

Design and Development of Boost Converter

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Abstract - With the shortage of the energy and ever increasing of the oil price, research on the renewable and green energy sources, especially the solar arrays and the fuel cells, becomes more and more important. How to achieve high step-up and high efficiency DC/DC converters is the major consideration in the renewable power applications due to the low voltage of PV arrays and fuel cells. In this paper digital simulation of closed loop controlled boost converter for solar installation is presented. Circuit models for open loop and closed loop controlled systems are developed using the blocks of simulink. The simulation results are compared with the theoretical results. This converter has advantages like improved power factor, fast response and reduced hardware.

I. INTRODUCTION

The huge usage of the fossil fuels, such as the oil, the coal and the gas, result in serious greenhouse effect and this pollutes the atmosphere, which has great effect on the world. Meanwhile, there is a big contradiction between the fossil fuels supply and the global energy demand, which leads to a high oil price in the international market recently. The energy shortage and the atmosphere pollution have been the major limitations for the human development. How to find renewable energy is becoming more and more exigent

From the energy point of view, output voltage regulation in the DC/DC converter is achieved by constantly adjusting the amount of energy absorbed from the source and that injected into the load, which is in turn controlled by the relative durations of the absorption and injection intervals .

Graphical model of the boost converter is shown in Fig. 1. The DC/DC boost converter only needs four external components: Inductor, Electronic switch, Diode and output capacitor. The converter can therefore operate in the two different modes depending on its energy storage capacity and the relative length of the switching period. These two operating modes are known as the discontinuous conduction mode, DCM, and continuous conduction mode, CCM, corresponding to the cases with and without an idling interval respectively.

II. METHODOLOGY

The DC/DC converter has two modes, a Continuous Conduction Mode, CCM for efficient power conversion and Discontinuous Conduction Mode DCM for low power or stand-by operation,

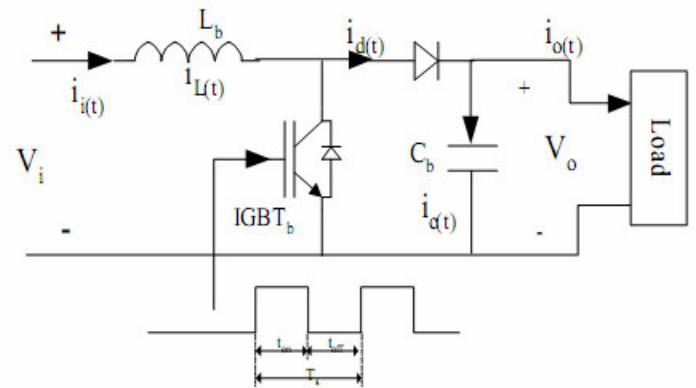


Fig. 1 Circuit Schematic of Step-up DC/DC Converter

2.1 Continuous Conduction Mode:

Mode 1 ($0 < t \leq t_{on}$)

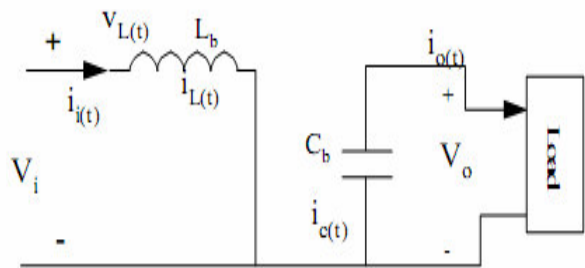


Fig.2a.Equivalent Circuit for boost Converter in CCM

Mode 1 begins when IGBT's is switched on at $t=0$ and terminates at $t=t_{on}$. The equivalent circuit for the mode 1 is shown in Fig. 2a. The inductor current $i_L(t)$ greater than zero and ramp up linearly. The inductor voltage is V_i .

Mode 2 ($t_{on} < t \leq T_s$)

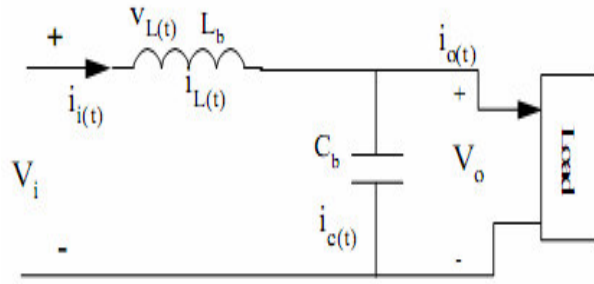


Fig.2b. Equivalent Circuit for boost Converter in CCM

Mode 2 begins when IGBT's is switched off at $t=t_{on}$ and terminates at $t=T_s$. The equivalent circuit for the mode 2 is shown in Fig. 2b. The inductor current decrease until the IGBT's is turned on again during the next cycle. The voltage across the inductor in this period is $V_i - V_o$. Since in steady state time integral of the inductor voltage over one time period must be zero.

$$V_i T_{on} + (V_i - V_o) T_{off} = 0 \quad (1)$$

Where,

V_i = the input voltage V,

V_o = the average output voltage V,

T_{on} = The switching on of the IGBT's, s

T_{off} = The switching off of the IGBT's, s

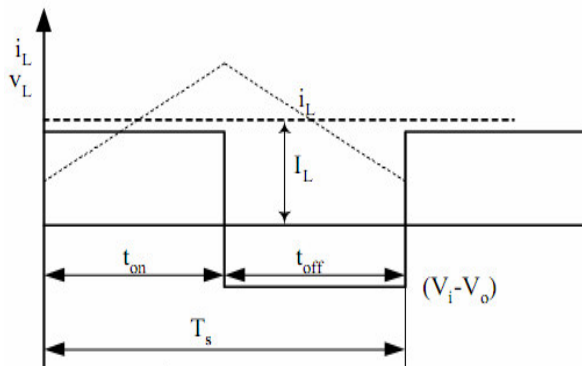
Dividing both sides by T_s and rearranging items yield

$$\frac{V_o}{V_i} = \frac{T_{on}}{T_{off}} = \frac{1}{1-D} \quad (2)$$

Where;

T_s = The switching period, s.

D = The duty cycle.



Thus, V_o is inversely proportional to $(1-D)$. it obvious that the duty cycle, D , can not be equal to 1 otherwise there would be no energy transfer to the output. assuming a lossless circuit, $P_i = P_o$, then

$$I_i V_i = I_o V_o$$

$$\frac{I_o}{I_i} = 1 - D \quad (3)$$

Where;

I_o = The average output current, Amp.

I_i = The average input current, Amp.

2.2 Selection of The Semiconductor Device:

The main switching element has been chosen to handle the worst case current and voltage stresses. The maximum voltage stress on the switching device occurs when the PV output voltage is maximized, so:

$$V_{max, stress} = V_{pv, max}$$

Where;

$V_{pv, max}$ = is the maximum input voltage from PV array, Volt.

The maximum current stress occurs when system power is predominately provided by the PV. Therefore, the peak current is

$$I_{peak} = I_{output} + I_{ripple} \quad (4)$$

$$I_{peak} = \frac{P_{in, max}}{V_{pv}} + \frac{\Delta \cdot P_{in, max}}{V_{pv}} \quad (5)$$

Where;

$P_{in, max}$ = Is the maximum output power from PV array which it is the input to boost converter.

Δ = Is the percentage of ripple current to load output current.

2.3 Selection of the inductor:

Large inductance values tend to increase the start-up time slightly while small inductance values allow the coil current to ramp up to higher levels before the switch turns off. Inductors with a ferrite core or equivalent are recommended. It should be ensured that the inductor's saturation current rating for highest efficiency is to be used a coil with low DC resistance. Boost inductance is selected based on the

maximum allowed ripple current at minimum duty cycle, D, at maximum input voltage, V_{in} . Given that the switching frequency, F_s , the boost inductor value may be optimally determined to set the converter operating mode in the required load and line range.

For parts where no inductor range is given, the following equation is a good estimation for the right

$$L_b = \frac{V_{in} * (V_{in} - V_{out})}{\Delta I_L * F_s * V_{out}} \quad (6)$$

Where,

V_{in} = typical input voltage

V_{out} = desired output voltage

f_s = minimum switching frequency of the converter

ΔI_L = estimated inductor ripple current, see below

A good estimation for the inductor ripple current is 20% to 40% of the output current.

$$\Delta I_L = (0.2 \text{ to } 0.4) * I_{out(max)} * \frac{V_{out}}{V_{in}}$$

Where,

ΔI_L = estimated inductor ripple current

$I_{out(max)}$ = maximum output current necessary in the application

2.4 Selection of the Diode:

The boost diode reverse voltage rating is limited to the output voltage. The diode conducts when the power switch is in the “OFF” state and provides a current path for the inductor to the output. Similar to the IGBT's the worst-case peak current through the diode occurs at low line input voltage and maximum load. Other important considerations in selecting the diode besides its ability to block the required off-state voltage stress and have sufficient peak and average current handling capability, is fast switching characteristics, low reverse-recovery, and low forward voltage drop.

To reduce losses, Schottky diodes should be used. The forward current rating needed is equal to the maximum output current:

$$I_f = I_{out(max)} \quad (7)$$

Where,

I_f = average forward current of the rectifier diode

$I_{out(max)}$ = maximum output current necessary in the application

Schottky diodes have a much higher peak current rating than average rating. Therefore the higher peak current in the system is not a problem.

The other parameter that has to be checked is the power dissipation of the diode. It has to handle:

$$P_D = I_f * V_f \quad (8)$$

Where,

I_f = average forward current of the diode

V_f = forward voltage of the diode

2.5 Selection of the capacitance required:

The primary criterion for selecting the output filter capacitor is its capacitance and equivalent series resistance, ESR. Since the capacitor's ESR affects efficiency, low-ESR capacitors will be used for best performance. For reducing ESR is also possible to connect few capacitors in parallel. The output filter capacitors are chosen to meet an output voltage ripple specifications, as well as its ability to handle the required ripple current stress. An approximate expression for the required capacitance as a function of ripple voltage requirement, ΔV_o , D, switching frequency, F_s and output voltage, V_o is given as

$$C_b = \frac{I_{out(max)} * D}{F_s * \Delta V_{out}} \quad (9)$$

Where,

$C_{out(min)}$ = minimum output capacitance

$I_{out(max)}$ = maximum output current of the application

D = duty cycle

f_s = minimum switching frequency of the converter

ΔV_{out} = desired output voltage ripple

The ESR of the output capacitor adds some more ripple, given with the equation:

$$\Delta V_{out} = ESR * \left(\frac{I_{out(max)}}{1 - D} + \frac{\Delta I_L}{2} \right) \quad (10)$$

Where,

$\Delta V_{out(ESR)}$ = additional output voltage ripple due to capacitors ESR

ESR = equivalent series resistance of the used output capacitor

$I_{OUT(max)}$ = maximum output current of the application

D = duty cycle

ΔI_L = inductor ripple current

III. SIMULATION RESULT

Simulation is done using PSIM Simulink and the results are presented. The conventional boost converter is shown in Fig.1 The simulation studies are performed in Simulink with the following specifications $V_i=24V$, $V_o=358V$, $C_1 = 22 \mu F$, $C_2=1 \mu F$, $L_1 = 45 \mu H$, $L_2=0.5mH$ and $R_0 = 50 \Omega$ (load resistance) using the model given in Fig. 3(a). and the simulation waveforms of are shown.

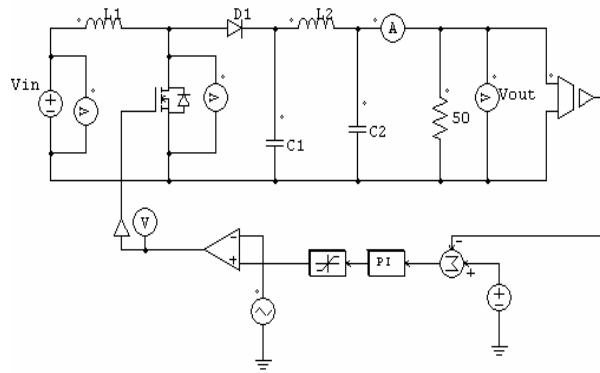


Fig.3.(a) Simulink model of Close Loop System

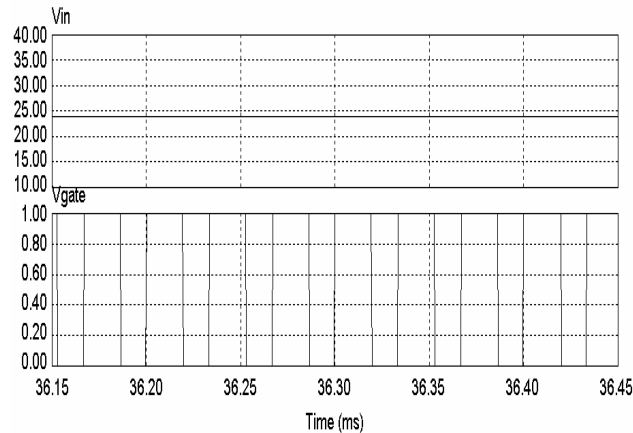


Fig.3.(b) Input Voltage and driving pulse

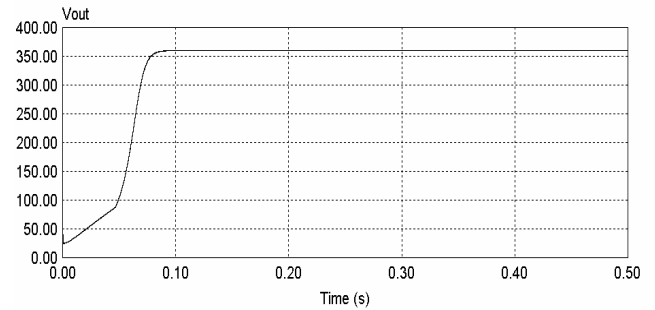


Fig.3c.Output Voltage

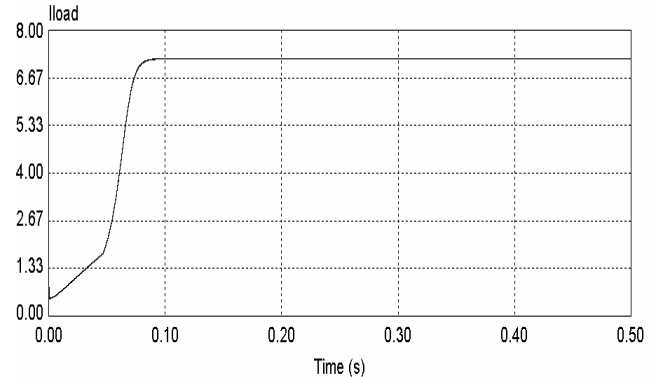


Fig.3d.Output Current

IV. CONCLUSION

This paper presents simulation of closed loop controlled boost converter system for high power system. PSIM models for closed loop systems are developed using the blocks of simulink and the same are used for simulation studies. The closed loop system is able to maintain constant voltage. This converter has advantages like reduced hardware and good output voltage regulation. Thus the boost converter is capable of improving the voltage level from 24 V to the required level.

V. References

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