



DESIGN OF BOOST CONVERTER FOR ELECTRIC VEHICLE APPLICATIONS USING PI CONTROLLER

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Abstract: In recent years the availability of petroleum resources has decreased, which has paved the way for Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs). In order to achieve a better drive range and improved performance of the motor, control techniques are necessary for the DC to DC power converters which are used in these vehicles. Designing of linear controllers for these converters like Proportional Integral (PI) gives constant output which improves the performance of Drive. The above concept is tested for DC to DC boost converters in simulation in this paper.

I-INTRODUCTION

With the dependency of the transportation sector on the petroleum resources, there is a fast decline in their availability. This has aroused the need to design vehicle on alternate propulsion technologies which has led to the progress of Electric Vehicle (EV) and Hybrid Electric Vehicle (HEV). Various topologies of the power converters which are used in operation of HEV or EV have been designed. But the main problems faced during the driving operation are the fluctuations in the input battery voltage, load variations, which decreases the performance of the drive. Hence proper control strategy should be implemented so that a better drive range and improved performance can be achieved [1].

In this paper a DC to DC boost converter is used to drive a PMDC motor. PMDC is used because of its simple operation, low cost and does not require complex controllers unlike induction and brushless DC motors. In order to have a constant output voltage from the DC to DC converter despite input fluctuations and load variations, linear control method (Proportional Integral control) is used to control the constant output.

This paper is divided into the following section as follows; the complete system description and the design of the converter are given in Section II. Section III Boost Converter & PMDC motor, Design of Boost Converter & PMDC motor with PI controller. In this paper, the values of the voltage and current are taken from the running electric vehicles. The simulation waveforms are discussed for open loop and closed loop Boost Converter. The effect of fluctuation on the output voltage is also shown with the simulation results and at last, conclusion and future work is also considered.

II- SYSTEM DESCRIPTION

The system taken up for this study consists of a three basic blocks i.e. DC input voltage, DC to DC boost converter and PMDC motor as load as shown in Fig. 1 with its control strategy.

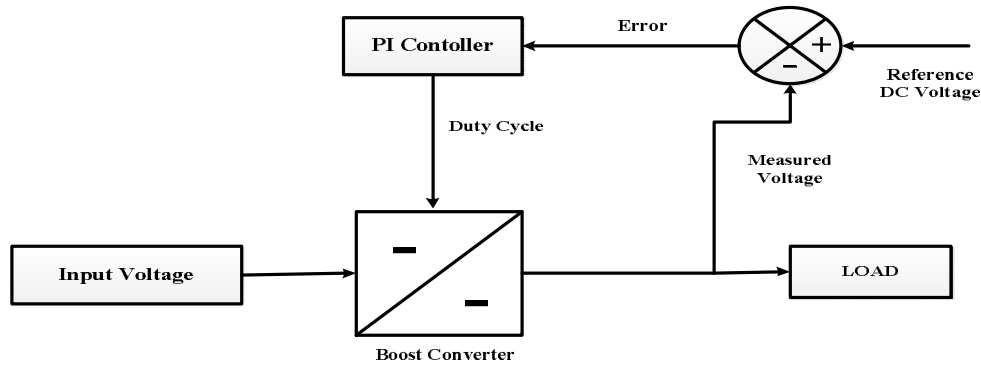


Fig. 1. Block diagram of DC/DC Boost converter with control strategies

The main idea is to control the output voltage of the converter during variations in the input voltage or at the time of change in the load. This is vital to ensure a constant input voltage in driving the PMDC motor during the motoring operation. The design parameters used in this study are given in Table I.

1. Design of Boost Converter:

The circuit diagram of DC to DC boost converter which is used is shown in Fig. 2. The converter can run both in continuous as well as in discontinuous mode. In this paper continuous conduction mode is considered which is determined by the value of the inductor, L.

TABLE-1 DESIGN PARAMETERS

Input Voltage to Converter	24 V
Output Voltage of Boost Converter	48 V
Frequency	32 KHz
Duty Cycle	50%

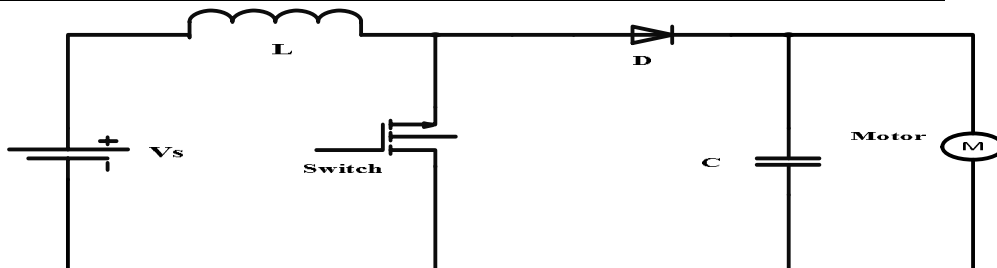


Fig. 2. Circuit diagram for Boost Converter

- 1) *Inductor and capacitor design:* For continuous mode of conduction in boost converter, the relation among the input and output voltage is given by equation (1)

$$\frac{V_a}{V_s} = \frac{1}{1-D} \quad (1)$$

Here D is the duty cycle, Vs is the input voltage (V) and Va is the output voltage (V) of the converter. The inductor and capacitor values are calculated from equations (2) and (3). For the converter to operate in continuous mode it should satisfy the condition which is given in equation (4).

$$L = \frac{V_s \times D}{f \times \Delta I} \quad (2)$$

$$L = \frac{I_a \times D}{f \times \Delta V} \quad (3)$$

$$L > D(1-D)R/2f \quad (4)$$

Where L is the inductor (H) and C is the capacitor (F) being used in the circuit, ΔI is the peak to peak ripple current of the inductor, R is the load resistance (Ω) and ΔV is the ripple voltage across the capacitor and f is the switching frequency (Hz).

2) *Design of PMDC motor:* PMDC motors are often used in electric vehicles because of their simple operation and low cost as compared to BLDC motors [4]. AC motors require an extra AC to DC converter for their operation, which is not required in the case of a PMDC machine. Hence the cost and complexity is reduced while using PMDC motors. PMDC motor can be modelled using the equations (5) - (8).

$$V = E_b + I_a \times R_a + L_a \times \frac{dI_a}{dt} \quad (5)$$

Where V is the terminal voltage of the machine, I_a is the armature current and R_a is the armature resistance, L_a is the armature inductance and E_b is the back emf of the machine. The mechanical equation of the motor is given by equation (6).

$$J \frac{d\omega}{dt} = T_e - T_l - B_m \times \omega - T_f \quad (6)$$

Where J is the inertia, B is the viscous friction coefficient, ω is the speed of the machine (rad/s), T_e is the electromechanical torque, T_l is the load torque and T_f is the Coulomb friction torque. Back emf (electromotive force, E_b) and torque (T_e) can be calculated using equations (7) and (8).

$$E_b = K_b \times \omega \quad (7)$$

$$T_e = K_t \times I_a \quad (8)$$

K_t and K_b are the voltage and torque constants respectively.

III- CONTROL STRATEGY

The demand for DC-DC converters is increasing at a very fast rate with the increase of battery operated devices. Electric vehicles also use such converters and their control is very important for the efficient working of the system. The boost converter has been operated in the closed loop mode with the help of PI Controller.

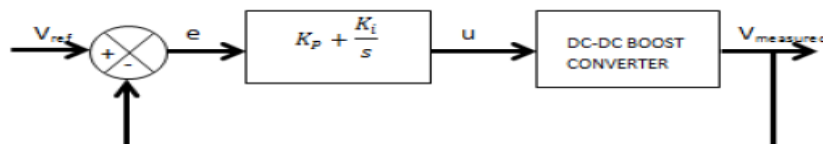


Fig. 3. Block diagram for PI control for boost converter

A PI controller is aimed for the DC to DC boost converter with PMDC motor as the load which is shown in Fig. 3. PI controller is considered for proper working of the converter during the transient period and to decrease the steady state error. The derivative term is not included because it results in oscillation of the duty cycle. The converter is designed using Ziegler–Nichols (ZN) controller tuning method. It is designed by setting the integral, K_i , and the derivative gain, K_d , to zero. The Simulink model for the DC/DC boost converter with PI controller is shown in Fig. 4.

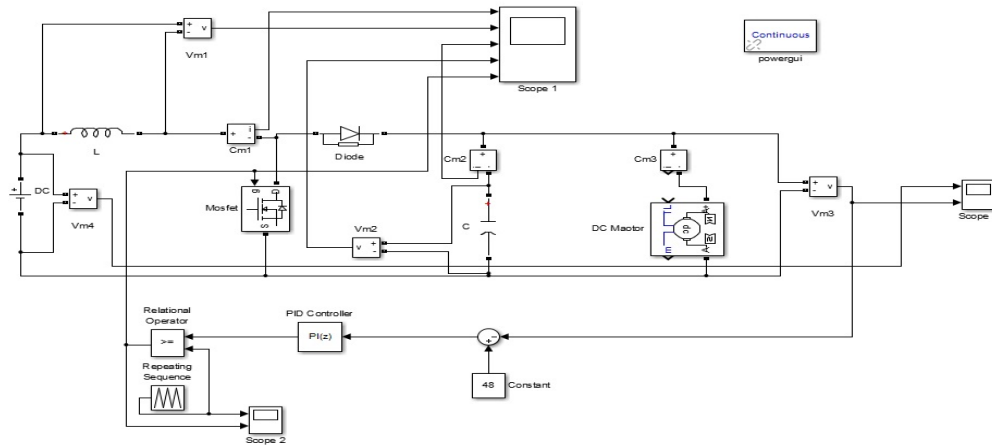


Fig. 4. Simulink model for PI controlled Boost converter.

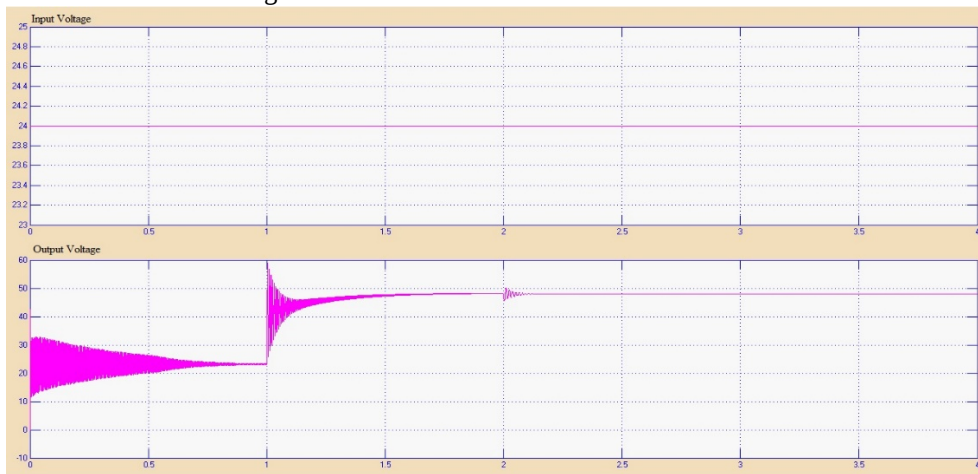


Fig. 5. Waveform of Scope 3 (For 24 Input Voltage)

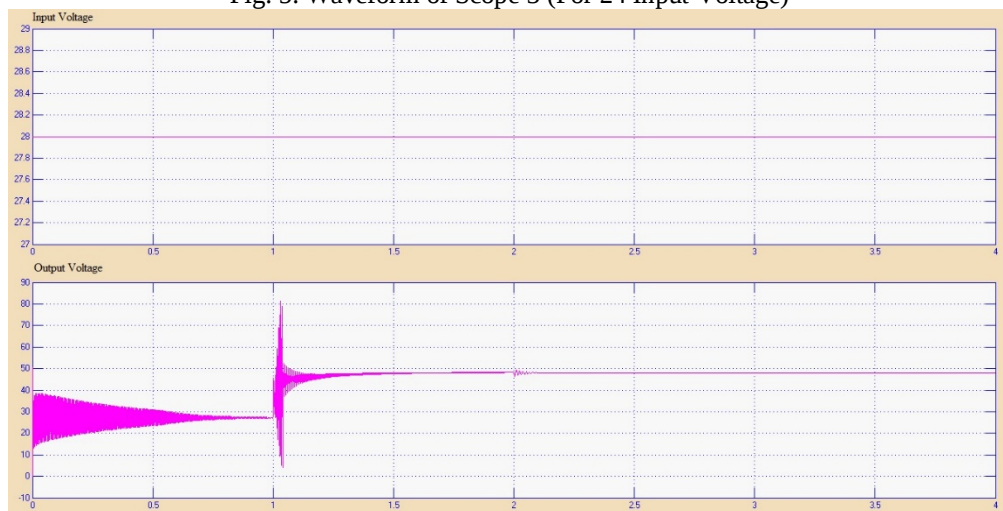


Fig. 6. Waveform of Scope 3 (For 28 Input Voltage)

IV- RESULTS AND DISCUSSIONS

Figure 4 is the closed loop of boost converter with PI controller and fig.5 and fig.6 are the waveforms of boost converter. When the input voltage is 24, we get 48 output voltage as shown in fig.5. and when the input voltage is 28, the output voltage is same as before 48 Voltage. So, with the change of input, output voltage is same 48 volts with the help of PI controller.

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