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Comparison of Zero Voltage Soft Switching and Hard Switching Boost Converter with Maximum Power Point Tracking

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***Abstract*—**The inherent nature of normal boost converter has more voltage stress across the power electronics switch and ripple. The presented formation of the front end rectifier stage for a photovoltaic (PV) organization is mainly used to give the supply. Further increasing of the solar efficiency is achieved by connecting the zero voltage soft switching boost converter. The zero voltage boost converter is used to convert the low level DC voltage to high level DC voltage. The inherent nature of zero voltage switching boost converter is used to shrink the voltage tension across the power electronics switch and ripple. The input stage allows the determined power point tracking to be used to extract supreme power from the sun when it is available. The hardware setup was implemented by using PIC Micro controller (16F877A).

***Keywords*—**Boost converter, duty cycle, hard switching, MOSFET, maximum power point tracking, photovoltaic, soft switching, zero voltage switching.

I. Introduction

THE renewable energy has more problems to next group energy source capable of solving the problems like global warming caused by cumulative energy consumption. PV energy system is used to avoid the needless fuel expenses and also avoids the air pollution, water pollution and other wastes. The input impedance of a zero voltage converter is mainly used to control the value by matching the finest impedance of the connected PV panel [4]. The extreme power idea tracker is used to control the PV group system below non-uniform separation or uniform separation condition [1]. A PV array is a collection of PV components, which are in turn made of multiple organized solar cells. Solar energy can be exploited in two ways: Solar warming or cooling and solar electricity. The main objective of this paper is to reduce the switching stress or switching loss across the power electronics switch (MOSFET) and to increase the output voltage compared to the traditional method.

II. Zero Voltage Boost Converter

The zero voltage boost converter is used to convert the low level DC voltage supply to high level DC output voltage. The output voltage is controlled by adjusting the pulse angle of the MOSFET. Zero voltage concepts are used to increase the productivity of converter and to reduce the power ripple in output side. The output voltage of solar panel is 12 V DC which is given to the soft switched boost converter. The PV cell array production power can be used to deliver the power to a load and then it can be capitalized using MPPT method. The execution time of the microcontroller is less than half of a millisecond while the sun irradiation and the air temperature change slowly during the daytime. This presented system is mainly used to track the PV maximum power point successfully, under normal changes of atmospheric conditions.

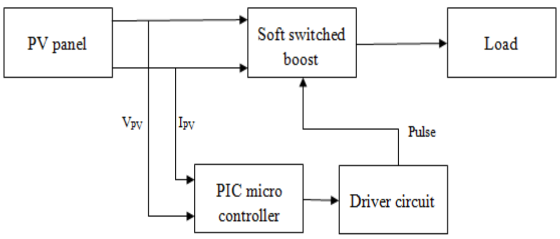

Fig. 1 Block diagram of PV system with zero voltage boost converter

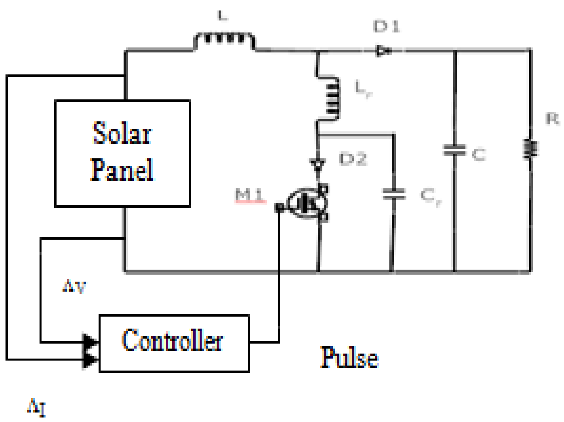

Fig. 2 Simplified Circuit diagram

The block diagram of the PV soft switched boost converter is shown in Fig. 1. It consists of PV carry, boost converter, load and MPPT. From solar cell, maximum power is tracked which is fed to the converter [13]. The boost converter is used to step-up the input voltage. The voltage of the PV array is sensed and given to the controller to calculate power of the array and accordingly adjust the duty cycle of the converter. Fig. 2 shows the soft switched boost converter module. Inductor L1, MOSFET active switch M1 and diode D1

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comprise one step-up conversion unit. The solar output voltage is connected to the input of boost converter [20].

The converter is mainly used to convert low level DC voltage supply to high level DC voltage supply. Input source is given with help of solar panel and the output voltage is controlled with the help of firing angle of the MOSFET. Zero voltage concept is used to progress the efficiency of converter and to reduce the power stress. The controller circuit is used to controlling the switching pulse width [16].

A. Modes of Operation

1. Mode-1 $\{t_0 < t < t_1\}$

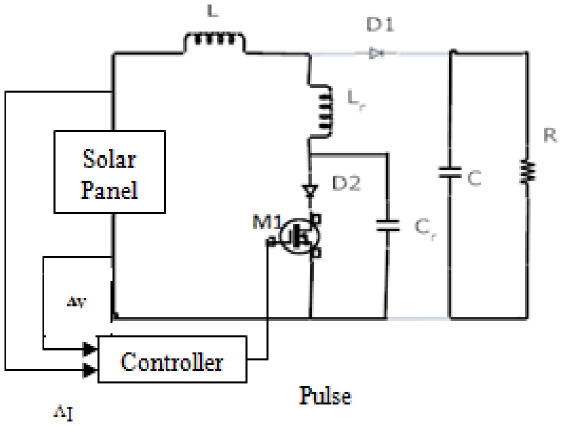


Fig. 3 Switch on condition

At mode-1, the gating signal goes to MOSFET M1 from MPPT as shown in Fig. 3. During this mode, the stock current flows to MOSFET M1 and the current does not flow to load continuously but the capacitor gives continuous current to load. In this mode, the ZVS is used to drop the voltage stress.

2. Mode II $\{t_1 < t < t_2\}$

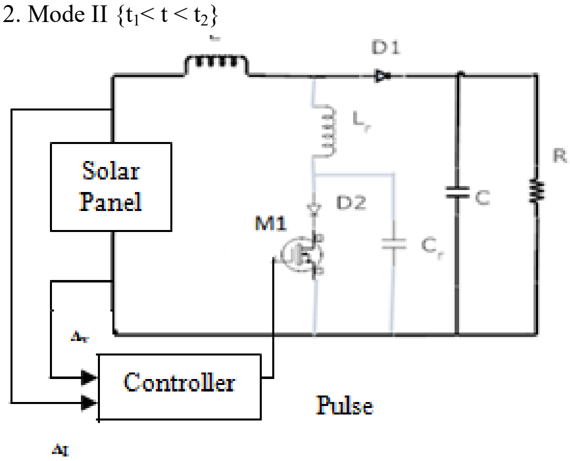


Fig. 4 Switch off condition

Fig. 4 shows the time interval of $t_1 < t < t_2$; the switching pulse is zero. Due to zero switching pulse, the MOSFET M1 is off. The supply current directly flows to load, at the same time capacitor will also charge. The capacitor is used to give continuous current to load.

III. Design of L, C, and D Values

The system parameters are:

- Input voltage (Vs) = 10V
- Output voltage (V_o) = 20V
- Ripple current (ΔI) = 0.025A
- Ripple voltage (ΔV_c) = 0.005V
- Switching frequency (Fs) = 100 KHz

The L, C, k values are designed using (1)-(3):

$$D = 1 - \frac{V_S}{V_O} \quad (1)$$

$$L = \frac{V_S * k}{\Delta I * F_S} \quad (2)$$

$$C = \frac{I_a * k}{\Delta V_C * F_S} \quad (3)$$

IV. Hardware of Zero Voltage Switching Converter

The power circuit of the zero voltage boost converter is used to control the switching loss of the system. This again produces degradation of the converter efficiency and in the worst case, can lead to switch damage during the turn off transition. Therefore, research has been done on resonant converter to reduce switching losses [15].

Basic operation of the MPPT is based on operational point of the MPP and the typical value of the PV present varies due to variation of reference current. The two inputs are managed by the controller and the output of the controller drives to switching pulse of MOSFET. The output of MPPT controller and the output pulse are given to the gate terminal of MOSFET. The output of PV is given to the zero voltage switching boost converter. The MPPT tracks the extreme power based on the master-rule [5].

The PV array current (I_{PV}) rises during switching on and falls during switching off because of the zero voltage boost converter in every switching cycle. The driver circuit is used to regulate current flowing through a circuit [14]. The IR2125 is a high speed power MOSFET and IGBT driver with over-current limiting protection circuitry [6]. Logic inputs are compatible with standard CMOS. The protection circuitry detects over-current in the driven power transistor and limits the gate drive voltage. An external capacitor directly controls the time interval between detection of the over-current limiting conditions. Gate drive supply ranges from 12 V to 18 V [17].

The control circuit consists of operational amplifier (LM358), driver IC (IR2125), PIC Micro controller (16F877A). The operational amplifier is used to amplify the low level signal into high level signal. The micro controller generates the PWM pulse and controls the switch. The driver is used to drive the switch and isolate the two different circuits [7]. The control circuit has two inputs: PV voltage and PV current from solar panel. The PV current is converted into voltage. T It amplifies the voltage from 0.25 mV to 3.8 V [2]. Two input pins, PA0, PA1, were used for port A and one output pin is used, PC3, for port C. The amplifier voltage is given to PA0. The micro controller generates the PWM pulse, the width of the pulse depends upon different value as shown in Table I.

TABLE I
DUTY CYCLE OF MOSFET (KNOWLEDGE BASED)

Volts / Amps	0 – 1 (0-2.4)	1.1 – 2 (2.5-4.8)	2.1 – 3 (4.9-7.2)	3.1 – 4 (7.3-9.6)	4.1 - 5 (9.7-12)
0 – 1	86	73	73	62	62
1.1 – 2	73	62	62	62	49
2.1 – 3	62	62	49	49	49
3.1 – 4	62	49	49	49	40
4.1 – 5	49	49	40	40	40

The output pulse is given to driver IC from PC3 of port C. The output pulse voltage from the controller is 5 V. The driver circuit converts this 5 V pulse to 12 V pulse and it is given to switch. The pulse width depends on solar panel voltage and current for example, if the voltage and current are less than 1 then the duty cycle value will be 86. If the solar voltage and current are 1.1 to 2 then the duty cycle is 73 and the solar voltage and current are 4.1 to 5 then the duty cycle is 40.

V. HARDWARE MODULE OF ZERO VOLTAGE BOOST CONVERTER

The hardware circuit of PV system with zero voltage boost converter using MPPT is shown in Fig. 6. The hardware prototype module consists of power circuit, control circuit, driver circuit, switched mode power supply unit and resistive load.

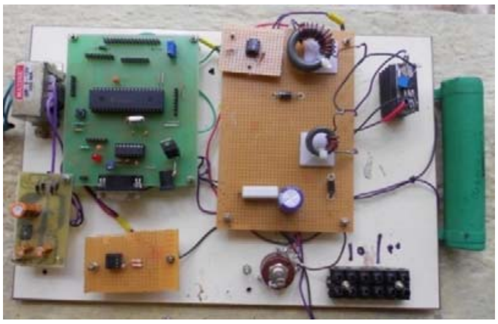


Fig. 6 Hardware module of zero voltage boost converter

In the low voltage alternative, the voltage drop across the switch is held close to zero during the turn on transition. The current increases while the voltage is low, so the losses during transition are low. This action is called Zero Voltage Switching (ZVS). The basic boost topology is improved to attain zero voltage changeovers across the switch. The resonant inductor and capacitor circuit is introduced to create the zero voltage condition [3]. The resonant capacitor produces a zero voltage through the switch at which instant the switch can be turned on or off. The output current can be expected to be a continuous during the high frequency resonant cycle [8].

The input voltage of power circuit is generated from the solar panel. The PV panel is the direct conversion of sunlight into electricity by means of solar cells. Solar cells are composed of various semiconductor materials which become electrically conductive when supplied by heat or light. The solar panel voltage is given to the input of power circuit. Fig. 7 shows the solar input voltage which is 10.2 V DC [18].

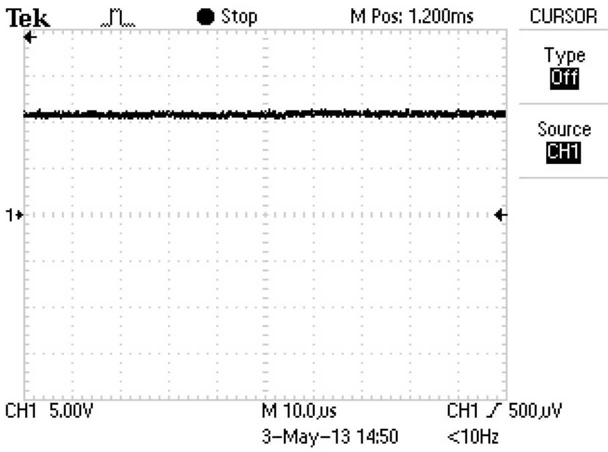


Fig. 7 Input voltage waveform of the power circuit from solar panel

Fig. 8 shows the switching pulse waveform from driver IC. The switching pulse from driver circuit goes to MOSFET M1. Depending upon on the switching pulse, the MOSFET switch goes to ON condition or OFF condition. The amplitude of the switching pulse is 12 V and the ON time is 4 µs. The switching frequency of the pulse is 83 kHz.

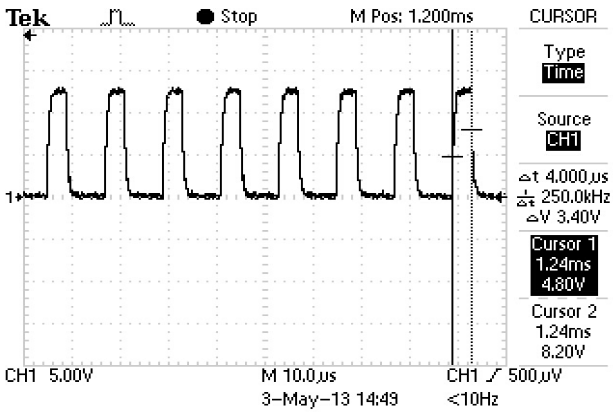


Fig. 8 Switching pulse waveform of MOSFET

Fig. 9 shows the output voltage of zero voltage boost converter using MPPT. The zero voltage boost converter is used to enhancement the input voltage from 10.2 V to 19 V.

The zero voltage boost converter is used to regulate the switching loss of the system. The basic boost topology is improved to attain zero voltage transition through the switch. The resonant inductor and capacitor circuit is introduced to produce the zero voltage condition. Fig. 10 shows voltage across the switch for zero voltage converters. In soft switching, voltage across the switch is slightly decreasing [9].

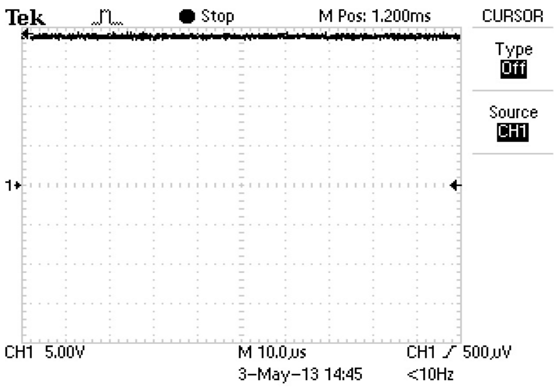


Fig. 9 Output voltage waveform of zero voltage converters

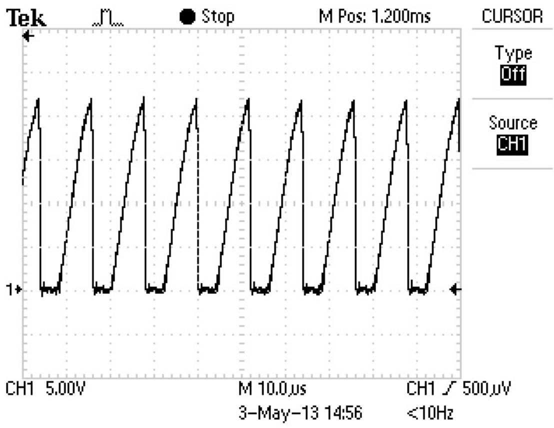


Fig. 10 Voltage waveform across the switch for zero voltage converters

The hard switching voltage across the switch is shown in Fig. 11 when the input voltage is 10.2V. The voltage across the switch is maximum and it will maintain high and low so the life time of switch is reduced [19].

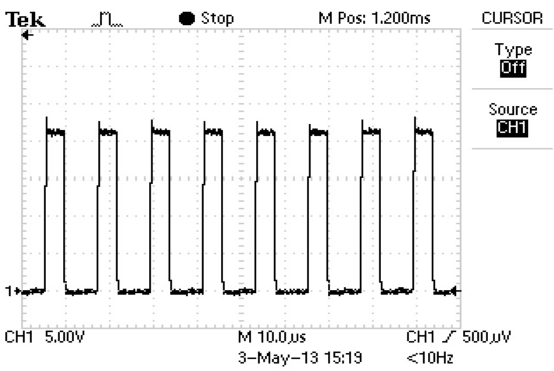


Fig. 11 Hard switching voltage waveform across the switch at 10.2V input

VI. Comparison of Zero Voltage and Hard switching

In conventional method hard switching technique has been used; the voltage stress across the power electronics switch is high and the switching losses are more. It reduces the life time of MOSFET switch. The presented method uses zero voltage technique where the voltage across the switch is less. The zero voltage converters reduced switching losses and increasing the life time of switch [10]. The PV system with zero voltage boost converter is simulated with analog fuzzy based MPPT. In hardware implementation, PIC microcontrollers are used with digital fuzzy based MPPT.

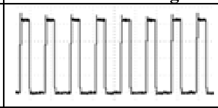
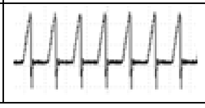
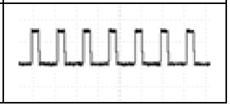
Si. No	Input voltage	Soft switching	Hard switching
1	10.2v		
2	2.3 v		

Fig. 11 Comparison of zero voltage and hard switching

During zero voltage condition, voltage across the switch is marginally reducing from peak but inflexible switching the voltage across the switch as maximum value. Due to this switching voltage, the life time of power electronics switch is decreasing and the voltage stress is maximum.

VII. Conclusion

This paper deals with the comparison of zero voltage and and hard switching using boost converter with MPPT. The maximum power is tracked from solar panel by using MPPT technique with micro controller. The control circuit drives the gate of MOSFET in zero voltage converter. The output voltage is twice than the input voltage of PV system with zero voltage boost converter. The converter losses are reduced and efficiency of the converter is improved. The PV array output power supplied to a load can be maximized using MPPT. Thus, the objective of the switching control in DC-DC converters is to realize efficiency and good tracking of output voltage. The main drawback of this project is installation cost of PV panel is high cost and the energy conversion is low (maximum 1.5V per cell). The modern techniques of developed crystalline panels are effective power adaptation and it is potential to make the PV project gainful [11]. The development of economic power conversion equipment for PV energy will have much effect in the future.

The PV system with zero voltage boost converter raises the efficiency and condense the switching losses. It is used for low and high power applications. In several applications, the soft switched boost converter can be used (hybrid electric vehicles, fuel cell power conversion etc.). In future the system will be designed by using hybrid system (using two power sources like solar, wind, tidal) with soft switched boost converter [12].

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