



Speed Control of dc Motor using dc to dc Converter(Boost Converter)

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ABSTRACT: The project is designed to the switched-mode dc-dc converters are some of the most widely used power electronics circuits for its high conversion efficiency and flexible output voltage. These converters used for electronic devices are designed to regulate the output voltage against the changes of the input voltage and load current. This leads to the requirement of more advanced control methods to meet the real demand. Many control methods are developed for the control of dc-dc converters. To obtain a control method that has the best performances under any conditions is always in demand.

Conventionally, the dc-dc converters have been controlled by linear voltage mode and current mode control methods. These controllers offer advantages such as fixed switching frequencies and zero steady-state error and gives a better small-signal performance at the designed operating point.. These controllers are robust concerning converter parameter variations, load and line disturbances. SM controlled converters generally suffer from switching frequency variation when the input voltage and output load are varied. This complicates the design of the input and output filters. The main objective of this research work is to study different control methods implemented in dc-dc converter namely (linear controllers, hysteresis control, and current programmed control.

Keywords: Boost Converter, Dc Motor.

1 Introduction:

If we have fixed D.C. source for any D.C. load like D.C. motor at that time motor can run at fixed speed according to that source voltage. Suppose now increase the speed of the motor without changing D.C. source. For this we want to use D.C. to D.C. converter (step up converter).

Supply for the boost converter may be any suitable dc sources, such as batteries, solar panels, rectifiers and dc generators. Today, most of the equipment's are working on dc voltage supply. So, using boost converter we convert low voltage into high voltage. The converter which converts D.C. to D.C. is called dc-dc converter. A dc-dc converter is a device used to convert low voltage input into high voltage output. This conversion can be achieved by a variety of circuits based on and using switching devices. The widely used switching devices are diodes, thyristors, power MOS, etc. Sometimes it is necessary to increase dc voltage. Boost converter is a dc-dc converter in which the output voltage is always greater than the input voltage which depends on switching frequency. 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. These two basic processes of energy absorption and injection constitute a switching cycle. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power given by formula $P=VI$ must be conserved, the output current is lower than the source current

In the first portion of this chapter, basic working principle and operation of dc to dc boost converter with various designs parameter like inductor and capacitor is discussed. In the second portion of this chapter MATLAB simulations for open loop dc to dc boost converter are discussed.

A boost converter or step-up converter is a dc to dc power converter with an average output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filter is made by capacitor and normally connected at the output of the boost converter and its function is to reduce output voltage ripple.

2 Operating principle

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost converter is shown in figure 1.

The operation of a boost converter can be divided into two modes. First when the switch is closed, current flows through the inductor in clockwise direction and the inductor stores the energy. Polarity of the left side of the inductor is positive

Second, when the switch is opened, current will be reduced, as the impedance is higher. Therefore, change or reduction in current will be opposed by the inductor. Thus the polarity will be reversed (means left side of inductor will be negative now). As a result, two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. Also while the switch is opened, the capacitor in parallel with the load is charged to this combined voltage. When the switch is then closed and the right hand side is shorted out from the left hand side, the capacitor is therefore able to provide the voltage and energy to the load. During this time, the blocking diode prevents the capacitor from discharging through the switch. The switch must of course be opened again fast enough to prevent the capacitor from discharging too much.

Figure 1 shows a step-up or a PWM based boost converter. It consists of dc input voltage source V_{in} , boost inductor L_b , controlled switch S_b , diode D_b , filter capacitor C_b , and load resistance R_o .

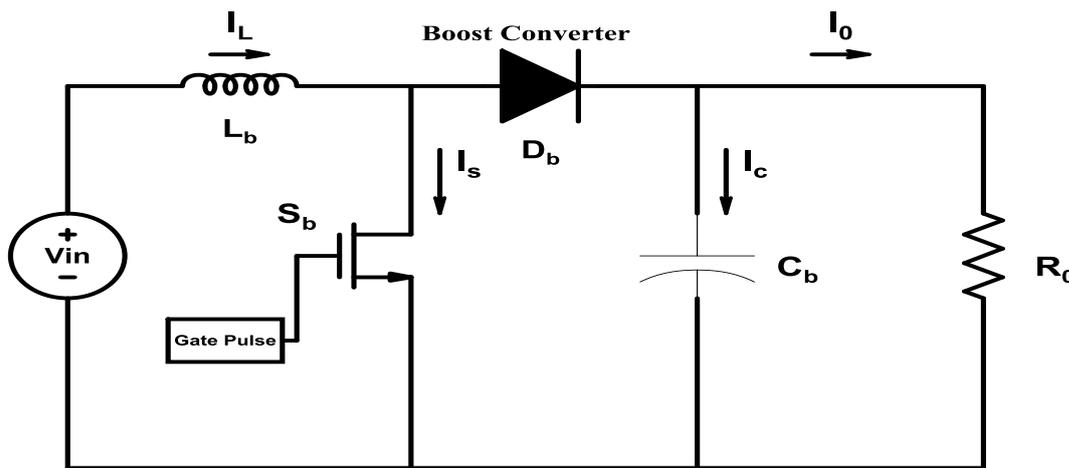


Figure 1 Circuit diagram of a boost converter

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, then energy stored in the inductor is released through the diode to the output RC circuit.

Using Faraday's law for the boost converter,

$$V_{in} D T = (V_o - V_{in}) (1-D) T \quad (1.1)$$

Where V_{in} = Input voltage of the converter

V_o = Output voltage of the converter

D = Duty ratio

T = Time period

The output voltage equation is given by

$$V_o = \frac{V_{in}}{1-D} \quad (1.2)$$

2.1 Design of Inductor and Capacitor for boost converter:

For designing of boost converter following parameter design should selected properly to get desired operation from boost converter.

2.1.1 Value of different parameters based on application

The following parameters are needed to calculate the power stage:

- (1) Input voltage range: $V_{in (min)}$ and $V_{in (max)} = 8$ to 12 volts
- (2) Nominal output voltage: $V_o = 14.4$ volts
- (3) Load resistance $R_L = 14.4 \Omega$
- (3) Maximum output current: $I_o (max) = 1$ A
- (4) Switching frequency $f_s = 10$ KHz

This is necessary, because if these parameters are known the calculation of the power stage can take place. Also inductor ripple current should not be more than 10 % and capacitor ripple voltage should not be more than 3 %.

2.1.2

Calculation of duty ratio

- (1) Taking input voltage $V_{in} = 8$ volts
- (2) Required output voltage $V_o = 12$ volts

$$V_o = \frac{V_{in}}{1 - D}$$

$$10 = \frac{8}{1 - D}$$

$$D = 0.305$$

2.1.3 Calculation of inductance value

During selection of inductor one should keep in mind is higher the inductor value, the higher is the maximum output current because of the reduced ripple current. And also lower the inductor value, the smaller is the solution size. Note that the inductor must always have a higher current rating than the maximum current because the current increases with decreasing inductance.

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

$$L = \frac{V_{in} D}{\Delta I_L f_s} \quad (1.3)$$

Where, V_{in} = Input voltage of the converter

V_o = Output voltage of the converter

ΔI_L = Inductor ripple current

ΔV_o = Output ripple voltage

D = Duty ratio

f_s = Switching frequency

By using above equation

$$L = \frac{10 \times 0.305}{0.1 \times 10000}$$

$$L = 3.05 \text{ mH}$$

2.1.4 Calculation of capacitance value

Best practice is to use low ESR capacitors to minimize the ripple on the output voltage. Ceramic Capacitors are a good choice if the dielectric material is X5R.

If the converter has external compensation, any capacitor value above the recommended value can be used, but the compensation has to be adjusted for the used output capacitance. With internally compensated converters, the recommended inductor and capacitor values should be used or the recommendations in the data sheet for adjusting the output capacitors to the application should be followed for the ratio of $L \times C$. With external

compensation, the following equations can be used to adjust the output capacitor values for a desired output voltage ripple

$$C = \frac{I_{o(max)} D}{f_s \Delta V_o} \quad (1.4)$$

$$C = \frac{1 \times 3.05}{10000 \times 0.144}$$

$$C = 211.8 \mu F$$

The ESR of the output capacitor adds some more ripples, given by the equation:

$$\Delta V_{o(ESR)} = ESR \times \left(\frac{I_o}{1-D} + \frac{\Delta I_L}{2} \right) \quad (1.5)$$

Where,

$\Delta V_{o(ESR)}$ = Additional output voltage ripple due to ESR of capacitor

ESR = Equivalent series resistance of capacitor

I_o = Output current

D = Duty cycle

ΔI_L = Inductor ripple current

2.1.5 Rectifier Diode Selection

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

$$I_F = I_{o(max)} \quad (1.6)$$

Where,

I_F = Forward current of the diode

$I_{o(max)}$ = Maximum output current

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

$$P_D = V_F \times I_F \quad (5.7)$$

Where,

V_F = Forward voltage of the diode

I_F = Forward current of the diode

2.2 Simulation results

In this portion open loop dc-dc boost converter and close loop dc-dc boost converter simulation results are presented with the help of MATLAB SIMULINK.

2.2.1 Open loop dc-dc boost converter

As shown in Fig.2 open loop dc-dc boost converter, we will observe boost output voltage with different input voltage. Basic components of the boost converter are inductor, capacitor, diode, semiconductor switch. The pulse generator provides the firing pulses to the semiconductor switch. Semiconductor switch MOSFET is used for switching as shown in fig.

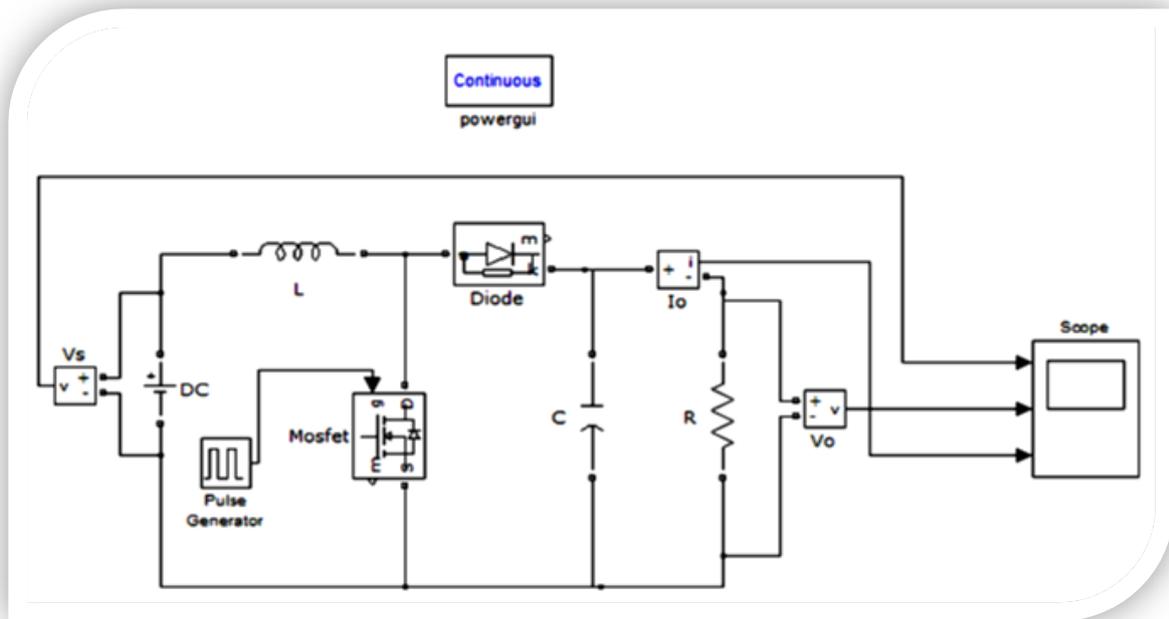


Figure 2 MATLAB model of open loop boost converter

2.2.2 Output result of open loop dc-dc boost converter

Fig. 3 to fig.5 shows open loop dc-dc boost converter output voltage waveform for different input voltage. In fig. 3 input voltage $V_{in} = 10V$, we got output voltage $V_{out} = 14.4 V$ and in fig. 4 input voltage $V_{in} = 12V$, we got output voltage $V_{out} = 17.7 V$ and as shown in fig. 5 input voltage $V_{in} = 14V$, we got output voltage $V_{out} = 20.5 V$ as shown

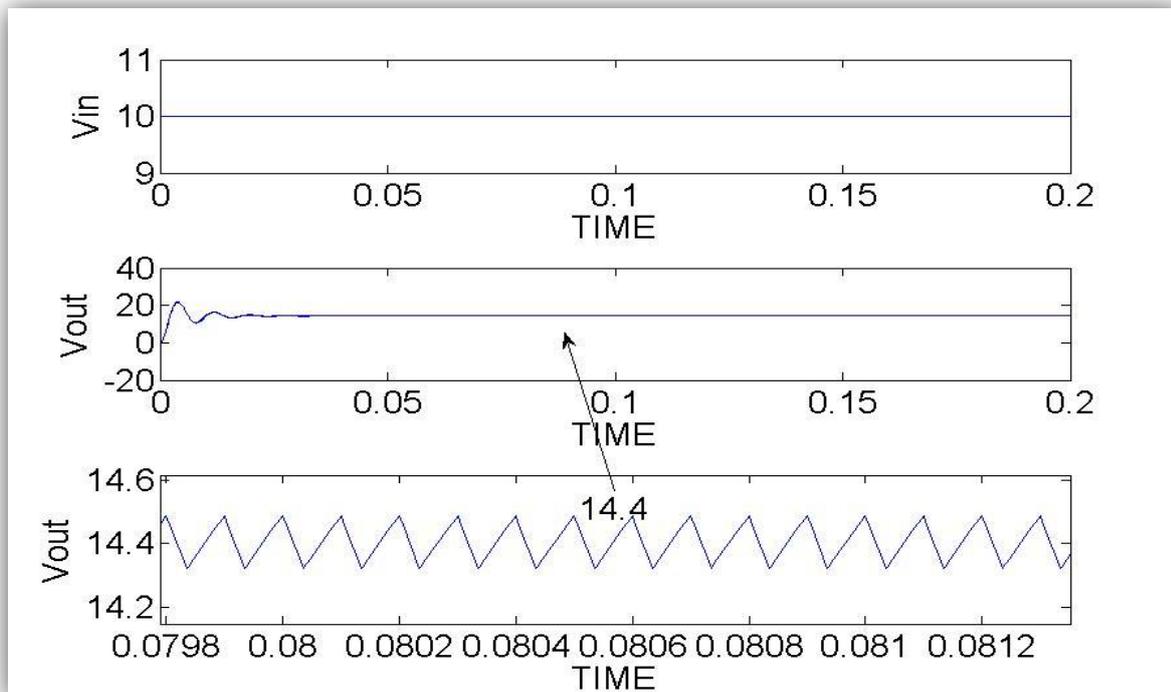


Figure 3 Waveforms open loop boost converter for input voltage of 10 V

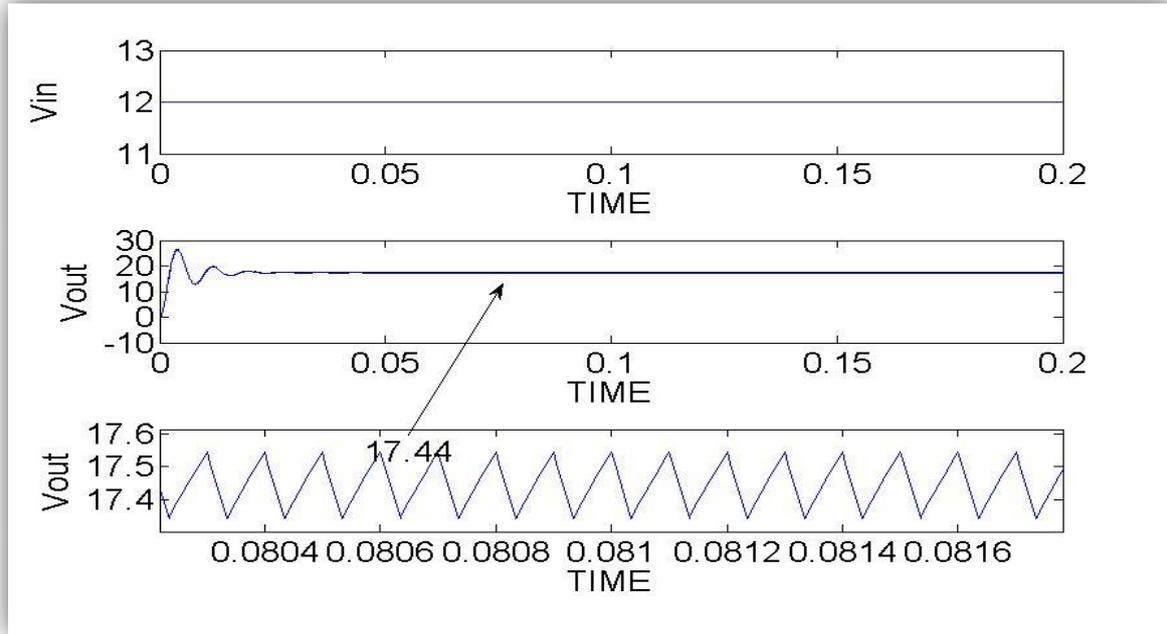


Figure 4 Waveforms open loop boost converter for input voltage of 12 V

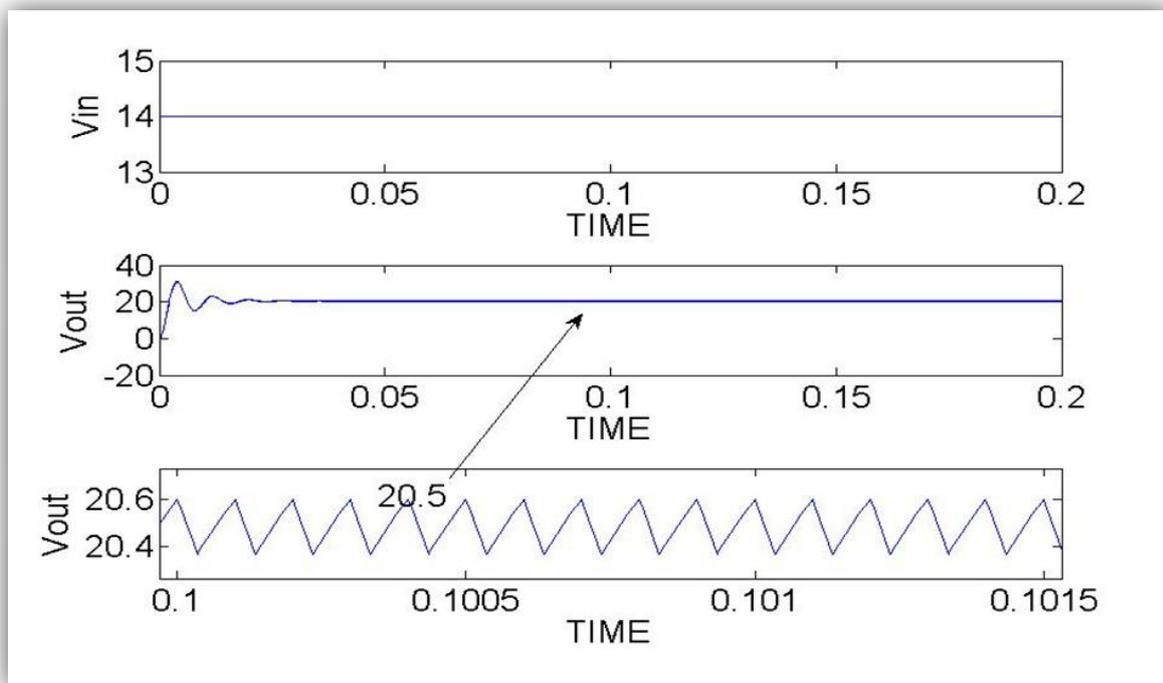


Figure 5 Waveforms open loop boost converter for input voltage of 14 V

From Fig.3 to fig 4 shows open loop dc-dc boost converter output voltage. It observed that in open loop dc-dc boost converter output voltage is varying with input voltage. To get output constant we need to go for close loop dc-dc boost converter.

Table 1 Simulation result of the open loop boost converter

INPUT VOLTAGE (V_{in})	SWITCHING FREQ. (KHz)	DUTY RATIO (D)%	L (mH)	C (μF)	R_L (Ω)	OUTPUT VOLTAGE (V_{out})
10	10	34.60	3.05	211.8	14.4	14.4
11						15.91
12						17.44
13						18.9
14						20.5

3 CONCLUSION

The speed of a dc motor has been successfully controlled by using chopper as a converter and Proportional-Integral type Speed and current control based on open loop model of dc motor. Initially a simplified open loop model for speed control of DC motor is considered and requirement of current control is studied. The simulation is done in MATLAB under load condition, varying reference speed condition and varying input voltage. The result are also studied and analysed under above mentioned condition. The model shows good results under all conditions employed during simulation.

4 REFERENCES

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