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A MODIFIED HIGH EFFICIENCY ZVZCS BOOST CONVERTER FOR PV POWER GENERATION SYSTEM

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ABSTRACT

Photovoltaic is credible technology budding worldwide in the production of electricity for terrestrial applications. The major drawback of this technology is low efficiency produced by PV panels and power converters. Maximum power point tracking techniques are used to improve the efficiency of the PV panels while the switching loss of converters reduces the efficiency. In this proposed work a modified Zero voltage Zero current switching boost converter is designed and integrated with the PV panel to produce lossless operation thereby increases the efficiency. In this work a well known perturb and observe algorithm is used to track maximum available power from the PV panel. The proposed system is simulated using MATLAB/SIMULINK software and also the results were verified with experimental outcomes.

Keywords: zero voltage zero current switching (ZVZCS) boost converter, maximum power point tracking (MPPT), Perturb & observe (P and O).

INTRODUCTION

Micro grid is an embryonic technology anticipated to possess a vital role in future power grid due to its massive benefits. Exigency of renewable energy sources like solar, wind, tidal etc increases due to the exhaustion of fossil fuels and to avoid ozone depletion. Solar power system is more popular because of huge accessibility and its harvesting is free of cost. In PV based power system the conversion efficiency is affected by various factors like panel efficiency, MPPT and converter efficiency. Effect of irradiance and temperature variations on the PV array causes its characteristics become highly non linear. To improve the efficiency of the panel in terms of energy conversion with variable climatic condition it is essential to track the MPP at which the voltage and current of the panel are maximum value. There are many MPP tracking techniques have been invented and implemented and they were varying with their cost, effectiveness, speed and complexity. In this work a well known perturb and observe (P and O) technique is implemented for modified ZVZCS boost converter.

In the high frequency DC-DC converter it is inevitable that parasitic capacitance of the switches produces switching loss and it decreases the efficiency of the converter. During hard switching voltage and current across the switches are overlapped together with each other and produces the power loss. In ZVZCS converters known as soft switching converters the resonant inductor and capacitor turns the switching voltage and current to zero during turn on and turn off of the switch respectively thereby minimizes the switching losses. In this proposed work a modified Boost converter with soft switching technique [1, 2] is designed for PV panel along with MPPT technique to achieve high efficiency. The PV panel is modeled using mathematical equations and MPP is obtained for various temperatures and irradiance conditions. The converter is designed and controlled using P and O algorithm. The proposed system was simulated using MATLAB/SIMULINK software and the simulation results are compared with experimental results.

This work contains VI subdivisions including introduction. Details about the proposed work are given in II subdivision. III division explains the panel design and MPPT techniques and in IV details about the converter is given. Results are discussed in V and conclusion is given in VI.

PROPOSED WORK

The main objective of this work is to design a high efficiency ZVZCS boost converter for PV power conversion system. Figure-1 shows the PV module fed from the proposed converter with P and O maximum power point tracking algorithm. This MPPT is used to control the switches S1 and S2 to maintain the output power maximum.

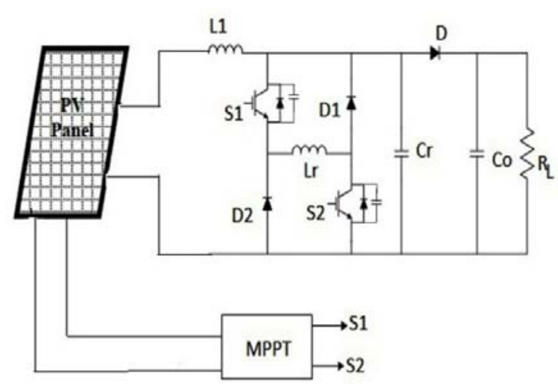

Figure-1. Proposed PV fed ZVZCS Boost converter with MPPT technique.

PV PANEL DESIGN AND MPPT

Series and parallel connection of several PV cells forms the PV module. 72 cell Polycrystalline panel is taken for this study and its parameter values are shown in Table-1. WACO solar irradiance tester is used to measure irradiance level and V-I, P-V curves are drawn for different irradiance levels as shown in Figures 2 and 3, respectively.

Table-1. Parameters of PV panel.

Open circuit voltage of the test panel (V_{oc})	36.4V
Short circuit current of the test panel (I_{sc})	7.6A
Maximum power of the test panel (P_{max})	250W
Temperature coefficient(K_s)	$3.18X10^{-3}A/^oC$

Table-2. Maximum power point voltage and current for different irradiance conditions.

Irradiance (W/m^2)	**Maximum power point condition**		
	Voltage (V)	**Current** (I)	**Power** (W)
455	28	3.5	98
470	28	3.5	98
820	24	6	144
900	26	6.5	169
930	28	6	168
1000	28	6.5	182

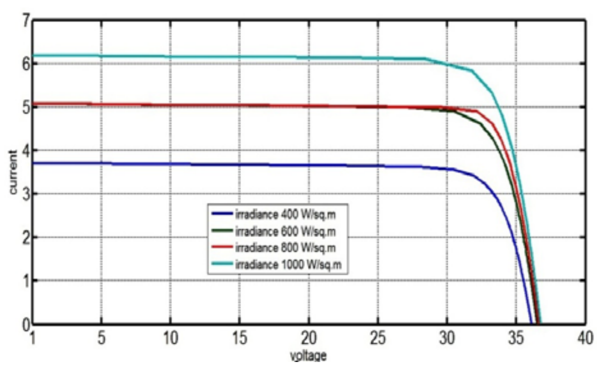

Figure-2. V-I characteristics for different irradiance level.

Following mathematical equations are used to design the PV panel in Matlab/simulink and the results were verified by experimental setup.

$$V_t = \frac{KT}{q} \quad (1)$$

$$V_{OC} = V_t \ln \frac{I_{ph}}{I_s} \quad (2)$$

$$I_d = \left[e^{\frac{(V+I r_s)}{nV_t C N_s}} - 1 \right] I_s N_p \quad (3)$$

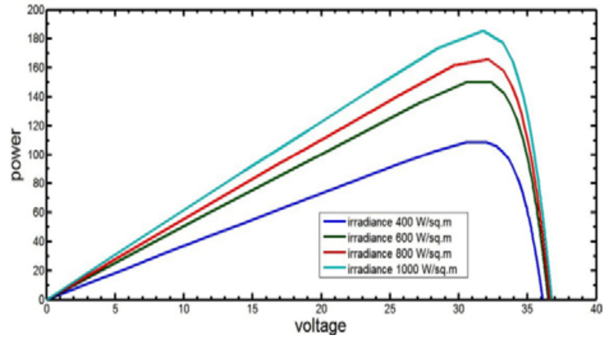

Figure-3. PV characteristics of the panel for different irradiance level.

$$I_s = I_{rs} (T/T_{ref})^3 e^{[qE_g/nK](1/T - 1/T_{ref})} \quad (4)$$

$$I_{rs} = \frac{I_{sc}}{\left[e^{\left(\frac{qV_{oc}}{KCnT}\right)} - 1\right]} \quad (5)$$

$$I_{sh} = \frac{V + I r_s}{R_p} \quad (6)$$

$$I_{ph} = GK\left[I_{sc} + KI\left(T - T_{ref}\right)\right] \quad (7)$$

$$I = I_{ph} N_p - I_d - I_{sh} \quad (8)$$

V_t = thermal voltage, V
K = boltzmann's constant, $1.38e^{-23}$
T = Operating temperature of cell in $^\circ$C
T_{ref} = Operating temperature of cell in 25°C
Q = Electron charge constant $1.6x10^{-19}$C
I_s = Reverse saturation current of Diode, A
I_{rs} = Reverse saturation current of diode at T
I = Current output from PV panel, V
n = ideality factor of Diode, 1.36
C = No. of cells in PV panel
N_p,N_s = Number of PV panel in parallel and series
E_g = Bandgap energy of the cell1.12 eV.

In order to harvest the maximum power the PV panel is integrated with modified ZVZCS boost converter and ease of computation the P and O method is used for MPPT [3]. The P and O algorithm is given in Figure-4.

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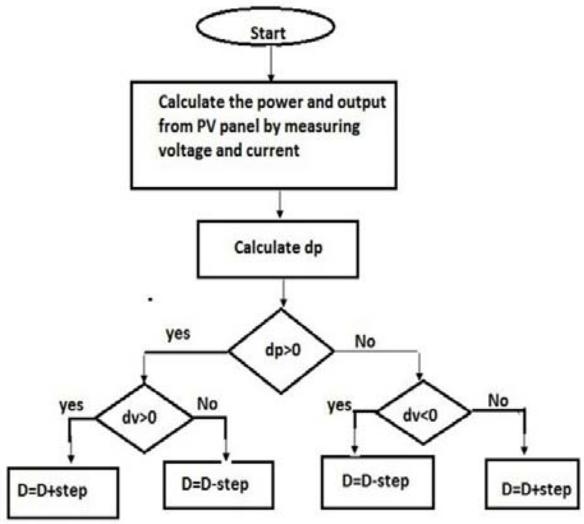

Figure-4. P and O algorithm.

MODIFIED ZVZCS BOOST CONVERTER

In high frequency DC-DC converters the power losses possesses a major problem and these are mainly due to switching losses of the converter system. Switching losses are produced due to overlapping of voltage or current during switching transition [4]. Power loss across the switch is given as $P_{sw} = \frac{1}{2} f_s C_o V_{off}{}^2$, where f_s - switching frequency, C_o-Parasitic capacitance and V_{off} - Transistor off state voltage. Here ZVS technique refers that forcing the voltage to zero during turn on and ZCS refers that forcing the current to zero during turn-off. Figure-5 shows the proposed ZVZCS converter in which the voltage or current overlap during the switching transition is eliminated with the help of resonant inductor and capacitor thereby increase the efficiency of the converter.

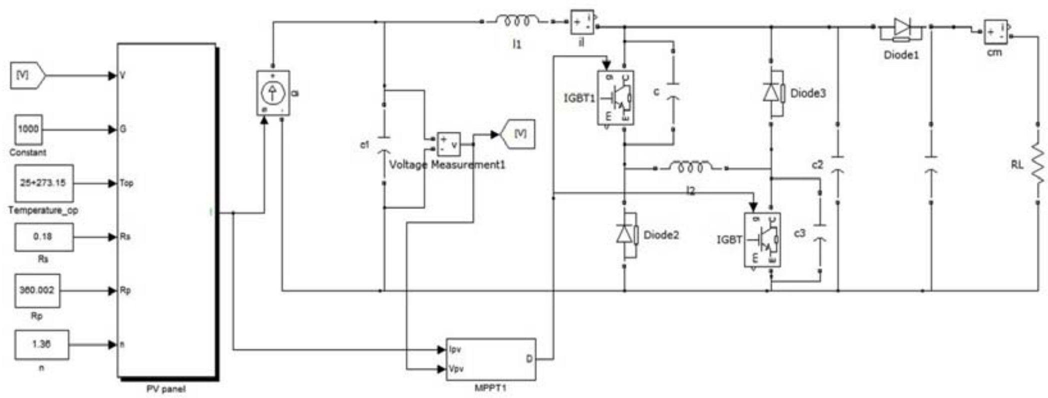

Figure-5. Proposed solar fed ZVZCS boost converter with MPPT control.

Modes of operation

The operation of the proposed ZVZCS converter is as shown in Figure-6.

Mode -I ($t_0 \le t < t_1$)

In this period both the switches S1 and S2 are in off condition as shown in Figure-1 and the main inductor discharges the energy stored in it. The circuit Current does not flow through the inductor used for resonance and the capacitor C_r has charged equal to the output voltage.

$$I_{Lr}(t) = 0$$

$$V_{Cr}(t) = V_o$$

Mode-II ($t_1 \le t < t_2$)

S1 and S2are turned on under ZCS condition by the current flow through L_r.

$$I_{Lr}(t) = \frac{V_o}{L_r} t$$

$$V_{Lr} = V_o$$

Mode -III ($t_2 \le t < t_3$)

In the operation of this mode the resonant capacitor C_r and inductor L_r starts resonating and the C_r starts discharging.

$$V_{Cr} = V_o \cos\omega_r t$$

$$\omega_r = \frac{1}{\sqrt{L_r C_r}}$$

Mode-IV ($t_3 \le t < t_4$)

This mode begins when C_r voltage equal to zero and L_r current reaches the maximum value.

$$I_{Lr}(t) = I_{Lr}(max)$$

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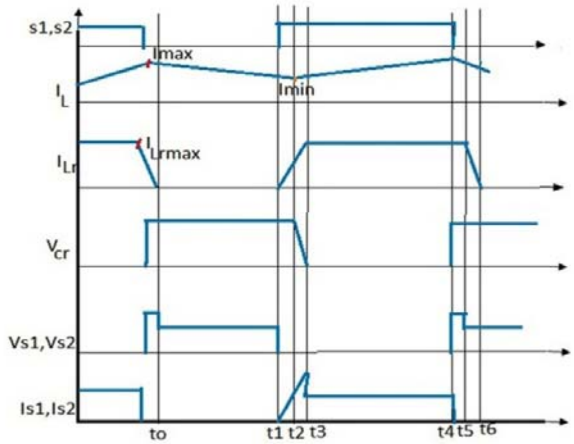

Figure-6. Modes of operation of ZVZCS boost converter.

Mode-V ($t_4 \leq t<t_5$)

ZVS is achieved in this mode and both the switches are turned off at zero voltage by C_r. At the end of this mode capacitor starts charging by inductor currents.

$$I_{Lr} = I_{Lr(max2)}$$
$$V_{cr} = 0$$

Mode-VI ($t_5 \leq t <t_6$)

When the resonant capacitor is fully charged and its voltage is equal to output voltage, output diode is in off condition under ZVS condition. This mode comes to end when energy discharged in to the inductor is fully discharged through the load.

RESULTS AND DISCUSSIONS

In this work a 36.4 V, 7.6A and 250W poly crystalline solar panel is used and WACO solar irradiance tester is used for measuring the irradiance in real time. Table-3 gives the converter parameters considered for the proposed work. The maximum power point voltage and current is tracked for every changing irradiance conditions of the panel and fed to ZVZCS boost converter. The operation of the converter is controlled using P and O algorithm to get constant output voltage irrespective of irradiation variation [5, 6, 7].

Table-3. Converter parameters.

Converter Parameters	
Input voltage of the converter(V_i)	36.4V
Output voltage of the converter(V_o)	73V
Switching frequency(f_s)	25Khz
Resonant inductor(L_r)	83mH
Resonant capacitor(C_r)	20nF

Inductor current, output voltage and switching pulses to the switches are given in Figures 7, 8 and 9 respectively. The proposed converter efficiency is compared with hard switching converter and shown in Figure-10. The observation from the Figure-10 shows that the proposed converter efficiency for different loading conditions is higher than the hard Switching converter [8, 9]. This can be achieved because of less switching losses in soft switching converters [10]. From Figure-7 it is clearly proven that for rapidly changing irradiance conditions load voltage remains constant and is maintained between 73-74V. Figure-11 shows the Experimental setup of the proposed converter and the experimental results are compared with simulation result. In the experimental setup efficiency is calculated for various loading conditions. The efficiency lies between 95%-97% and it is shown in Figure-10.

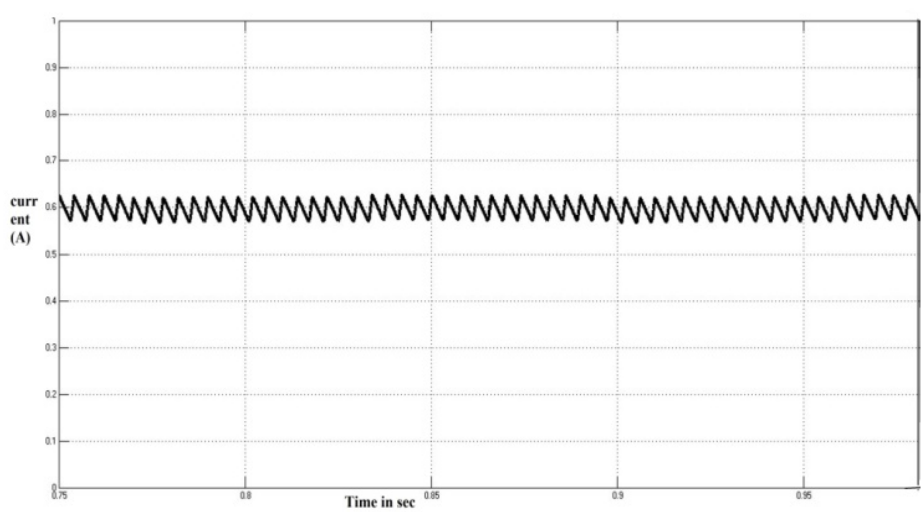

Figure-7. Inductor current.

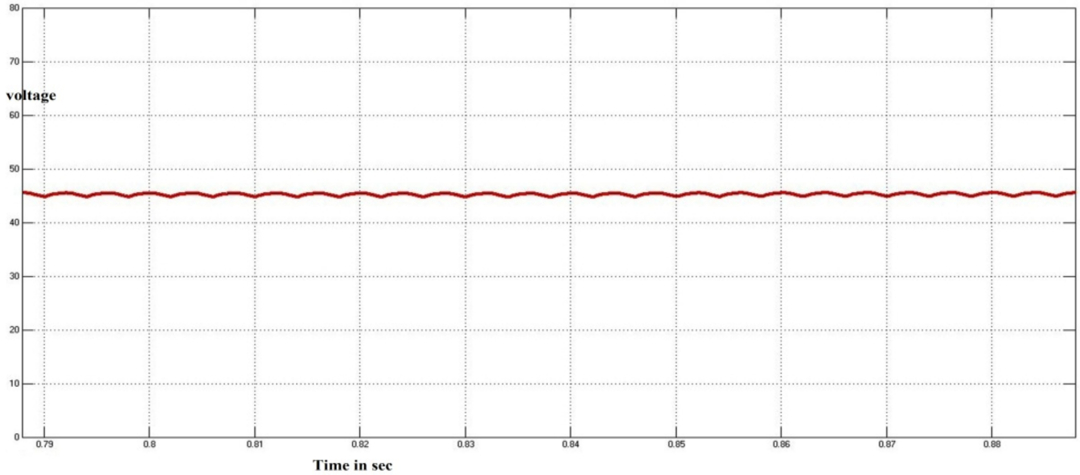

Figure-8. Output voltage.

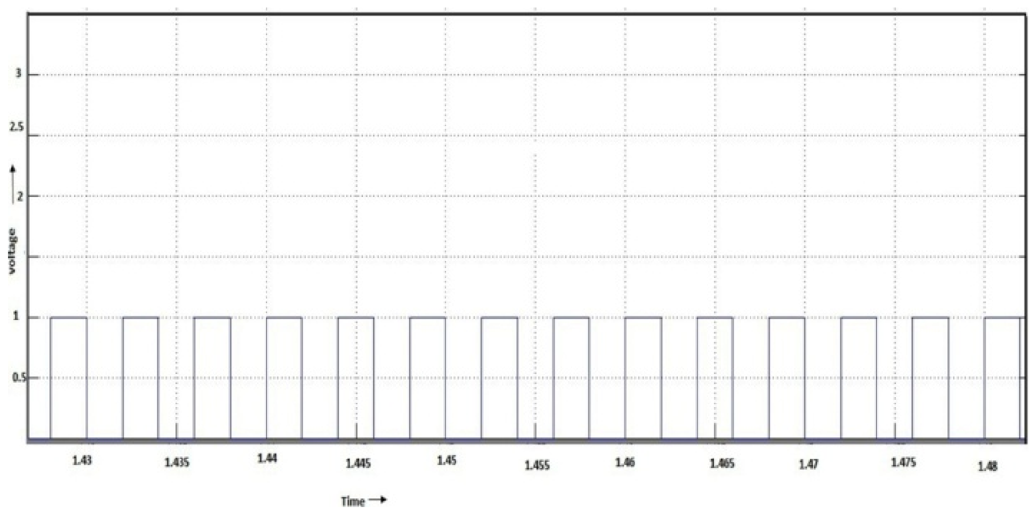

Figure-9. Pulses to switch S1 and S2.

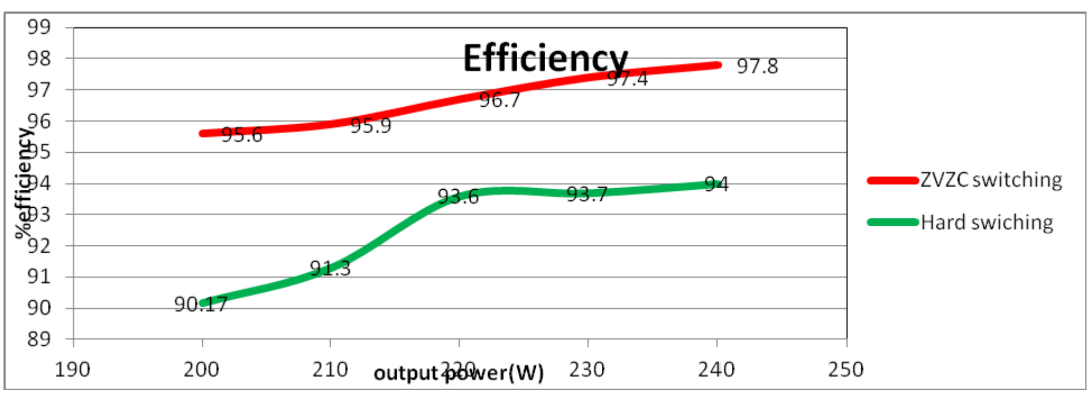

Figure-10. Efficiency of ZVZCS converter.

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Figure-11. Experimental setup.

CONCLUSIONS

High conversion efficiency is essential in renewable energy system. In this proposed system maximum power is harvested by P and O MPPT technique and converter efficiency is increased by ZVZCS boost converter. For different load variations efficiency is calculated and it is compared with hard switching converter. From this it is proven that the proposed converter efficiency is 95-97% for load variations and it is comparatively better than the conventional boost converter.

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