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Analysis of PV based Soft Switching Boost DC-DC Converter with Zero Current Switching Technique

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***Abstract*—This paper presents the analysis of photovoltaic (PV) based soft switching boost DC-DC converter with zero-current switching (ZCS) technique. The availability of solar energy varies widely with ambient temperature and different atmospheric conditions and hence the maximum power point (MPP) of PV system is not stable. Therefore, a Maximum Power Point Tracking (MPPT) controller is needed to operate the PV at its MPP. The modified perturb and observation (P&O) is used to track MPP and implemented in a Soft Switching Boost DC-DC Converter. This new technique eliminates the switching loss and *dv/dt* noise due to the discharging of MOSFET's junction capacitances and the reverse recovery of diodes and enables the converters to operate at high frequencies. Consequently, the total turn-off switching losses can be significantly reduced and as a result, a high switching frequency of the used switches can be actually realized. The size and weight of the devices are reduced as the heat sink is not required. The effectiveness of the proposed converter topology is provided for PV system by the simulation results and power loss analysis. The effectiveness of the proposed system is proved with the help of simulation. The simulation is performed in simulation software PSIM.**

***Index Terms*—Photovoltaic Array (PV), Maximum Power Point Tracking (MPPT), modified perturb and observation (P&O), Soft Switched Boost DC-DC Converter, Zero Current Switching (ZCS).**

I. INTRODUCTION

The increasing demand for renewable energy has increased significantly over the years because of shortage of fossil fuels and greenhouse effect. Among various types of renewable energy sources, solar energy and wind energy have become very popular and demanding due to advancement in power electronics techniques. Photovoltaic (PV) sources are used today in many applications as they have the advantages of being maintenance and pollution frees [1-4].

The grid-connected PV system can reduce investment outlay because it does not need battery to store energy; it became a hot subject by now. Moreover, the increasing use of power electronic devices and nonlinear loads is known to cause serious problems in electric power systems. Therefore, the technology that combines PV grid-connected generation and active filtering is proposed and develops rapidly. Both of PV grid-connected generation and active filtering need to keep DC bus stable and the key of unified control is generating the uniform current reference accurately [5-7].

The buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. Two different topologies are called buck–boost converter. Both of them can produce a range of output voltages, from an output voltage much larger (in absolute magnitude) than the input voltage, down to almost zero. The efficiency of the PV generation depends on maximum power extraction of PV system. Therefore, to maximize the efficiency of the renewable energy system, it is necessary to track the maximum power point of the PV array [8].

The PV array has a single in service point that can supply maximum power to the load. This point is called the maximum power point (MPP). The locus of this point has a nonlinear distinction with solar irradiance and the cell temperature. Thus, in order to operate the PV array at its MPP, the PV system must contain a maximum power point tracking (MPPT) controller. Many MPPT techniques have been reported in the literature. The perturb and observation (P&O) method is an iterative algorithm to track the MPP by measuring the current and voltage of the PV module. This algorithm is easy to implement but the problem of oscillation of operating point around MPP is unavoidable and implementation of PWM control as discussed in [9-10]. The incremental conductance (INC) method presented in [11] is most widely used method. It tracks the MPP by comparing instantaneous conductance to the incremental conductance. The fuzzy logic controllers have the advantages of robustness, simplicity in design and it does not need accurate mathematical model. The selection of parameters and membership function in fuzzy logic is not easy as it needs expert knowledge and experimentation as discussed in [12-14].

From all the above analysis, conclude that the objective of this paper is to analyze the buck-boost version is selected because of its ability to develop voltage less than or more than the input voltage. The PV based soft switching boost DC-DC converter with zero current switching (ZCS) technique and P&O MPPT algorithm being used to extract the maximum DC power from PV module various isolation and cell temperature. One of the major trends in power electronics is increasing the switching frequencies. The advances in

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semiconductor fabrication technology have made it possible to significantly improve not only voltage and current capabilities but also the switching speed.

In this proposed work, first, the faster semiconductors working at high frequencies result in the passive components of the converters-capacitors, inductors and transformers-becoming smaller thereby reducing the total size and weight of the equipment and hence to increase the power density. Second, the dynamic performance is also improved. This frequency elevation is responsible for the growing importance of pulse-width modulation on the one hand and for the use of resonance. Third, resides in reduction of voltage and current stresses on the semiconductors and limitation of the conducted and radiated noise generated by the converters due large *di/dt* and *dv/dt*. Both these requirements, size and noise, are minimized if each switch in a converter utilizes soft switching technique to change its status. The proposed soft switching three-level boost converter for PV system is shown in Fig. 1.

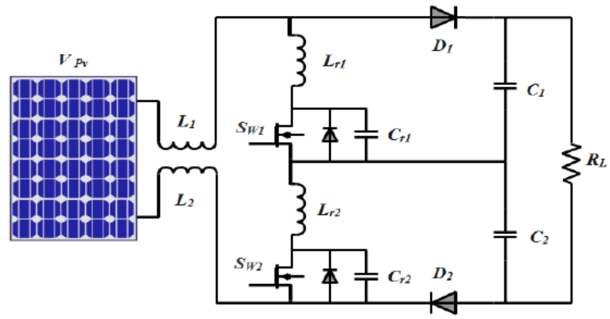

Fig.1. Proposed soft switching three-level boost converter for PV system

II. PV ARRAY MODELING AND SIMULATION

A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a grid by using proper energy conversion devices. This photovoltaic system consists of main parts such as PV module, charger, battery, inverter and load [15-16]. A Photovoltaic cell is a device used to convert solar radiation directly into electricity. It consists of two or more thin layers of semiconductor material, most commonly silicon. When the silicon is exposed to light, electrical charges are generated. A PV cell is usually represented by an electrical equivalent one-diode model shown in Fig. 2.

In this model, a PV cell is represented by a current source in parallel with a diode and a series resistance, the basic current equation is given in Eq. (1).

$$I=I_{pv,\,cell}-I_{0,\,cell}\{[\exp(qv/akT)]-1\} \qquad (1)$$

Where $I_{pv,\,cell}$ is current generated by the incident light (directly proportional to sun irradiation), $I_{0,\,cell}$ is leakage current of the diode, q is electron charge 1.6021e10-19 C, k is Boltzmann constant, T is Temperature of the PN junction, a is Diode ideality constant is explained in [15-16].

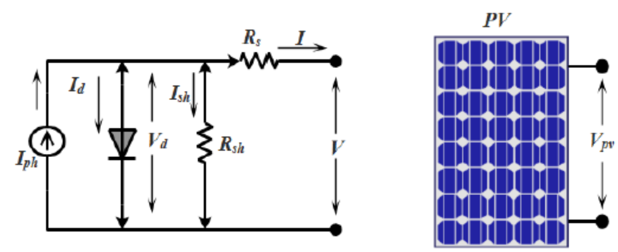

Fig. 2. Equivalent circuit of PV cell

III. PERTURB AND OBSERVE (P&O) MPPT CONTROL

The tracking algorithm works based on the fact that the derivative of the output power *P* with respect to the panel voltage *V* is equal to zero at the maximum power point. The module P-V characteristics are shown in Fig. 3 show further that the derivative is greater than zero to the left of the peak point and is less than zero to the right.

$$\delta P/\Delta v=0 \text{ for } V=Vmp \qquad (2)$$

$$\delta P/\Delta v>0 \text{ for } V<Vmp \qquad (3)$$

$$\delta P/\Delta v<0 \text{ for } V>Vmp \qquad (4)$$

In the literature, various MPPT algorithms are available in order to improve the performance of PV systems by effectively tracking the MPPT. However, most widely used MPPT algorithms are considered here.

The most commonly used MPPT algorithm is P&O method [17] and is also known as hill climbing algorithm. This technique employs simple feedback arrangement and few measured parameters. In this approach, the array voltage is periodically given a perturbation and the corresponding output power is compared with that at the previous perturbation cycle. However, the operating point oscillates around the MPP as the system is continuously perturbed. In this simple algorithm, the operating voltage is perturbed with a small change $+\Delta V$ and the power output is observed.

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Depending on the sign of observed power, further perturbation will be given to voltage as described in Fig. 4.

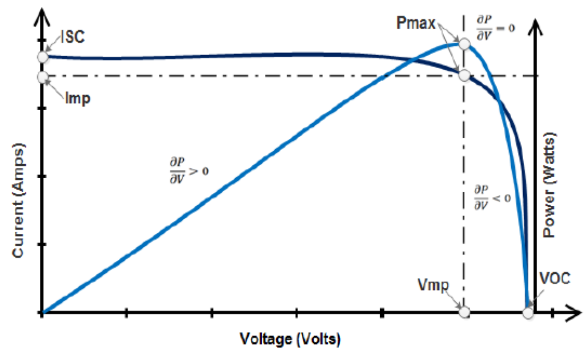

Fig. 3. P-V Characteristics of a PV module

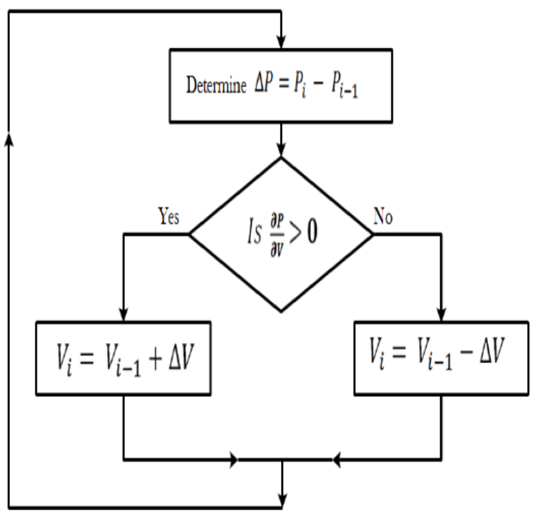

Fig. 4. P&O MPPT flow chart

IV. PROPOSED SOFT-SWITCHING DC-DC CONVERTER AND ITS MODES OF OPERATION

The resonant power converter utilizes the resonance theory by incorporating an *LC* resonant circuit as shown in Fig. 1. The switching-on and switching-off instants of power switch occurs at zero voltage, it will help to reduce the switching losses, switching stress, *dv/dt* and *di/dt* surge, and thus EMI. The circuit consists auxiliary Diode *D* is connected across the switch with the appropriate polarity to ensure turned on instant of power switch at zero voltage. The Inductor *Lr* is connected in series with power switch *SW* to limit *di/dt* of the power switch and the capacitor *Cr* is connected across the switch to limit *dv/dt* of the power switch. The ZVS is used during a turn *ON* of the device. Initially the main switch is *OFF* and the auxiliary switch is *ON*. So the current through the main switch is zero, but the voltage is not zero. During the turn *ON*, voltage is made zero and current is given some time delay so that the current will begin to rise after the voltage is zero. Fig. 5 presents switch waveforms on the proposed soft switching three-level boost converter [18].

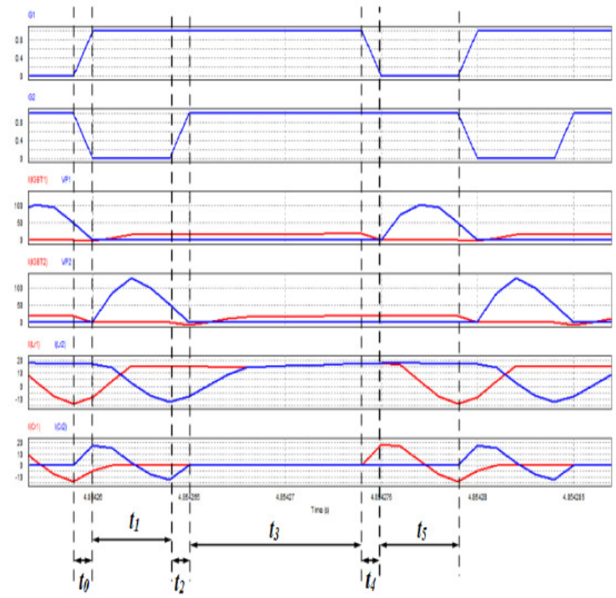

Fig. 5. Waveforms of the soft switching three-level boost DC-DC converter

Mode 1 at (t_0): In this mode SW_1 is turn ON and SW_2 is turn OFF. A decrease the value of voltage is flowing in the SW_2 to zero voltage and drop in the value of current flowing in the SW_2 to zero current value.

Mode 2 at (t_1): In this mode SW_1 is ON and SW_2 is OFF. In the SW_1 current starts to increase until it reaches the maximum value and so with the stability of the voltage value zero, in the SW_2 starts the voltage from zero increases up any maximum values, then decline to near zero volts, and so with the stability of the current value of zero.

Mode 3 at (t_2): In this mode SW_1 is ON and SW_2 is turn ON. In the SW_1 with the stability of the current value when the maximum value, in the SW_2 decrease in the value of the voltage until it reaches zero volts.

Mode 4 at (t_3): In this mode SW_1 is ON and SW_2 is ON. In the SW_1 with the stability of the current value when the maximum value, in the SW_2 current starts to increase until it reaches the maximum value so organized and so with the stability of the voltage value zero.

Mode 5 at (t_4): In this mode SW_1 are turn OFF and SW_2 is ON. In the SW_1 decrease in the current value until it reaches zero current, in the SW_2 with the stability of the current value when the maximum value.

Mode 6 at (t_5): In this mode SW_1 is OFF and SW_2 is ON. In the SW_1 starts the voltage from zero increases up any maximum values, then decline to near zero volts, and so with the stability of the current value at zero, in the SW_2 with the stability of the current value when the maximum value.

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V. SIMULATION RESULTS AND DISCUSSION

Simulations have been carried out on the circuit shown in Fig. 6 using the simulation software PSIM. The operating point oscillates around the MPP as the system is continuously perturbed.

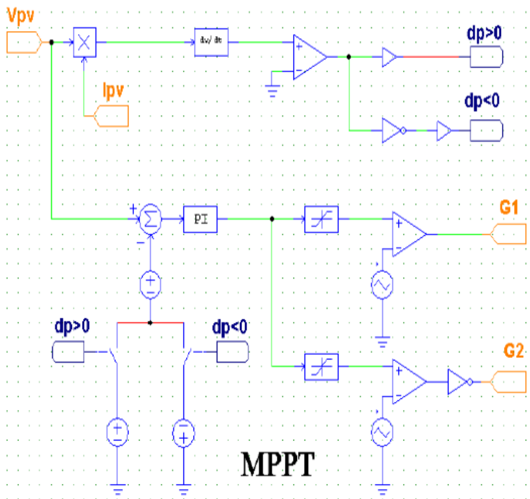

Fig. 6. Implementation of P&O technique

The P & O technology is used on a large scale because of the P & O simplicity of implementation as it is shown in Fig. 7. Fig. 8 shows the waveforms of the voltage *Vpv*, current *Ipv* and the power output *Ppv* of PV cells.

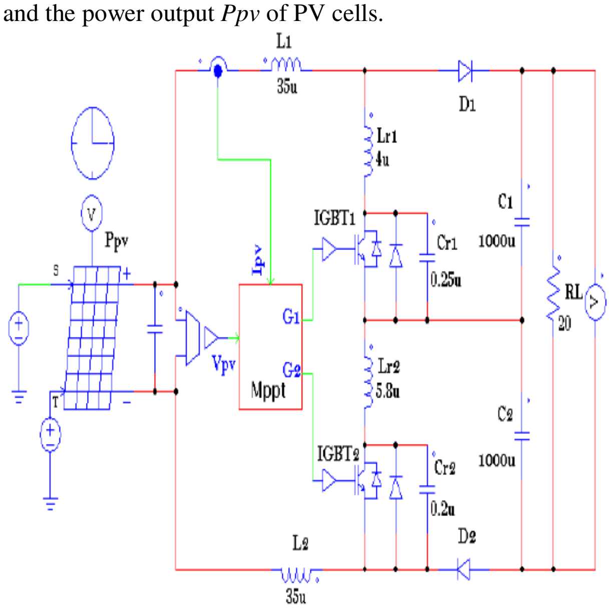

Fig. 7. Simulation diagram of the proposed system

Fig. 9 shows the waveforms of the output voltage *Vout* and output current *Iout* and output power *Pout* for process simulation of the proposed circuit. The simulation shows that the output voltage 286.57 volts and the output current of 0.75 amperes and the power output 216.11 Watt as well as achieving an efficiency of 91.5%. This clearly shows that the proposed technique is effective and efficient.

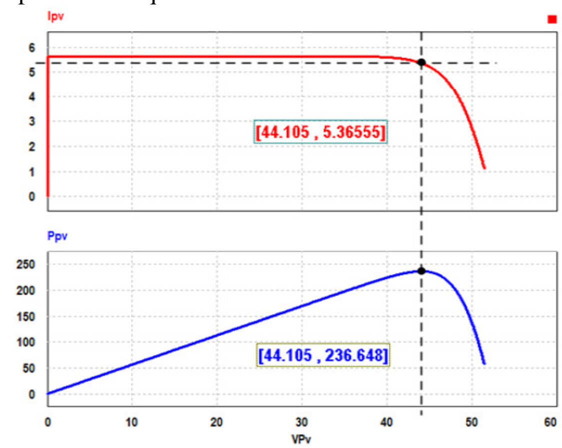

Fig. 8. Simulation Output – Photovoltaic- (I-V) characteristics and (P-V) characteristics

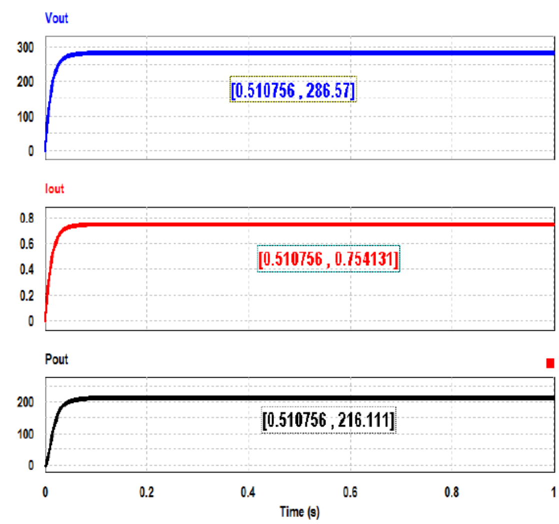

Fig. 9. Waveforms of the output voltage (*Vout*), the output current (*Iout*) and the output power (*Pout*)

VI. CONCLUSION

The analysis of photovoltaic (PV) based soft switching boost DC-DC converter with zero-current switching (ZCS) technique is implemented. The configuration for the proposed system is designed and simulated using software PSIM. Due to the importance of PV systems especially in green energy field, this paper introduces an efficient identification method for maximum power point (MPP) function for PV module using P&O algorithm. The proposed P&O algorithm shows good dynamic performance to track the MPP of the PV even under the rapid change of the irradiation and cell temperature. The proposed converter is simulated with various modes of operation and the working principle and the response. This converter is highly efficient because the proposed technique can reduce the switching losses and electromagnetic interference by putting some stress on the devices. Moreover, when either current or voltage is zero during the turning *ON* or turning *OFF* periods, then the product of the voltage and current becomes zero, which leads to zero power loss. The simulation result also proves the effectiveness of the proposed P&O which uses maximum power point tracking. The results clearly show that the proposed topology can effectively work as a P&O based maximum power point tracking for photovoltaic system. Therefore, this topology enables the converter to use the low rating switch to improve efficiency. This high-efficiency converter topology provides for the various applications related to renewable energy, and it also can be extended easily to other power conversion systems for satisfying high-voltage demands.

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