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Simulation of Three Level Boost Converter for voltage regulation of DC link Capacitor

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Abstract — There has been a significant increase in demand of high power high efficiency DC DC converters therefor in high power rating with high voltage gain requires boost converter with controller to maintain the DC bus voltage constant. When a DC voltage has to be stepped up, the boost converter has long been the preferred scheme. This is because of its adjustable step up voltage conversion ratio, continuous input current, simple topology and high efficiency. This paper include a design and open loop and closed loop simulation of three level boost converter.

Keywords— Three level boost converter, operation of TLBC without overlapping, simulation model of TLBC.

I. INTRODUCTION

The recent increase in the interfacing of renewable energy sources to the power grid demands new strategies for the operation and management of electric power. Irrespective of the renewable energy sources, the DC link voltage needs to be boosted up to reduce the transmission losses and eliminate the need of a step up transformer at the point of common coupling. In response to this growing demand for medium and high power applications, DC/DC converters and multilevel inverters are turn out to be the inevitable appliance for power conversion. The multilevel converter provides advantages such as lower harmonic distortion and reduction in dV/dt of the output voltage.

The three-level boost (TLB) converter has several advantages in high voltage applications such as reduced switching losses and lower reverse recovery losses of the diode [1],[3] compared to the conventional boost converters. In [1], [2], [4] the circuit is employed and studied with a different approach for power factor correction by controlling the duty ratio of the switches. The maximum power point tracking by direct duty ratio control of TLB converter using a power hysteresis is presented in [3]. Independent control of TLB switches for balancing of dc-link capacitors is discussed in [5]. In [6] the SSPDC method is proposed for TLB circuit to balance the neutral point voltage with simulation results.

Three level boost (TLB) converter has several advantages in high voltage applications such as reduced switching losses and lower reverse recovery losses of the diode with compare to conventional boost converter.Three level boost converter has high output voltages is advantageous due to reduce input filter size and reduced inductor current ripple. A smaller size inductor can be used with compare to conventional boost converter Switching devices voltage rating is half of the output voltage; this leads to increase the power density, efficiency, and reduction in cost. Also, providing constant DC output voltage.

II. THREE LEVEL BOOST CONVERTER

In the schematic diagram of Three level boost converter (TLBC) shown in Fig. 2.1(a), the input is a DC voltage source in series with an inductor *L*. The resistive loads are connected across the capacitors to provide output voltages *Vo*. The midpoint of the capacitors C_1 and C_2 are connected to the centre point of the switches *S*1 and *S*2. This circuit allows four different modes of operation. The circuit gives different behaviours depending on the switching sequence and the time of operation of each mode. It is assumed that the inductance L is large enough to maintain the current in continuous conduction mode and the capacitors are large enough to keep the output voltage constant. The following are the four modes of operations without overlapping (fig 2.1b) of TLBC.

Switches in the TLBC may operate with five different algorithms (five regimes) and the simplest one of them repeats the algorithm of switching in the BC [7]. Compared to the BC the switching frequencies of the TLBC can be as follows:

1. Frequency of each switch in the TLBC is higher than the frequency of switch in the BC.
2. The frequency of each switch in the TLBC equals frequency of the switch in the BC.
3. The frequency of each switch in the TLBC is lower than the frequency of the switch in the boost converter. Each of these variants has advantages and drawbacks. The first variant allows decreasing the size of the choke greatly; however the loss in the switches and diodes increase.

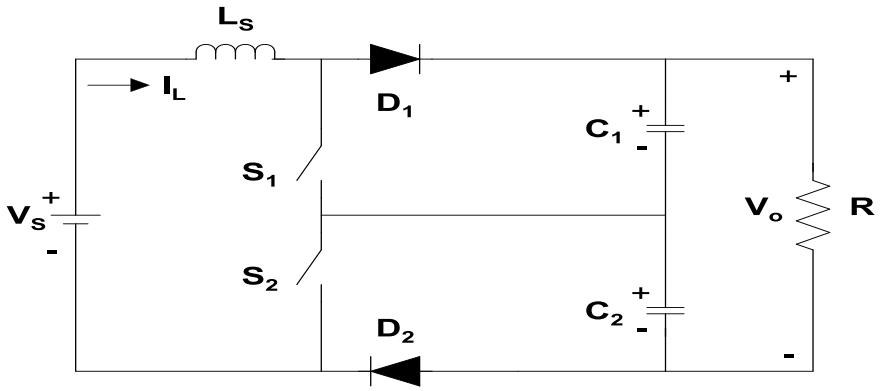

Fig. 2.1 (a): Three Level Boost Converter

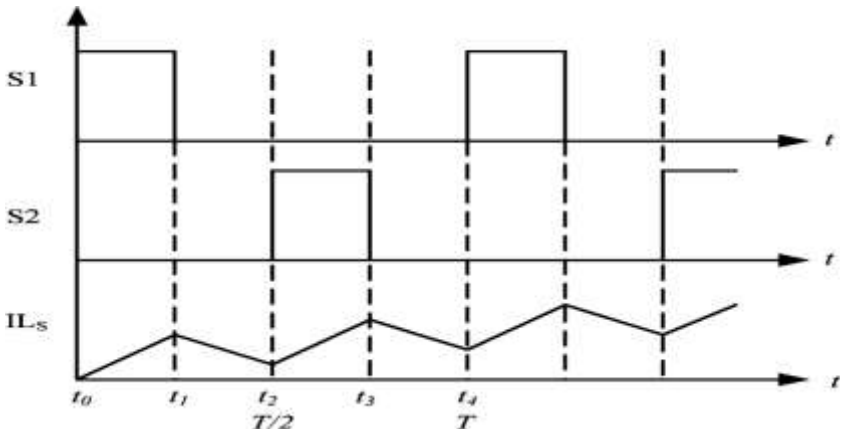

Fig. 2.1 (b): Switching waveform of TLBC without overlapping

III. OPERATION OF TLBC WITHOUT OVERLAPPING

There are four modes to understand an operation of three level boost converter circuit which are explain below with their mode diagrams.

Mode 1

In this mode from figure 2.1b for time period t_o to t_1 switch S_1 is on and switch S_2 is off, energy is stored in inductor L_S, inductance current flow in circuit as shown in figure 11. The equation corresponding to these mode is:

$$V_L = V_S - \frac{V_O}{2}$$

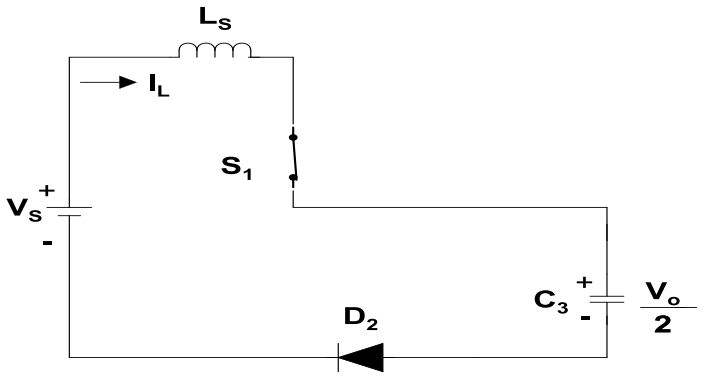

Fig. 3.1: Equivalent circuit of TLBC for Mode 1

Mode 2 & Mode 4

In this modes from figure 2.1b for time period t_1 to t_2 and t_3 and t_4 switch S_1 and switch S_2 are off, energy is stored in inductor L_S is transferred through capacitor C_2 and C_3, inductance current flow in circuit as shown in figure 12. The equation corresponding to these modes is:

$$V_L = V_O - V_S$$

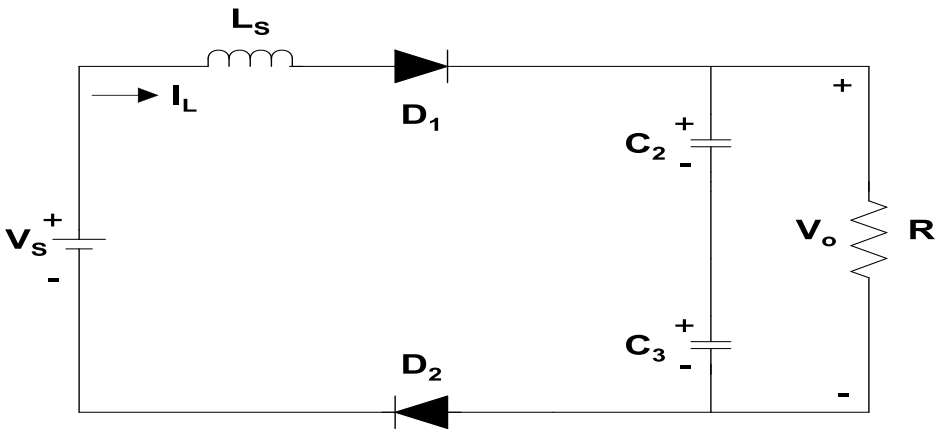

Fig. 3.2: Equivalent circuit of TLBC for Mode 2 and mode 4

Mode 3

In this mode from figure 2.1b for time period t_2 to t_3 switch S_1 is off and switch S_2 is on, energy is stored in inductor L_S, inductance current flow in circuit as shown in figure 11. The equation corresponding to these mode is:

$$V_L = V_S - \frac{V_O}{2}$$

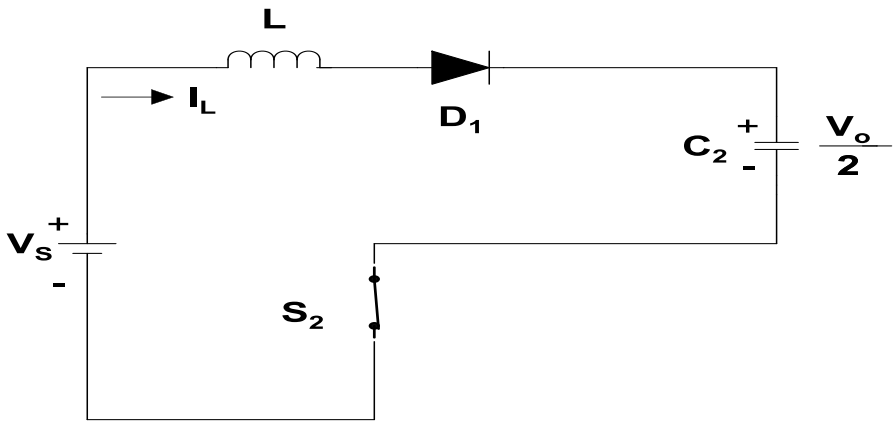

Fig. 3.3: Equivalent circuit of TLBC for Mode 3

IV. SIMULATION RESULTS OF THREE LEVEL BOOST CONVERTER

In this section open loop and closed loop simulation analysis of Three Level Boost Converter for voltage regulation is described. The system parameter given in Table I is used for simulation. In open loop system of TLBC by applying voltage source as $V_S = 90$ and produce boost output voltage as $V_O = 164$ shown in figure 4.1. In figure 4.2 shows result of TLBC with boost output voltage and voltage across capacitor $C_1 = 82V$ and Capacitor $C_2 = 82V$.

Table 1 Simulation parameter for Three Level Boost Converter

PARAMETERS	VALUE
Power rating P	1.1kW
Voltage source V_S	90V
Output Voltage V_O	164V
Inductor L	12mH
Capacitor C_1 and C_2	2200µF
Carrier frequency in TLBC	5kHz
R Load	24 Ω

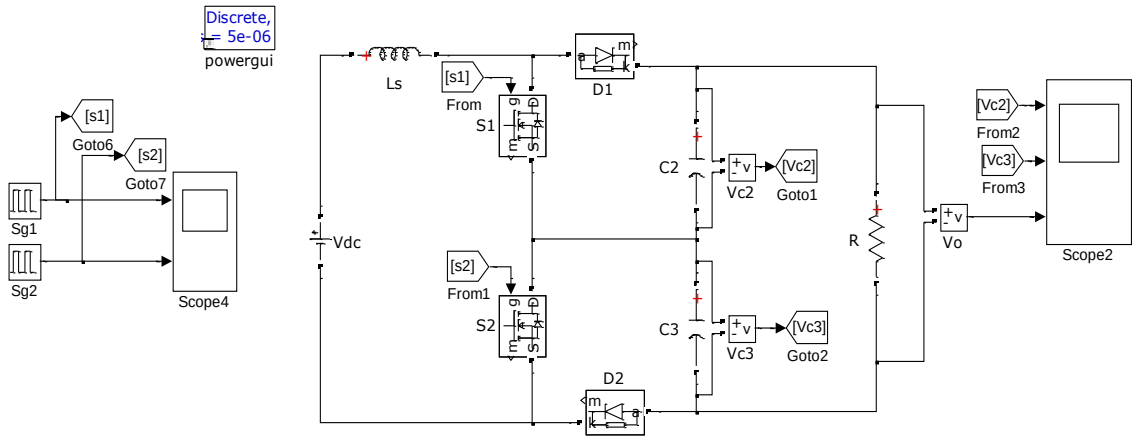

Fig. 4.1: open loop simulation of Three Level Boost Converter

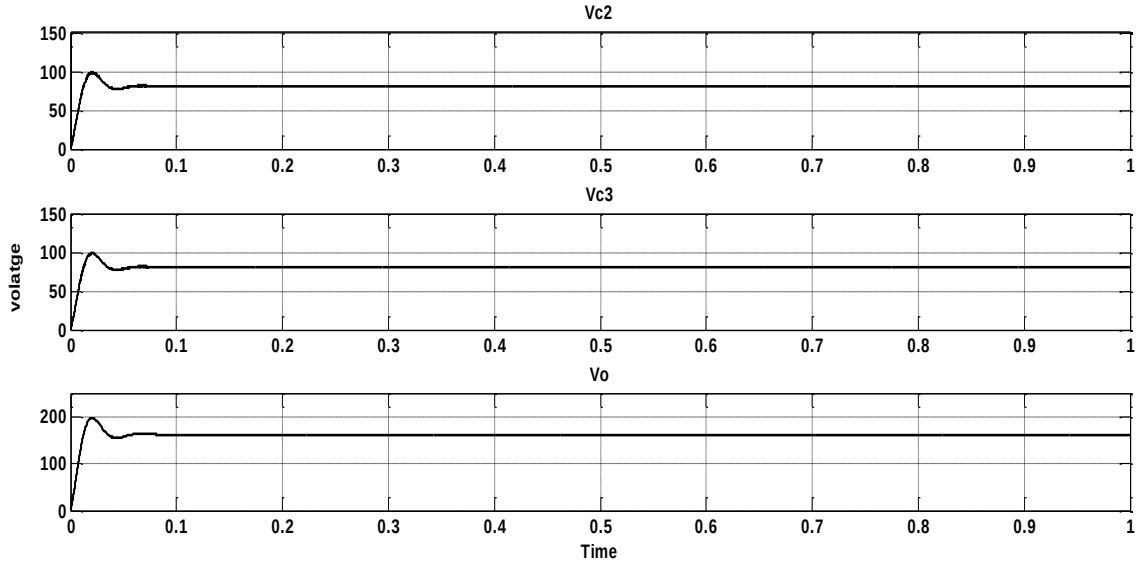

Fig. 4.2: Open loop Simulated results of TLBC (a) Voltage across capacitor C_1 (b) Voltage across capacitor C_2 (c) Output Voltage

Controller circuit of TLBC shown in figure 4.3 in which using PI controller voltage across both capacitors are become equal and giving boost output voltage. Figure 4.4 shows a closed loop simulated result of TLBC.

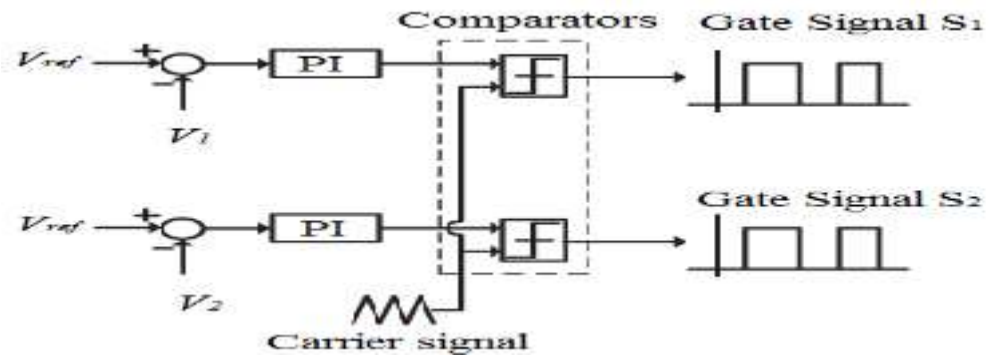

Fig. 4.3: Three Level Boost Converter Controller circuit

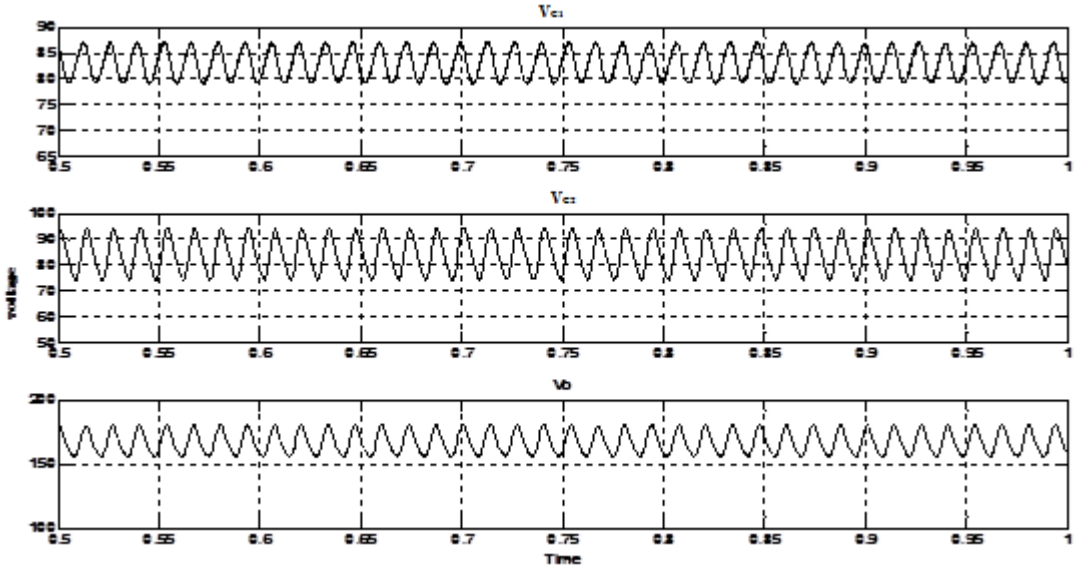

Fig.4.4: Closed loop Simulated results of TLBC (a) Voltage across capacitor C_1 (b) Voltage across capacitor C_2 (c) Output Voltage

V. CONCLUSION

Three Level Boost Converter with without overlapping switching is giving boost output voltage with equally balanced voltage across both capacitors. This work is simulated with open loop and closed loop system using PI controller circuit.

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