Priya P et al. Int. Journal of Precious Engineering Research and Applications
www.ijpera.com
ISSN : 2456-2734, Vol. 1, Issue 3,October 2016, pp.26-29

RESEARCH ARTICLE OPEN ACCESS

Investigation of Sic MOSFET Based Quadratic Boost Converter for Photovoltaic Applications

Priya P[1], Shabbeer Basha G[1], Sujith Niranjan S V[1], Dr. R. Seyezhai[2]
[1](*UG Scholars, Department of EEE, SSN College of Engineering, Chennai, India)*
[2](*Associate Professor, Department of EEE, SSN College of Engineering, Chennai, India)*

ABSTRACT
In this paper, a comprehensive study of Quadratic boost converter using Silicon Carbide (SiC) MOSFET is carried out. Quadratic Boost Converter is chosen for the study as it is a two-stage converter with a single switch and has double the gain as that of the conventional boost converter. A 100 kHz, SiC DC-DC Quadratic Boost Converter is designed and the investigations are done using Matlab-Simulink. The characteristics of SiC MOSFET are studied. The performance parameters such as conversion gain, output voltage ripple, input current ripple and voltage stress are calculated and compared with the classical boost converter. The simulation results are verified.
Keywords: High frequency, Photovoltaic, Quadratic Boost converter, **S**iC MOSFET, Two stage converter

I. INTRODUCTION

Nowadays, renewable energy systems such as fuel cell stacks and photovoltaic power systems are becoming the most attractive and promising electrical energy generating sources as they produce clean electricity. Unlike conventional energy sources, PV systems produce clean electricity and are environmentally friendly. However, these systems have relatively low voltage output characteristics and demand a high step-up DC- DC converter for any potential practical application. Therefore, different topologies of boost converters are employed for the boost-up action [1]-[2].

The conventional boost converter has some disadvantages such as they are unable to switch faster, cannot withstand high temperatures and high gain cannot be achieved as there is a limitation in duty ratio. Whereas the proposed quadratic boost converter offers high voltage gain, high efficiency without extending the duty cycle or adding additional switches [3].The switches used in the converters are generally Silicon MOSFETs. Some of the disadvantages of Silicon (Si) MOSFETs are that they have a low breakdown voltage and cannot be employed for high voltage applications. Also this device cannot be used for high switching frequencies and cannot withstand high temperatures. On the other hand, the Silicon Carbide (SiC) MOSFETs are more advantageous in various aspects as they have wide band gap, high thermal conductivity, high breakdown electric field strength and chemical inertness [4]-[5]. Previous research works on QBC have been done with Si MOSFETs [6]-[8]. And so, this paper presents the design and analysis of a new quadratic boost converter topology that has high voltage gain, less switching loss, high temperature stability that will be ideally suited for photovoltaic applications.

II. SIC MOSFET

Silicon Carbide (SiC) is a wide band gap semiconductor material as well as a compound semiconductor material. Its electron mobility much less than silicon but it has a high band gap energy of 3.3eV. Its high critical field allows it to operate at high temperatures. It also conducts heat more efficiently. SiC is capable of high temperature operation upto 600˚C. Higher breakdown electric field allows for thinner and more highly doped devices. Since it can be made thinner and doped higher, faster switching speeds can be achieved. The lower on-state resistance can save conduction losses and also facilitate high frequency application. The junction structure of SiC power MOSFET is shown in Fig.1.

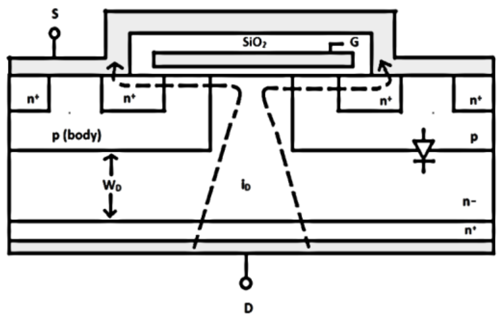

Fig. 1. The junction structure of a SiC MOSFET

For this research work, CM0160120D SiC MOSFET from CREE Corporation is chosen for analysis in Matlab-Simulink.

2.1. Characteristics – Simulation results

The output characteristics of the SiC MOSFET are simulated and the characteristic curve is presented in Fig.2.

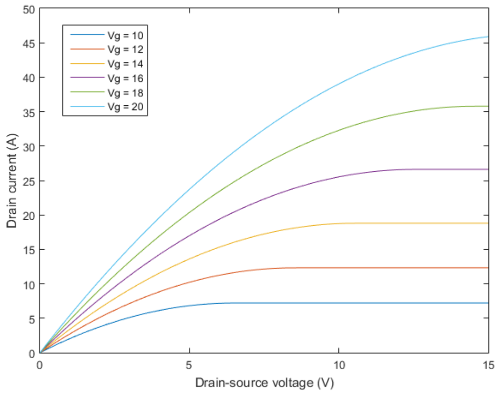

Fig.2. Static characteristics of SiC MOSFET.

The dynamic characteristics of the SiC MOSFET are simulated and the switching curve is presented in Fig.3. and it provides the information of corresponding dynamic parameters turn on time (ton)=35ns, turn off time (toff)=76ns, fall time (tf)=36ns & rise time (tr)=22ns.

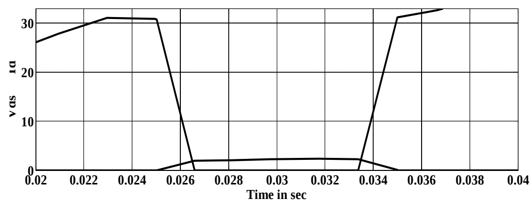

Fig. 3. Dynamic characteristics of SiC MOSFET.

III. SIC BASED QUADRATIC BOOST CONVERTER (QBC)

The circuit of SiC QBC is shown in Fig.4.The circuit has two inductors, two capacitors, three diodes and a load resistance.

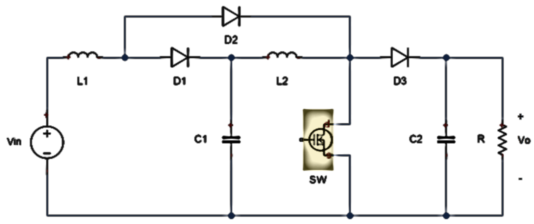

Fig.4. Circuit diagram of SiC Quadratic Boost Converter

3.1. Operation Of QBC

The circuit has two modes of operation [9-11]. First when the switch is turned on, D_2 is forward biased, whereas D_1 and D_3 are reverse biased. Currents are supplied to L_1 and L_2 by V_{in} and C_1 respectively, while C_2 is discharged by the load resistance. Secondly, when the switch is turned off, D_1 and D_3 are forward biased, whereas D_2 is reverse biased. L_1 and L_2 are charging C_1 and C_2 respectively. Thus both the modes work one after the other [11].

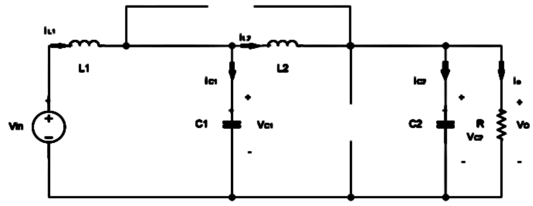

Fig. 5.a. Quadratic Boost Converter: Topology when SW is turned on

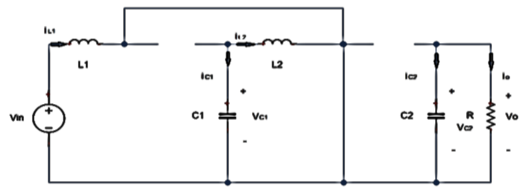

Fig. 5.b. Quadratic Boost Converter: Topology when SW is turned off

3.2. Design Equations

The design equations for SiC based quadratic boost converter is given by

$V_o = V_{in}/(1-D)^2$ -- (1) &
$R = V_o/I_o$ -- (2)
$V_{C1} = V_{in}/((1-D))$ -- (3) &
$V_{C2} = V_{C1}/((1-D))$ -- (4)
ΔV_{C1}= 5% of V_{C1} -- (5) &
ΔV_{C2} = 5% of V_{C2} -- (6)
$C_1 = (I_o*D)/((1-D)*\Delta V_{C1}*f_s)$ -- (7) &
$C_2 = (I_o*D)/(\Delta V_{C2}*f_s)$ -- (8)
$I_{L1} = I_o/(1-D)^2$ -- (9) &
$I_{L2} = I_o/((1-D))$ -- (10)
$L_1 = (V_{in}*D)/(0.2 * I_{L1}*f_s)$ -- (11) &
$L_2 = (V_{in}*D)/(0.2 * (1-D)*I_{L2}*f_s)$ -- (12)

3.3. Design Values

By using the equations (1) - (12) the values for various parameters have been designed and tabulated in Table 1.

Table 1. Design Values of SiC QBC

Parameters	**Value**
Input V_{in}	12V
Output V_o	36.64 V
Frequency f_s	100 kHz
Duty cycle D	50%

ISSN : 2456-2734, Vol. 1, Issue 3,October 2016, pp.26-29

L_1	60 uH
C_1	10 uF
L_2	240 uH
C_2	2.6 uF
Load R	30 ohm

IV. SIMULATION RESULTS

The SIMULINK model of SiC based quadratic boost converter is shown in Fig.6.

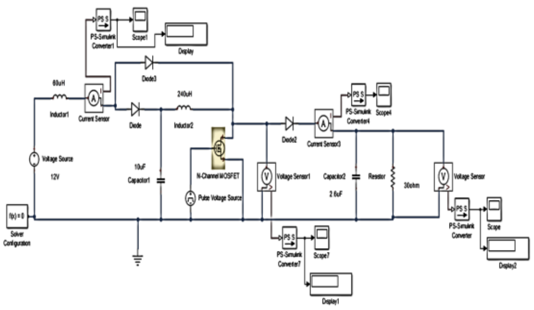

Fig. 6. Simulink model of the SiC quadratic boost converter

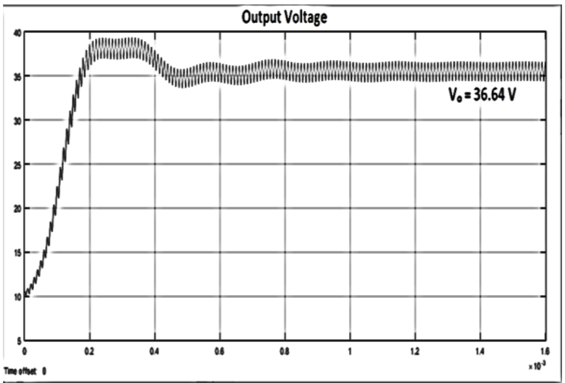

Fig.7. Output voltage of SiC quadratic boost converter

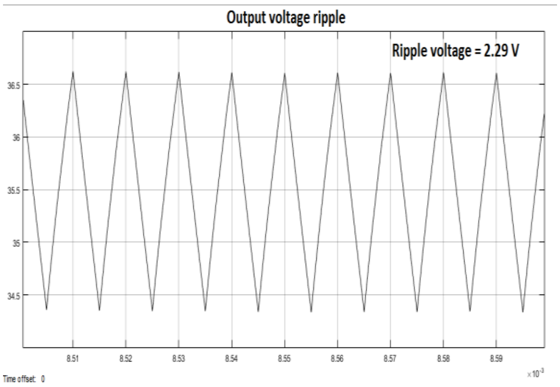

Fig. 8. Output voltage ripple of SiC quadratic boost converter

Fig.7. shows the output voltage obtained is about 36.64V and the output voltage ripple is 2.29V which is depicted in Fig.8.

V. ANALYSIS OF SIC QUADRATIC BOOST CONVERTER

This section provides the simulation results of the boost and quadratic boost converter using both Si and SiC MOSFETs. The simulation results are carried out using Matlab-Simulink.

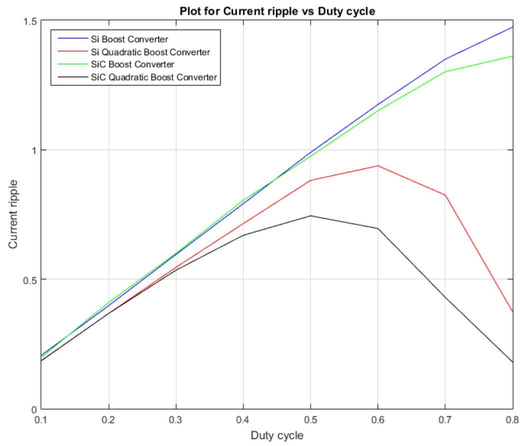

Fig. 9.a. Plot for Current ripple Vs Duty cycle

From Fig.9.a., it is found that SiC QBC has the lowest current ripple(0.745A) compared to other configurations.

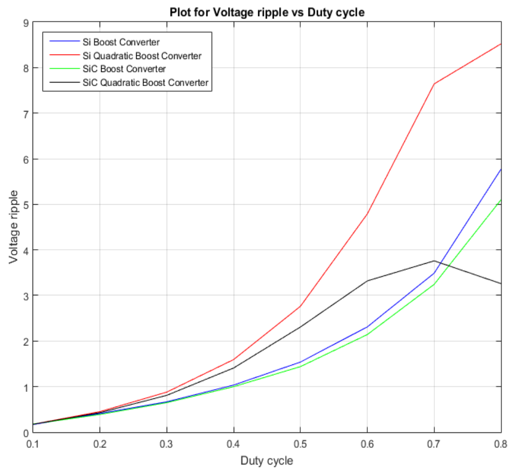

Fig. 9.b. Plot for Voltage ripple Vs Duty cycle

From Fig. 9.b., it is found that SiC based converter has a lower voltage ripple(1.44V) than the conventional configuration.

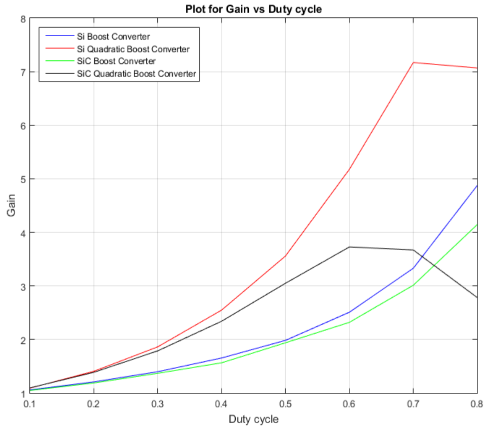

Fig. 9.c. Plot for Gain Vs Duty cycle

From Fig. 9.c., it is found that for 50% duty cycle the gain is maximum in Si quadratic boost converter(3.56) followed by the SiC quadratic boost converter(3.051).

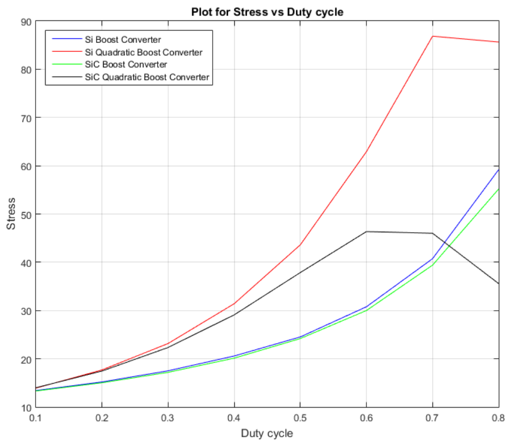

Fig. 9.d. Plot for Stress Vs Duty cycle

From Fig. 9.d., on comparing the Si Quadratic Boost converter for 50% duty cycle ,the stress is minimum for SiC Quadratic Boost converter(37.87).

VI. CONCLUSION

This paper has presented the design, analysis and comparison of SiC Quadratic Boost Converter with the conventional Si based boost converters. From the results, it is inferred that the SiC Quadratic Boost Converter offers significantly high gain, reduced output voltage ripple and reduced voltage stress and has the capability to operate at high switching frequency with minimum switching losses. The advantages of SiC MOSFET along with its characteristics have been presented. Henceforth, SiC Quadratic Boost Converter is the best choice for PV applications compared to the classical Si based DC-DC converters.

REFERENCES

[1]. Mustafa A. Al-Saffar, Esam H. Ismail and Ahmed J. Sabzali, "High efficiency quadratic boost converter", Twenty-Seventh Annual IEEE Applied Power Electronics Conference and Exposition (APEC), 2012 .

[2]. Muhammad H. Rashid, "Power Electronics, Circuits, Devices, and Applications", Third Edition, Pearson Education, Inc., 2004.

[3]. Raid Kadri, Jean-Paul Gaubert, Gerard Champenois, Mohamed Mostefai, "Performance analysis of Transformless single switch quadratic boost converter for grid connected photovoltaic systems.", IEEE, International Conference on Electrical Machines, Rome, 2010.

[4]. Xiangxiang Fang, "Characterization and modelling of SiC Power MOSFETs" – Thesis, The Ohio State University, 2012.

[5]. Keshava Gopalakrishna, "Frequency Characterization of Si, SiC, and GaN MOSFETs using Buck converter in CCM as an application" – Thesis, Wright State University, 2013.

[6]. R. Dhanasekaran and T. ArunPrasath, "Performance comparison of solar power using quadratic boost converter with coupled inductor", International Conference on Advanced Communication Control and Computing Technologies (ICACCCT), 2014.

[7]. Pranshu Agarwal and Rajeev Kumar Singh, "A modular magnetically coupled quadratic boost converter for Microsource Applications.", 7th IET International Conference on Power Electronics, Machines and Drives (PEMD 2014) .

[8]. Ping Yang and Jianping Xu, "A new quadratic boost converter with high voltage step-up ratio and reduced voltage stress", IEEE, International Power Electronics and Motion Control Conference, ECCE Asia, 2012.

[9]. K.H. Beena and Anish Benny, "Analysis and Implementation of Quadratic boost converter for Nanogrid applications", IJAREEIE, Vol. 4, Issue 7, July 2015.

[10]. Abdul Fathah, "Design of a Boost Converter"- Thesis, National Institute of Technology, Rourkela, 2013.

[11]. K. Tattiwong and C. Bunlaksananusorn, "Analysis design and experimental verification of a quadratic boost converter.", IEEE Region - 10 Conference, TENCON, 2014.