International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459,ISO 9001:2008Certified Journal, Volume 4, Issue 4, April 2014)

Design of Solar Power Optimizer And Eliminating Leakage Current In Multi-Level Inverter For PV Systems

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***Abstract*- This paper proposes a high step-up Solar Power Optimizer (SPO) harvests maximum energy from a photovoltaic (PV) panel with high efficiency. DC-DC converter structure is used to get high step-up voltage gain. It is the structure designed to coupled inductor and switched capacitor. The inductance energy can be recycled, and it is reducing the voltage stress and power loss. Particle Swarm Optimization(PSO) method based Maximum Power Point Tracking (MPPT) algorithm is used to improve the efficiency of the tracking system. Three phase transformer-less neutral point clamped inverters are used to eliminate the leakage current in photovoltaic systems using the multi-level inverters. The three phase neutral point diode clamped inverter can be designed to provide functions of low pass filters. Diode clamped multi-level inverters are used to reduce the harmonic, and also to eliminate the leakage current in PV panels.**

***Keywords*- solar power optimizer (SPO), High step-up voltage gain, maximum power point tracking (MPPT)**

I. INTRODUCTION

Solar energy is one of the most important renewable energy sources that have been gaining increased attention in recent trends. It has the more availability compared to other energy sources. Solar energy is converted into electrical energy has many application fields. Solar to electrical energy conversion can be done in two ways, namely solar thermal and solar photovoltaic. Solar thermal is similar to conventional AC electricity generation by steam turbine excepting that instead of fossil fuel.

In this paper, it is presented the photovoltaic solar panel's operation. The foremost way to increase the efficiency of a solar panel is to use a Maximum Power Point Tracker (MPPT), a power electronic device that significantly increases the system efficiency. By using it the system operates at the Maximum Power Point (MPP) and produces its maximum power output.

In addition, it is attempt to design the MPPT by using the algorithm of a selected MPPT method which is "Particle Swarm Optimization" and implement it by using a DC- DC converter. It has found various types of DC-DC converter. PV generation systems generally use a microcontroller based charge controller connected to a battery and the load.

II. BASIC BLOCK DIAGRAM

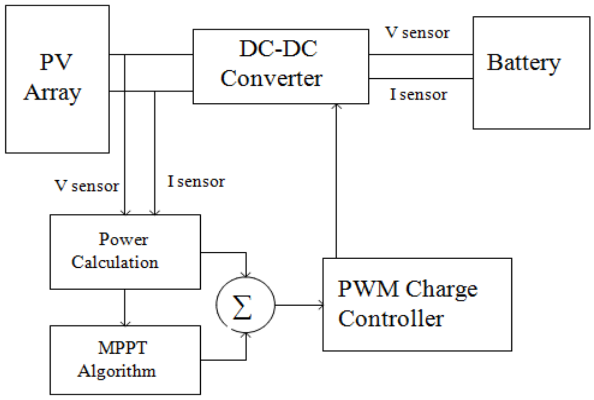

Fig 1. Block diagram of basic method

Fig 1 shows the basic block diagram of the solar system.

A. Solar panel

Solar panel is a packaged connected assembly of photovoltaic cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Solar panels use light energy photon from the sun to generate electricity through the photovoltaic effect. The majority of modules use wafer based cells or thin film cells based on non-magnetic conductive transition metals, or silicon. In stand-alone photovoltaic system, the electrical energy produced by the PV array cannot always be used when it is produced because the demand for energy does not always coincide with its production. Energy storage capacity and autonomy to store electrical energy when it is produced by the PV array and to supply energy to electrical loads as needed or on demand.

B. Charge controller

A charge controller or charge regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may prevent against overvoltage, which can reduce battery performance, and may pose a safety risk. In simple words, solar charge controller is a device, which controls the battery charging from solar cell and also controls the battery drain by load.

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Solar power available then it assumes that it is night time and switch on the load. The functions of a microcontroller in charge controller are,

- Measures solar cell voltage.
- Measures battery voltage.
- Decides when to start battery charging.
- Decides when to stop battery charging.
- Decides when to switch on the load.
- Decides when to switch off the load.

Most importantly in the microcontroller also tracks the MPP of the output power.

C. Maximum power point tracker

The Maximum power point tracker (MPPT) is now prevalent in grid-tied PV power system and is becoming more popular in stand-alone systems. MPPT is made up with a switch-mode DC-DC converter and a Controller. A conventional method, incremental resistance method, incremental conductance method was taken by the paper [4],[5], It is combined with a DC-DC converter that performs the MPPT function. In this proposed method, therefore, chooses a method "Particle Swarm Optimization" algorithm for digital control for MPPT. The design and simulations of MPPT will be done on the premise that is going to be built with a microcontroller.

D. DC-DC Converter

DC-DC converters are power electronic circuits that convert a dc voltage to a various step dc-dc converter include a conventional boost and fly-back converters. The key ingredient of MPPT hardware is a switch-mode DC-DC converter. The boost types are integrated with coupled inductors[6]. MPPT is one of many applications of power electronics, and it is a relatively new area. This investigates it in detail and provides better explanations. In order to understand and design MPPT, it is necessary to have a good understanding of the behaviors of PV. This facilitates using MATLAB models of PV cell and module. The solar power optimizer design of dc-dc converter is used in the proposed method.

III. CONVENTIONAL METHOD

The micro-inverter includes dc-dc converter and dc-ac inverter. It is proposed a single-stage dc-ac inverter with fewer components to fit the dimensions of the ac module, efficiency levels are lower than the conventional PV inverters. The micro-inverter used to an every individual panels [7], and may partially eliminate the shadow problem, a micro-inverter structure contains the system energy's harvesting efficiency and entails high cost

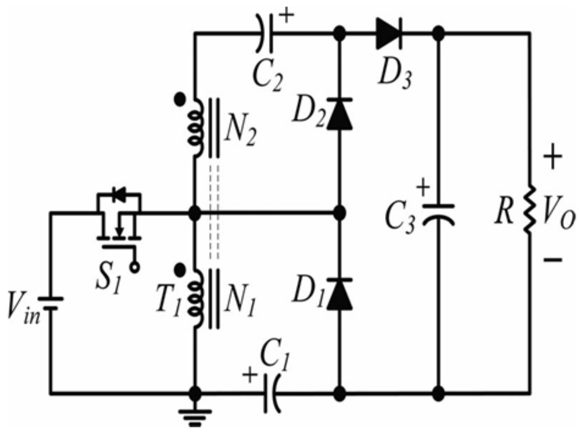

Fig 2 Circuit diagram for conventional method

The circuit diagram of conventional method is shown in fig.2 taken by[1]. Input as ac supply to the PV panel, and the dc output voltage is connected to the micro-inverter. The single stage dc-ac inverter only used in this method. The efficiency and voltage gain of the dc-dc converter are constrained by the parasitic effect of the power switches or the reverse recovery issue of the diodes. In addition, the Equivalent Series Resistance (ESR) of the capacitor and the parasitic resistances of the inductor also effect the overall efficiency. The connection of the two pairs of inductors, capacitor, and diode gives a large step-up voltage ratio. It is the dc-dc converter working in the discontinuous and continuous modes of operation.

By combining active snubber, auxiliary resonant circuit, synchronous rectifiers, or switched- capacitor-based resonant circuits and so on, these techniques made active switch into zero voltage switching (ZVS) or zero current switching (ZCS) operation and improved converter efficiency. However, when the leakage-inductor energy from the coupled inductor can be recycled, the voltage stress on the active switch is reduced, which means the coupled inductor employed in combination with the voltage-multiplier or voltage-lift technique successfully accomplishes the goal of higher voltage gain.

Since the energy of the coupled inductor has been recycled, the voltage stress across the active switch $S_1$is constrained, which means low ON-state resistance R_{ds}(ON) can be selected.. The switching signal action is performed well by the floating switch during system operation, on the other hand, the residential energy is effectively eliminated during the non-operating condition, which improves safety to system technicians.

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IV. BLOCK DIAGRAM OF PROPOSED METHOD

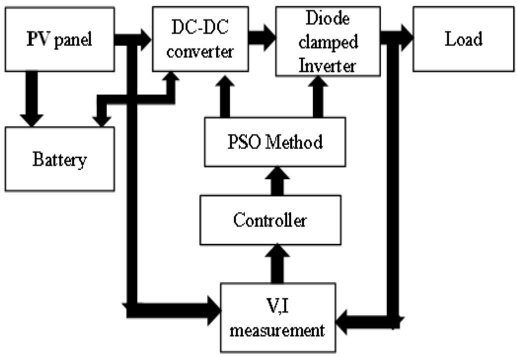

Fig 3 Block diagram of proposed method

In this proposed method, PV panel output is connected to the dc-dc converter. It is the boost converter is used to high step-up voltage gain from PV panel. In case of low power condition battery can be used in this method. The diode clamped four-level inverter is proposed.

Particle Swarm Optimization method is tracking purpose of the system. Boost converter output is connected to the multi-level inverter, if the number of levels are increased, it is no need to filter circuit. And the panel voltage, current values are measured. It is the neutral point clamped inverters are proposed in order to eliminate the leakage current in transformer-less PV systems. And the system efficiency improved in this proposed method.

V. PROPOSED METHOD

This method deals the high power application with low input voltage. It gives more advantages over conventional method. The PV cell converts heat energy into electrical energy. And the multi-level inverters are used to eliminate the leakage current in PV panels. Two PV panels are connected to series and it is grounded. The three phase NPC inverters are proposed in order to eliminate the leakage current in transformer-less PV systems.

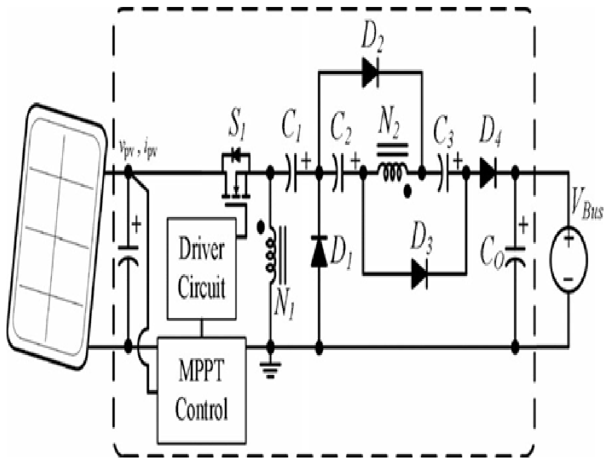

Fig 4 Circuit diagram for Proposed method

The proposed SPO configuration is based on a high step-up dc–dc converter with a MPPT control circuit. The converter includes a floating active switch S and a coupled inductor T_1 with primary winding N_1 , which is similar to the input inductor of a conventional boost converter capacitor C_1 , and diode D_1 recycle leakage inductance energy from N_1. Secondary winding N_2 is connected to another pair of capacitors, C_2 and C_3 , and to diodes D_2 and D_3. Rectifier diode D_4 connects to output capacitor C_0 and load R. The duty ratio is modulated by the MPPT algorithm, which uses the particle swarm optimization method that is employed in the proposed SPO. It detects PV module voltage V_{PV} and current I_{PV} to determine the increase and decrease in the duty cycle of the dc converter. The proposed converter has the following features

1. It is a voltage conversion ratio efficiently increased by using the switched capacitor and coupled inductor technique.
2. The leakage inductance energy of the coupled inductor can be recycled to increase efficiency, and the voltage spike on the active switch is restrained.
3. The floating active switch isolates the PV panel's energy during non-operating conditions, thereby preventing any potential electric hazard to humans or facilities. The MPPT control algorithm exhibits high-tracking efficiency. hence, it is widely used in the energy harvesting of PV systems.

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The operating principles for Continuous Conduction Mode (CCM) and Discontinuous Conduction Mode (DCM) are presented in detail. It illustrates a typical waveform of several major components in CCM operation during one switching period. To simplify the circuit analysis of the proposed converter, the following assumptions are made

1. All components are ideal, except for the leakage inductance of coupled inductor T_1 which is taken into account. On-state resistance $R_{ds}(ON)$ and all the parasitic capacitances of main switch S are disregarded, as are the forward voltage drops of diodes D_1 to D_4.
2. Capacitors C_1 to C_3 and C_0 are sufficiently large that the voltages across them are considered constant,
3. The equivalent series resistance (ESR) of capacitors C_1 to C_3 and C_0, as well as the parasitic resistance of coupled inductor T_1 , is neglected,
4. Turns ratio n of coupled inductor T_1 windings is equal to N_2/N_1.

A. Multi-level inverter

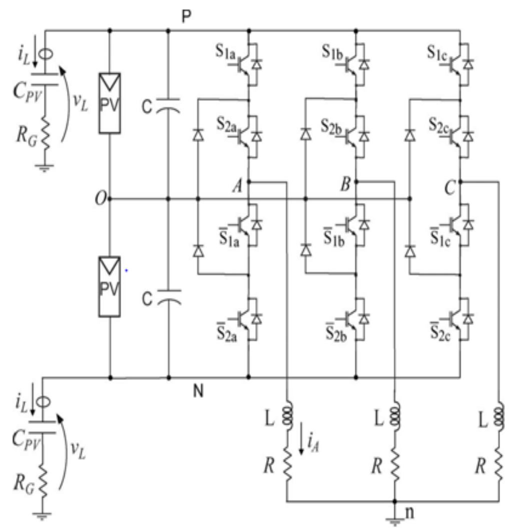

Fig 5 Three-phase NPC inverter to evaluate leakage current

In the above fig 5 taken by[2]. The transformer-less centralized configuration with one-stage technology uses only one inverter and a large number of series-connected PV modules, called strings, are used in order to generate sufficient voltage to connect to the grid. In PV systems where series modules are connected to a conventional two-level inverter, the occurrence of partial shades and the mismatching of the modules lead to a reduction of the generated power. This problem can be reduced in this proposed method. The multilevel converter maximizes the power obtained from the arrays, reduces the device voltage stress, and generates output voltages with lower Total Harmonic Distortion (THD).

Avoiding transformers is a benefit of multilevel inverters and normally Neutral Point Clamped (NPC) inverters are not used with transformers. In PV applications, the transformer-less systems have problems related to leakage currents, thus it is necessary to pay special attention to this issue. In this method, PWM techniques for three-phase NPC inverters are proposed to eliminate the leakage current in transformer-less PV systems without requiring modification on the NPC inverter. Furthermore, the NPC inverter is studied for PV systems with function of active filter using the p-q theory to increase the system utilization. The common-mode voltages (CMV) and leakage currents in three-level inverters are analyzed. modulation techniques for three-phase NPC inverters are proposed in order to eliminate the leakage current in transformer-less PV systems. It is possible to express the voltages between the positive (P) or negative (N) dc bus and the neutral (n) (V_{Pn} or V_{Nn}) terms of the inverter output voltages. The negative inverter output voltage in equ (3.1)

$$V_{Nn} = V_{kn} - V_{kN} \qquad (5.1)$$

$$V_{pn} \quad V_{Pn}=V_{kn} - V_{kP} = V_{kn} - (V_{kn} - V_{PN}) \qquad (5.2)$$

where k = A,B,C

Under balanced operation, the following condition for the inverter voltages can be written in equ (5.3)

$$V_{An}+V_{Bn}+V_{Cn}=0. \qquad (5.3)$$

Using (5.1) – (5.3)

$$V_{Nn} = -\frac{V_{AN}+V_{BN}+V_{CN}}{3} \qquad (5.4)$$

The positive inverter output voltage is in equ (5.5)

$$V_{Pn}=V_{PN} - \frac{V_{AN}+V_{BN}+V_{CN}}{3} \qquad (5.5)$$

The CMV for the three-phase inverter can be calculated as in equ (5.6)

$$V_{CM}= \frac{V_{AN}+V_{BN}+V_{CN}}{3} \qquad (5.6)$$

The voltage V_{Nn} is the negative of the CMV and the voltage V_{Pn} is V_{PN} + V_{Nn}. Therefore, the leakage currents can be attenuated by the control of the CMV.

B. Space vector modulation

The space vector PWM (SVPWM) is generally used to control the three-level inverter output voltages.

The maximum amplitude of the phase-to-neutral voltages is $V_{PN}/\sqrt{3}(m-1)$ in the linear region, where modulation index is defined as

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$$m = \frac{\sqrt{3}\, V^{*}{}_{kn}}{V_{PN}}$$

and $V^{*}{}_{kn}$ is the reference amplitude of the phase-to-neutral voltages, Depending on the choice of which space vectors are used to produce the phase reference voltages, the CMV may vary during the switching period.

VI. Simulation Results

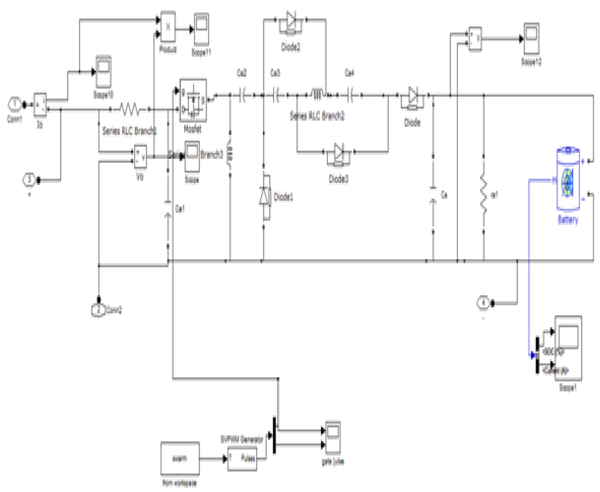

Fig 6 Simulink model of the proposed method

The PV panel simulation circuit is shown in fig 6 PV panel is connected to dc-dc converter. Two panels are connected in series and it is neutral point connected to multi-level inverter. To eliminate the leakage current in PV systems using the multi-level inverter.

Simulation results

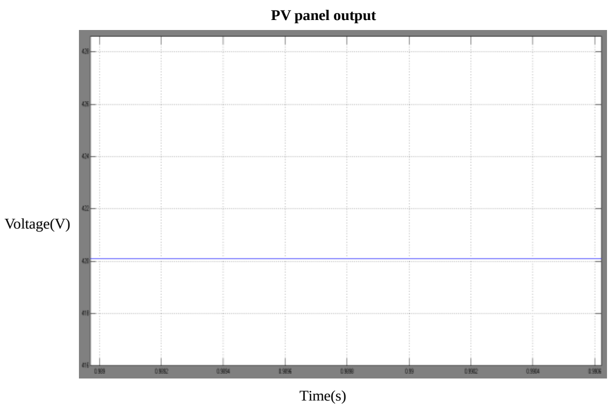

Fig 7 PV panel output voltage waveform

In the above fig 7 represents the PV panel output voltage waveform. The heat energy is converted into electrical energy used by the PV cells. Two panels are connected to series. In the panel output dc voltage level is more than 420volts.

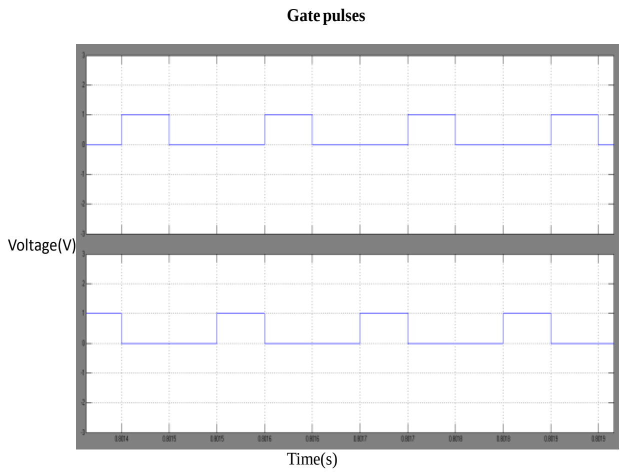

Fig 8 Gate switching pulses waveform

In the fig 8 represents the gate switching pulses. The pulse generator is used to gate drive requirements of mosfet switch. And Particle Swarm Optimization (PSO) method is connected to the pulse generator. This method is used to the tracking purses of the solar panel. so, that the efficiency is increased.

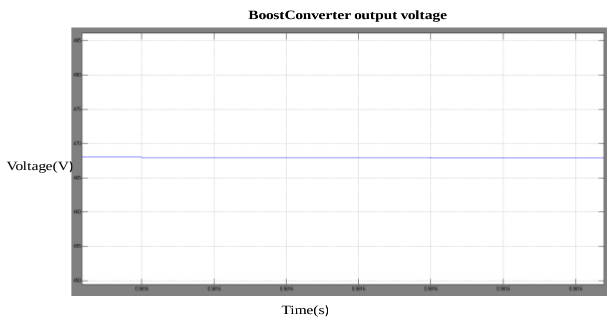

Fig 9 Boost converter output voltage

In the above fig 9 is the boost converter. It is the design of solar power optimizer. DC-DC converter is used to the step-up from PV panel output voltage. Each and every individual panel is connected to the dc-dc converter. It optimize the solar power from every panel. Battery pack-up is connected to the boost converter, in case of low power level it compensates the voltage level.

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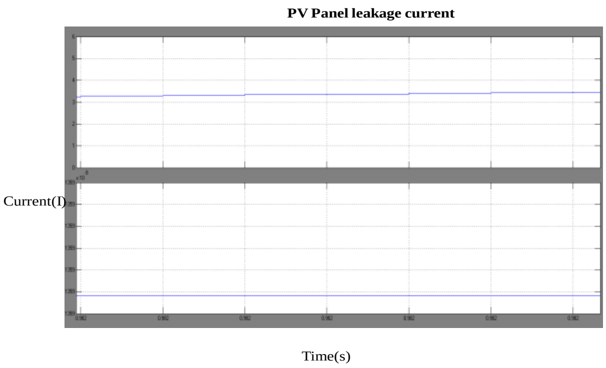

Fig 10 PV panel leakage current waveform

The fig 10 is the PV panel leakage current waveform. The three-phase NPC inverters are proposed in order to eliminate the leakage current in transformer-less PV systems.

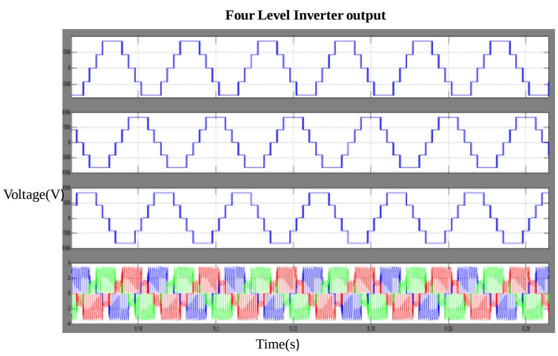

Fig 11 Four level inverter output waveform

In this, fig 11 is the four-level inverter output waveform. Three phase NPC inverters are proposed to eliminate the leakage current in PV panels. Four-level inverter is proposed in this method. (SVPWM) space vector pulse modulation technique is used in the various switching combinations to different regions.

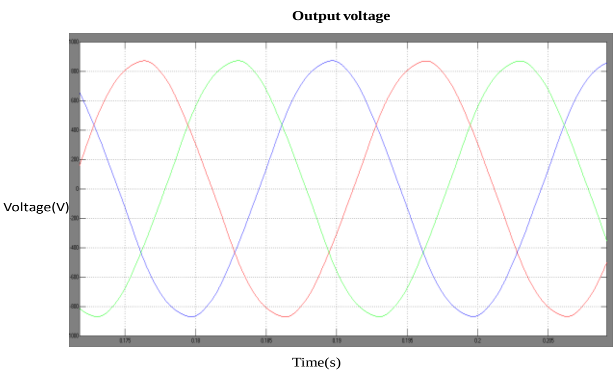

Fig 12 Three phase output voltage waveform

The above fig 12 represents the three-phase output voltage of the proposed method. In this method four-level inverter is proposed and use the active filter to get the three-phase output voltage is connected to grid. The output voltage level is above 900 volts.

VII. CONCLUSION

A new design approach to boost, dc–dc converters and also multi level inverter has been presented. In the dc-dc converter, solar power optimization is designed in proposed system. Particle Swarm Optimization algorithm is used in tracking purpose. To eliminate the leakage current in PV panel, the multi-level inverters are used and Total Harmonic Distortion also reduced, system efficiency can be improved. The simulation analysis using MATLAB 2011a software helps to predict the output voltage and output current of the isolated boost dc-dc converter as well as output voltage and current waveforms. The simulated results of proposed method are obtained.

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International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459,ISO 9001:2008Certified Journal, Volume 4, Issue 4, April 2014)

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