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SIMULATION OF A BOOST CONVERTER BASED BOOTSTRAP CAPACITOR AND BOOST INDUCTOR FOR PMDC DRIVE

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Abstract: In this project, novel high voltage-boosting converters are presented. By changing the connection position of the anode of the diode and by using different pulse-width-modulation control strategies, different voltage conversion ratios can be obtained. These converters are constructed based on bootstrap capacitors and boost inductors. Above all, two boost inductors with different values, connected in series, can still make the proposed converters work appropriately. Furthermore, although there are three switches in each converter, only one half-bridge gate driver and one low-side gate driver are needed, but no isolated gate driver would be needed. After some mathematical deductions, some experimental results are provided to verify the effectiveness of the proposed converters. A new voltage-boosting converter, combining a charge pump and a coupling inductor, together with a passive voltage-clamping circuit which pumps part of the leakage inductance energy to the output, is presented herein. Therefore, by doing so, the efficiency tends to be flat between the minimum and rated loads. Moreover, the implementation of the passive voltage-clamping circuit for this converter with multiphase is very easy. In this paper, some mathematical derivations are given first, and second, simulated and experimental results are provided to verify the effectiveness of the proposed voltage-boosting converter topology.

Keyword: Boost converter, bootstrap capacitor, Pulse-width-modulation (PWM), voltage-boosting converter, voltage conversion ratio,PMDC Drive

1. INTRODUCTION

There are many applications with high-voltage sources fed, such as the burn-in test plant with energy recycling, the dc–dc converter used in the car as the prestage of the dc–ac converter, etc. Hence, it is indispensable for low voltage to be boosted to high voltage. In general, the boost or Buck-boost converter is widely used in such applications. However, it is not easy for such converters to achieve high voltage ratio. In theory, the voltage ratios of these two converters can reach infinity but, in actuality, about four or five, limited by parasitic component effect and controller capability. Consequently, if the voltage ratio of the converter is desired to be over five, then a two-stage converter based on the boost or buck-boost converter is utilized or different converter topologies are created. In the Luo converter and its derivatives are presented, whose voltage lift technique is similar to that of the Cuk converter or the single-ended primary inductor converter (SEPIC) converter, based on the energy transfer from one inductor via the intermediate capacitor and then to the other inductor. Therefore, the transferred energy is mainly determined by the capacitance, thus causing the current stress on the capacitor to be serious. For the reasons stated above, two high voltage-boosting circuits, based on two bootstrap capacitors and two inductors, are presented here. Above all, although two inductors are connected in series during the demagnetizing period, variations in values of these inductors allow such converters to work appropriately. In addition, based on different switch turn-on types and different diode connections, two voltage-boosting converters with different voltage conversion ratios are generated under similar circuit structure. Under the same condition that two inductors and two capacitors are used except the input capacitor, any one of the proposed voltage conversion ratios is higher than all the other voltage conversion ratios in the KY boost converter, in the self-circuit and re-lift circuit, and in the positive output self-lift Luo converter, positive output super lift converter and positive output re-lift Luo converter. On the other hand, under the condition where the same components are used, the proposed converters have higher voltage conversion ratios than the other two shown. In addition, for each converter, only one half-bridge gate driver and one low side gate driver are needed, but no isolated gate driver would be needed. In this paper, a brief illustration of the operation of these two converters is given along with some experimental results provided to demonstrate the effectiveness of such converters[1]-[25].

2. CONVERTER TOPOLOGIES

The two high voltage-boosting converters have individual voltage conversion ratios and individual pulse-width modulation (PWM) control strategies. Hence, the type 1 converter is described in Fig. whereas the type 2 converter is shown in Fig. It is noted that the difference in circuit between Fig. is the location of the anode of $D1$. Each converter contains three MOSFET switches $S1$, $S2$, and $S3$, two bootstrap capacitors $Cb$and Ce, three bootstrap diodes Db, $D1$, and $D2$, one output diode Do, two inductors $L1$ and $L2$, one output capacitor Co, and one output resistor RL. In addition, the input voltage is signified by Vi, the output voltage is represented by Vo, the voltages across Cb, Ce, $D1$, and $D2$ are shown by VCb, VCe, $vD1$, and $vD2$, respectively, and the currents flowing through $L1$, $L2$, and Do are denoted by $iL1$, $iL2$, and iDo, respectively. It is noted that the proposed converters are based on the charge pump of the KY converter and the series boost converter. By doing so, the conversion ratios can be upgraded further. Above all, if the anode of the diode $D1$ is connected to the cathode of the diode Db, the conversion voltage ratio in continuous conduction mode (CCM) is $(3 + D)/(1 - D)$, where D is the duty cycle of the PWM control signal created from the controller, whereas if the anode of the diode $D1$ is connected to the anode of the diode $Db$with switch turn-on types different from those of the former, the conversion ratio in CCM is $(3 - D)/(1 - D)$.Therefore, the proposed converters can be used according to industrial applications.

3.FUZZY LOGIC CONTROLLER

Fuzzy logic is a form of many-valued logic; it deals with reasoning that is approximate rather than fixed and exact. Compared to traditional binary sets (where variables may take on true or false values) fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false.[1] Furthermore, when linguistic variables are used, these degrees may be managed by specific functions. Irrationality can be described in terms of what is known as the fuzzy active.

3(A)Overview

Classical logic only permits propositions having a value of truth or falsity. The notion of whether 1+1=2 is absolute, immutable, mathematical truth. However, there exist certain propositions with variable answers, such as asking various people to identify a color. The notion of truth doesn't fall by the wayside, but rather a means of representing and reasoning over partial knowledge is afforded, by aggregating all possible outcomes into a dimensional spectrum. Both degrees of truth and probabilities range between 0 and 1 and hence may seem similar at first. For example, let a 100 ml glass contain 30 ml of water. Then we may consider two concepts: Empty and Full. The meaning of each of them can be represented by a certain fuzzy set. Then one might define the glass as being 0.7 empty and 0.3 full. Note that the concept of emptiness would be subjective and thus would depend on the observer or designer. Another designer might equally well design a set membership function where the glass would be considered full for all values down to 50 ml. It is essential to realize that fuzzy logic uses truth degrees as a mathematical model of the vagueness phenomenon while probability is a mathematical model of ignorance.

3(B) Applying truth values

A basic application might characterize sub ranges of a continuous variable. For instance, a temperature measurement for anti-lock brakes might have several separate membership functions defining particular temperature ranges needed to control the brakes properly. Each function maps the same temperature value to a truth value in the 0 to 1 range. These truth values can then be used to determine how the brakes should be controlled.

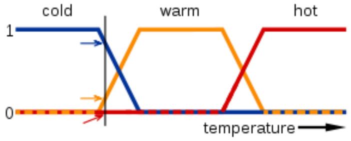

Fig.1 Basic Fuzzy Logic Controller Technique

4. CIRCUIT DIAGRAM

The two high voltage-boosting converters have individual voltage conversion ratios and individual pulse-width modulation (PWM) control strategies. Hence, the type 1 converter is described in whereas the type 2 converter. It is noted that the difference in circuit between is the location of the anode of $D1$. Each converter contains three MOSFET switches $S1$, $S2$, and $S3$, two bootstrap capacitors Cb and Ce, three bootstrap diodes Db, $D1$, and $D2$, one output diode Do, two inductors $L1$ and $L2$, one output capacitor Co, and one output resistor RL. In addition, the input voltage is signified by Vi, the output voltage is represented by Vo, the voltages across Cb, Ce, $D1$, and $D2$ are shown by VCb, VCe, $vD1$, and $vD2$, respectively, and the currents flowing through $L1$, $L2$, and Do are denoted by $iL1$, $iL2$, and iDo, respectively. It is noted that the proposed converters are based on the charge pump of the KY converter and the series boost converter. By doing the conversion ratios can be upgraded further. Above all, if the anode of the diode $D1$ is connected to the cathode of the diode Db, the conversion. voltage ratio in continuous conduction mode (CCM) is $(3 + D)/(1 - D)$,

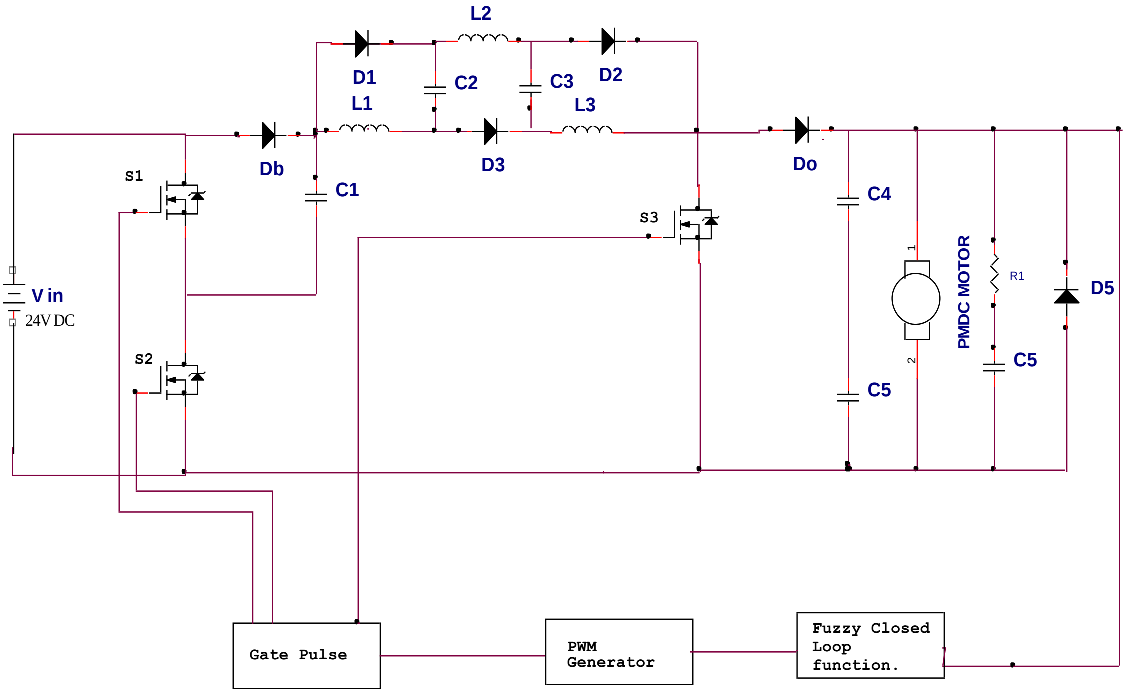

Fig.2 Circuit Diagram

where D is the duty cycle of the PWM control signal created from the controller, whereas if the anode of the diode $D1$ is connected to the anode of the diode $Db$with switch turn-on types different from those of the former, the conversion ratio in CCM is $(3 - D)/(1 - D)$. Therefore, the proposed converters can be used according to industrial applications.

4(A) Continuous mode

A buck converter operates in continuous mode if the current through the inductor (I_L) never falls to zero during the commutation cycle. When the switch pictured above is closed (On-state, top of figure 2), the voltage across the inductor. The current through the inductor rises linearly. As the diode is reverse-biased by the voltage source V, no current flows through it When the switch is opened (off state, bottom of figure 2), the diode is forward biased. The voltage across the inductor is (neglecting diode drop). Current I_L decreases. The energy stored in inductor L is

$$E = \frac{1}{2} L \cdot I_L^2 \qquad (1)$$

Therefore, it can be seen that the energy stored in L increases during On-time (as I_L increases) and then decreases during the Off-state.

The rate of change of I_L can be calculated from:

$$V_L = L \frac{dI_L}{dt} \qquad (2)$$

With V_L equal to during the On-state and to during the Off-state. Therefore, the increase in current during the On-state is given by,

$$\Delta I_{L_{on}} = \int_0^{t_{on}} \frac{V_L}{L} dt = \frac{(V_i - V_o)}{L} t_{on}, \; t_{on} = DT \qquad (3)$$

If we assume that the converter operates in steady state, the energy stored in each component at the end of a commutation cycle T is equal to that at the beginning of the cycle. That means that the current I_L is the same at t=0 and at t=T

So we can write from the above equations

$$\frac{V_i - V_o}{L} t_{on} - \frac{V_o}{L} t_{off} = 0 \qquad (4)$$

It is worth noting that the above integrations can be done is proportional to the area of the yellow surface, and to the area of the orange surface, as these surfaces are defined by the inductor voltage (red) curve. As these surfaces are simple rectangles, their areas can be found easily for the yellow rectangle and for the orange one. For steady state operation, these areas must be equal. As can be seen. , $t_{on} = DT$ and $t_{off} = (1-D)T$. Where *D* is a scalar called the *duty cycle* with a value between 0 and 1. From this equation, it can be seen that the output voltage of the converter varies linearly with the duty cycle for a given input voltage. As the duty cycle D is equal to the ratio between t_{On} and the period T, it cannot be more than 1. Therefore, $V_o \leq V_i$. This is why this converter is referred to as *step-down converter*. So, for example, stepping 12 V down to 3 V (output voltage equal to a fourth of the input voltage) would require a duty cycle of 25%, in our theoretically ideal circuit.

4(B) Discontinuous mode

In some cases, the amount of energy required by the load is too small. In this case, the current through the inductor falls to zero during part of the period. The only difference in the principle described above is that the inductor is completely discharged at the end of the commutation cycle (see figure 5). This has, however, some effect on the previous equations. We still consider that the converter operates in steady state. Therefore, the energy in the inductor is the same at the beginning and at the end of the cycle (in the case of discontinuous mode, it is zero). This means that the average value of the inductor voltage (V_L) is zero; i.e., that the area of the yellow and orange rectangles in figure 5 are the same. The output current delivered to the load (I_o) is constant, as we consider that the output capacitor is large enough to maintain a constant voltage across its terminals during a commutation cycle. This implies that the current flowing through the capacitor has a zero average value. And substituting δ by the expression given above yields
This expression can be rewritten as:

$$V_o = V_i \frac{1}{\frac{2LI_o}{D^2 V_i T} + 1} \qquad (5)$$

Where $\bar{I}_L$ is the average value of the inductor current. As can be seen in figure 5, the inductor current waveform has a triangular shape. Therefore, the average value of I_L can be sorted out geometrically as follow

$$\begin{aligned} \bar{I}_L &= \left(\frac{1}{2} I_{L_{max}} DT + \frac{1}{2} I_{L_{max}} \delta T\right) \frac{1}{T} \\ &= \frac{I_{L_{max}} (D + \delta)}{2} \\ &= I_o \end{aligned} \qquad (6)$$

The inductor current is zero at the beginning and rises during t_{on} up to I_{Lmax}. That means that I_{Lmax} is equal to

$$I_{L_{Max}} = \frac{V_i - V_o}{L} DT \qquad (7)$$

Substituting the value of I_{Lmax} in the previous equation leads to

$$I_o = \frac{(V_i - V_o) DT (D + \delta)}{2L} \qquad (8)$$

It can be seen that the output voltage of a buck converter operating in discontinuous mode is much more complicated than its counterpart of the continuous mode. Furthermore, the output voltage is now a function not only of the input voltage (V_i) and the duty cycle D, but also of the inductor value (L), the commutation period (T) and the output current (I_o).

5. SIMULATION CIRCUIT DIAGRAM

The designed converter rated at 500 W was first simulated using mat lab and then built in the laboratory to verify the analysis, design, and performance of the converter. Simulation results for two extreme operating conditions *Vin*= 41 V, 10% load are presented in the results. When both the main switches are on, vAB = Lm is flowing through ilk and are constant. Whenever, one main switch is off, vAB appears across the transformer and the current ilk and iLm change direction. At higher voltage and light load condition, the duty cycle is low and therefore vAB appears for longer time. It makes the currents ilk and iLm to be constant for a very small duration and their appearance look like triangular in shape with higher peak value compared to full-load condition. It is clear that the leakage inductance current ilk is continuous due to the circulation of magnetizing current when all the H-bridge switches are on. It should be noticed that with increase in input voltage and/or reduction in load current, the duty cycle of main switches reduces, which results in increase in peak value of magnetizing inductance current. It adds to leakage inductance current to achieve ZVS of main switches even at such a wide variation in input voltage and load. At light load condition, anti parallel body diode conduction time is increased due to magnetizing current assuring ZVS.

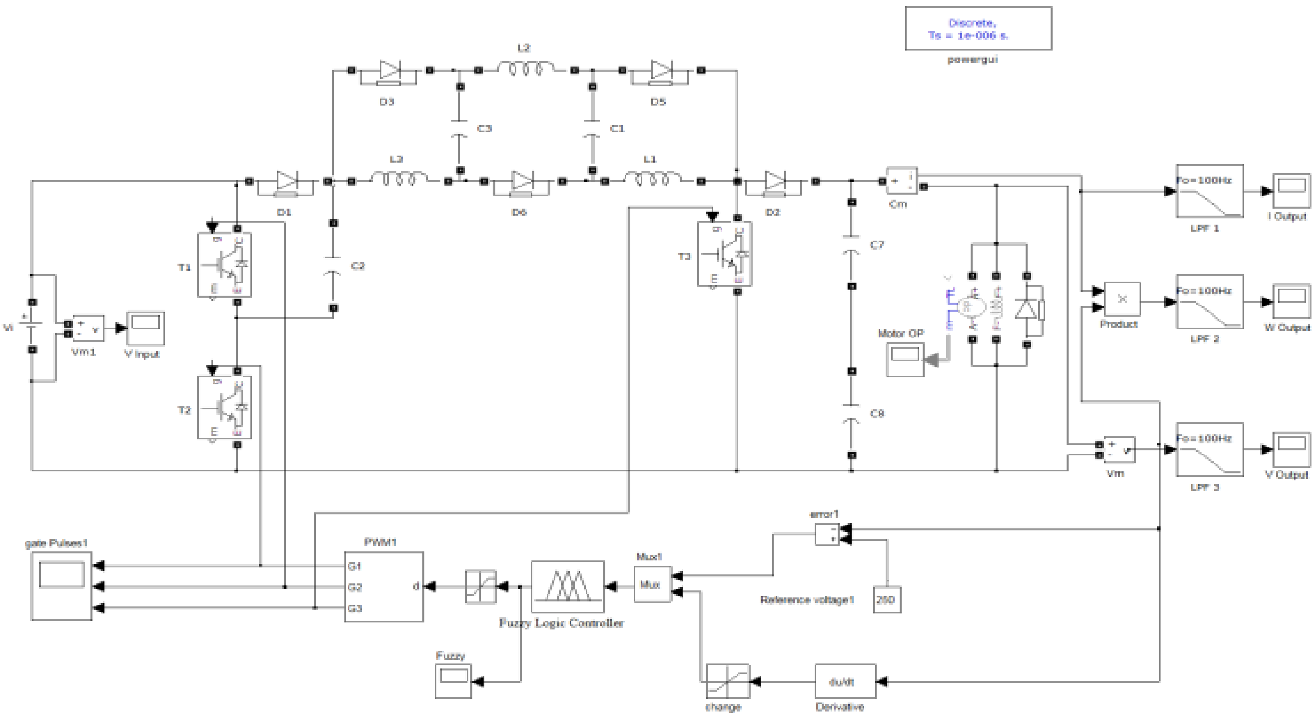

Fig.3 Simulation Circuit Diagram

5(A) Simulation Results

5.1 GATE PULSE

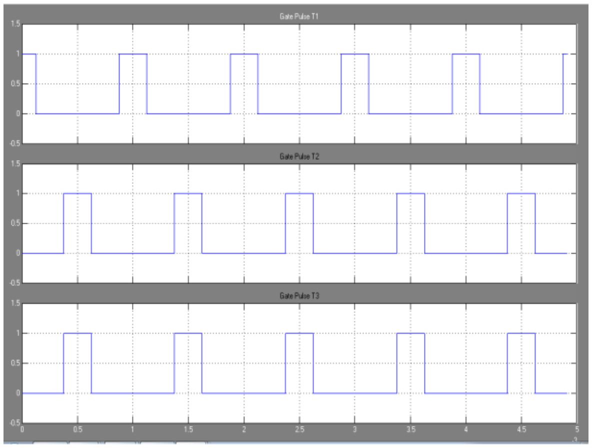

Fig 4 Gate Pulse Waveform

5.2 OUTPUT CURRENT WAVEFORM

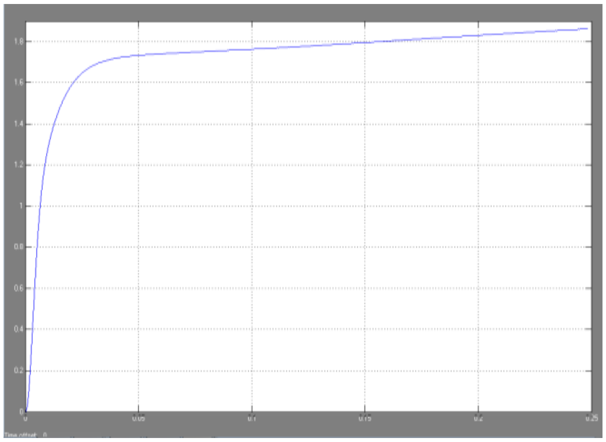

Fig 5 Output Current Waveform

5.3 OUTPUT VOLTAGE WAVEFORM

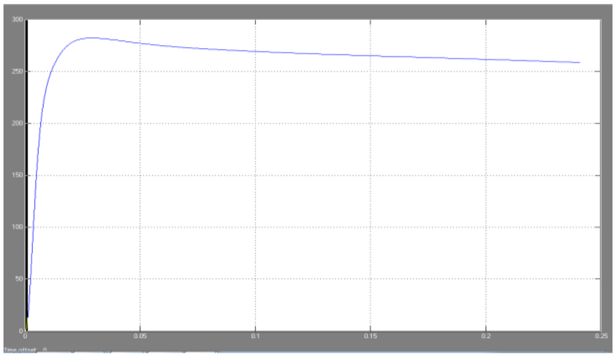

Fig 6 Output Voltage Waveform

5.4 OUTPUT POWER WAVEFORM

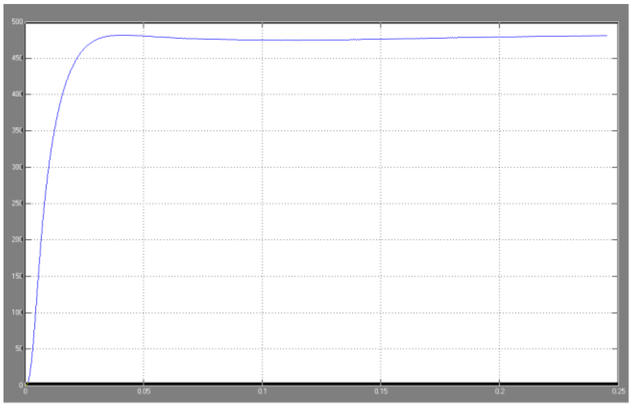

Fig 7. Output Power Waveform

5.5 FUZZY OUTPUT WAVEFORM

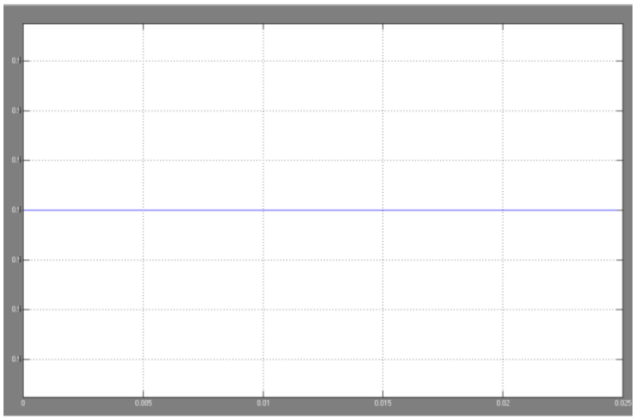

Fig 8.Fuzzy Output Waveform

6. CONCLUSION

In this paper, high voltage-boosting converters are addressed, which is based on inductors connected in series with bootstrap capacitors. There are two types of high voltage-boosting converters, depending on the circuit connection and the PWM control strategy. In addition, for each converter, the power switches are easy to drive via one half-bridge gate driver and one low-side gate driver. From the experimental results, such converters exhibit good performances even with different inductances, and hence are suitable for industrial applications, such as the energy-recycling burn-in test of the buck-type converter, isolated or non-isolated.

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BIOGRAPHY

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