PV Based Speed Control of Dc Motor Using Interleaved Boost Converter With Sic MOSFET and Fuzzy Logic Controller

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***Abstract*—A prototype model is designed with interleaved dc-dc boost converter for photo voltaic based dc motor speed control. By comparing the carrier signal and the fuzzy logic signals, the motor speed can be modified. Controlling the electrical and mechanical devices is mostly done by fuzzy controller due to the multi input and multi output operation and its performances. Due to the increased switching speed SiC-based applications is more predominant for SiC MOSFETs as compared to Si IGBTs. The proposed system features the dc motor speed control by the varying the duty cycle of the gate signals given to the power devices. Interleaved boost converter is preferred for high voltage gain from the solar panel. Effectiveness of the proposed scheme was checked for various duty cycles with Matlab/Simulink.**

***Index Terms*—Sic Mosfet, PV array, Interleaved dc-dc boost converter, Fuzzy logic controller.**

I. INTRODUCTION

Wide band gap materials have the property to operate at high switching frequencies with high accuracy reducing the overall cost and volume of the system. SiC technology has emerged in the power electronics market as it has superior properties like high level of switching speed, withstanding high temperature capability, low switching losses, higher operating frequency. The low switching losses of the silicon carbide (Sic) MOSFET enable the reduction of end-system cost, even at low frequency. A voltage source inverter (VSI) designed by Cree with commercially available 1200V Sic and Si modules evaluated operating at conventional frequencies [1-3]. A 100A Sic module has the capacity to replace at least a 150A Si module operating at low 5 kHz operation which provides significant performance and reliability advantages. For overload and thermal margin requirements, the 100A Sic module replaces up to a 300A Si at modest 16 kHz operation.

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Thus comparing the traditional Silicon (Si) based devices SiC switches has more benefits in hard switched DC/DC-converters. In the investigated dc/dc converter system, SiC-based technology gives better performances than Si- based power semiconductor devices. At present scenario, Sic is the only wide band gap material with high performance 1200V and 1700V devices to address the power electronics market needs[4-6]. The Sic devices with low switching loss improves the overall converter efficiency reduces the temperature stress of the designed power devices. To investigate the performance of high temperature and high frequency of Sic devices, some research works have been carried out in power electronics technology. The prototype developed is a PV system using a fuzzy controller with a Coupled-Inductor Interleaved Boost Converter (CIBC) fed with a fuzzy feed forward method. A parallel connection technique of boost converter for unity power factor was proposed in. This system is based on two cell converter which is operated in continuous inductor current mode. With an extra small inductance, two Mosfet pulse width modulation are connected in parallel, which provides an increased output power. Any number of PWM cells can be paralleled by this method. DC to DC switching converters with parallel connection of N-identical boost converters with Current-Mode Control (CMC) is presented. This method helps in equal current sharing between two parallel connection boost converters.

The rest of the work is organized as follows: Part II gives an overview on system description and modeling. Proposed method and operating modes is described in Part III and IV. Part V and VI gives the comparison of four reduction techniques and the results are mentioned with experimental setup, Section VII gives the conclusion of this paper.

II. SYSTEM DESCRIPTION AND MODELING

The modeled system is a simple structure consists of PV array, Interleaved Boost Converter, Silicon Carbide MOSFET, Fuzzy controller, Battery and a dc motor. The designed converter boost up the input voltage given to the dc motor. By adjusting the duty ratio of the fuzzy technique [7-10], the output voltage of the converter is varied; thereby speed of the dc motor is controlled.

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Input for the interleaved boost converter is obtained by solar panel or battery.

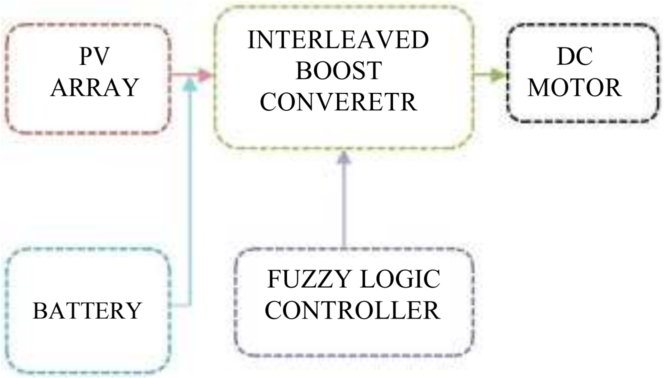

Fig. 1. Block Diagram

In the hardware circuit diagram first we get the supply from the photovoltaic (PV) panel and then the voltage is boosted by using the interleaved boost converter which doubles the supply voltage by varying the duty cycle of the silicon carbide MOSFET with the help of the fuzzy logic controller.

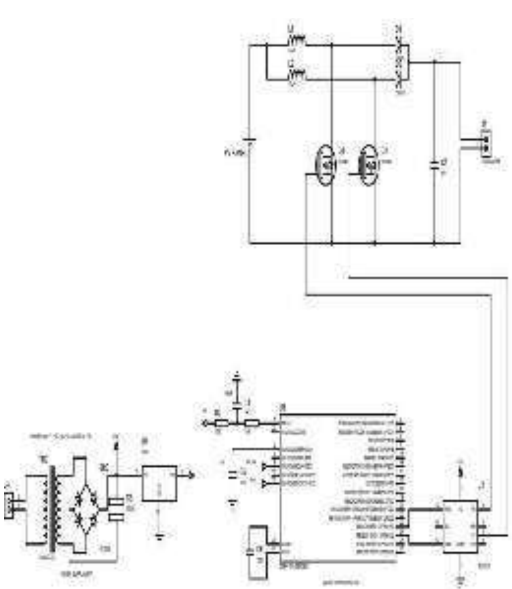

Fig. 2. Hardware Setup

III. PROPOSED METHOD

The proposed system consists of PV array, Interleaved Boost Converter, Silicon Carbide MOSFET, Fuzzy controller, Battery and Dc motor. Interleaved boost converter boosts up the input voltage and send it to the dc motor which is done by using the Sic MOSFET.

Speed of the dc motor is controlled by the fuzzy controller based on the fuzzy logic technique. Input for the interleaved boost converter is obtained by using PV array or battery**.**

In the normal boost converter more number of ripples is present having 50 percent ON time and the 50 percent OFF time which results in more on-state resistance and hence it affects the performance.

To overcome this effect , the interleaved boost converter is used in which it divides the ON and OFF time further more in which it have in the first cycle 25 percent ON time and 25 percent OFF time and same as that of in the second cycle.

The advantages of the proposed converter are as follows:

1) Low input current ripple with low conduction losses, increases the lifetime of type of source used which is suitable for high-power applications.
2) Withstanding high temperature capability (Tj max >150 °C) which reduces PCB form factors (simplified thermal management) improving the system reliability
3) Minimum switching losses (variation with temperature) resulting in miniaturized circuit designs (with small passive components)

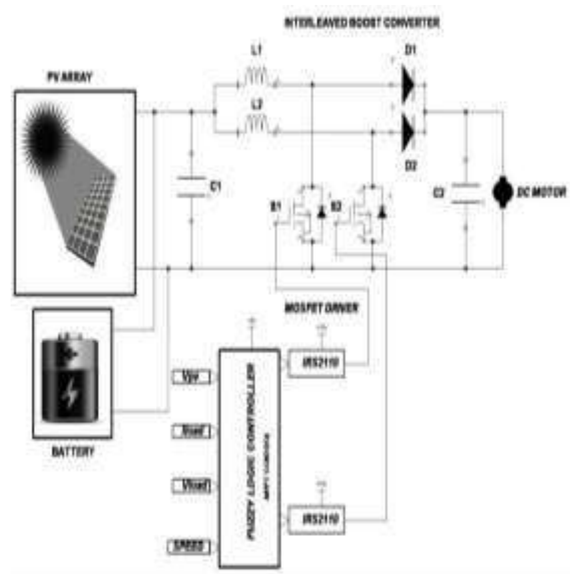

Fig. 3. Equivalent circuit of proposed model

4) Low on-state resistance (80 mΩ @ 25 °C) resulting in higher system efficiency (reduced cooling requirements)
5) Reduced cooling requirements which enables compact and light weight system (cost-effective network driving)
6) Very fast and robust intrinsic body diode (external freewheeling diode not needed, thus more compact systems)

IV. OPERATING MODES

During the mode 1, the current flows through the L_1 with positive and negative polarity and reaches the negative terminal. So the current will not flow to the load because it forms a reverse bias.

In the mode 2, the gate pulse is switched off. So the inductor L_1 discharges with polarity of negative and positive, forms a forward bias and supplies the voltage to the load.

In the mode 3, the gate pulse is given to the Mosfet switch S_2.The current flows through L_2 with a polarity of positive and negative and reaches the negative terminal. so the current will not flow through the load because it forms an negative bias.

In the mode 4, the gate pulse is switched off. So the inductor L_2 discharges with a polarity of negative and positive, forms a forward bias and supplies the voltage to the load.

TABLE I
DESIRED SPECIFICATIONS OF INTERLEAVED BOOST CONVERTER

Parameter	Values
PV voltage	100.25V
L_1, L_2	$2.773X10^{-5}$ H
C_1, C_2	$3.1746X10^{-4}$ F
D_1, D_2	0.8 V(Forward voltage)

V. FUZZY CONTROLLER

Fuzzy logic controller modeled for boost converter is shown in Fig. 5. By comparing the output voltage of the converter with the reference voltage by the comparator thereby error signal is generated which is fed to the Fuzzy controller along with the change in error signal [6]. Duty cycle from the controller output is fed to the PWM block which acts as a switching signal to the converter as shown in Fig. 4.

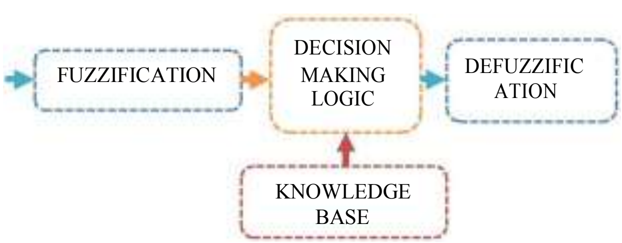

FIG. 4. MODEL OF FUZZY LOGIC CONTROLLER

The fuzzy system comprises of two inputs a. error (e) b. change in error (ce). Further the inputs are divided into 5 membership functions.

In the circuit diagram, motor speed is controlled by varying the duty cycle in which the duty cycle compares the input signal of error (e) Fig. 6 and the change in the error (ce) Fig. 7 gives the output of duty cycle fig.8 to the Sic MOSFET as a gate pulse.

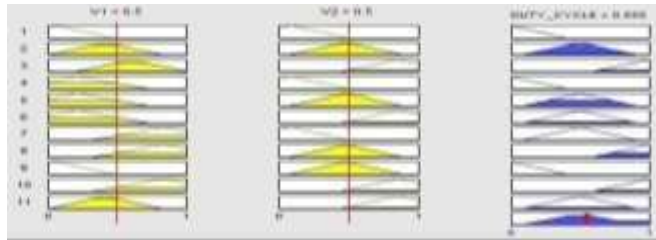

Fig. 5. Rules of fuzzy logic controller

Fig. 5 represents the view of the rules for the proposed fuzzy logic control. The rules represent the two error inputs and error change combinations for a given output.

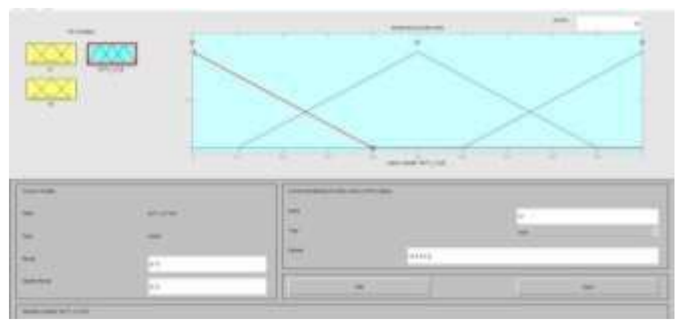

Fig. 6. Graphical diagram for the triangular membership for error (e)

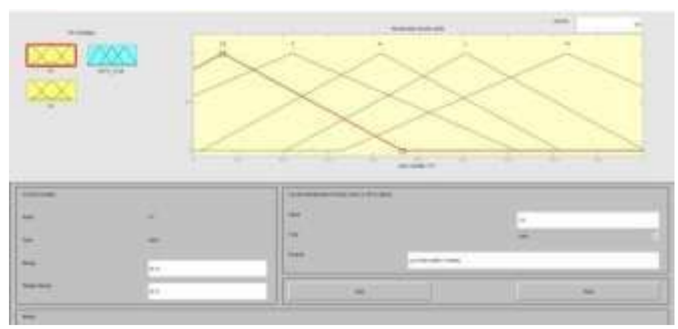

Fig.7. Graphical diagram for the triangular membership for change in error (ce)

Fig. 8. Graphical diagram for the triangular membership for the duty cycle

The design parameters are,

$$L_{out\,(min)} = \frac{I_{out\,(max)} \text{ x } D}{\partial S \text{ x } V_{out}}$$

Where
∂S = Switching frequency
ΔV_{out} = Desired output voltage ripple

$$\Delta V_{out} = ESR \text{ x } \frac{2I_{out\,(max)} + \Delta I_c}{(1\text{-}D)\ 2}$$

Where
I_{out} = Output Current
I_c = Capcitive Current

$$L = \frac{V_{in} \text{ x } (V_{out}\text{-}V_{in})}{\Delta I_L \text{x} \partial S \text{ x } V_{out}}$$

Where
V_{in} = Input Voltage
V_{out} = Output Voltage
I_L = Line Current

$$P_m = \text{Tx}\omega$$

Where
P_m=Motor Power
T = Total Power

VI. SIMULATION BLOCK

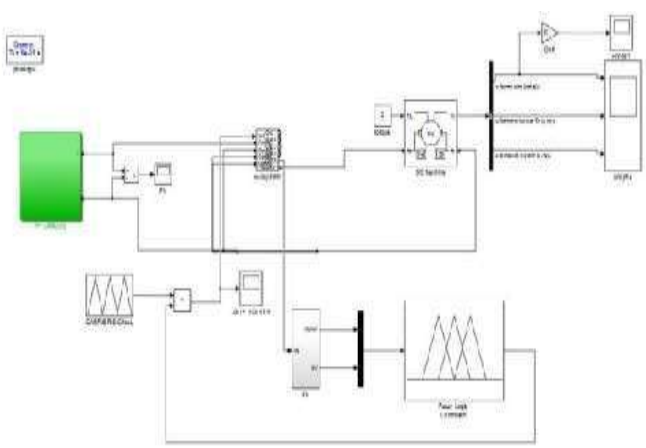

Fig. 9. Simulation circuit

VII. SIMULATION RESULTS

The simulation results of the proposed system is shown here

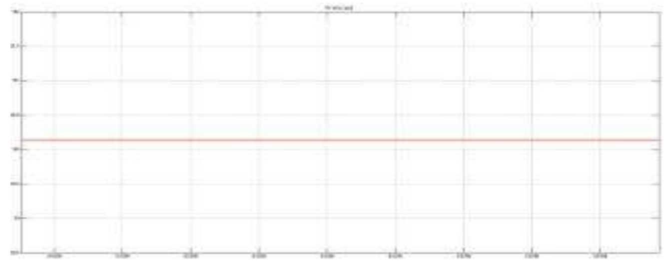

Fig. 10. Photo voltaic panel output

In the normal existing method, Mosfet and diode cannot withstand very high temperature so we have to reduce the heat by using the heat sink[11-13]. But in our proposed method we are using the Silicon Carbide MOSFET in which it can withstand very high temperature 800/spl deg/C for 30 min and voltage up to 1200V which is shown in the above simulation diagram Fig. 10. DC bus voltage:

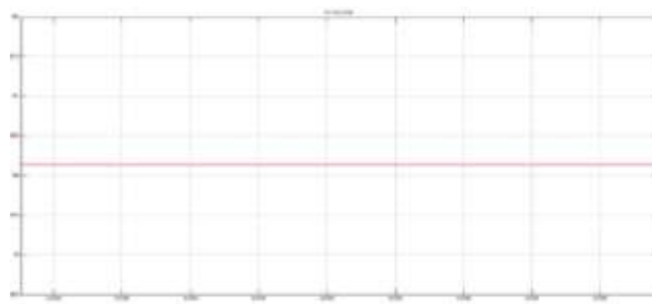

Fig. 11. Interleaved boost converter output.

The output of the converter [9] in Fig. 11 indicates that the voltage is tripled three times by varying the duty cycle with the help of the fuzzy logic controller.

TABLE II
PREDICTED PARAMETERS

Parameter	Values
Dc motor voltage(volt)	325 V
Torque(N-m)	450 N-m
Speed(rad/sec)	1717.2 RPM
Armature current(Amps)	250 A

EXPERIMENTAL SETUP

Fig. 12. Hardware Prototype

Motor output

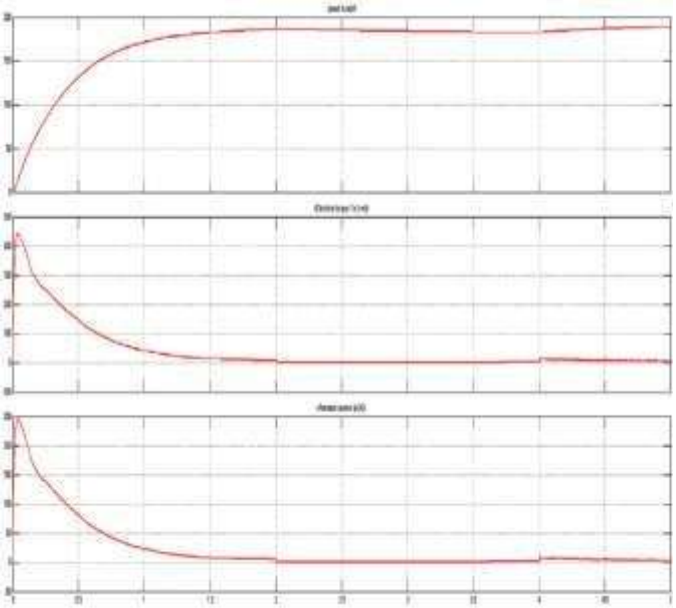

Fig. 12. Output of dc motor

The above figure shows the output of the DC motor. In simulation results it gives speed of dc motor which is measured in rad/s, Electrical Torque in Nm and the Armature current in amps.

SIC MOSFET Driving Requirements

SiC Mosfet can be driven easily than Silicon Mosfet

- Just need V_{gs}= 20V to get the right Ron
- Adequate current capability to ensure high speed (3-5A would be the best)
- To avoid gate voltage oscillations, high drain current with negative voltage is suggested.
- The negative voltage (up to -5V) have an impact on the turn-off switching losses reduction. This of course will depend on the sinking current driver's capability.

VII. CONCLUSION

The details of the PV based Speed Control of the DC Motor using the Interleaved Boost Converter are presented. Based on the design details illustrated, a prototype is developed in the laboratory. The experimental results demonstrate the Interleaved Boost converter, Sic Carbide Mosfet and the Fuzzy logic controller effectively which provide low on state resistance, increased withstanding temperature. Also it has very high efficiency than the normal MOSFET, Diode and the boost converter.

REFERENCES

[1] CMF20120D-Silicon Carbide Power MOSFET

[2] Z-FeT™ MOSFET, www.cree.com/power© cree Inc.2012

[3] Design of Photovoltaic Power Generation MPPT Controller Based on SIC MOSFET. Shuangming Duan, Gangui Yan, Liguang Jin, Jun Ren, Wei Wu School of Electrical Engineering, Northeast Dianli University Jilin, China,*TENCON,IEEE* 2015

[4] Maximum Power Point Tracking Converter Based on the Open-Circuit Voltage Method for Thermoelectric Generators, Andrea Montecucco, Student Member, *IEEE*, and Andrew R. Knox, Senior Member, *IEEE* Transactions on power electronics, vol. 30, no. 2, February 2015

[5] A Review of WBG Power Semiconductor Devices José Millán, Centro Nacional de Microelectrónica, CNM. Instituto de Microelectrónica de Barcelona, IMB CNM-CSIC,Campus Universitad Autónoma de Barcelona, 08193 Bellaterra, Barcelona, Spain, 978-1-4673-0738-3/12,PP.57-66, 2012 *IEEE*.

[6] Speed Control of Separately Excited Dc Motor using Fuzzy Logic Controller Logic Control Based on Matlab Simulation Program Atul Kumar

[7] Dewangan[1], Sashai Shukla [2],Vinod Yadu[3], International Journal of Scientific & Technology Research Volume 1, Issue 2, March 2012 ISSN 2277-8616

[8] Characterization, Modeling, and Application of 10-kV SiC MOSFET, Jun Wang, Student Member, *IEEE*, Tiefu Zhao, Student Member, *IEEE*,Jun Li, Alex Q. Huang, Fellow, *IEEE*, Robert Callanan,Fatima Husna, and Anant Agarwal, Member,pp.1798 – 1806, 2008 *IEEE*.

[9] J. Wang ; X.Zhou ; J.Li ; T.Zhao, IEEE Transactions on Industry Applications (Volume:45, Issue:6) September 2009,pp 2056 – 2063

[10] Analysis and Minimization of the Input Current Ripple of Interleaved Boost Converter, Zhang, Saijun Power Electronics Group Tewksbury, MA 01876 justinhustee@gmail.com, 978-1-4577-1216-6,2012 *IEEE*

[11] Design and Experimental Analysis of a 1 kW, 800 kHz All-SiC Boost DC-DC Converter Xueqian Zhong, Xinke Wu, Weicheng Zhou, Shidong Cheng, Kuang Sheng* College of Electrical Engineering, Zhejiang University Hangzhou, China shengk@zju.edu.cn,pp. 492, 16-20 March 2014 APEC 2014

[12] M. Godoy Simoes, N. N. Franceschetti, "Fuzzy optimisation based control of a solar array system" *IEEE* Proceedings - Electric Power Applications, September 1999, Vol. 146, Issue 5, pp. 552-558 320 – 3765 ISSN (Online): 2278 – 8875

[13] M.Godoy Simões and M. Friedhofer, "An implementation methodology of a fuzzy based decision support algorithm," International Journal of Knowledge-Based Intelligent Engineering Systems, October 1997, vol.1 no. 4, pp. 267-275.