PV array and ground give rise to capacitive leakage current and these currents can cause grid current distortion and losses in the system. Therefore to overcome this Neutral Point Clamped Inverter (NPC) is proposed in this paper to overcome the above limitations of VSI and CSI. It eliminates the presence of the higher frequency component in the common mode voltage, thereby anticipating the common mode leakage current. The Neutral Point Clamped (NPC) inverter which also been used as an shunt active filters used for suppressing the harmonics. The suppression of harmonics uses the Instantaneous Reactive Power Theory together with the modulation technique for anticipating the ground leakage current in the input PV side. Here the Active Power Filter is connected parallel to the phases in order to suppress the harmonics. The NPC inverter which is connected parallel to the phases generates a compensating harmonic voltage. Thus the harmonics and the filter current injected into the phases will cancel out each other without disturbing the fundamental part. Hence the load current harmonics are reduced along with decreased leakage current. The use of Space Vector Pulse Width Modulated (SVPWM) for grid connected PV applications are suggested in [11]. The proposed inverter can be modulated with the Space Vector Pulse Width Modulation (SVPWM) technique.

II. EXISTING SYSTEM

Usually solar PV inverters uses Voltage Source Inverter (VSI) topology [3]–[5]. While considering that topology, the higher current ripple absorbed/ supplied by the dc-link capacitor in VSI, requires larger value of capacitance to limit the output voltage ripple across solar PV terminals. The utilization of the VSI when compared to CSI may not be economically efficient. Also, voltage source based solar inverters will have don't have longer operational life as compared to current source based solar inverters. But in VSI another important issue is their reduced size of the dc capacitor which results in higher (switching) frequency ripple voltage on the dc bus increases, which results in reduced MPPT efficacy [8].Therefore the above disadvantages of VSI is replaced by CSI. But in CSI due to the generation of

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the Common Mode (CM) voltage which induces higher leakage current [12]. Therefore the use of the NPC inverter is usually preferred for its improved efficiency.

III. PROPOSED SYSTEM

Before the power produced by the renewable solar energy source is injected into the grid via the shunt active power filter (SAPF), which is considered as the improved three phase voltage source inverter[13]. This filter transfers the power from the energy sources as well as performs the job of elimination of harmonic, compensation of reactive power and the power factor correction by maintaining power factor as unity at the input source side. This paper focus the analysis and simulation of a PV which being supported by a MPPT controller interactive with Shunt Active Filter topology for simultaneous harmonic current damping, leakage current suppression and the reactive power compensation. For this the Shunt Active Filter reference current calculation the real and imaginary instantaneous powers theory is used. For gating signal generation the carrier-based Space Vector PWM modulation technique is used.

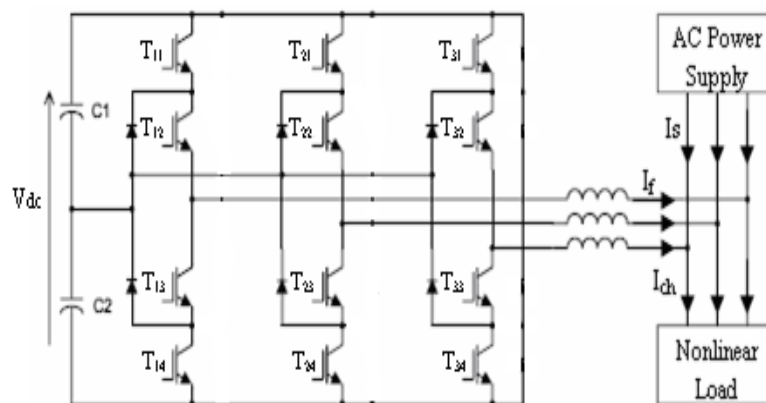


Fig.2. Three level Neutral point clamped (NPC) inverter

IV. MAXIMUM POWERPOINT TRACKING TECHNIQUE

Perturb and Observe (P&O) is one of the most commonly used MPPT algorithms in PV tracking systems because the search for the MPP is done independent corresponding to the environmental conditions. The operation, of the P&O algorithm is that it calculates the PV output power $P(n-1)=I(n-1)*V(n-1)$ and causes a disturbance on the duty cycle D . After the perturbation, if the power $P(n)=I(n)*V(n)$ increase $P(n)>P(n-1)$, the disturbance is kept at the same direction as before. On the other hand, after the perturbation if the power $P(n)=I(n)*V(n)$ decreases, $P(n)<P(n-1)$, the direction of the duty cycle is inverted.

V. REAL AND IMAGINARY INSTANTANEOUS POWERS THEORY

The Shunt Active Filter/NPC inverters the six switch current bi-directional converter which consists of filter components and the switching network. The other side of the NPC inverter is connected to the utility grid, here being represented as the three phase voltage source. Each of the switches in the switching network are IGBTs with anti-parallel diodes which allow the current flow in both directions. This NPC inverter utilizes instantaneous reactive power theory for suppressing the current harmonics. This theory is based on time-domain, which controls the shunt active power filters in real-time. The second important characteristic of this theory is the simplicity in calculations, because it involves only algebraic calculation. This theory applies an algebraic transformation (Clarke transformation) of three-phase system voltages and the load in the a-b-c coordinates to the $\alpha - \beta$ coordinates respectively is explained in Fig. 3.

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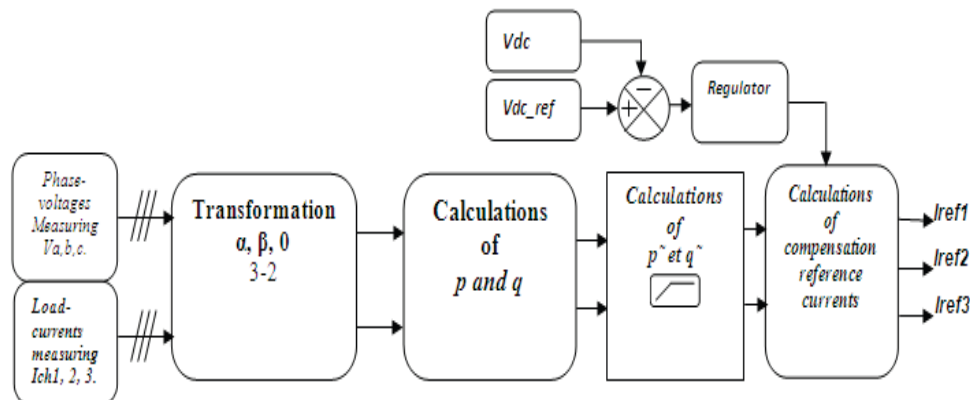


Fig. 3.p-q theory power calculation

The Three phases abc variables of voltage and current are transformed to orthogonal $\alpha\beta$ variables is given as,

$$\begin{bmatrix} i_{\alpha} \\ i_{\beta} \end{bmatrix} = \frac{\sqrt{2}}{\sqrt{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} V_{\alpha} \\ V_{\beta} \end{bmatrix} = \frac{\sqrt{2}}{\sqrt{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (2)$$

Instantaneous real and the reactive input power are given as,

$$\begin{bmatrix} P_{in} \\ Q_{in} \end{bmatrix} = \begin{bmatrix} V_{\alpha} & V_{\beta} \\ -V_{\beta} & V_{\alpha} \end{bmatrix} \begin{bmatrix} i_{\alpha} \\ i_{\beta} \end{bmatrix} \quad (3)$$

The source should equalize the input power taken by load and the power required by the compensator is given as,

$$P_{in} = P_{load} + P_{loss} \quad (4)$$

where,

$$P_{load} = V_{\alpha} \times i_{\alpha} + V_{\beta} \times i_{\beta} \quad (5)$$

The reference source current can be given as,

$$\begin{bmatrix} i_{\alpha}^* \\ i_{\beta}^* \end{bmatrix} = \begin{bmatrix} V_{\alpha} & V_{\beta} \\ -V_{\beta} & V_{\alpha} \end{bmatrix} \quad (6)$$

By taking inverse Clarke's transform the reference current can be transformed into abc coordinates is given as,

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$$\begin{bmatrix} I_{ref1} \\ I_{ref2} \\ I_{ref3} \end{bmatrix} = \frac{\sqrt{2}}{\sqrt{3}} \begin{bmatrix} 1 & 0 \\ -1 & \sqrt{3} \\ -1 & -\sqrt{3} \end{bmatrix} \begin{bmatrix} i_{\alpha} \\ i_{\beta} \end{bmatrix} \quad (7)$$

VI. CURRENT CONTROL BY PWM CARRIER STRATEGY

The Shunt Active power Filter is controlled by a Space Vector PWM (pulse width modulated) technique carrier strategy. The reference currents I_{ref1} , I_{ref2} and I_{ref3} and the injected currents I_{meas1} , I_{meas2} and I_{meas3} are used in a PI (proportional integral) loop control. The Control signal is limited and then compared to a PWM carrier signal in order to command VSI (voltage source inverters) switches to turn on.

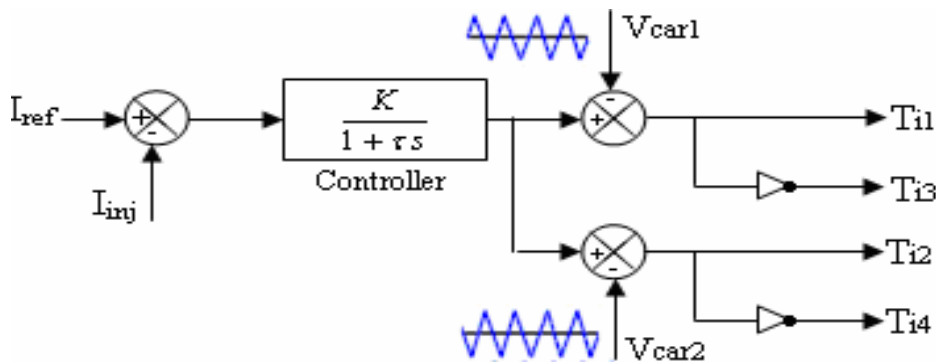
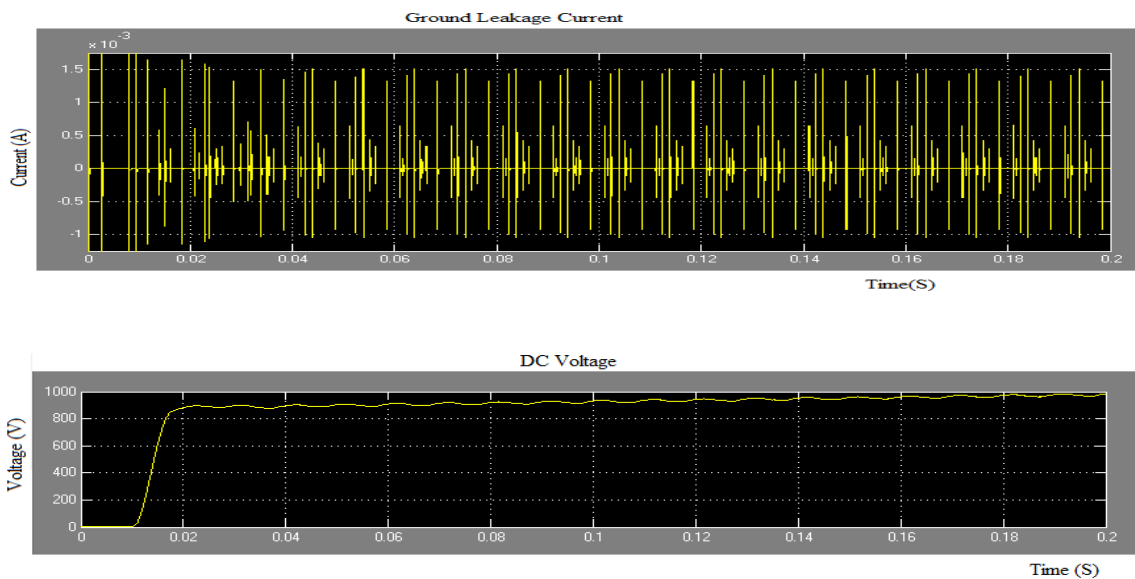


Fig.5. Block Diagram of Current Control

VI. THE SIMULATION RESULTS

The Results of simulation shows that work of the SAPF after active filtering is shown in Fig. 4 & 5. The load side current THD (total harmonic distortion) is reduced to 5.04% on the grid network, which confirms the good quality of power after filtering. Also the leakage current is within the safe limit of around 1.5 mA. Also the current harmonics filtered in phase with the voltage, shows good mode of filtering the harmonic currents and a perfect compensation of reactive power.



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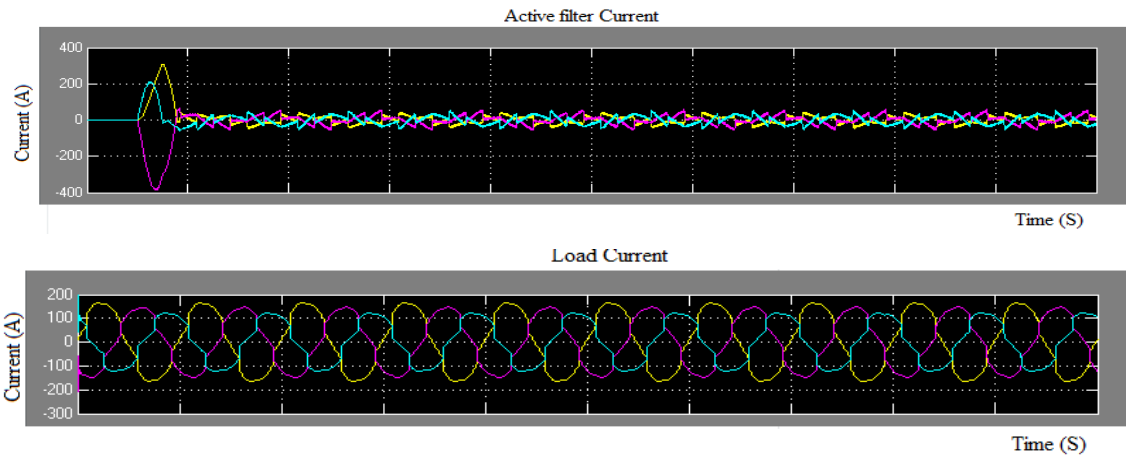


Fig. 4 Ground leakage current, DC Voltage, Active filter Current, Load Current

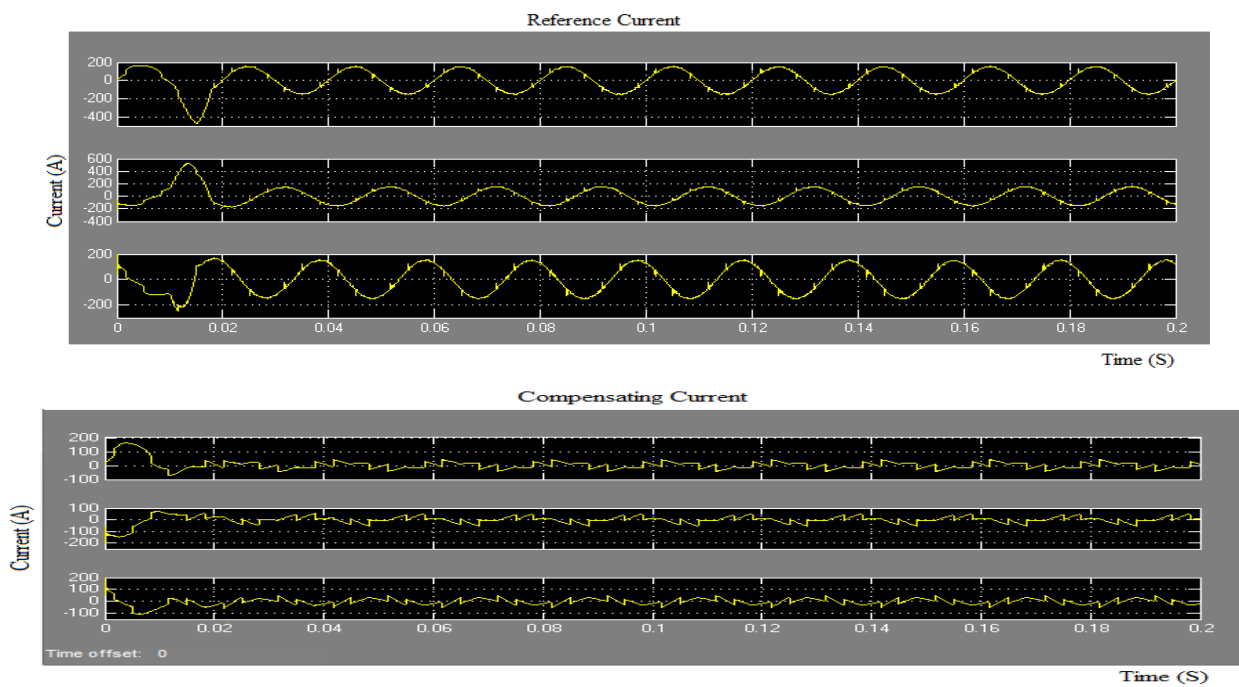


Fig.5 Reference Current, Compensating Current

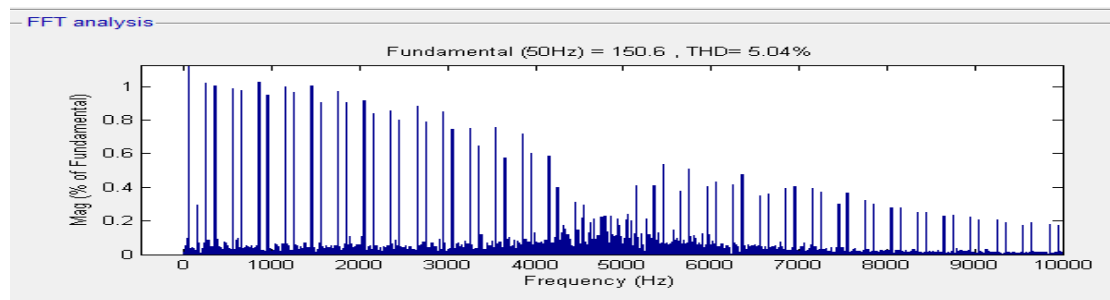


Fig. 6 THD after compensation

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VII. CONCLUSION

This paper contributes the analysis and simulation of a PV being supported by a P& O MPPT controller interactive with Shunt Active power Filter. This system is used to eliminate ground leakage current by appropriate modulation technique and also to minimize the harmonics generated by a nonlinear load and reactive power compensation. The shunt active filter is used because of its adaptability to the changing load condition. As regards the control strategy, this control method is based on optimal voltage space vector current was explained in this paper; because of the accuracy in the selection of inverter's switch state is becoming much better, with reduced Switchgear Malfunction and improved switch life. The results shows that a good compensation effect with reduced THD.

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