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# Comparative Study of Hard Switching and Soft Switching Boost Converter Fed from a PV Source

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**Abstract - This paper presents a comparative study of hard switching and soft switching boost converter for interfacing photovoltaic (PV) systems. This paper mainly focuses on the minimization of switching loss by adopting soft switching technology when compared to hard switching.**

**Key Words – SPV, Zero Voltage Switching, Zero Current Switching, PSPICE**

## I. INTRODUCTION

The electric power generation from the photovoltaic (PV) system has various constraints and its efficiency is low. In order to increase its efficiency PV system is interfaced with converters. But in hard switching converters as frequency increases switching loss increases. Soft switching technology, which includes both zero voltage switching (ZVS) and zero current switching (ZCS), is adopted to minimize the switching loss at high frequencies [1]-[4]. In this work, PV system is interfaced with both hard switching and soft switching boost converter to boost the output voltage of the PV system [5]. For this work, simulations are performed using Pspice to prove that switching losses are reduced by adopting soft switching technology at a high frequency.

## II. PV MODELLING

The modelling of PV source which consists of 36 cells in series has been simulated using Pspice. The reference equations have been taken from [6]-[8]. For isolation, G = 1000 W/m$^2$ and temperature, T = 37$^0$C the characteristics of PV panel with peak watt of 37.08 W is shown in Fig 1.

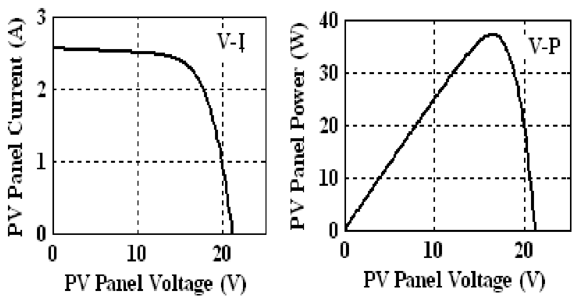


Fig 1. Simulated Characteristics of PV system

## III. BLOCK DIAGRAM OF THE PROPOSED SYSTEM

The block diagram of the proposed model is depicted in Fig 2. PV source is connected to a dc-dc boost converter. The reference voltage (Maximum power point voltage) is compared with the terminal voltage of the PV array. This error voltage is processed via PWM modulator to produce control pulses to the converter to improve the system's efficiency, gain and steady state tracking accuracy.

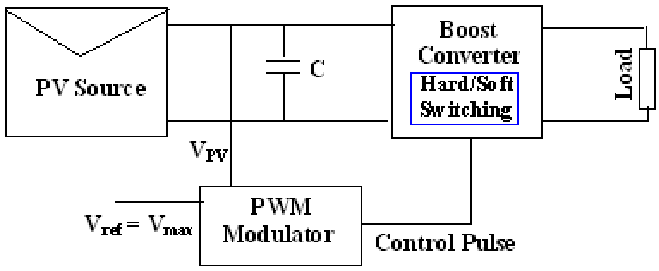


Fig 2. Schematic diagram of the proposed model

## IV. HARD SWITCHING BOOST CONVERTER

Boost converter is a DC-DC converter whose output voltage is greater than the input voltage. In PV fed system, this acts as a maximum power point tracker. It consists of a switch, a diode, a capacitor and an inductor. The switch used here is MOSFET (IRFP460). Capacitor is normally added in output side to reduce the ripples. The input to the boost converter is fed from PV system. The switching losses are high in hard switching converter because there is overlapping of voltage and current during switching. As power is the product of current and voltage (i.e., the overlapped area) switching loss is more in hard switching. There is a sudden breaking of current through the device that leads to Electromagnetic interference in hard switching converters. The Pspice model of PV fed hard switching converter is shown in Fig 3.

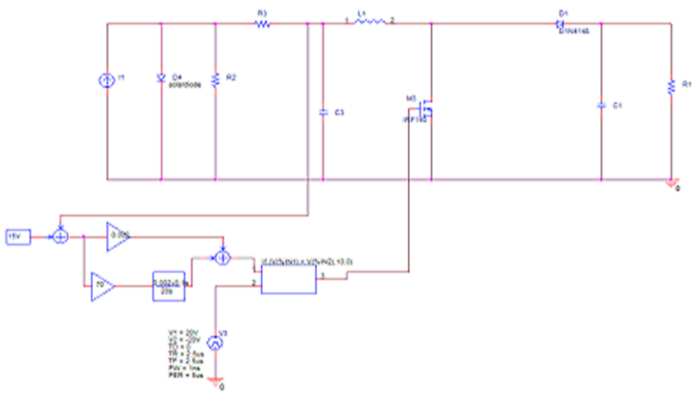

Fig 3. Pspice model of PV fed hard switching boost converter

## V. SOFT SWITCHING BOOST CONVERTER

Soft switching boost converter has an auxiliary resonant circuit along with the conventional boost converter circuit. The auxiliary resonant circuit consists of an inductor, a capacitor, a diode and a switch. Zero voltage switching and zero current switching minimize the overlapped area of current and voltage during switching which in turn reduces the switching losses at higher frequencies. The input to the soft switching boost converter is fed from the PV system. In zero voltage switching, the switch is turned on when voltage across the resonant capacitor is zero. In zero current switching, the switch is turned off when the current through the resonant inductor is zero [9]. From this it is understandable that, the overlapped area is small when compared to hard switching which in turn reduces the switching loss. The use of auxiliary resonant circuit naturally reduces the electromagnetic interference (EMI). The Pspice model [10] of PV fed soft switching converter is shown in Fig 4.

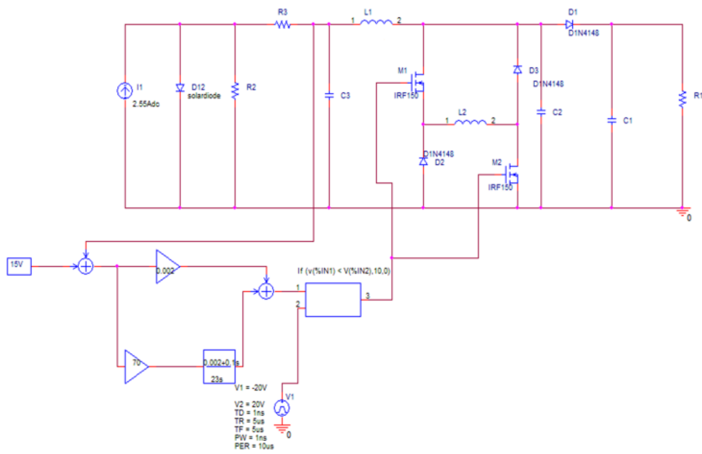

Fig 4. Pspice model of PV fed soft switching boost converter

## VI. Results and Tables

SOLKAR PV module which is rated at 37 W peak under STC (Standard test Condition: G=1000 W/m$^2$, T=25$^0$C) have been considered for this work. The simulated characteristics of this panel at G=1000 W/m$^2$ and T=39$^0$C have been presented in Fig 5. For different insolation and temperatures, the maximum power point voltage has been taken from the characteristics using Pspice. These are tabulated and presented in Table 1.

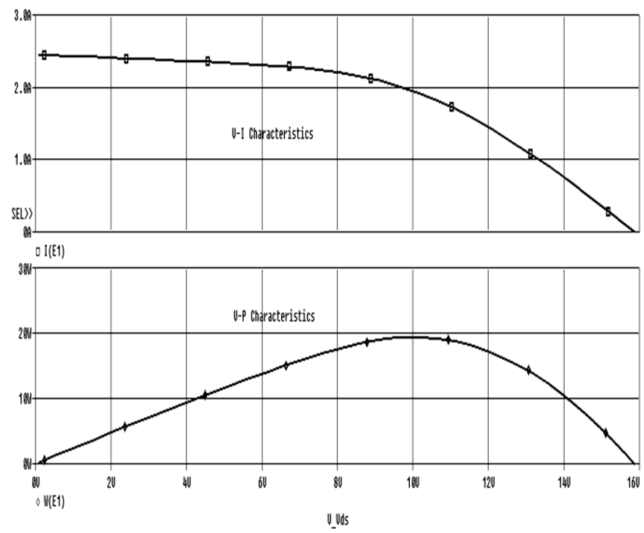


Fig 5. Simulated characteristics of SOLKAR PV panel using Pspice

Table 1. PV analysis for different values of isolation

| G (W/m$^2$) | $I_{in}$ (A) | $V_{oc}$ (V) | $V_{mp}$ (V) | $P_{mp}$ (W) |
|---|---|---|---|---|
| 1000 | 2.55 | 18.2 | 15.86 | 36 |
| 900 | 2.29 | 18.0 | 15.8 | 32 |
| 800 | 2.04 | 17.8 | 15.73 | 28 |
| 700 | 1.78 | 17.6 | 15.67 | 24 |
| 600 | 1.55 | 17.4 | 15.52 | 20 |
| 500 | 1.27 | 17.2 | 15.32 | 16 |
| 400 | 1.02 | 17.0 | 15.06 | 12 |

For different maximum power point voltage, the soft switching and hard switching operations of the dc-dc converters have been simulated at 10 kHz. The zero voltage and zero current switching operations for the reference voltage of 18 V are presented in Fig 6 and Fig 7.

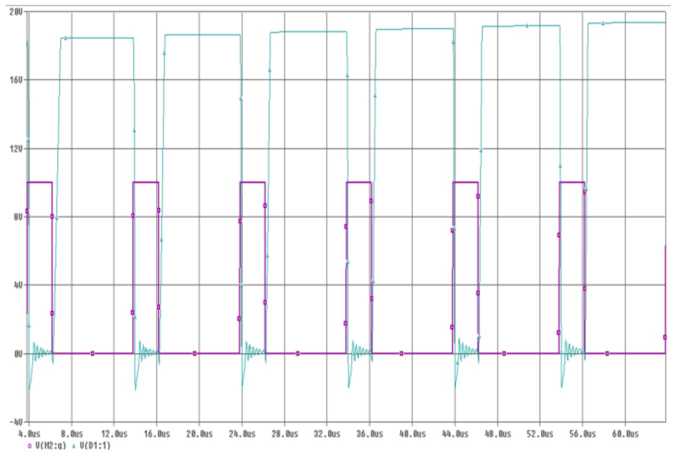

Fig 6. Zero voltage switching waveform

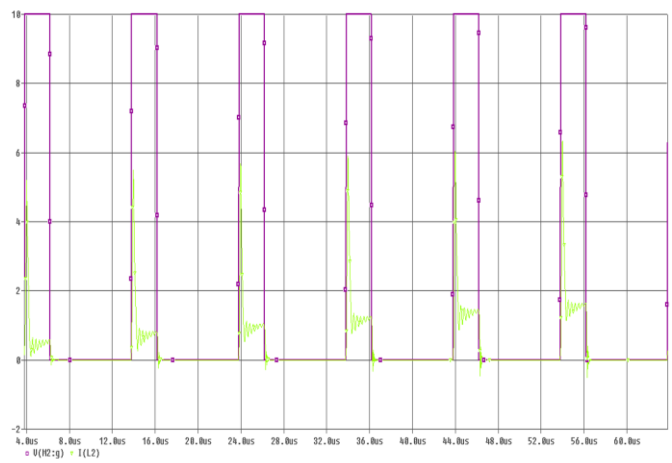

Fig 7. Zero current switching waveform

The switching losses for different insolations have been calculated and tabulated (Table 2)using the formula

$$P_{SW} = \frac{1}{2} V_{out} I_{in} (t_r + t_f) f_s \tag{1}$$

Where, $V_{out}$-output voltage; $I_{in}$-input voltage; $t_r$-rise time; $t_f$-fall time; $f_s$-Switching frequency.

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Table 2. Switching loss comparison

| Insolation G (W/m$^2$) | Switching losses, $P_{sw}$(W) | |
|---|---|---|
| | **Hard switching** | **Soft switching** |
| 1000 | 2.24 | 0.44 |
| 900 | 1.632 | 0.286 |
| 800 | 1.425 | 0.242 |
| 700 | 1.235 | 0.198 |
| 600 | 1.06 | 0.168 |
| 500 | 0.896 | 0.14 |
| 400 | 0.74 | 0.092 |

From Table 2, it is clear that the switching loss is less in case of soft switching when compared to hard switching.

## VII. THE HARDWARE IMPLEMENTATION

PV fed soft switching boost converter has been implemented and the hardware set-up is shown in Fig 8. Table 3 shows the components that are used to implement the hardware.

Table 3 Devices used for hardware implementation

| Device/Components | Specifications/Values |
|---|---|
| Switches | IRFP460(N channel MOSFET) |
| Diode | 1N5408 |
| Inductor(E core) | 200μH |
| Filter Capacitor | 200μF |
| Load Resistance | 50Ω |
| Opto coupler | MCT2E |

The pulses for triggering the switches were generated by using PIC18F4550 microcontroller. The gating pulses were given to the devices through an opto-coupler circuit. The control circuit is shown in Fig 9. The converter was operated using SPV panel as the source. The corresponding outputs were obtained and analyzed to verify the results obtained by simulation with PV panel at the input side.

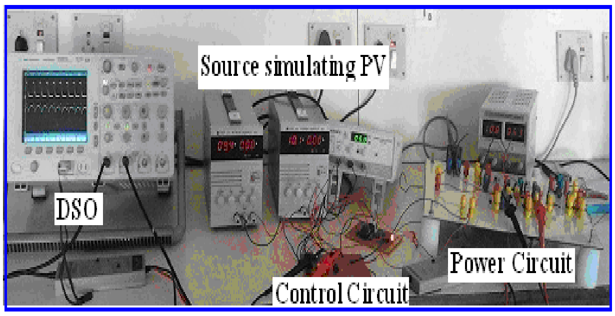


Fig 8. Hardware set-up of the PV fed soft switching converter

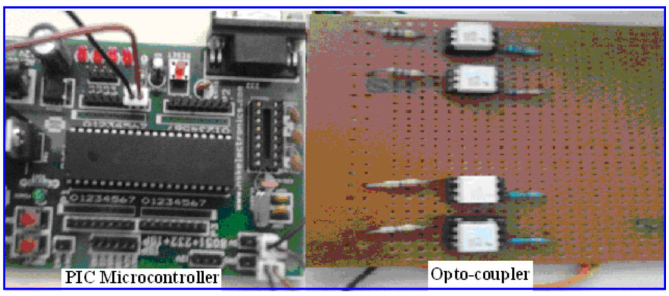


Fig 9. Control circuit

The observed pulses from the opto-coupler are shown in Fig 10. Fig 11 shows the soft switching phenomenon. From Fig 11, it is seen that ZVS operation is performed in hardware and the results are shown in which when the voltage across the resonant capacitor is zero the switch is turned ON.

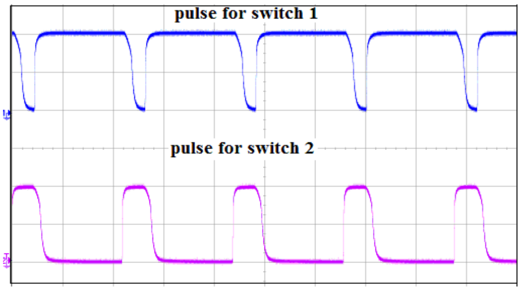


Fig 10. PIC Controller Output Pulse

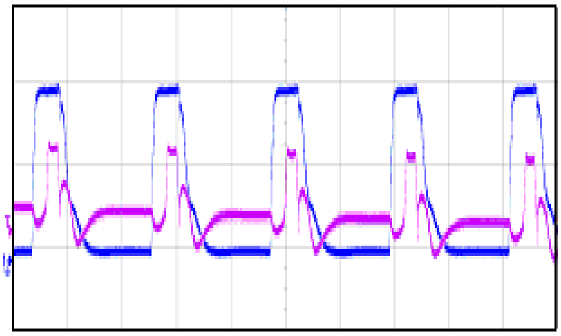

Fig 11. Soft Switching Phenomenon

## VIII. CONCLUSION

In this paper, the comparison between hard switching and soft switching boost converter fed from a PV source has been made. It was observed that the soft switching reduces the stress on the switches and hence reduces the switching losses in the converter. The hardware implementation of the soft switching boost converter has been done and the results are presented.

## IX. ACKNOWLEDGEMENT

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