Nonisolated ZVZCS RPWM dc-dc Converter for PV Systems with MPPT

Deepa K.Suresh
Assistant Professor:dept.of EEE
MBC College of Engineering and Technology,peermade.

Abstract— **This paper deals with the design and simulation of a simple PV with MPPT using nonisolated ZVZCS RPWM dc-dc converter. Among different MPPT algorithms, incremental conductance method is used. The RPWM dc-dc converter used for the MPPT provide high step-up with less switching losses, also the capacitance in the auxiliary circuit is significantly reduced. The proposed system provide a simple PV system with maximum power extraction for various applications. The system is simulated using MATLAB and the prototype of the dc-dc converter is developed.**

Keywords— *Maximum power point tracker, photovoltaic, resonant pulse width modulation, zero voltage zero current switching.*

I. INTRODUCTION

The rapid increase in the demand for electricity and the recent change in the environmental conditions such as global warming led to a need for a new source of energy that is cheaper and sustainable with less carbon emissions. Solar energy has offered promising results in the quest of finding the solution to the problem. Photovoltaic (PV) generation is becoming increasingly *important as a renewable source since it offers many advantages such as incurring no fuel costs, not being polluting, requiring little maintenance, and emitting no noise, among others. PV modules still have relatively low conversion efficiency; therefore, controlling maximum power point tracking (MPPT) for the solar array is essential in a PV system.*

The Maximum Power Point Tracking (MPPT) is a technique used in power electronic circuits to extract maximum energy from the Photovoltaic (PV) Systems [1]. In the recent decades, photovoltaic power generation has become more important due its many benefits such as needs a few maintenance and environmental advantages and fuel free. However, there are two major barriers for the use of PV systems, low energy conversion efficiency and high initial cost. To improve the energy efficiency, it is important to work PV system always at its maximum power point. So far, many researches are conducted and many papers were published and suggested different methods for extracting maximum power point. This paper presents in details simulation of PV system with Incremental Conductance MPPT using nonisolated ZVZCS RPWM dc-dc Converter. The simulation has been accomplished in software of MATLAB Math works**.**

II. PROPOSED SYSTEM

The model shown in Fig.1 represents a diagram of a PV array connected to a load through a dc/dc (nonisolated ZVZCS RPWM) converter with MPPT controller.
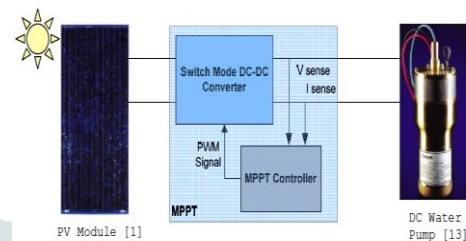

Fig.1. PV array connected to the load.

A. PV Module

There are different sizes of PV module commercially available (typically sized from 60W to 170W). Usually, a number of PV modules are combined as an array to meet different energy demands. The module selected for the proposed system is 150W, BP SX 150S multi-crystalline PV modules [2].

The use of equivalent electric circuits makes it possible to model characteristics of a PV cell. The method used here is implemented in MATLAB programs for simulations. The same modeling technique is also applicable for modeling a PV module.

The simplest model of a PV cell is shown as an equivalent circuit in Fig.2 that consists of an ideal current source in parallel with an ideal diode.
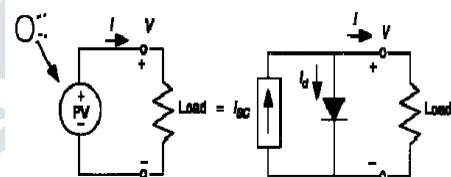

Fig.2. Equivalent circuit of PV cell with a load.

The current-voltage relationship of PV cell is written as [3]:

$$I = I_{sc} - I_0 \left[e^{q\left(\frac{V+I.R_S}{nkT}\right)} - 1 \right] - \left[\frac{V+I.R_S}{R_p} \right] \qquad (1)$$

Rewritten as,

$$I = I_{sc} - I_0 \left[e^{q\left(\frac{V+I.R_S}{nkT}\right)} - 1 \right] \qquad (2)$$

It is possible to solve the equation of *I-V* characteristics by simple iterations, the Newton's method is chosen for rapid convergence of the answer [3].

B. Maximum Power Point Tracker

There are a number of methods that have been proposed, search algorithm using a closed-loop control can achieve higher efficiencies, thus it is the customary choice for MPPT. Among different algorithms, the Incremental Conductance (incCond) method is used here.

The basic idea is that the slope of *P-V* curve becomes zero at the MPP. It is also possible to find a relative location of the

operating point to the MPP by looking at the slopes. The slope is the derivative of the PV module's power with respect to its voltage and has the following relationships with the MPP.

$$\frac{dP}{dV} = 0 \text{ at MPP} \tag{3}$$

$$\frac{dP}{dV} > 0 \text{ at the left of MPP} \tag{4}$$

$$\frac{dP}{dV} < 0 \text{ at the right of MPP} \tag{5}$$

The above equations are written in terms of voltage and current as follows.

$$\frac{dP}{dV} = \frac{d(V.I)}{dV} = I\frac{dV}{dV} + V\frac{dI}{dV} = I + V\frac{dI}{dV} \tag{6}$$

If the operating point is at the MPP, the equation (6) becomes:

$$I + V\frac{dI}{dV} = 0 \tag{7}$$

$$\frac{dI}{dV} = -\frac{I}{V} \tag{8}$$

If the operating point is at the left side of the MPP, the equation (6) becomes:

$$I + V\frac{dI}{dV} > 0 \tag{9}$$

$$\frac{dI}{dV} > -\frac{I}{V} \tag{10}$$

If the operating point is at the right side of the MPP, the equation (6) becomes:

$$I + V\frac{dI}{dV} < 0 \tag{11}$$

$$\frac{dI}{dV} < -\frac{I}{V} \tag{12}$$

The flowchart shown in Fig.3 explains the operation of this algorithm. It starts with measuring the present values of PV module voltage and current. Then, it calculates the incremental changes, dI and dV, using the present values and previous values of voltage and current. The main check is carried out using the relationships in (8), (10), and (12). If the condition satisfies the inequality (10), it is assumed that the operating point is at the left side of the MPP thus must be moved to the right by increasing the module voltage. Similarly, if the condition satisfies the inequality (12), it is assumed that the operating point is at the right side of the MPP, thus must be moved to the left by decreasing the module voltage. When the operating point reaches at the MPP, the condition satisfies (8), and the algorithm bypasses the voltage adjustment. At the end of cycle, it updates the history by storing the voltage and current data that will be used as previous values in the next cycle. Another important check included in this algorithm is to detect atmospheric conditions.

C. MPPT Controller

Analog controllers have traditionally performed control of MPPT. However, the use of digital controllers is rapidly increasing because they offer several advantages over analog controllers. First, digital controllers are programmable thus capable of implementing advanced algorithm with relative ease. For the same reason, modification of the design is much easier with digital controllers. They are immune to time and temperature drifts because they work in discrete, outside the linear operation. As a result, they offer long-term stability. They are also insensitive to component tolerances since they implement algorithm in software. They allow reduction of parts count since they can handle various tasks in a single chip. *Direct control method is used here as the MPPT controller, it is simpler and uses only one control loop, and it performs the adjustment of duty cycle within the MPP tracking algorithm.*

D. DC-DC Converter

The heart of MPPT hardware is a switch-mode dc-dc converter. MPPT uses the converter for regulating the input voltage at the PV MPP and providing load matching for the maximum power transfer. Nonisolated ZVZCS RPWM DC-DC converter is used in the proposed system [4]. An improved switching method, called resonant PWM (RPWM) is used for the soft-switched CCM boost converter in order to reduce the turn-off switching losses. Since the RPWM is performed by utilizing Lr–Cr resonance in the auxiliary circuit, the capacitance is significantly reduced. Also, because of the proposed RPWM operation, the switching losses associated with diode reverse recovery become negligible even in the small duty cycle and the duty cycle loss is further reduced resulting in increased step-up ratio.

The converter consists of a general boost converter as the main circuit and an auxiliary circuit which includes capacitor *Cr* , inductor *Lr* , and two diodes *DL* and *DU*. Two switches are operated with asymmetrical complementary switching to regulate the output voltage. Owing to the auxiliary circuit, not only output voltage is raised but ZVS turn-on of two switches can naturally be achieved in CCM by using energy stored in filter inductor *Lf* and auxiliary inductor *Lr* . Unlike PWM method in which the switches are turned OFF with high peak current [5]-[7], the proposed converter utilizes *Lr–Cr* resonance of auxiliary circuit, thereby reducing the turn-off current of switches. Furthermore, for resonance operation, the capacitance of *Cr* is reduced by at least 20-fold, resulting in reduced volume. Also, switching losses associated with the RPWM converter is significantly reduced.
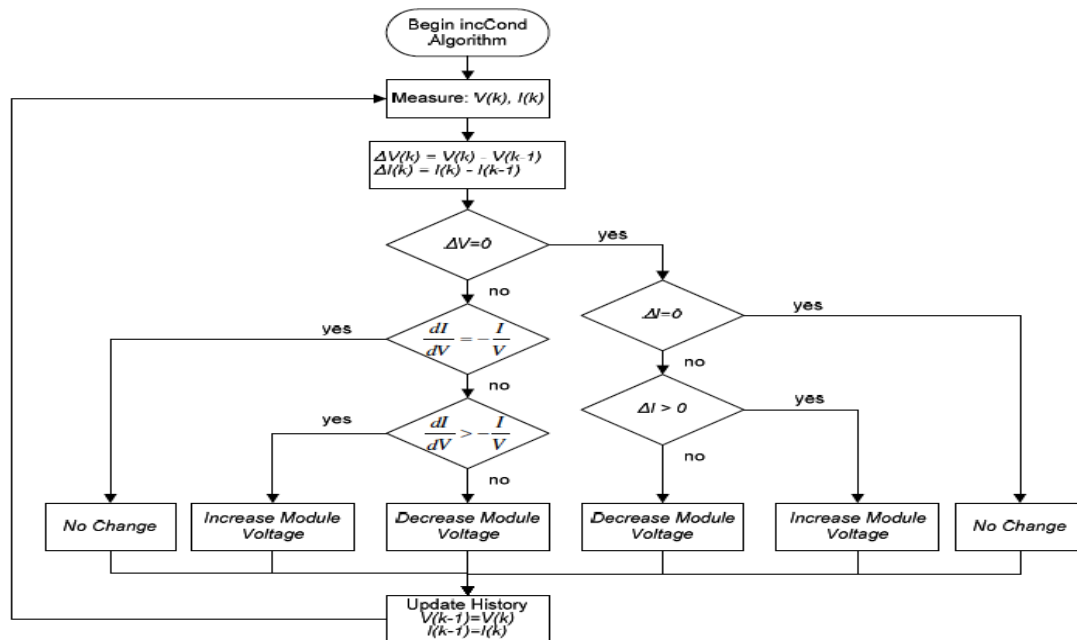
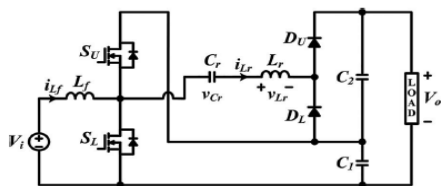Fig.3. Flowchart of the incremental conductance algorithm.

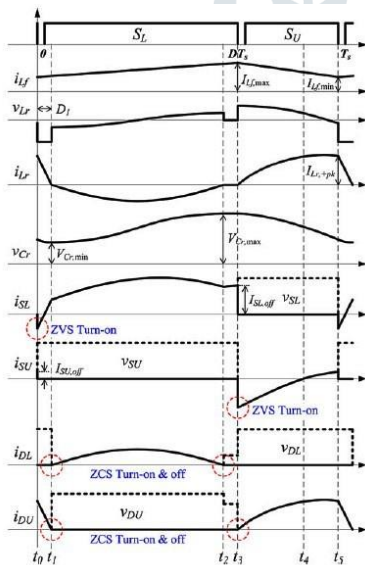Fig.4. Nonisolated zvzcs resonant pwm dc–dc Converter.

Fig.5. Key waveforms of dc-dc converter.

Fig.4 shows the circuit diagram of dc-dc converter and Fig.5 represent the key waveforms of the converter. The five operating modes of converter is explaining below.

Mode 1 ($t_0 - t_1$): This mode begins when upper switch S_U which was carrying the current of difference between i_{Lf} and i_{Lr} is turned OFF. S_L can be turned ON with ZVS if gate signal for S_L is applied before the current direction of S_L is reversed. Filter inductor current i_{Lf} and auxiliary current i_{Lr} starts to linearly increase and decrease, respectively. *This mode ends when decreasing current i_{Lr} changes its direction of flow. Then D_U is turned OFF under ZCS condition.*

Mode 2 ($t_1 - t_2$): This mode begins with Lr–Cr resonance of the auxiliary circuit. Current i_{Lf} is still linearly increasing. The voltage and current of resonant components are determined, respectively. This resonance mode ends when i_{Lr} reaches to zero. Note that D_L is turned OFF under ZCS condition.

Mode 3 ($t_2 - t_3$): There is no current path through the auxiliary circuit during this mode. Output capacitors supply the load. At the end of this mode the turn-off signal of S_L is applied. It is noted that the turn-off current of S_L , $I_{SL,off}$ is limited to filter inductor current at t_3 , $I_{Lf,max}$ which is much smaller than that of PWM method.

Mode 4 ($t_3 - t_4$): This mode begins when lower switch S_L is turned OFF. S_U can be turned ON with ZVS if gate signal for S_U is applied before the current direction of S_U is reversed. Filter inductor current i_{Lf} starts to linearly decrease since voltage V_{Lf} becomes negative. Like Mode 2, the other Lr–Cr resonance of auxiliary circuit is started, and D_U starts conducting. This mode ends when i_{Lr} is equal to i_{Lf} .

Mode 5 ($t_4 - t_5$): After i_{Lr} equals i_{Lf} , i_{SU} changes its direction, then this mode begins. At the end of this mode, turn-off signal of S_U is applied and this mode ends.

Fig.6. Simulink model of RPWM dc-dc converter.
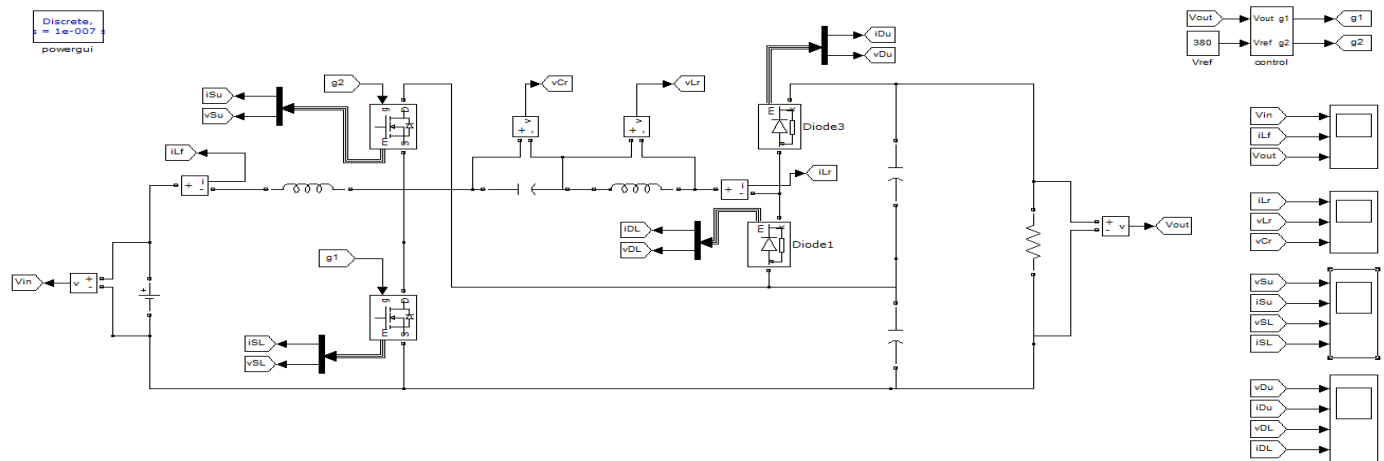
III. SIMULATION RESULTS

The software used for simulating the proposed PV system is MATLAB. The simulink model of the RPWM dc-dc converter is shown in Fig.6. And the obtained simulation results are shown in Fig.7 to 11.
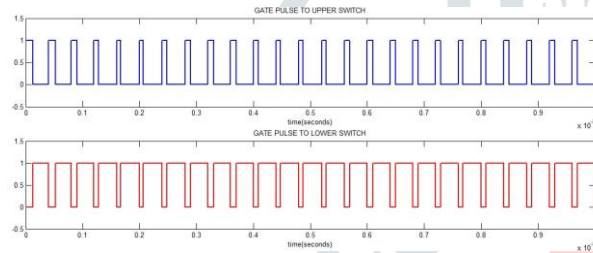

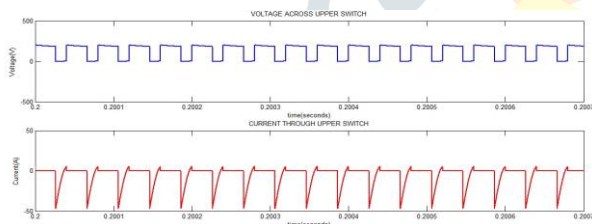Fig.7. Gate pulses to upper and lower switch.

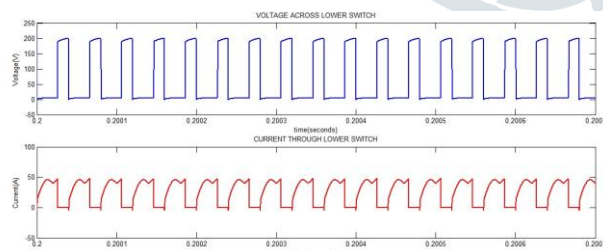

Fig.8. Voltage and current waveforms of upper switch.

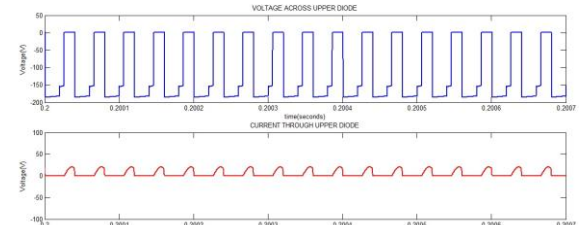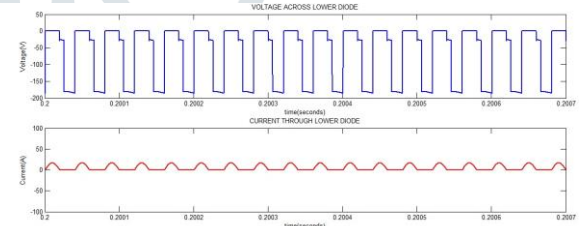Fig.9. Voltage and current waveforms of lower switch.

Fig.10. Voltage and current waveforms of upper diode.

Fig.11. Voltage and current waveforms of lower diode.

The simulink model of the PV system with MPPT using RPWM dc-dc converter is shown in Fig.12. The subsystem representing the PV module and the MPPT shown in Fig.13 and 14 respectively. The V v_s P graph of PV module drawn using simulink is shown in Fig.15. The output power obtained for irradiance of 1000W/m^2 is 150W.

The irradiation and corresponding output power obtained using the simulink model of proposed system are shown in Fig.16. From this simulation result it is clear that the output power obtained for the irradiation of 1000W/m^2 is 150W. That is the maximum power of PV module obtained in the V v_s P graph. Hence, the proposed system provide a simple PV system for various applications with maximum power extraction.
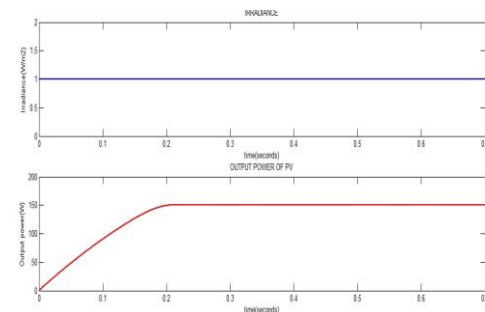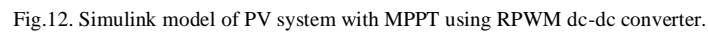
Fig.12. Simulink model of PV system with MPPT using RPWM dc-dc converter.

Fig.13. Subsystem of PV module.

Fig.16. Irradiance and corresponding output power of PV.

IV. EXPERIMENTAL RESULTS

The converter used in the proposed system is a nonisolated ZVZCS RPWM dc-dc converter [4]. The effectiveness of the converter is verified using a prototype designed with the specifications filter inductor L_f and resonant inductor L_r are 70 and 5 µH, respectively. Resonant capacitor C_r is 1µF. Fig.17 shows the photograph of the prototype and Fig.18 and 19 shows the experimental voltage and current waveforms of upper and lower switch. Fig.20 shows the voltage waveform of diodes and Fig.21 shows the gate pulses of switches.

Fig.14. Subsystem of MPPT.

Fig.17. Photograph of the dc-dc converter prototype

Fig.15. V v_s P curve of PV module.

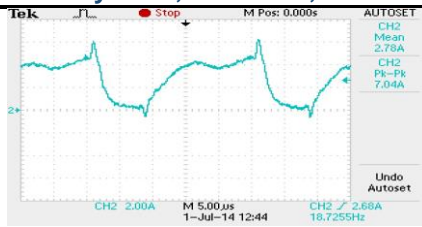Fig.18. Voltage and current waveforms of upper switch.

Fig.19. Voltage and current waveforms of lower switch.
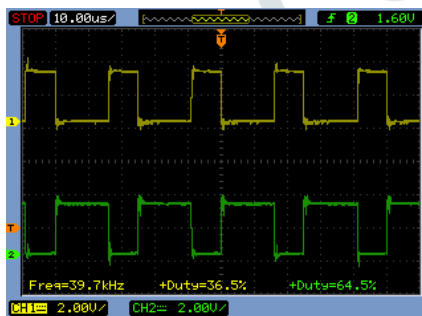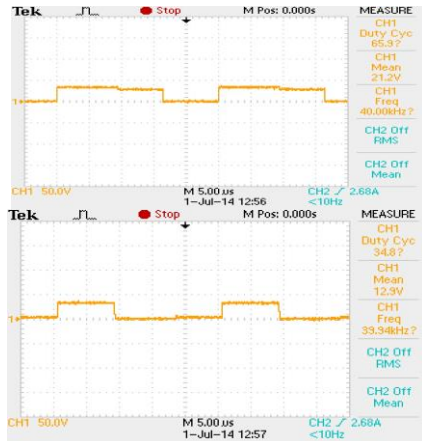

Fig.21. Gate pulses to upper and lower switches.

Fig.20. Voltage across upper and lower diodes.

V. CONCLUSION

The proposed system provides a simple PV system with maximum power extraction using nonisolated ZVZCS RPWM dc-dc converter for various applications. MPPT is used for extracting the maximum power and hence increases the efficiency of the proposed PV system. Among different algorithms, incremental conductance method is used. The maximum power (150W) of PV module used in the proposed system is obtained for an irradiation of 1000W/m^2 using the MATLAB simulation. The prototype of nonisolated ZVZCS RPWM dc-dc converter is developed.

REFERENCES

[1] Hohm, D. P. & M. E. Ropp "Comparative Study of Maximum Power Point Tracking Algorithms" Progress in Photovoltaics: Research and Applications November 2002, page 47-62.

[2] BP Solar BP SX150 - 150W Multi-crystalline Photovoltaic Module Datasheet, 2001.

[3] Walker, Geoff R. "Evaluating MPPT converter topologies using a MATLAB PV model" Australasian Universities Power Engineering Conference, AUPEC '00, Brisbane, 2000.

[4] Yohan Park, Byoungkil Jung, and Sewan Choi,"Nonisolated ZVZCS Resonant PWM Dc-Dc Converter For High Step-Up And High Power Applications" IEEE Transactions On Power Electronics, Vol. 27, No. 8, August 2012.

[5] S. Park and S. Choi, "Soft-switched CCM boost converters with high voltage gain for high-power applications," *IEEE Trans. Power Electron.*, vol. 25, no. 5, pp. 1211–1217, May 2010.

[6] *H. Do, "Zero-voltage-switching boost converter using a coupled inductor," J. Power Electron., vol. 11, no. 1, pp. 16-20, Jan. 2011.*

[7] *J. Kim, D. Jung, S. Park, C. Won, Y. Jung, and S. Lee, "High efficiency soft-switching boost converter using a single switch," J. Power Electron.,vol. 9, no. 6, pp. 929-939, Nov. 2009.*