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Performance enhancement of DC/DC converters for solar powered EV

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Article Info

ABSTRACT

The paper initially presents the essential drive arrangement required for electric vehicle. It requests high power bidirectional stream ability, with wide info voltage range, and yield voltage of vitality stockpiling gadgets, for example, super capacitors or batteries shift with the adjustment in stack. At that point the tenacity and outline of previously mentioned converter is proposed in this paper. The converter which relates a half extension topology, has high power stream ability and least gadget focuses on that can appropriately interface a super capacitor with the drive prepare of a crossover electric vehicle. Besides, by contrasting the fundamental qualities and applications with some ordinary bidirectional DC/DC converter, the proposed converter has low gadget rating and can be controlled by obligation cycle and stage move. Finally, the most essential attributes of this converter is that it utilizes the transformer spillage inductance as the essential vitality exchange component and control parameters, Simulation waveforms in light of MATLAB recreation are given to exhibit the integrity of this novel topology, and this converter is additionally reasonable for high power application, specifically to control the charge-release of super capacitors or batteries that can be utilized as a part of cross breed solar based electric vehicle.

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1.   INTRODUCTION

In the recent years, solar base HEV (Hybrid Electric Vehicles) has pulled in an ever-rising number of considerations of numerous nations' vehicle industry [1]. Cars fueled by inward burning motors speak to an enormous framework venture, and around 33% oil utilization [2, 3]. Therefore, the progress to an all-electric versatile armada has all the earmarks of being extremely alluring and attractive, however it has been restricted by a few key innovation and business issues [4]. Therefore, the change in exploring on Hybrid Vehicles seems, by all accounts, to be alluring. Limited Vehicles have a few favorable circumstances over traditional autos [5, 6]. An inverter to drive the engine and DC/DC power converter is placed among the battery and high voltage transport [7]. This chopper must remain operated bi-directionally meanwhile the energy can spill out of the energy storage device to the DC interface or the other way [8, 9]. This paper utilizes an illustration that can coordinate with the current gas and power foundation is using module HEV [10]. The generalized block diagram is depicted in Figure 1. In this paper chapter 2 describe the proposed electric vehicle solar based converters requirements. Chapter 3 delineates the simulation circuits and results of proposed work. Finally, it is concluded in Chapter 4.
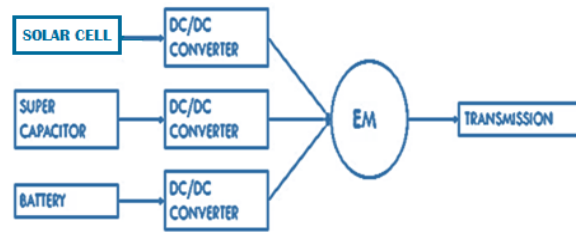
Figure 1. Block diagram

2. PROPOSED PV BASED ELECTRIC VEHICLE

In the event of interconnecting the solar panel with the load, the DC/DC power converter is utilized [11]. Wide varieties of DC-DC converter topologies may be available for synchronizing solar cell with the DC - Bus [12, 13]. However, some outline inspections for EV applications found to be lesser weight, higher efficiency, smaller volume, lower electromagnetically produced interferences, and lower current ripples sucked from the power sources, controlling the bidirectional DC/DC power converters power flow is subjected to the wider range of voltage variation in the input of the converter [14, 15]. The categories of DC/DC power converters studied and simulated in the proposed work are Boost Converter, full-bridge Converter, Interleaved boost Converter. The performance different performance is analysed namely Inductor Loss, Capacitor Loss, Diode Loss, Switching Los, Total Loss and Efficiency [16, 17].

2.1. Design and analysis of boost convertor

A bidirectional power converter generates the DC output voltage that must be larger than the input voltage. It is similar to the switched mode of supplying power with minimum to two semiconductor power switches and a single element of storage device [18]. The output voltage and current is supposed to consists of ripples. A capacitor is utilized as filter for the reduction of ripple content generated in the output voltage [19]. An inductor based filter is provided for reducing the ripples present in the output current. Figure 2 depicts the schematic representation of the converter model with the filters.

Inductor Value is given by (1)

$$L \geq \frac{Vi \times D}{fs \times \Delta I_l} \tag{1}$$

Capacitance Value is given by (2)

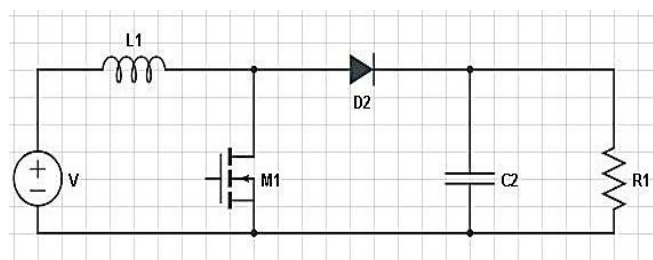$$C = \frac{I_o D}{fs \times \Delta V} \tag{2}$$

Figure 2. Circuit diagram of boost converter

2.2. Design and analysis of full-bridge converter

The configuration of bridge type of DC-DC power converter with four power switches are connected across AC transformer. Converter type called full bridge is one among the commonly utilized structure which provides isolation in the system in addition to stepping up or stepping down the voltage offered in the input side [20]. It also offers many other properties such as reversal of polarities and gives multiple outputs as shown in Figure 3. The three stages of bridge type power converters are: Square wave type, Rectifier network type and Energy transfer network.

The basic system model comprises of four power switches such as IGBTs, MOSFETs, Thermistors (or) Bipolar transistors and also its accompanying driver circuit systems. The isolated type of bridge power converter consists of a transformer that can provide isolation apart from stepping down or stepping up of voltages [21]. MOSFET type of power semiconductor switches are broadly used for high power rated converters because of its power handling capabilities, simple driver circuits when compared with BJTS.

In general, pair of power switches is involved during one half cycle of the input control signal. Whereas the other pair of power switches is operated during another half cycle of the signal [22]. Pulse width modulated technique is utilized for generating the firing pulses to driving the switches. Switching control signal may be either a square wave or a sine wave. Out of those two square wave is preferred because its simplicity. On the other hand it possesses little higher harmonics content. However, the system with higher frequency of about 20 kHz or above, this can be utilized [23]. Examples for such loads are SMPS, RF heating system etc., that require tuning of filters for minimizing the harmonics effect. For the lower order frequencies like converter fed AC motors are costly and bulky.
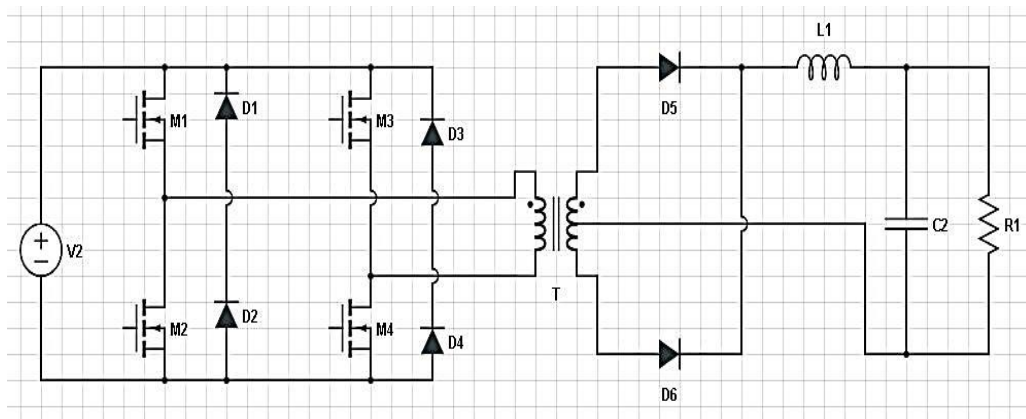

Figure 3. Circuit diagram of full bridge converter

Inductor Value is given by (3)

$$L = \frac{Vi \times D}{2 \times fs \times \Delta I} \tag{3}$$

Capacitor Value is given by (4)

$$C = \frac{D \times V_o}{(R \times fs) \times \Delta V} \tag{4}$$

2.3. Interleaved DC/DC boost converter

The Interleaved type of DC/DC Boost converter contains two individual DC/DC boost converters coupled in parallel. This type can provide better performance while comparing with conventional DC/DC boost converter. It promised for improved efficiency, decreased size, lesser THD and better reliability. 360/n is the phase shifting difference used for firing the two power switches [24]. Here n denotes the total number of DC/DC boost converters connected in parallel. Figure 4 shows the proposed DC/DC power converter.

The converter under study is functioning in Continuous Conduction Mode, CCM that cause reduced input peak current and conduction loss. Input current of the Interleaved DC/DC Boost power converter be the addition of two inductor currents and has the phase shifted difference of 180°, it leads to decreased input current ripple [25]. Inductor Value is given by (5)

$$L = \frac{Vi \times D}{\Delta I_{ph} \times fs} \tag{5}$$

Capacitor Value is given by (6)

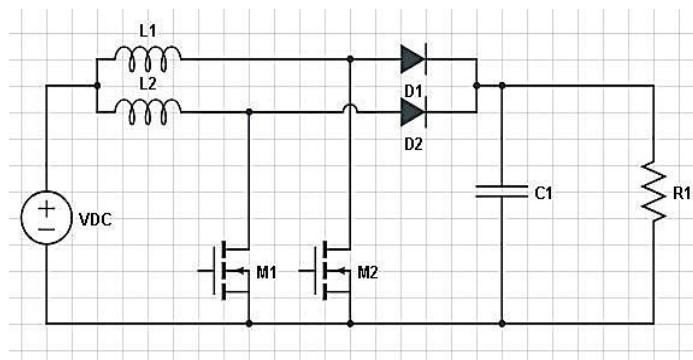$$C = \frac{V_o \times D}{R \times \Delta V_o \times fs} \qquad (6)$$

Figure 4. Circuit diagram of interleaved boost converter

3. RESULTS AND DISCUSSIONS

The software simulation of proposed solar based interleaved DC/DC boost power converter is shown in Figure 5. An unregulated DC supply voltage is given as the input. DC/DC power converter is used to convert unregulated DC input to controlled DC output. The Interleaved Boost converter comprises of two DC/DC boost power converters that are coupled with each other. The converter uses two MOSFET power switches, two numbers of inductors, two numbers of diodes, single capacitor and resistive load. The solar panel has been designed for the proposed boost converters based on the basic principle of PV panel design. The solar panel design is given by the simulation depicted in Figure 6. The power and current are illustrated in Figures 7 and 8 respectively.
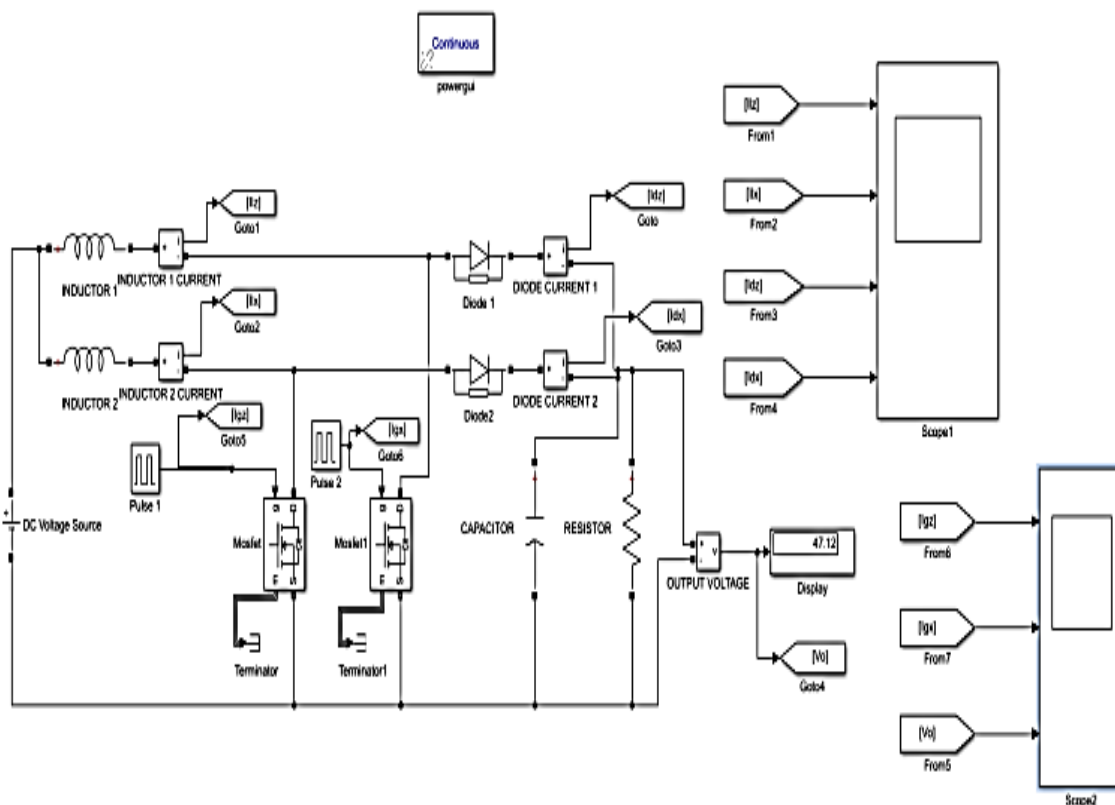

Figure 5. Simulation of interleaved boost converter
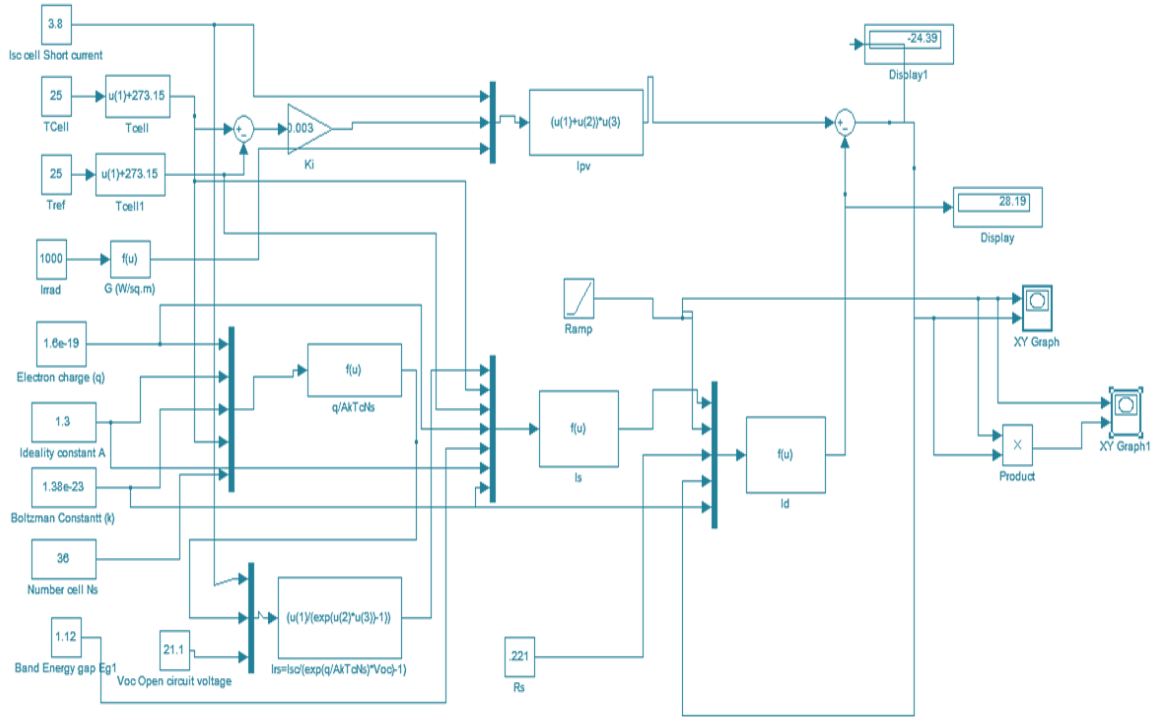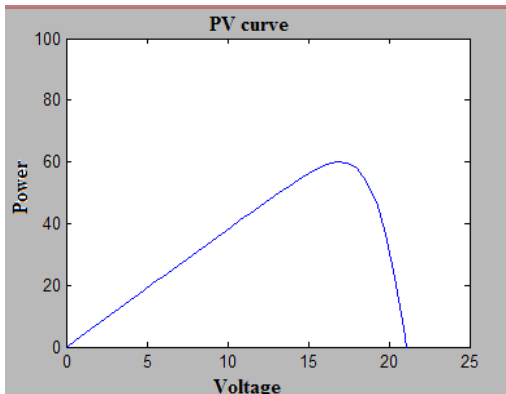
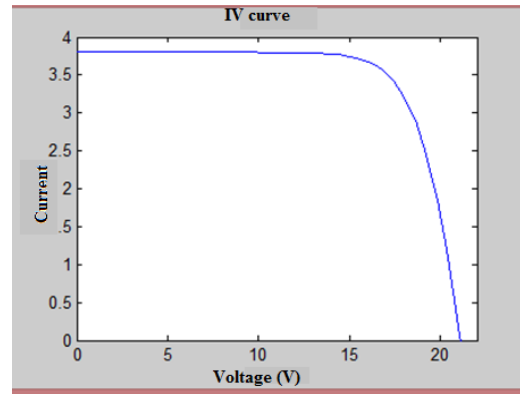Figure 6. Simulation of solar panel

Figure 7. Voltage of solar panel

Figure 8. Current of solar panel

$$Diode\ Loss = V_d \times I_o \times (1 - D) \tag{7}$$

$$Switching\ loss\ (Psw) = \frac{(t_1 + t_2) \times V_o \times I_o}{2 \times fs} \tag{8}$$

$$Conduction\ Loss = I_o^2 \times D \times R \tag{9}$$

$$Efficincy = \frac{Output}{Output + Losses} \tag{10}$$

The simulation of inductor current, diode current and output voltage are described in Figure 9. Starting the diode current is 40 A in amplitude then from 0.002 seconds to 0.0039 seconds 5 A current flowing through the circuits, after 0.004 the diode current maintained constant. The output voltage is 50 V in

amplitude. The inductor current also high in starting then it is reduced to 10 A. The pulses for the proposed converter are illustrated in Figure 10.

The simulation of full converter transformer output voltage is described in Figure 11. The output voltage is 50 V in amplitude after the transformer. The inductor current and diode current are illustrated in Figure 12. The simulation of interleaved boost converter output voltage, inductor current, diode current and are described in Figures 13 and 14 respectively. The diode and inductor current are 4 A in amplitude. Table 1, rephrases the switching losses, inductor losses, diode losses, total losses and efficiency of each converter. It can be noticed that the boost converter has the largest inductor loss among all due to the inductor used. This inductance value can be reduced by increasing the switching frequency of the converter. We can notice that the best entrant for the application is the Interleaving boost topology which has the higher efficiency and lower total losses. We can also notice that efficiency of full bridge is lowest due the high losses calculated. Boost converter is in the middle i.e. its efficiency is greater than full bridge and lower than interleaved similarly goes with losses. The parameters are depicted in Table 2.

Table 1. Parameters of proposed research work

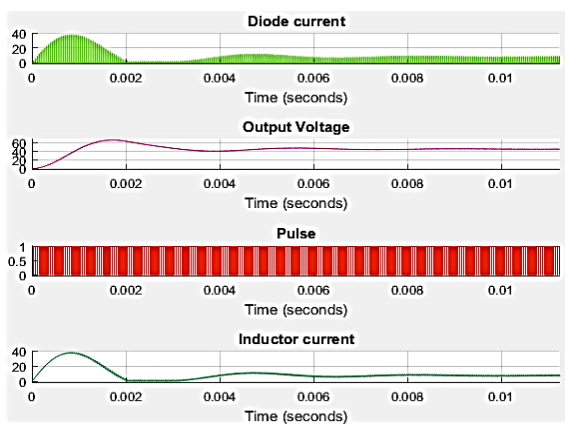| DC-DC CONVERTER	Vin	INDUCTOR (L)	CAPACITOR (C)	RESISTOR (R)	SWITCHING FREQUENCY (f)	DUTY CYCLE (D)	(Vout)
BOOST	12V	144e-6	130e-6	23.04	25kHz	0.75	45.1
FULL BRIDGE BOOST	12V	202e-6	50e-6	23.04	25kHz	0.75	46.48
INTERLEAVED BOOST	12V	6.75e-3	95e-6	23.04	2kHz	0.75	47.24

Figure 9. Simulation results graphs of inductor current, diode current, pulse generator, output voltage
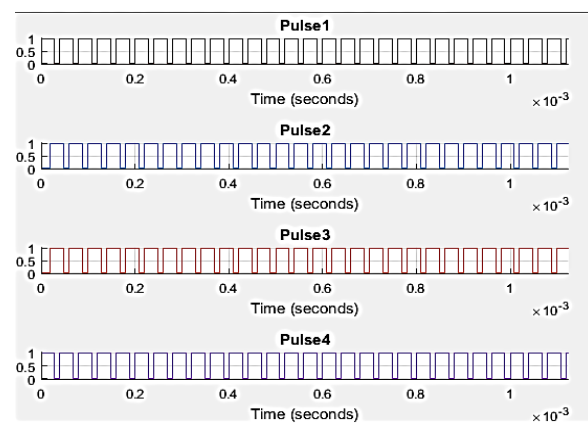

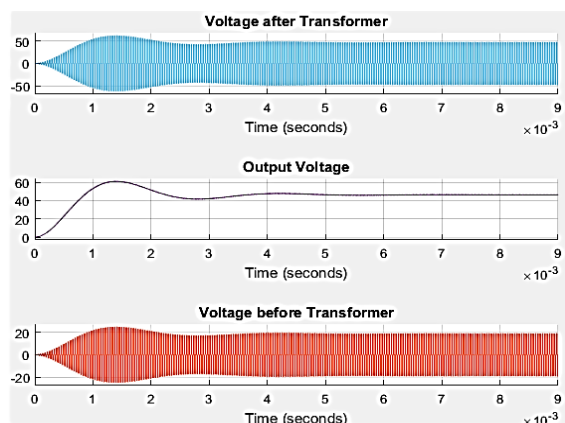Figure 10. Simulated graphs of pulse generators

Figure 11. Simulated graphs of primary and secondary sides of transformer, output voltage
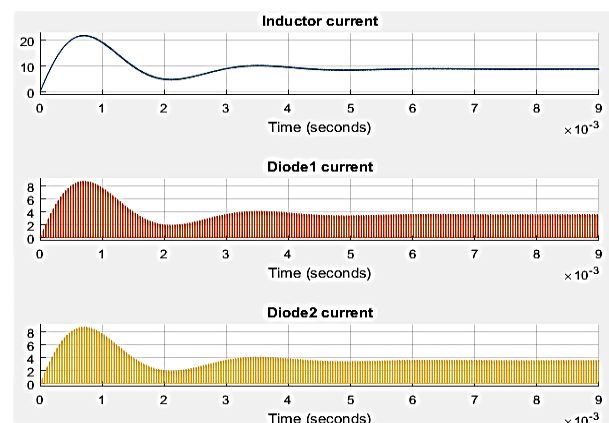

Figure 12. Simulated graphs of inductor current, diode 1 current, diode 2 current
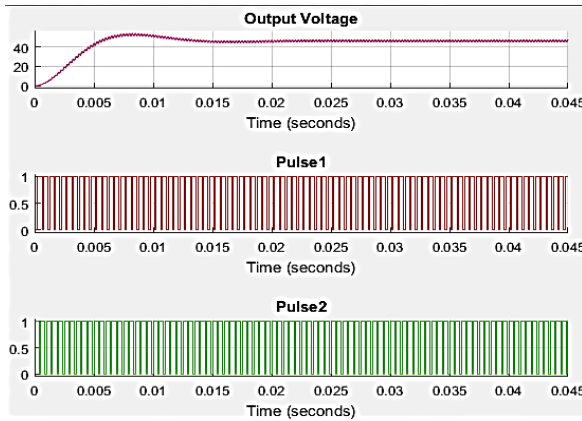
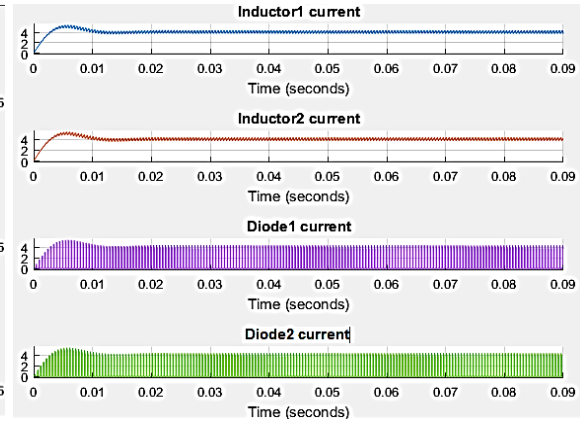Figure 13. Simulated graphs of output voltage, pulse 1, pulse 2

Figure 14. Simulated graphs of inductor 1 current, inductor 2 current, diode 1 current, diode 2 current

Table 2. Performance comparison of different convertets

Converters	Switching Loss (W)	Inductor Loss (W)	Conduction Loss (W)	Diode Loss (W)	Total Losses (W)	Efficiency
Boost	3.9	2.29	0.2869	6.5	13	87.26%
Full Bridge Boost	4.538	1.0185	0.0301	6.293	11.9696	88.67%
Interleaved Boost	1.9188	0.7016	0.0310	6.273	8.9244	91.5%

4.   CONCLUSION

This article comparatively studies the three different types of solar panel based chopper topologies (Bi-directional DC/DC power converter, interleaved converter and Full-bridge converter). Interleave converter enhance the current taken from the solar panel, promised very less power losses and improved output efficiency compared to all other conventional methods. It also has the capability of generating high step up output voltage. Simulations results shows bi-directional solar based interleaved proposed power converter has been a better choice to the PV application.

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