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CASCADED DC-DC CONVERTER WITH DUAL OUTPUT

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Abstract:

Extremely high duty cycle of boost converter may result in higher conduction losses. To achieve a high conversion ratio without operating at extremely high duty ratio, some converters based on transformers or coupled inductors or tapped inductors have been provided. However, the leakage inductance in the transformer, coupled inductor or tapped inductor will cause high voltage spikes in the switches and reduce system efficiency. A novel single switch cascaded dc-dc converter of boost and buck boost converters have extended voltage conversion ratio to $d/(1-d)^2$. The features of the converter are high voltage gain; only one switch for realizing the converter, the number of magnetic components is small etc. So comparing with other topologies cascaded converter is more effective. Simulation of the converter for a dc input voltage and fixed duty cycle was done, and the same was verified experimentally for a low input voltage. The software used for simulation was MatlabR2014a.

Keywords — **Conduction *loss, leakage, Voltage, Cascaded converter, Voltage conversion ratio, Dual output.***

I. Introduction

In recent year, high voltage gain dc-dc converters play more and more important role in many industrial applications such as uninterrupted power supplies, power factor correctors, distributed photovoltaic (PV) generation systems and fuel cell energy conversion systems. In these applications, a classical boost converter is normally used, but the extremely high duty cycle will result in large conduction loss on the power devices and serious reverse recovery problems. Thus, the conventional boost converter would not be acceptable for realizing high step-up voltage gain along with high efficiency.

Most recognized application for this kind of converters were UPS systems for network servers and telecom equipment. Nowadays new applications emerge: fuel cell (FC) and photovoltaic (PV) based distributed generators up to few kilowatts. Usually, in such cases, the low voltage from the dc source (25-50 Vdc) is converted to the higher dc link voltage (350-400 Vdc). Nowadays many applications incorporate many smaller, paralleled and interleaved dc-dc converters instead of one large converter. The modular architecture provides better reliability, scalability, possibly higher efficiency and lower costs of production and maintenance. Also in some applications transformer-less converters are found as more efficient, smaller and cheaper solution [1]. To

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II. Literature Review

Dual active bridge (DAB) dc-dc converters have been popular for various applications due to the advantages of high frequency galvanic isolation, soft-switching characteristic, and bidirectional power flow

[2],[3]. Moreover, it can be easily extended to multi terminal topologies to integrate dc sources, energy storage devices, or loads. In a quasi-resonant converter topology [4], it uses a single switch. This improves its reliability and saves space for redundant circuitry implementation. Moreover, pulse-width-modulation (PWM) for the switching control is sufficient instead of dead-time control. The resonant tank contains an inductor (Lin) and a capacitor (Cin) connected to the primary side of the transformer in series and parallel respectively. Hence, the proposed topology incorporates the leakage inductor and stray capacitor of the transformer into the equivalent circuit. Using a single switch, the proposed topology is able to achieve zero-current-switching (ZCS) that result in a reduction of switching noise and voltage spike. Cockcroft-Walton voltage multiplier (VM) is utilized as the rectifier circuit.

As compared to the Marx generator that generates a high voltage the VM does not need a large number of switches. Furthermore, the output voltage ripple of the VM in the proposed topology is smaller than other topologies. But this topology mainly focuses on the satellite propulsion systems and not for ordinary applications. So far, most of the international research on DAB has focused on the following aspects: basic characterization, topology and soft-switching solution, control strategy, and hardware design and optimization. The basic characteristics, such as transmission power characterization, dead-time effect, and dynamic model, have been studied. Many new topologies and soft-switching solutions have also been proposed to increase soft-switching range and to improve efficiency. We focus on cascaded converters.

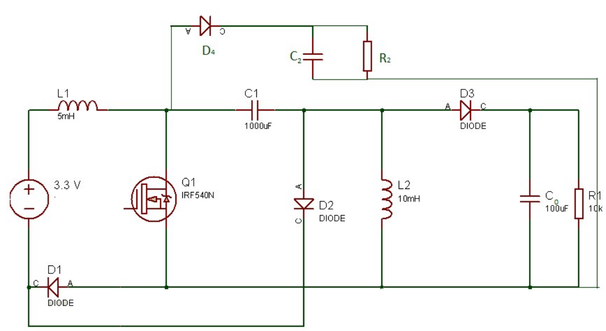

Fig.1 Cascaded converter

The circuit structure of the dc-dc converter, which consists of an active switch S, diodes D_1, D_2 and D_3, an input inductor L_1, an output inductor L_2, a storage energy capacitor C_1 and an output capacitor Co, for one of the output and second is added as a simple boost at the input side. So in operation cascaded output section is only explained. The input inductance L_1 is assumed to be large enough so that input current i_{L1} is continuous. Capacitors C_1 and C_0 are sufficiently large, and the voltages across them are considered constant during one switching period. When the inductor current i_{L2} is in continuous conduction mode, L_2-CCM is used to denote the operating mode; and L_2-DCM stands for the mode in which i_{L2} is in discontinuous conduction mode.

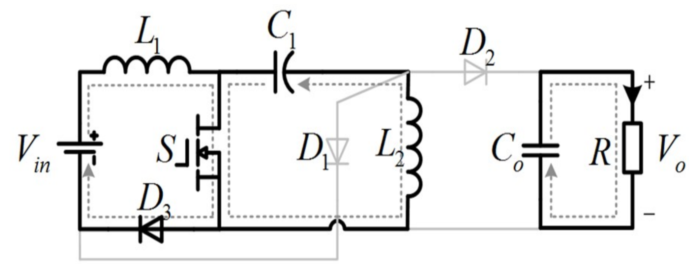

Fig.2 mode 1 operation

Switch S conducts. Diodes D_1 and D_2 are reverse-biased by V_{C1} and V_{C1} + Vo, respectively. Only diode D is ON. The energy of dc source V_{IN} is transferred to the inductor L_1 through S and D_3. Therefore, inductor current i_{L1} is increasing linearly. The voltage of the inductor L_2 is V_{C1} and the capacitor C_1 is discharging its energy to L_2 though S. The inductor current iL2 is increasing. Meanwhile, the load R is supplied by the output capacitor Co. Once S is turned OFF, i_{L1} is forced to flow through D_1, inductor L_1 and dc source V_{in} charge capacitor C_1 instantaneously. Therefore, i_{L1} declines linearly. At the same time, i_{L2} is forced to flow through D_2 and the energy stored in inductor L_2 is transferred to the output capacitor Co and load R. Thus, i_{L2} declines linearly and D_3 is reverse-biased by V_{in}.

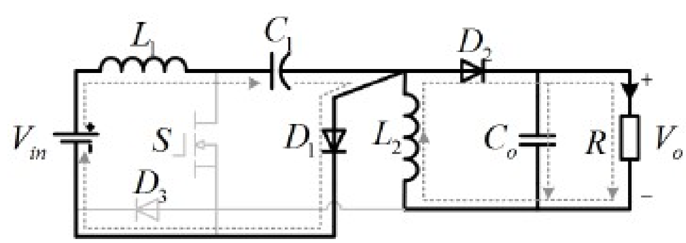

Fig.3 mode 2 Operation

There are three main stages during one switching cycle in DCM mode. Modes I and II are same with L_2-CCM, and only case III is presented. Diode D_2 is blocked when the current i_{L2} reaches zero at $t=t_2$. During this time interval, switch S and diodes D_2, D_3 are turned OFF, only diode D_1 is turned ON. The current path is shown in figure. The dc source V_{IN} is in series with inductor L_1 and keeps transferring energy to the capacitor C_1 through D_1. Since the energy stored in L_2 is empty, the energy stored in Co is discharged to load R. This stage ends when switch S is turned ON, the next switching period will begin again.

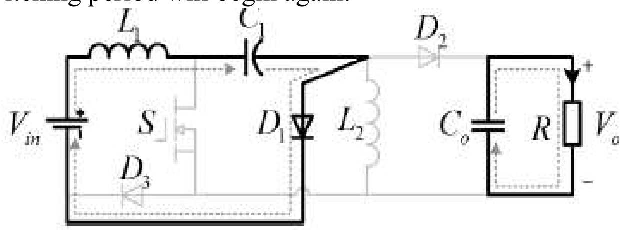

Fig.4 mode 3 Operation

III. Component selection

The selection of components for simulation is listed as below.

Table 1

COMPONENT	PARAMETERS
Input inductor	5mH
Output inductor	10mH
Input capacitor	1000µF
Output capacitor c,c₂	100µF

IV. Simulation Results

The performance of the dc-dc converter under the PWM control strategy has been investigated during normal operating condition. The corresponding simulation results are shown.

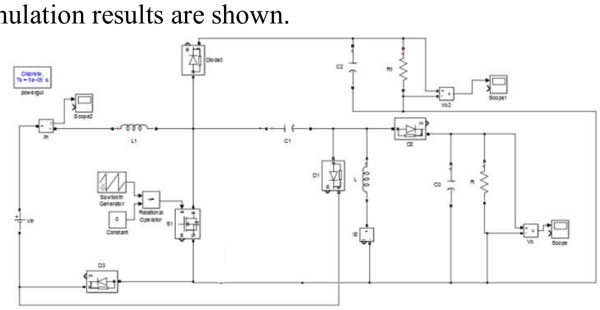

Fig.5 Simulink model

The Simulink model for cascaded converter is shown above. It has lesser number of passive elements but a high gain at the output. The corresponding gate pulse to the switch is shown in fig.6.

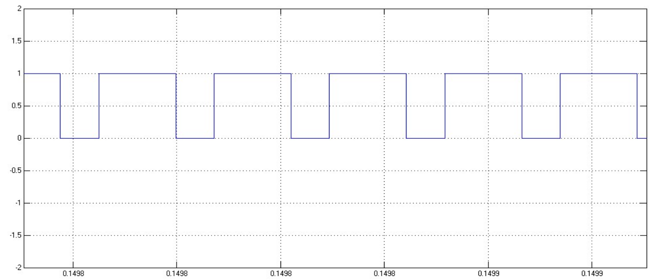

Fig.6 Gate pulse

To obtain boost operation a duty cycle of 0.65 for a frequency of 50kHz were chosen. 3.3V DC is applied as input. Input inductor current and output inductor current wave forms are shown. Inductor currents rises and declines as the on and off of the switch occurs.

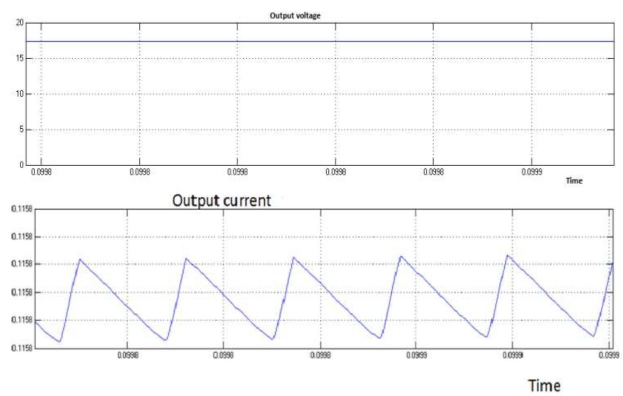

Fig.7 Output voltage and current for cascaded boost

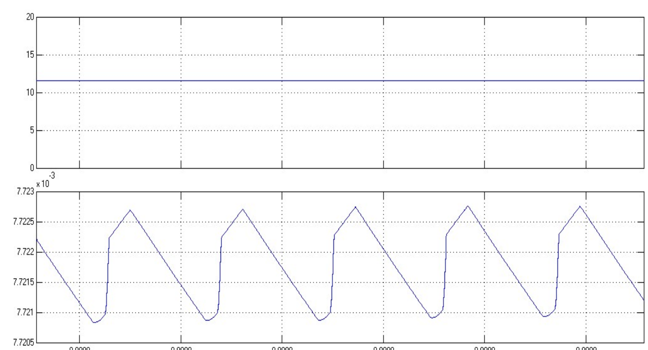

Fig.8 Output waveforms for simple boost

The output voltage for boost converter is lower than the cascaded output. Hence we can say the outputs are asymmetrical. Multiple outputs provide more and more applications for the converter.

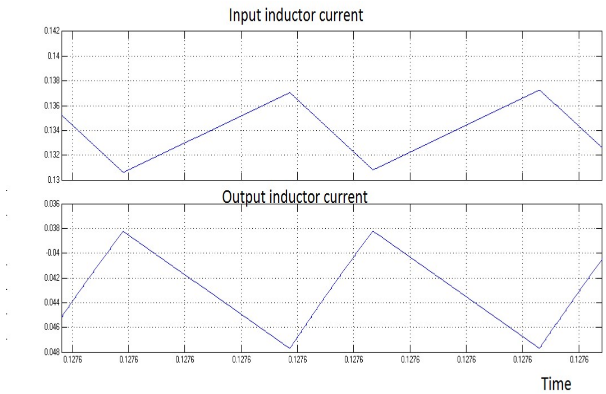

Fig.9 Inductor currents

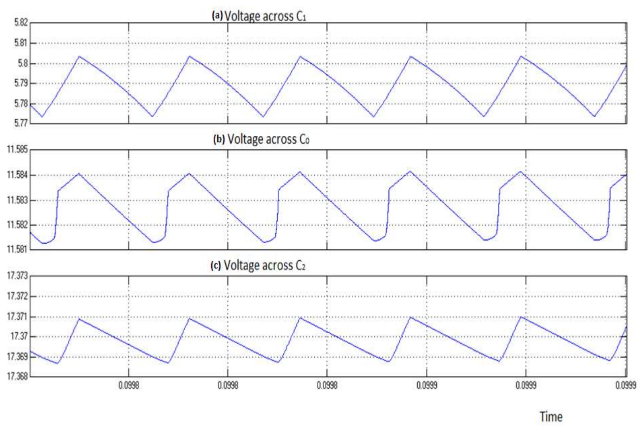

Fig.10 Capacitor voltages

Capacitor voltages rises and decreases as the charging and discharging occurs. Voltage rises when capacitor charges and voltage declines when discharges.

V. Experimental Results

In order to validate the results obtained from simulation the prototype model is developed in the laboratory. Input supply of 3.3V is given and the output was observed. First shows the gate pulse and then the two outputs.

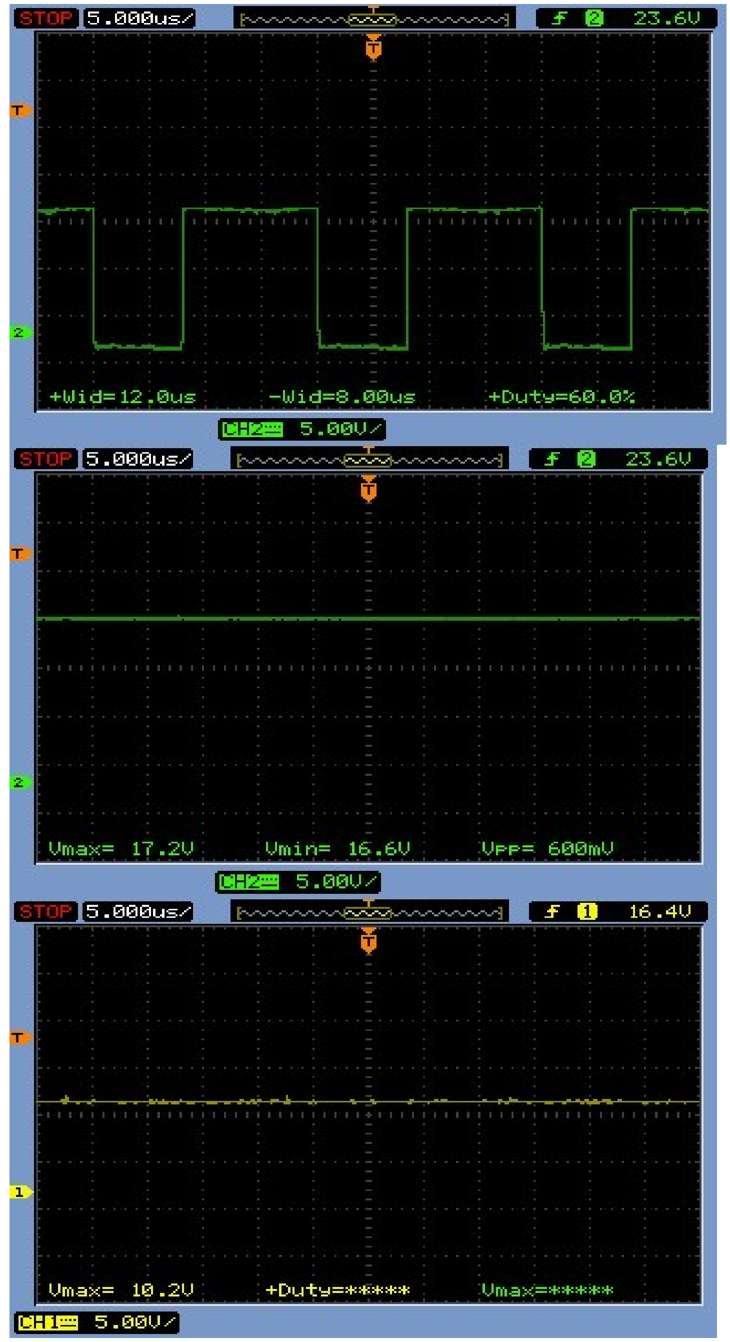

Fig.11 Experimental Result

VI. Conclusions

From the above discussions it can be concluded that a single input dual output converter with different values of output can be achieved by the cascaded dc-dc converter topology. The topology uses a single switch and achieves high or medium conversion ratio as required by the two outputs. In future we can extend the work to multiple outputs or symmetrical outputs.

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