

SPEED CONTROL OF DC MOTOR USING DC/DC BOOST CONVERTER

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Abstract - This paper presents a design and simulation of DC/DC boost converter. This system has a nonlinear dynamic behavior, as it works in Dc-Dc Boost Converter switch-mode. When the changes on the load or on the line voltage at the input. The input usually is obtained by PV array and therefore the design and simulation in this paper covers the whole range of radiations and temperature. In this paper we analyze the equations of a boost converter and propose a design components and simulation of DC/DC boost converter. It is a high gain Transformer less Inverter modeling which is used for smart Grid Technology or as stand alone for home appliances is proposed. The proposed Transformerless topology provides higher voltage gain, low cost, small size, and simple control. Stand alone Transformer less Inverter for home appliances.

Key Words: photovoltaic (PV), Boost Converter and matlab simulation.

1. INTRODUCTION

The mass usage of the fossil fuels, such as the oil, the coal and the gas, result in serious greenhouse effect and pollute 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. The PV cell is density of power radiated from the sun at the outer atmosphere is 1.373 kW/m². Final incident sun light on the earth surface has the peak density of 1 kW/m² at noon in the tropics. Solar cell can convert the energy of sunlight directly in to electricity [1].

1.1 EQUIVALENT CIRCUIT OF A PV CELL

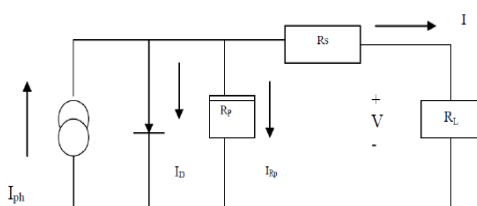


Fig -1 Equivalent circuit of a PV cell

A simplified equivalent circuit of a solar cell consists of a current source in parallel with a diode variable resistor is connected to the solar cell generator as a load. Relationship between the current and voltage may be determined from the diode characteristics equation:

$$I = I_{ph} - I_d = I_{ph} - I_0(e^{qV/kt} - 1)$$

Where q is the electron charge, k is the Boltzmann constant, I_{ph} is the photocurrent, I_0 is the reverse saturation current, I_d is the diode current and T is the solar cell operating temperature (K).[3] Switch mode DC to DC converters are used to match the output of a PV generator to a variable load. DC to DC converters allow the charge current to be reduced continuously in such a way that the resulting battery voltage is maintained at a specified value. A practical photovoltaic energy conversion system block diagram is shown in Fig. 2.

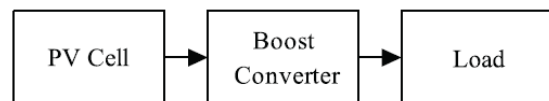


Fig -2 Block Diagram of a DC-DC Boost converter

1.2 OVERVIEW OF A DC-DC CONVERTER

DC-DC converters can be used as switching mode regulators to convert an unregulated dc voltage to a regulated dc output voltage. The regulation is normally achieved by PWM at a fixed frequency and the switching device is generally BJT, MOSFET or IGBT. The minimum oscillator frequency should be about 100 times longer than the transistor switching time to maximize efficiency. This limitation is due to the switching loss in the transistor. The transistor switching loss increases with the switching frequency and thereby, the efficiency decreases. The core loss of the inductors limits the high frequency operation. Control voltage Vc is obtained by comparing the output voltage with its desired value. Then the output voltage can be compared with its desired value to obtain the control voltage Vcr. The PWM control signal for the dc converter is generated by comparing Vcr with a sawtooth voltage Vr.[3]. There are four topologies for the switching regulators: buck converter, boost converter, buck-boost

converter, cuk converter. Dc-Dc Boost Converter is a output dc voltage is greater than input dc voltage

2. DC-DC BOOST CONVERTERS

The DC/DC converters are widely used in regulated switch mode DC power supplies. The input of these converters is an unregulated DC voltage, which is obtained by PV array and therefore it will be fluctuated due to changes in Radiation and temperature. In these converters the average DC output voltage must be controlled to be equated to the desired value although the input voltage is changing. 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, the converter can herefore operate in two different modes depending upon its energy storage capacity and the relative length of the switching period. These two modes are known as discontinues conduction and continuous modes. 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. The DC/DC converter has two modes, a Continuous Conduction Mode for high power conversion and Discontinuous Conduction Mode for low power or stand-by operation.

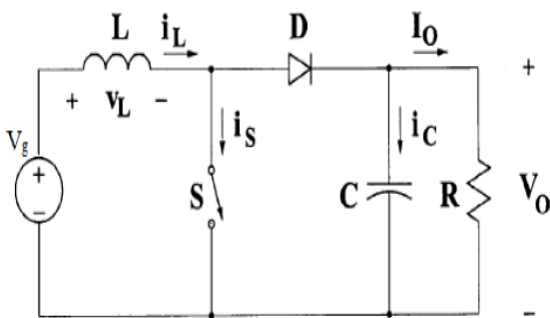


Fig -3 Circuit Diagram of a Dc-Dc Boost Converter

In the figure (3) shows a step up or PWM boost converter. It consists of a dc input voltage source V_g ; boost inductor L , controlled switch S , diode D , filter capacitor C , and the load resistance R . When the switch S is in the on state, the current in the boost inductor increases linearly and the diode D is off at that time. When the switch S is turned off, the energy stored in the inductor is released through the diode to the output RC circuit [4].

a) MODE 1 ($0 < t < t_{on}$) ON STATE:

In the ON state, the circuit diagram is as shown below in Figure 4, Mode 1 begins when IGBT's is switched on at $t=0$

and terminates at $t=t_{on}$. The inductor current $i_L(t)$ greater than zero and ramp up linearly. The inductor voltage is V_i . When the switch is ON, the inductor is charged from the input voltage source V_g and the capacitor discharges across the load.

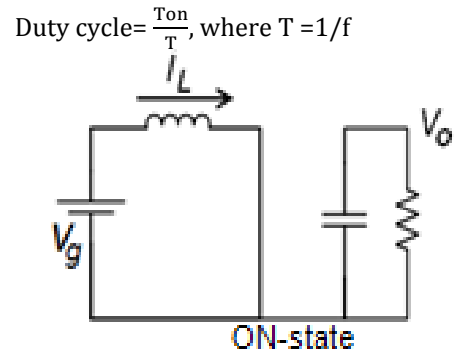


Fig -4 Equivalent circuit of ON STATE Boost Converter.

b) MODE 2 ($t_{on} < t < T$) ON STATE:

In the OFF state, the circuit becomes as shown in the Figure.

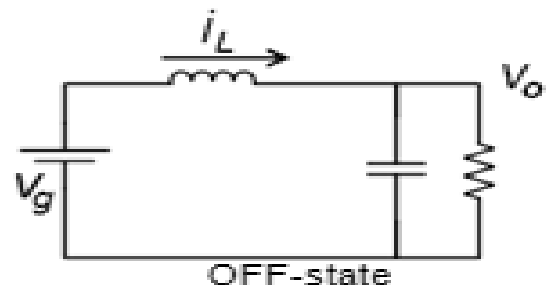


Fig -5 Equivalent circuit of OFF STATE Boost Converter

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. 5. 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 the steady state time integral of inductor voltage over one time period must be zero. When the switch is off, the sum total of inductor voltage and input voltage appear as the load voltage. Show the waveform on output voltage across the inductor and flow of the inductor current.

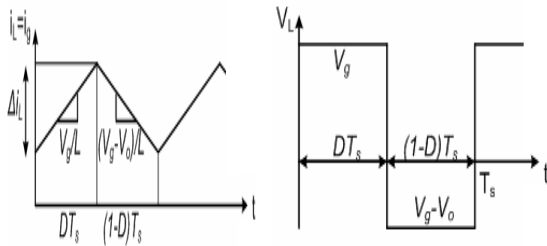


Fig 6 (a) Inductor current waveform. **Fig 6 (b)** Inductor voltage waveform.

From the balance equation,

- $V_g(T_{on}) + (V_o - V_g)(T_{off}) = 0$
 - $V_g(DT_s) + (V_o - V_g)(1-D)T_s = 0$
 - $V_g(DT_s) - V_g(DT_s) - V_gTs + V_oDT_s - V_oTs = 0$
 - Dividing both sides by T_s ,
- $$\frac{V_o}{V_g} = \frac{T_s}{T_{off}} = \frac{1}{1-D}$$

Where,

- Vi: The input voltage, V.
- Vo: The average output voltage, V.
- Ton: The switching on of the IGBT's, s
- Toff: The switching off of the IGBT's, s
- Ts: The switching period, s.
- D: The duty cycle.

So, Output Voltage $V_o = \frac{1}{1-D} * V_g$

- Conversion ratio $M = \frac{V_o}{V_g} = \frac{1}{1-D}$

From inductor current ripple analysis, change in inductor current,

- $\Delta I_l = I_{max} - I_{min}$
- $\Delta I_l = (V_g/L) * T_{on}$
- $\Delta I_l = (V_g/L) * D * T_s$
- $\Delta I_l = V_g * D / F_s * L$
- $L = V_g * D / F_s * (\Delta I_l)$

The boost converter operates in continuous conducting mode for $L > L_b$ where,

$$L_b = \frac{R * D * (1-D)^2}{2 * F_s}$$

The critical inductance, L_b , is defined as the Inductance at the boundary edge between continuous and discontinuous modes; the current supplied to the output RC circuit is discontinuous. Thus a large filter capacitor is used to limit the output voltage ripple. The filter capacitor must provide the output dc current to the load when the diode D is off.

The minimum value of the filter capacitance that results in the voltage ripple V_r [8] is given by,

$$C_{min} = \frac{D * \Delta V_o}{V * R * f}$$

3. DESIGN OF THE BOOST CONVERTER

Current ripple factor (CRF):

Current ripple factor should be bounded within 30%

So that, $\frac{\Delta I_1}{I_1} = 30\%$

Voltage ripple factor (VRF):

Voltage ripple factor should be bounded within 5%,

So that is, $\frac{\Delta V_o}{V_o} = 5\%$

Switching frequency (fs):

In a boost Converter Switching frequency on a IGBT is a 30 KHZ Apply.

➤ **GIVEN DATA:-**

- Input Voltage: 25 Volt
- Output Voltage: 400 Volt
- Load Resistance: 400 Ω
- Output Current: 1Amp.

(a) CALCULATION OF DUTY CYCLE:-

Conversion ratio $M = \frac{V_o}{V_g} = \frac{1}{1-D}$

$\frac{V_o}{V_g} = \frac{1}{1-D} = \frac{400}{25} = 16$

Duty Cycle $D = 93.75\%$

(b) CALCULATION OF A RIPPLE CURRENT:-

$I_1 = 1\text{Amp}$

So that $\frac{\Delta I_1}{I_1} = 30\%$

$\Delta I_1 = 1 * 0.3 \text{ Amp} = 0.3 \text{ Amp.}$

(c) CALCULATION OF A RIPPLE VOLTAGE:-

$\frac{\Delta V_o}{V_o} = 0.05\%, \Delta V_o = 0.05$

(d) CALCULATION ON INDUCTOR VALUE (L):

➤ Inductance $L = \frac{V_g * D}{f * \Delta I_1}$

- Inductance $L = \frac{25 * 0.9375}{30 * 10^3 * 0.3}$
- Inductance $L = 2.60$ m Henry.

(e) CALCULATION OF A CAPACITOR VALUE:-

- Capacitance $C = \frac{D * \Delta V_o}{V * R * f}$
- we have, $\frac{\Delta V_o}{V} = \frac{D * T_s}{R_o * C}$ and $R = \frac{400V}{1AMP} = 400\Omega$

- Capacitance $C = 468$ uF.

3. SIMULATION OF Open Loop DC -DC BOOST CONVERTER

Using the MATLAB simulation program we get the result of Dc-Dc boost converter for 24V-400V DC Voltage. So design section value of inductor $L=2.60$ Mh,Capacitor value $C= 468$ uF and Resistor value $R=300$ ohm .show the waveform across the load voltage and inductance across the flow of current and gate pulse, and show observation various duty cycle and across the load voltage.

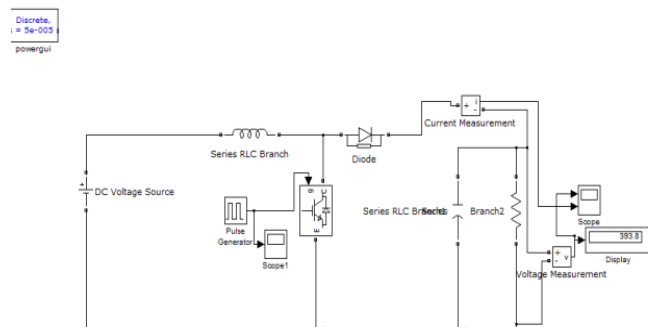


Fig -7 Simulation on DC-DC boost converter

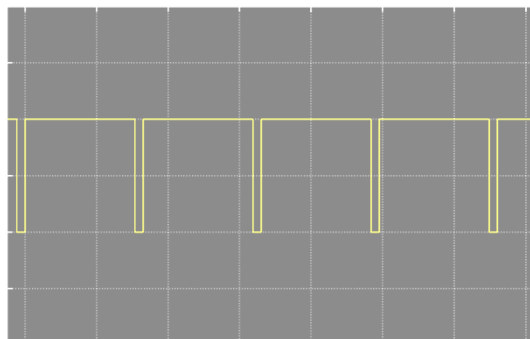


Fig -8 Gate pulse of IGBT Waveform

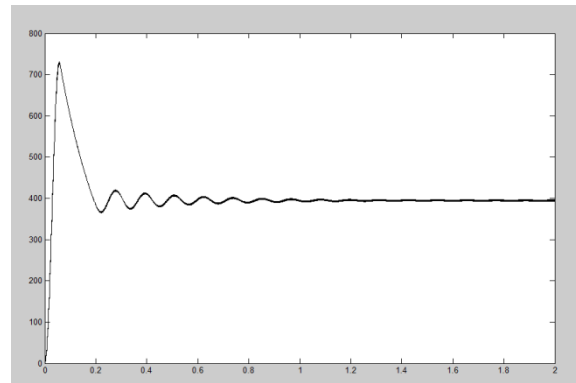


Fig -9 Output voltage across load

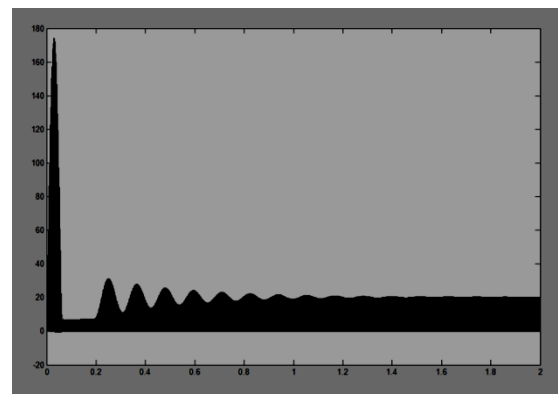


Fig -10 Inductive current waveform.

TABLE- I

- Various duty cycle and output voltage across load

Varying Duty Cycle	Output Voltage	Speed
40	45.84	600
60	78.15	900
70	129.9	1050
93	393.8	1395

4. SIMULATION ON A CLOSE LOOP DC-DC BOOST CONVERTER

Using the MATLAB simulation program get the result of Dc-Dc close loop boost converter for 24V-400V DC Voltage. So design section value of inductor $L=2.60$ Mh,Capacitor value $C= 468$ uF and Resistor value $R=400$ ohm .show the waveform across the load voltage and inductance across the flow of current and gate pulse, and show observation various duty cycle and across the load voltage.

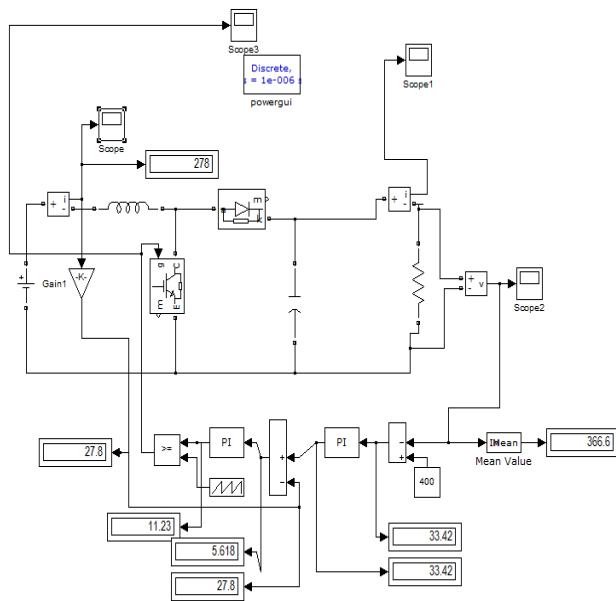


Fig -11 Boost converter close loop circuit.

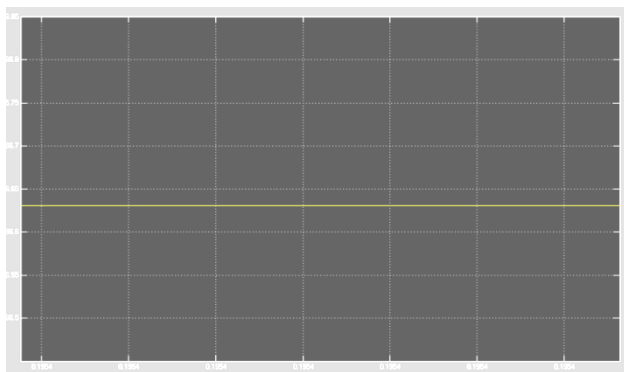


Fig -12 Output voltage across load

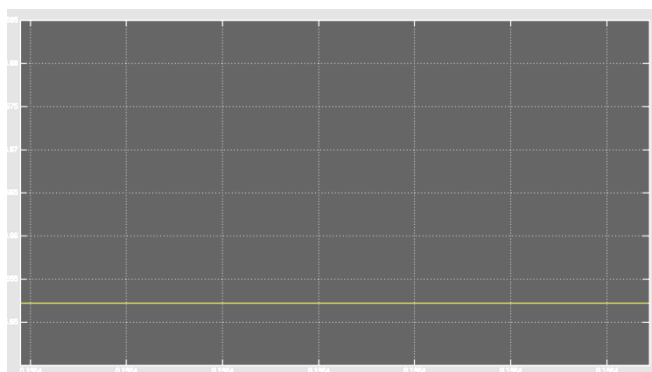


Fig -13 Inductive Current waveform.

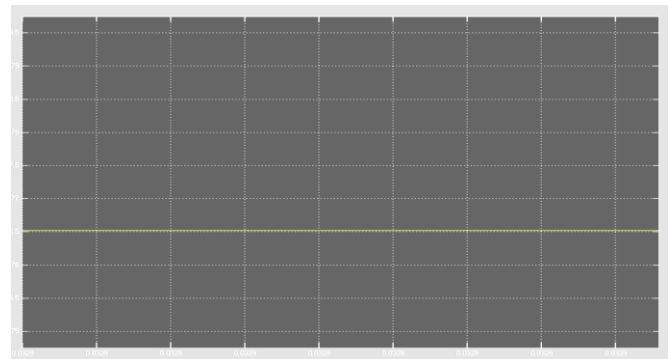


Fig -14 Input current Waveform.

3. CONCLUSIONS

This design of open loop and closed loop DC-DC Boost Converter provides smooth control of DC output for open loop and smooth output voltage for close loop DC-DC Boost Converter.

REFERENCES

1. Md. Rabiul Islam, Youguang Guo, Jian Guo Zhu, M.G Rabbani, "Simulation of PV Array characteristics and Fabrication of Microcontroller Based MPPT", Faculty of Engineering and Information technology, University of Technology Sydney, Australia, 6th International Conference on Electrical and Computer Engineering ICECE 2010, 18-20 December 2010, Dhaka, Bangladesh.
2. SERBIAN JOURNAL OF ELECTRICAL ENGINEERING Vol. 7, No. 1, May 2010, 121-130 121 Simulation of Closed Loop Controlled Boost Converter for Solar Installation Athimulam Kalirasu1, Subharensu Sekar Dash2.
3. Muhammad H. Rashid, "Power Electronics circuits, Devices and Applications", Third Edition.
4. Modelling and Control design for DC-DC converter, Power Management group, AVLSI Lab, IIT-Kharagpur.
5. B.M Hasaneen, Faculty of Eng., Al-Azhar University, Kena, Egypt. And Adel A. Elbaset Mohammed Faculty of Engineering, Minia University, Minia, Egypt. "DESIGN AND SIMULATION OF DC/DC BOOST CONVERTER" From the SelectedWorks of Dr. Adel A. Elbaset December 2008
6. Athimulam Kalirasu1, Subharensu Sekar Dash2 "Simulation of Closed Loop Controlled Boost Converter for Solar Installation" SERBIAN JOURNAL OF ELECTRICAL ENGINEERING Vol. 7, No. 1, May 2010, 121-130