Performance study of a transformer less ZVS buck DC-DC converter for photovoltaic application

Shamkumar B. Chavan[1], Mahesh S. Chavan[2]

[1](Electronics & Comm. Technology, Department of Technology, Shivaji University, Kolhapur, India
[2](Dept. of Electronics Engg. KIT College of Engineering, Kolhapur India)

Abstract: *This paper aim to design a transformer less soft switched buck DC-DC converter for a photovoltaic application. Hard switched DC-DC converters generate electromagnetic interference, higher switching losses and stress on power devices. Soft switching leads to reduce these demerits. In this paper a quasi-resonant ZVS buck converter is designed and its switching behavior is studied. Simulation model is prepared and results have shown that soft switching scheme does not allow power switch to suddenly turn ON and OFF thereby reducing the switching losses.*
Keywords: *soft switching converter, photovoltaic converter, transformer less single transistor converter*

I. Introduction

In hard switched DC-DC converters, power switches work under high stress and tolerates high voltage and current simultaneously due to sharp turn ON and turn OFF. Though snubber circuits minimize dv/dt and di/dt effects they bring limitation on the maximum frequency of operation. Soft switching reduces transient effects and stress, hence operating frequency of power switches can be increased [1]. Reference [2] compares performance of two high gain transformers less topologies designed for fuel cell application. In ref. [3] new single switched step down PWM converters are presented for high frequency and wide range voltages. Series connection of DC-DC converters is presented in [4] where efficiency between 95-98 % is obtained. Ref [5] deals with the reliability aspects of power switches in power processing stages. Since soft switching reduces the stress on devices the reliability of power switch improves greatly which is meritorious on hard switching scheme. Ref [6] studies the change in climatic condition and the converter design issues. Here optimum designing issues under atmospheric variations are focused.

This paper aims to study and analyze the operation of soft switched transformer less buck converter for a photovoltaic array. The effect of resonant components on IGBT switching, output voltage and current has been analyzed here.

II. Converter Description

Figure 1 shows transformer less soft switched single transistor converter. L1 and C1 are used for soft switching the IGBT.
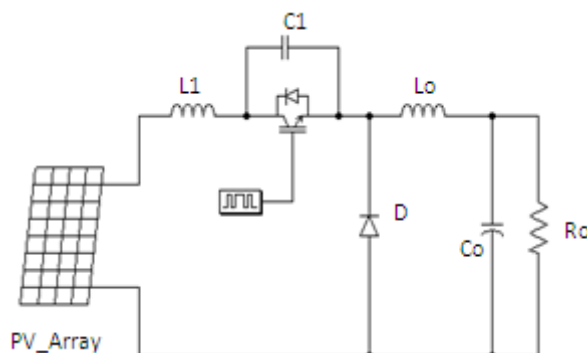

Figure 1- Soft switched buck converter topology

In hard switching whenever pulses are applied to IGBT gate, it turns ON and OFF suddenly thereby creating EMI noise, since C1 is connected in parallel and L1 is connected in series with the switch, this combination act as resonant circuit and does not allow the switch to on/off suddenly. Therefore simultaneous switching of voltage and current is avoided reducing the stress on power switches.
L1 and C1 are selected from

$$f_{resonant} = \frac{1}{2\pi \sqrt{L_1 C_1}}$$

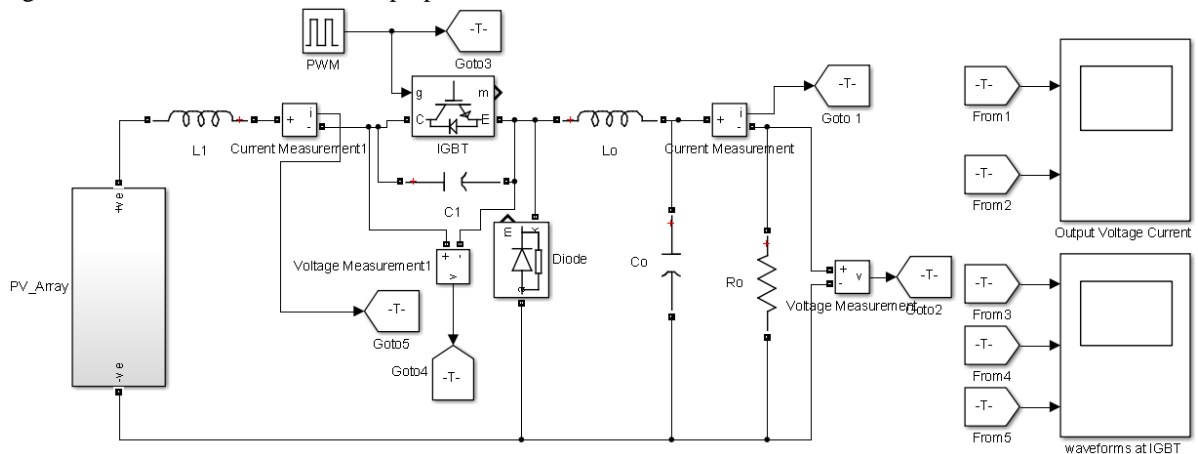Figure 2 shows the converter model prepared in MATLAB 2013b.

Figure 2- MATLAB model

Figure 3 shows the V-I characteristics of photovoltaic array at 1000 Watt/ m^2 irradiance level and at 25^oC.
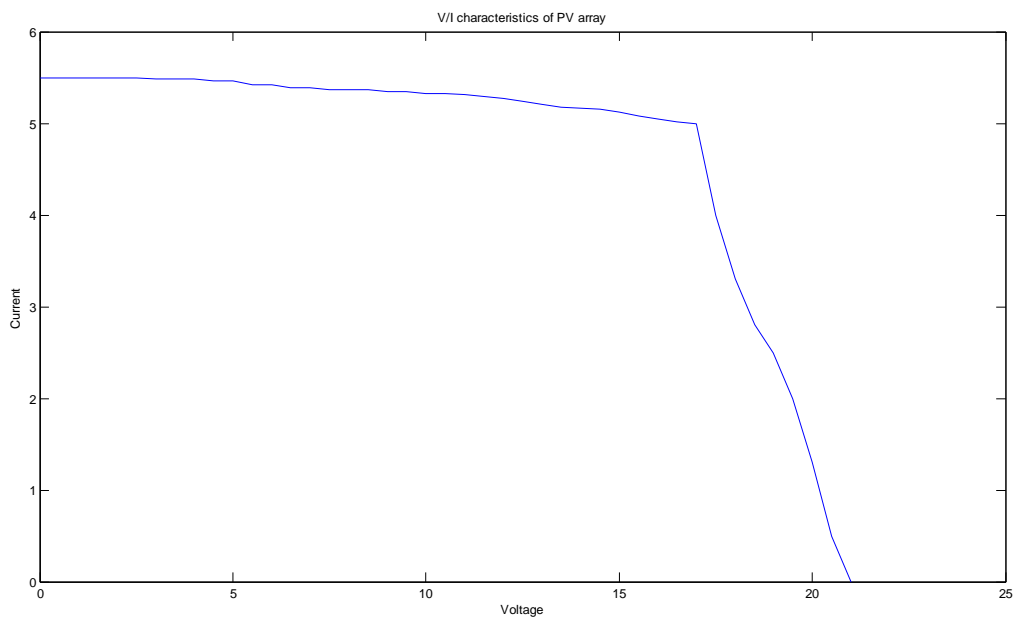

Figure 3- V-I characteristics of photovoltaic array

III.   Results And Discussion

Figure 4 shows output current and voltage waveforms while in figure 5 ripple contents are shown. The ripple contents are 100µV at output.
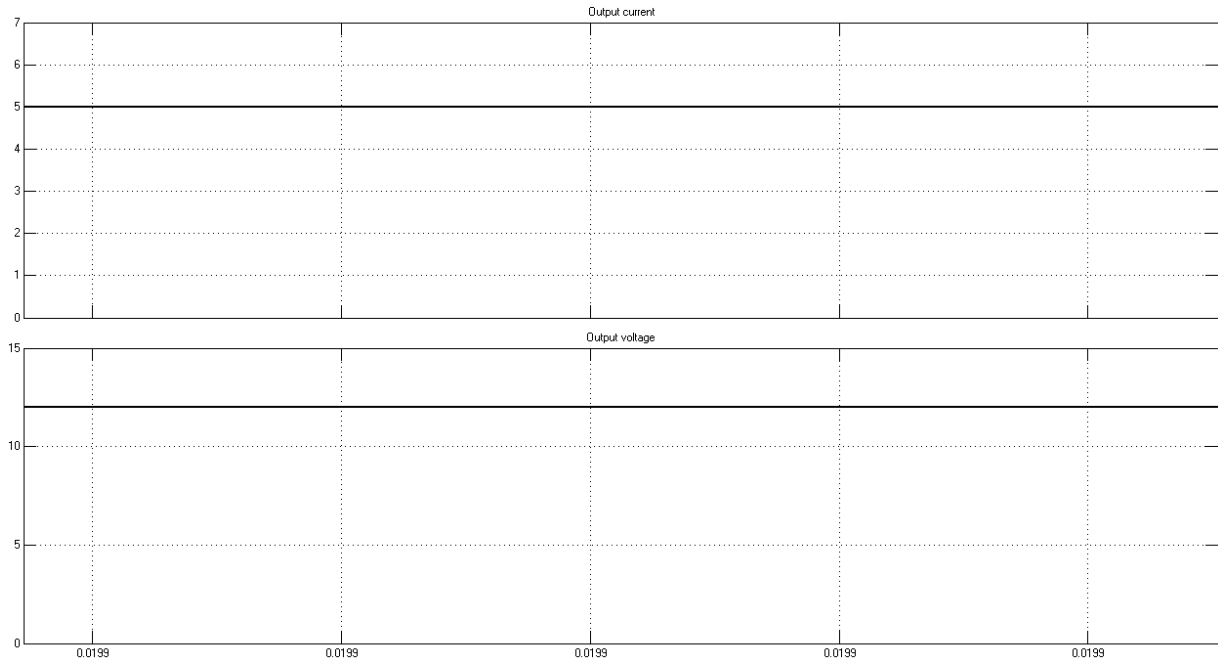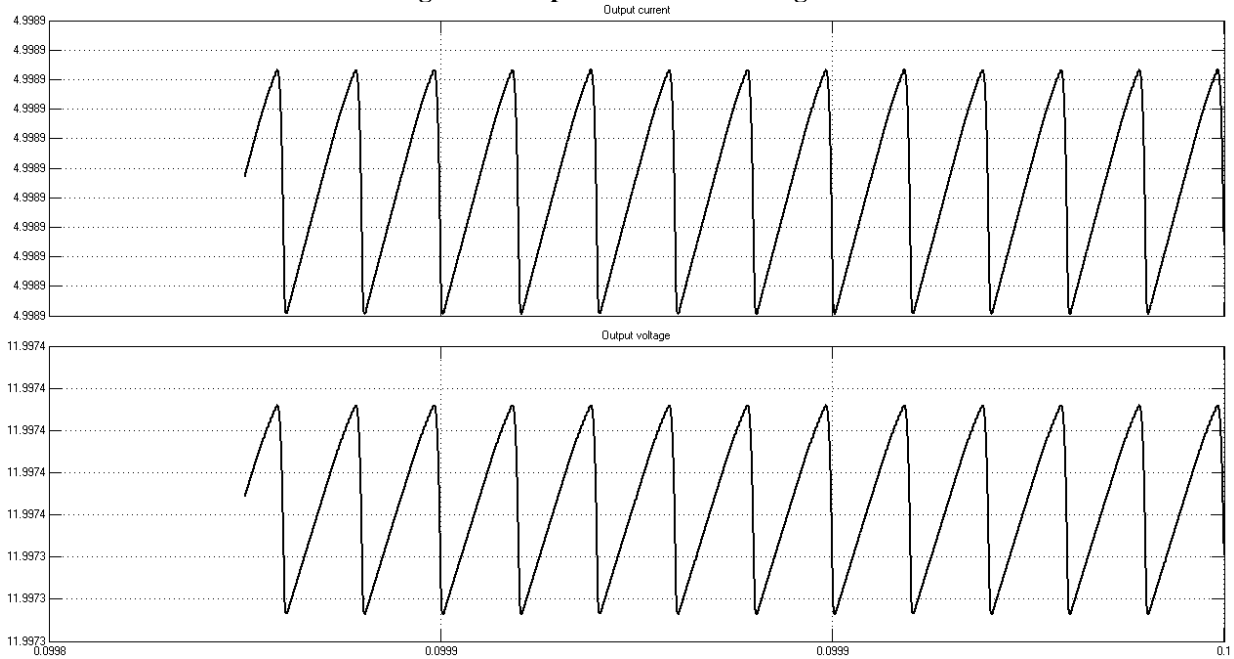
Figure 4- Output current and voltage

Figure 5-Ripple content in output

Figure 6 shows IGBT gate pulses, voltage across IGBT and current through IGBT. When gate pulse is switched off, voltage across IGBT starts increasing from 0 to maximum. Sudden increase in voltage across IGBT is avoided. Also the current through IGBT reaches slowly to zero. A small ringing effect is observed when IGBT is switched ON.
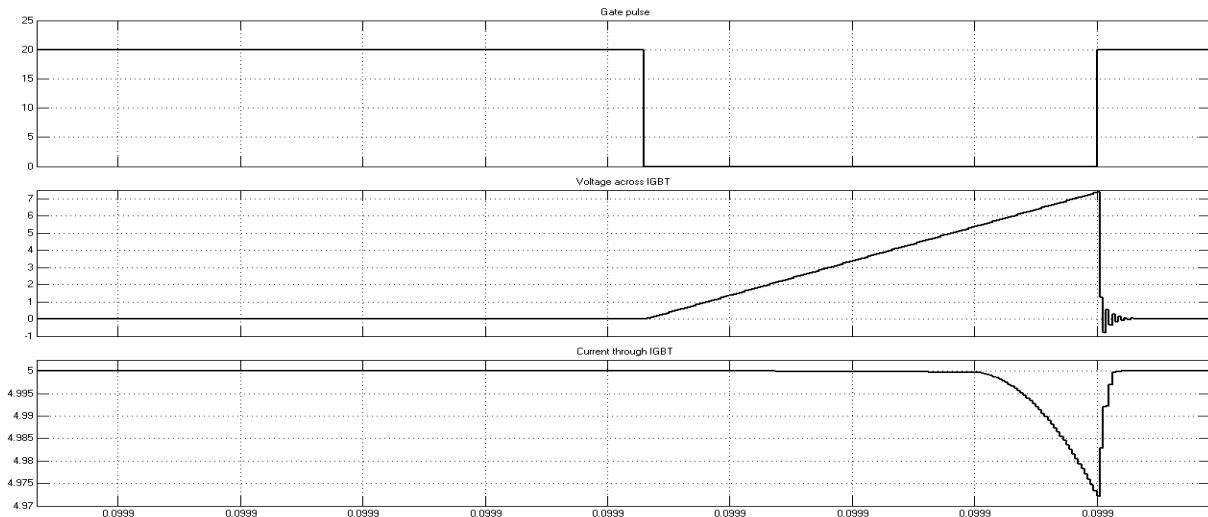
Figure 6- a) IGBT gate pulses b) V_{CE} across IGBT c) current through IGBT

It is clear that IGBT is smoothly operated in SOA.
Table 1 provides the converter specifications.

Table 1- Component specifications

Parameter/ Component	Rating
Vpv_{rated}	17V
Ipv_{rated}	5.5A
V_{oc}	21V
I_{sc}	7A
Vo	12V
Io	5A
Duty Cycle	0.63
L1	1 mH
C1	2.5 μF
L0	40 μH
C0	100 μF
R0	2.4 Ω

IV.   Conclusion

From results it is clear that simultaneous rise and fall of IGBT voltage and current is avoided which reduces the device stress. The effect of EMI is also reduced. Switches are operated at safer side in SOA curve thereby improving the switch reliability. Further ripple voltage and ripple current are also very low which shows that addition of resonant inductor and capacitor does not harm the output parameters. In future work device capacitance can be used for resonance.

Acknowledgement

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