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PV source based high voltage gain current fed converter

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Abstract: This work involves designing and simulation of a PV source based high voltage gain, current fed converter. It deals with an isolated DC-DC converter which utilizes boost converter topology. The proposed converter is capable of high voltage gain and above all have very high efficiency levels as proved by the simulation results. The project intends to produce an output of 800 V dc from a 48 V dc input. The simulation results obtained from PSIM application interface were used to analyze the performance of the proposed converter. Transformer used in the circuit steps up the voltage as well as to provide electrical isolation between the low voltage and high voltage side. Since the converter involves high switching frequency of 100 kHz, ultrafast recovery diodes are employed in the circuitry. The major application of the project is for future modeling of solar powered electric hybrid cars.

1. Introduction

Electric powered vehicle production has been at the peak in different nations mainly because it is an alternative source of saving fossil fuels. In India, the market has been low but several companies have engaged themselves in the production of electric vehicles. Certain companies are already in the business of powering motor vehicles using battery power. These include Mahindra e2o, Mahindra e-Verito, Toyota Prius, Mahindra Scorpio, Tesla electric cars etc. The e2o was launched in 2013 and incorporates a 48 V Lithium ion battery which churns about 48 V and 53 N-m of torque and once fully charged it can cover a distance of approximately 120 km.

The Tesla model of cars also rely on battery performance [3, 4]. As a proposed solution in this paper we will try to achieve an alternative solution of using solar energy to power electric vehicles. In this paper, we utilize a high gain current fed Converter topology with an input of 48 V and output of 800 V.

This isolated current fed converter[1,2] has many advantages which include complete electrical isolation of the input from the output and also immunity from transformer –flux imbalance and no output inductor [5].

2. Circuit Description

The topology under consideration is shown in Figure 1. Here, the input voltage V_{in} is 48 V_{DC}. After this, current fed bridge converter topology has been used to produce a 50 V_{AC} which is to be fed to the transformer. The overlapping period for the bridge configuration is 10 %. The transformer steps up the voltage to 4 times the input. The Secondary has voltage multiplier configuration which rectifies the AC output to DC as well as further boosts up the DC voltage by four times to get 800 V_{DC} as the output at point V_O.

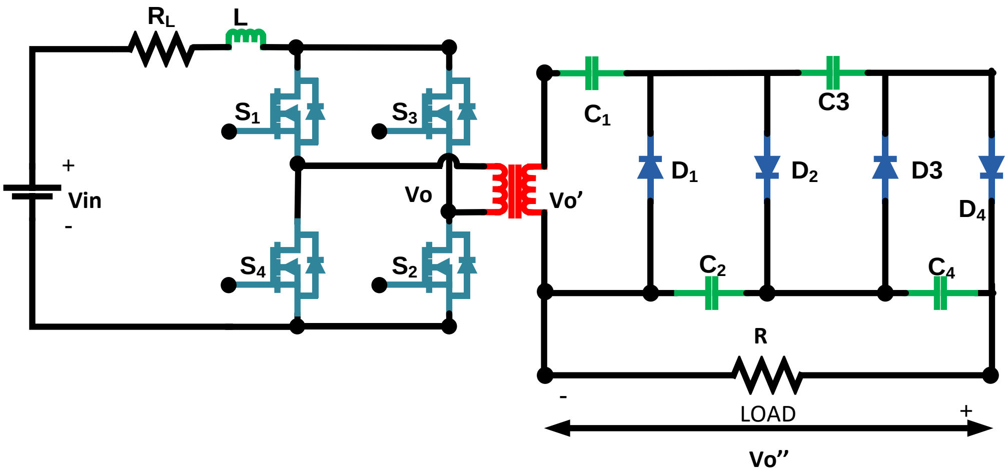

Figure 1. Isolated current fed boost converter topology

The input side has three modes of operation as discussed below. Optimal switch overlapping period has also been chosen as per the need to charge the inductor. The inductor and capacitor values are designed based on the following equations:

$$L_{\min} \geq \frac{D}{2V_o f_s}\left[V_{in}(1-D)R - V_o(R_L + R_{on})\right] \tag{1}$$

$$C_{\min} \geq \frac{(1-D)V_o}{8Lf_s^2 \Delta V_o} \tag{2}$$

3. Operating principle

INPUT SIDE: As previously discussed, the input side has three modes of operation [6, 7]. The switching frequency has been chosen to be 100 kHz.

3.1. Mode I operation

Here, switches S_1 and S_2 are turned ON. Hence, the current flows through the path as shown in Figure 2.

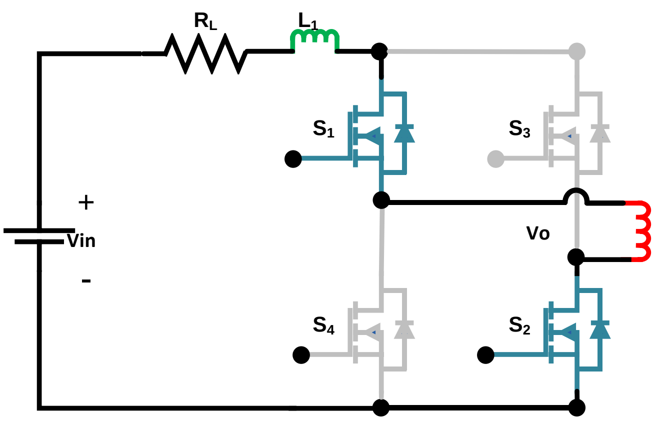

Figure 2. Current flow when S_1, S_2 are ON

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3.2. Mode II operation

In this mode, all the switches are turned ON. However the current flowing path, as presented in Figure 3. Shows a closed loop between the supply, inductor and the switches S_1 and S_4. This is the overlapping period which produces the boost action in the primary side.

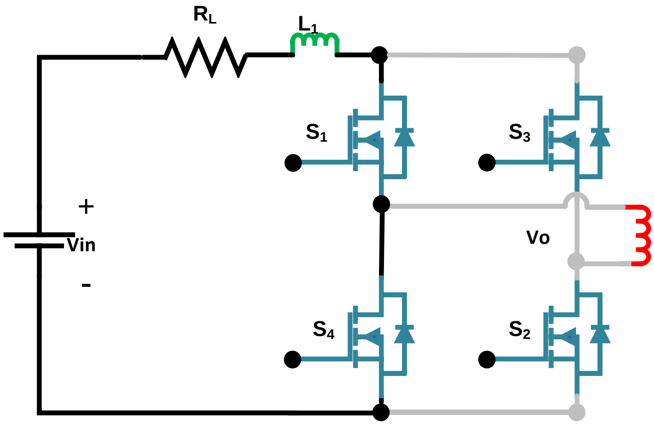

Figure 3. Current flow when S_1, S_2, S_3, S_4 are ON

3.3. Mode III operation

In this mode, the switches S_3 and S_4 are turned ON. Hence, the current flows through the path is shown in Figure 4. It is seen that the direction of current flow through the primary of the transformer reverses. Hence in this way AC is fed to the primary of the transformer.

OUTPUT SIDE: To achieve rectification and to increase the boost operation we have incorporated a Voltage multiplier (voltage Quadruppler) as shown in Figure 5. It helps to achieve a DC voltage which is equal to four times the transformer secondary AC voltage.

The operation is similar to that of a voltage doubler. In fact it is simply an extension of a half wave voltage doubler. The diode D_1 conducts during the positive half cycle, thereby, charging the capacitor C_1 to Vm with polarity as shown in the figures. During the first negative half cycle, the diode D_2 conducts charging the capacitor C_2 to 2 V_m.

During the second positive half cycle the diode D_3 conducts in addition to the diode D_1, charging C_1 and the voltage across C_2 charges the third capacitor C_3 to the same value that is double the maximum value of voltage 2 V_m. On the second negative half cycle, the diode D_2 and diode D_4 conducts and capacitor C_3 charges C_4 to 2 V_m. The voltage levels 2 V_m, 3Vm and 4 V_m are shown in the figure above. This process repeats itself and voltage is multiplied to 4 V_m that is 800 V_{dc} in this project.

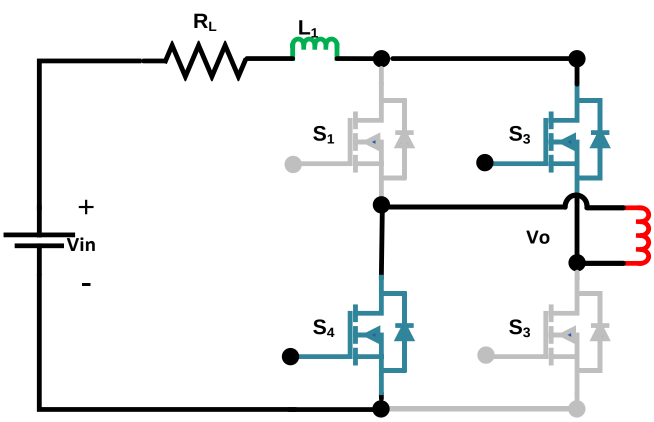

Figure 4. Current flow when S_2, S_4 are ON

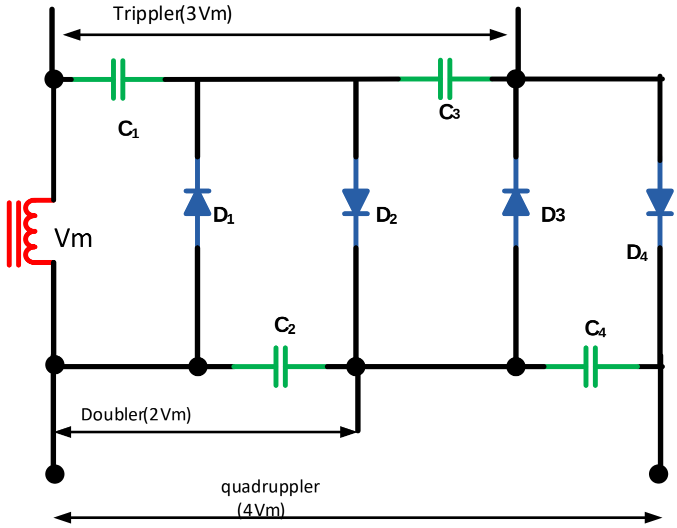

Figure 5. Voltage multiplier

4. Design specification

The project design specification is given in the Table 1.

Table 1. Design specification

Parameters	Values	Parameters	Values
Input voltage	48V	Output voltage	815V
Inductor	4mH	Capacitor	10uF

5. Results

The simulation results shown below are done using PSIM software and the outputs shown below were obtained. The Input current is 11.2 A and the input voltage is 48 V. After the boost action takes place the output current becomes 0.62 A and the output voltage is 780 V. This is an open loop system. When a closed loop is implemented an exact output of 800 V_{DC} can be obtained. The switching pulses Current and voltage profile of the Input Side and across load are presented in Figure 6.

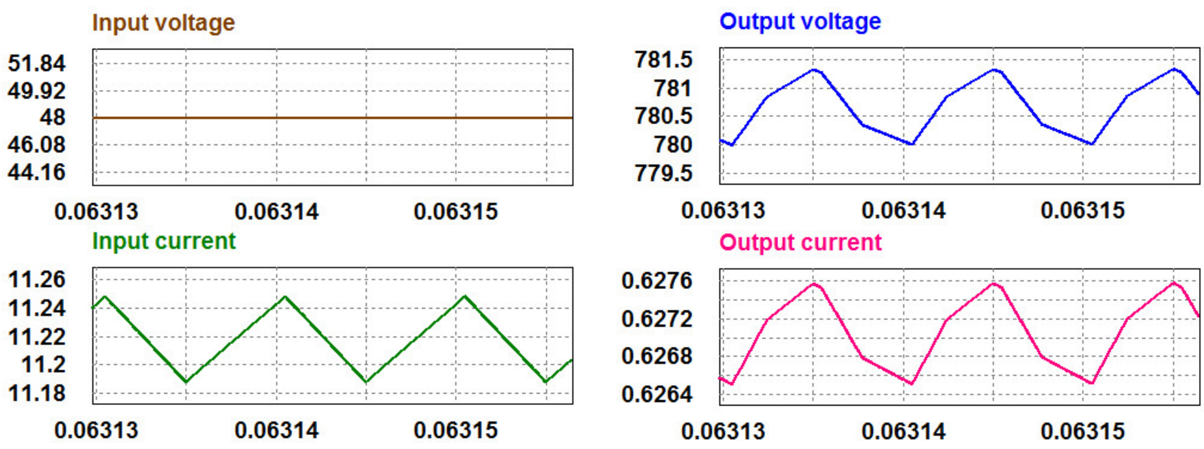

Figure 6. Simulation results of V_{in}, I_{in}, V_O, I_O

The Figure 7 gives the simulation results obtained at transformer primary and secondary voltages, primary and secondary currents with duty cycle of diagonal and non-diagonal switches. The transformer turns ratio used here is 1:4.

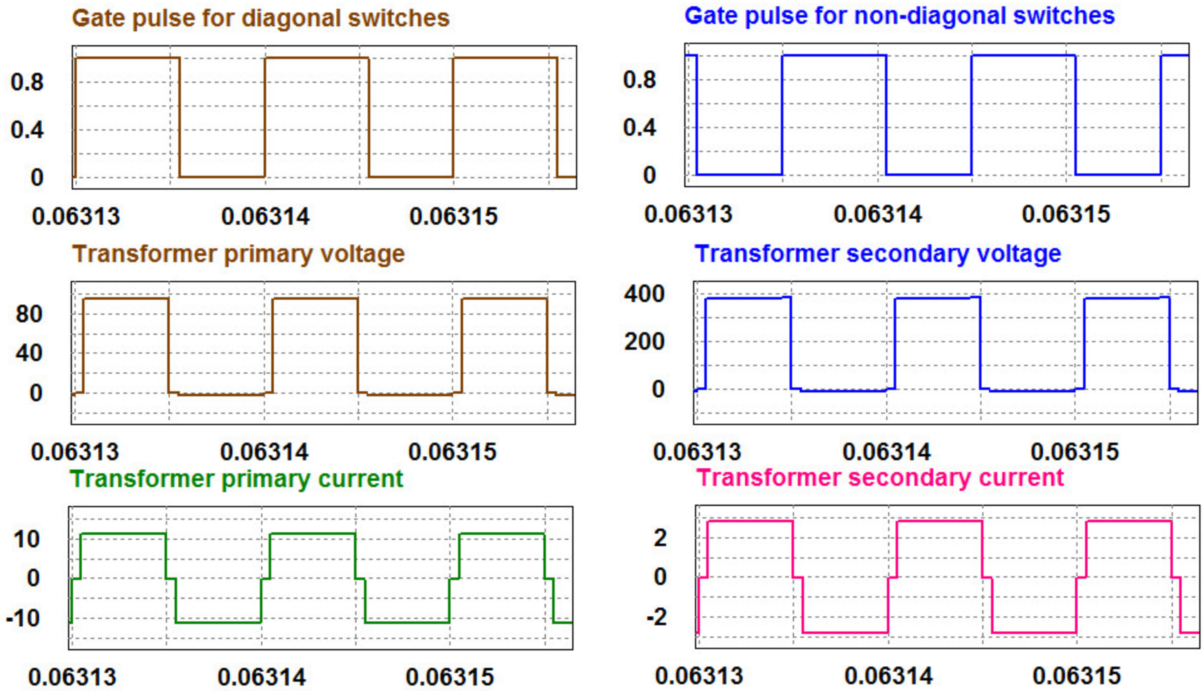

Figure 7. Simulation results of gate pulse for switches, V_{pri1}, V_{sec1}, I_{pri1} and I_{sec2}.

6. Conclusion

The high voltage gain current fed boost converter was simulated and output of 780 V has been obtained. An overall steady state efficiency of 95.51 % has been obtained as per simulation results. Further work includes reducing the transient voltage and current peaks. These may be achieved using closed-loop control.

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