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A DC-DC converter using dickson charge pump voltage multiplier

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ABSTRACT

The system is used to boost 20 V (from a solar cell or other sources) to 400 V. The converter is used to obtain 400 V which needs for integrating to 400V DC bus. Interleaved boost converters at the input side and Dickson charge pump based voltage multiplier at the output side are the main parts. Single source or two independent sources can be used. The modified Dickson charge pump voltage multiplier results in lower voltage stress on each capacitor for its voltage multiplier circuit and less number of diodes. Interleaved boost converter and Dickson charge pump voltage multiplier have been studied, designed and simulated. The design, open loop simulation and closed-loop simulation of the interleaved boost DC-DC converter based on modified Dickson charge pump voltage multiplier were done and compared with a conventional boost converter. The desired output voltage (400V) obtained. From the simulation results, it is evident that the output ripple voltage of the system with modification exhibits fewer ripples and it offers continuous input current than the conventional one. Also, the voltage across the capacitor is reduced and become uniform. Hence low rated capacitors with the reduced size are needed. The hardware part for the interleaved boost DC-DC converter based on modified Dickson charge pump voltage multiplier and conventional boost converter with Dickson charge pump voltage multiplier was done and desired output was obtained.

Keywords— *Interleaved boost converter, Dickson charge pump voltage multiplier*

1. INTRODUCTION

The 400V DC offers better efficiency, high reliability and low cost as compared to Ac distribution system. It offers integration with renewable energy resources, energy vehicles, and energy storage device. DC distribution system has so many applications in the field of Telecom centers, data center, micro grids etc.

The output of the solar panel is about 20 V-40 V, therefore, stepping up of this voltage to 400 V and integrating this to 400 V Dc bus shows the relevance of converters. If the output is a high voltage value then the voltage stress on switches and diode is high so this may cause low reliability, big size, stability problems in order to avoid this interleaved boost converter with two stages and followed by it a Dickson charge pump voltage multiplier is used. The duty ratio is fixed at above 0.5. Both single source and two independent sources can be used. The system requires low voltage rating capacitors and less number of diodes. When the system is replaced with a normal boost converter the system performance can be tracked and simulated and compared with interleaved boost converter hence we could able to understand the advantages of the interleaved boost converter.

2. DC –DC BOOST CONVERTER

2.1 Conventional boost converter

It is a switch mode DC to DC converter where the output is greater than the input. The inductor in the input circuit resists sudden variations in input current .when switch is OFF the inductor stores energy in the form of magnetic energy and discharges it when switch is closed .the capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high .both continuous and discontinuous mode of operation are there. These are used in regulated supply, regenerative braking of DC motors. But this converter faces so many disadvantages. The closed loop simulation of the same has been done in MATLAB.

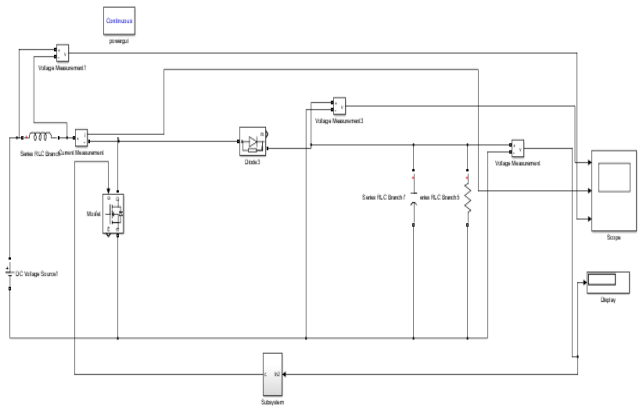


Fig. 1: Closed loop simulation of the boost converter

2.2 Interleaved boost converter

Interleaved boost converter consists of two stage boost converter. Two switches and two inductors are the main parts. Interleaving technique is an interconnection of multiple switching cells that will increase the effective pulse frequency by synchronizing several smaller sources and operating them

with a relative phase shift. This technique saves energy and improves power conversion without affecting conversion efficiency. One can obtain an overall reduction of boost inductor together with reduced switching loss. The presence of two inductors provides continuous input current. The voltage stress on switches can be reduced by this converter also we could obtain perfect output voltage.

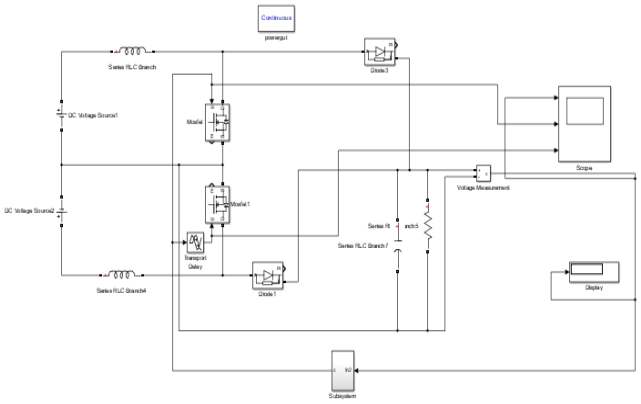


Fig. 2: Closed loop simulation of the interleaved boost converter

2.3 Design of the inductor

The voltage equation across the inductors is noted. The duty ratio of the pulse is 0.8. The overall equations have been written and formulated as follows. In the proposed converter, the input power is transferred to the output by charging and discharging the voltage multiplier circuit capacitors. The voltage gain of the converter can be derived as described below. For inductors *L*1 and *L*2, the average voltage across the inductors according to volt-second balance can be written as

The voltage Equations are $< V_{L1} > = <V_{L2} > =0$

Voltage second balance of L1

$$V_{AN}=V_{C2}+V_{C3}=V_{OUT} - V_{C1}- V_{C4} = (V_{in1})/(1-d_1)$$

Voltage second balance of L2

$$V_{BN}=V_{C1}-V_{C2}=V_{C4} - V_{C3} = (V_{in2})/(1-d_2)$$

$$V_{C2}=0.5(V_{in1})/ (1-d_1)$$

By substituting the value of V_{C2} in V_{BN}

$$V_{C1} = V_{C4} = 0.5(V_{in1})/ (1-d_1) + (V_{in2})/(1-d_2)$$

The design of inductance value is

$$L_1= L_2 = L = (V_{in}* d)/\Delta I_L*f_{SW}$$

$$=100\mu H$$

3. DICKSON CHARGE PUMP VOLTAGE MULTIPLIER

The second stage of the system is voltage multiplier. The Dickson charge pump voltage multiplier gives a boosted dc output voltage by charging and discharging its capacitors the voltages of the capacitors in the Dickson charge pump double at each stage as one traverse from the input side capacitor *C*1 to the load side capacitor *C*4. For an output voltage of *Vout* = 400V. The voltages of capacitors C1, C2, C3, and C4 are only 150V, 50V, 50V, and 150V, respectively, therefore, the volume of the capacitors used in the system is small.

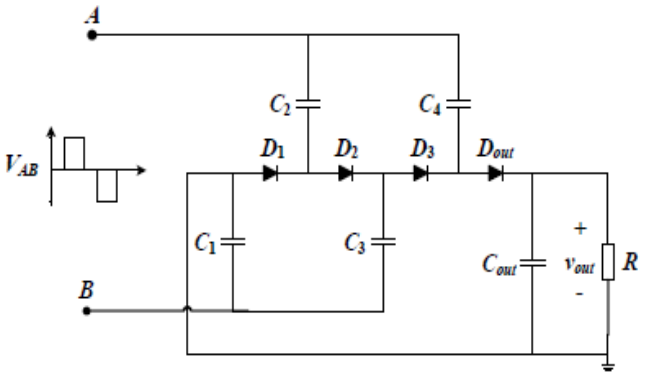


Fig. 3: Dickson charge pump voltage multiplier

4. CONVENTIONAL BOOST WITH DICKSON CHARGE PUMP VOLTAGE MULTIPLIER

The input voltage of 20 V is given to a conventional boost converter. The output of the conventional boost converter is 200 V. This is given to the second stage of the system which consists of Dickson charge pump voltage multiplier. The output of the second stage is of 400 V but a discontinuous input current and there is a presence of voltage stress on the switches. These are some drawbacks of the system.

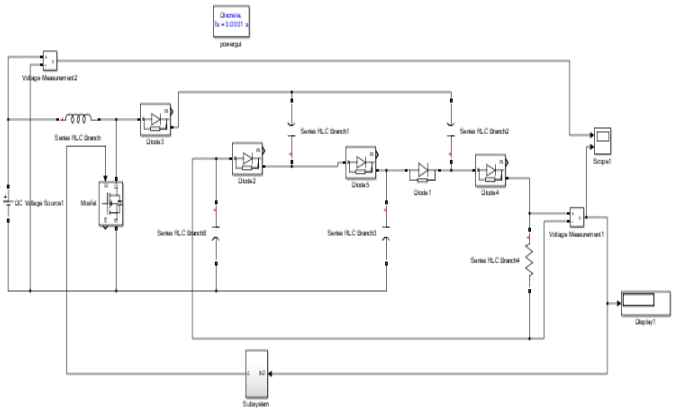


Fig. 4: Closed loop simulation of the system with a conventional boost

5. INTERLEAVED BOOST WITH DICKSON CHARGE PUMP VOLTAGE MULTIPLIER

The input voltage of 20 V is given to an interleaved boost converter. The output of the interleaved boost converter is 200 V. This is given to the second stage of the system which consists of Dickson charge pump voltage multiplier. The output of the second stage is of 400 V Also we can obtain continuous input current and presence of voltage stress on the switches is the less .perfect output voltage is obtained.

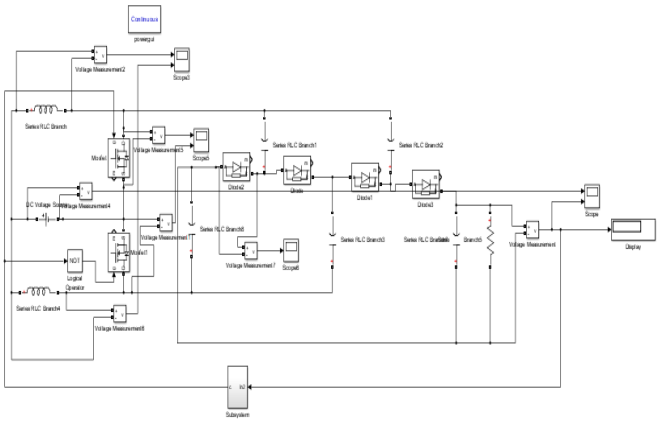


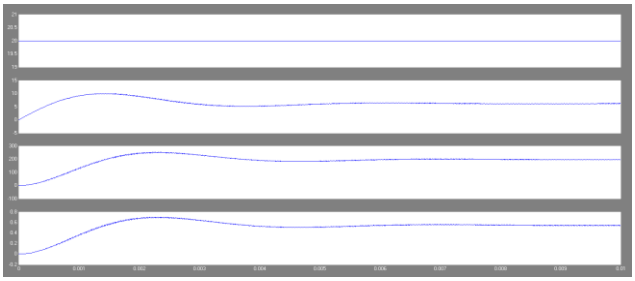
Fig. 5: Closed loop simulation of the system with an interleaved boost converter

6. SIMULATION RESULTS

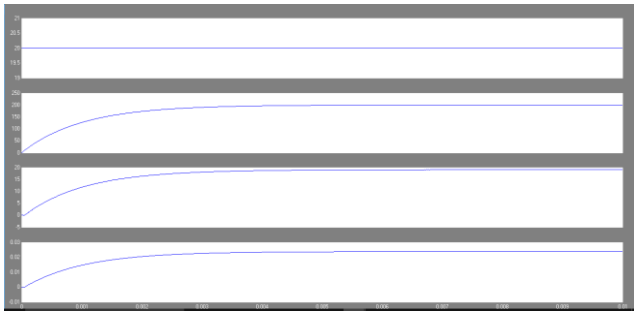
Table 1: Simulation parameters

Parameter	Value
Input voltage	20V
Output voltage	400V
Load resistance	800 ohm
Switching frequency	100 KHz
Inductors L1 and L2	100 micro H
VM capacitors	60 micro F
Output capacitors	22 micro F

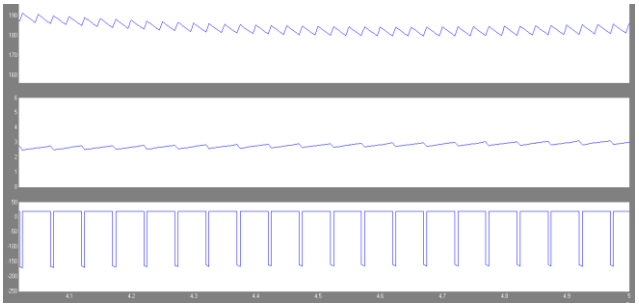
The simulation results of the system with a conventional boost converter and interleaved boost converter is shown below



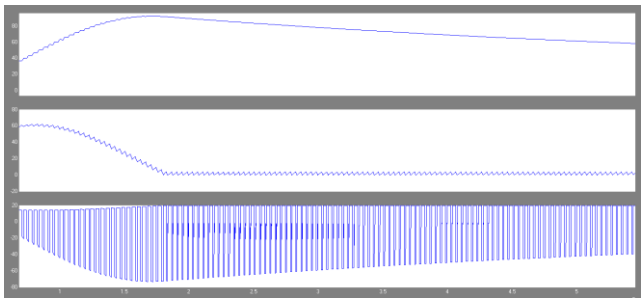
(a)



(b)



(c)



(d)

Fig. 6: (a) Input voltage and current, output voltage and current waveform of interleaved boost, (b) Input voltage and current, output voltage and current waveform of conventional boost, (c) Output ripples voltage, inductor current and voltage waveform of interleaved boost, (d) Output ripples voltage, inductor current and voltage waveform of conventional boost.

7. HARDWARE PROTOTYPE

The proposed system is developed into a hardware prototype where the driver circuit has been used to trigger the MOSFET. Here providing TLP350 IC for IRF740 MOSFET. The values of the capacitors used are 10µF and 22µF. The inductor is of 100 µ H. The hardware is done to obtain 400V by giving input as 20V.

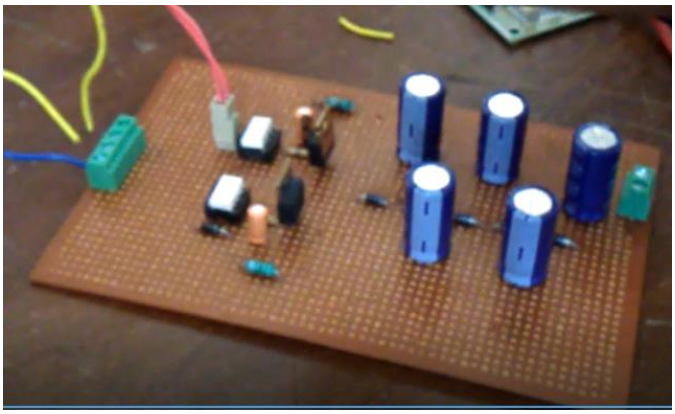


Fig. 6: Hardware prototype of the proposed system

8. CONCLUSION

The paper discussed the advantages of interleaved boost converter over conventional boost converter which is applied in a converter which converts 20 V to 400 V DC. The system consists of a Dickson charge pump voltage multiplier. The paper discussed the simulation results of the two systems and it founds that interleaved is very much effective in function.

9. ACKNOWLEDGMENT

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