Design a DC to DC Boost Converter and Analysis the Performance of Converter in MATLAB

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Abstract
A DC-DC Boost converter Designed and analyzed the performance of the converter. The main objective is to design a DC-DC boost converter and compare the converter with a PID-controlled closed-loop DC to DC boost converter is to maintain a constant output voltage despite variations in source voltage. A simple PID controller has been applied to the designed Boost converter and simulated in MATLAB-Simulink environment showing voltage regulation. PID implementation of the converter maintains constant output voltage despite variation in input voltage and crucially reduces overshoot thereby improving the efficiency of the converter. The outcome of this work has the potential to add in a better way in electric vehicles, industry, communication and renewable energy sectors.

Keywords—*DC-DC converter, voltage regulation, Boost converter, overshoot, PID, stability.*

I. INTRODUCTION

Power Electronics revolt which over the past decade across the energy conversion, renewable energy system and automation sector. DC-DC converter plays an important role for energy conversion resulting in extensive implementation in LED driver, cellular phones, laptop computers, maximizing energy production for photovoltaic systems and for wind turbines, electric vehicles, hydro power plants and et cetera[1][2][3][4]. This application needed

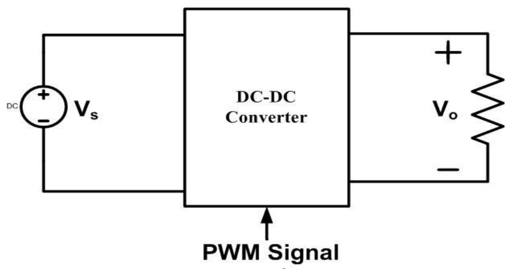

Fig. 1: Block Diagram of DC-DC converter

that the converter should gain highest efficiency, improved power factor (PF) at the load and also decreasing size and cost of the device and increasing availability[5][6][7][8].

DC-DC converter frequently known as a switched mode DC-DC converter as shown in Fig.1, either steps up or steps down the source voltage,Vs according to the specification of the load connected, by doing adjustments in the duty cycle applied to the switching device.

In a DC-DC converter it is always desirable that a constant output voltage, Vo is achieved despite changes in the source voltage, Vs the load current, Load and variations in element values of the converter circuit[9][10]. These disturbances can be originated from second harmonic periodic variations of an off - line power system generated from the rectifier circuit and applied to the DC-DC converter, variation of the source voltage Vs due to switching (on/off) of neighboring power system loads and variations in the load current, load amongst many. There are different types of DC to DC converters namely – Buck, Boost, Buck-Boost, Cuk, Sepic and Zeta. One of the most leading research interests in this time is the application of DC-DC converters with high step-up voltage gain.

Different control techniques have been proposed to make sure stability as well as fast transient response that is to say - Fuzz Logic controller, Artificial Neural Network (ANN), PID controller and PI controller. Various Optimization techniques such as Genetic Algorithm, Particle Swarm Optimization, and Bacterial Foraging Optimization have also been proposed[11][12][13][14].

Most widely used DC-DC converter is the Boost converter amongst all converters. A step up converter which impart a higher voltage at the load side, Vo compared to the source voltage Vs. Open loop mode of operation of Boost converter show substandard voltage regulation and unfortunates dynamic response. That's why loosed loop mode of operation is preferred for proper voltage regulation and performance improvement.

In this paper proper voltage regulation of Boost converter is achieved employing PID controller, tuned using trial and error method to find appropriate values for the proportional, integral and derivative gains, thereby improving converter performance. Section II of this paper share out the conventional Boost converter followed by a brief idea about PID Controller in Section III, and the simulation and results are presented by comparing the conventional Boost converter with the proposed or modified Boost converter with PID controller in section IV and finally discussed Conclusion in section V. The proposed circuit parameters, simulation and experimental results exhibit the effectiveness and feasibility of the prefer scheme.

II. CONVENTIONAL BOOST CONVERTER

A conventional DC-DC Boost converter is combination of a boost inductor, two semiconductors (a diode and a transistor) and an output capacitor in parallel with the load as shown in Fig.2

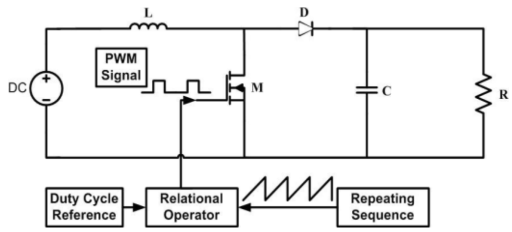

Fig. 2: Conventional Boost Converter

Boost converter is a converter which provides an output voltage that is greater than the input voltage. Input voltage use as a simple DC source such as a battery, solar panel or can be obtained directly from an AC source through a rectifier. The inductors try to resist current variations due to changes in the magnetic field is the key principle that drives the Boost converter. Boost converter is operating in two modes. The switching is achieved by using either a MOSFET or an IGBT. For low voltage applications MOSFET is preferred over IGBT due to its higher computational speed compared to IGBT. Modes of operation of Boost converter is as follows:

- Mode 1 begins at t=0s when the transistor is switched on. So, the rising input current to flow through the inductor L, storing energy in its magnetic field. During this mode of operation as shown in Fig. 3(a) the load side is completely isolated from the source side.

- Mode 2 begins at t = t1 when the transistor is switched off. Inductor, L produces a back emf having opposite polarity of the Mode 1 due to rapid drop in current. The voltage across the inductor and the source minus the small forward voltage drop across the diode, D charges the capacitor, C and also supplies the load. The conduction path is shown in Fig. 3(b).

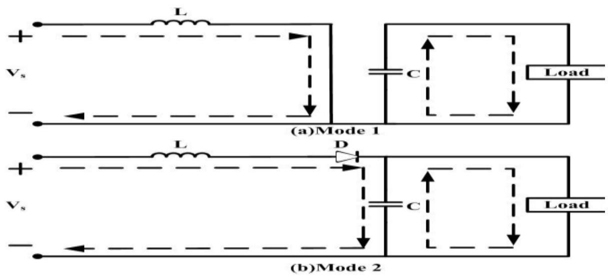

Fig. 3: Mode of operation of boost converter

Transistor switching period is given by

Mode 1 $T_{on}=DT_p$

Mode 2 $T_{off} = (1-D)T_P$ (1)

Voltage across the inductor,

Mode 1 $L\frac{di}{dt} = V_i$

Mode 2 $L\frac{di}{dt} = (V_i - V_o)$ (2)

Putting equation (1) in equation (2)

Mode 1 $L\frac{\Delta i}{DT_P} = V_i$

Mode 2 $L\frac{\Delta i}{(1-D)T_P} = V_0 - V_i$

Ripple current Δi is given by

Mode 1 $\Delta i_{on} = \frac{V_i D T_P}{L}$ (3)

Mode 2 $\Delta i_{off} = \frac{(1-D)(V_0 - V_i)T_P}{L}$ (4)

Equating the ripple current equation (3) and (4) of Mode 1 and Mode 2

$$\Delta i_{on} = \Delta i_{off}$$

$$V_i D = V_o - V_i - DV_o + DV_i$$

$$V_i = V_o - DV_o$$

$$V_i = V_o(1 - D)$$

$$\frac{V_o}{V_i} = \frac{1}{1 - D}$$

Where,

V_i Input voltage, V

V_o Output voltage, V

t_{on} MOSFET on, sec

t_{off} MOSFET off, sec

T_0 Switching Period, sec

D Duty cycle

Δi Ripple current

III. PID CONTROLLER

One of the simplest and most widely used controller for decades is the PID controller. PID stands for proportional (P), integral (I) and derivative (D) controller. Fig.4 shows the block diagram of a typical PID controller.

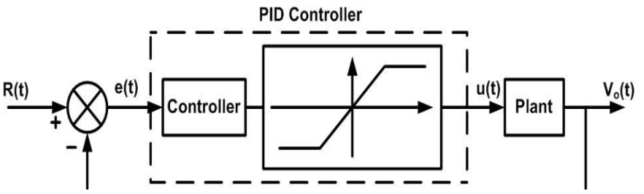

Fig. 4: Typical PID control Structure

The system under study is the plant to which necessary excitation is provided thereby achieving overall closed loop control effectively. A PID can be expressed as –

$$C(s) = \frac{K_D s^2 + K_p s + K_I}{s}$$

$$C(s) = K_P + \frac{K_P s}{s} + K_D s \qquad (6)$$

Where,

K_P Proportional gain
K_I Integral gain
K_D Derivative gain

The signal e(t) as shown in Fig. 4 represents the tracking error obtained from the difference between the reference signal which serves as the input R(t) and the actual output signal Vo(t). The tracking error is fed on to the PID controller which computes the derivative and integral of the signal provided. The output of the PID controller u (t) to be applied to the plant is equal to the proportional gain (K_P) times the magnitude of the error signal plus the integral gain (K_I) times the integral of the error signal plus the derivative gain (K_D) times the derivative of the error signal.

Time domain representation of the signal u (t) fed to the plant is given by –

$$u(t) = K_P e(t) + K_I \int e(t)dt + K_D \frac{de(t)}{dt} \qquad (7)$$

The plant on receiving the signal u (t) will generate a modified output $V_o(t)$ which will be again compared to the reference signal until the desired level is reached thereby forming a close loop system. Effect of proportional, integral and derivative control on close loop system is summarized in the Table I. provided below.

Table I: Effect on Close Loop System

	Rise Time	Overshoot	Setting Time	Steady State error
Proportional	Decrease	Increase	Small change	Decrease
Integral	Decrease	Increase	Increase	Eliminate
Derivative	Small Change	Increase	Decrease	Small Change

IV. RESULT AND SIMULATION

Simulation was done in MATLAB-Simulink environment. The parameters used for this simulation are given Table II. as shown below –

Table II: Simulation Parameters

Parameter	value
Input voltage	24V-44V
Output voltage	48V
Duty cycle	22kHz
Inductor	50uH
Capacitor	220uF
Load	20Ω
K_p	0
K_I	19
K_D	0

Conventional Boost converter as shown in Fig. 5, was simulated at 50% duty cycle and the output wave shapes observed for variations of input voltage from 24V – 44V with increment of 10V. It can be observed that the output voltage fluctuates with variation of input voltage by a large amount. Moreover the converter exhibits significant increase in overshoot as the input voltage varies as shown in Fig. 6, 7, 8.

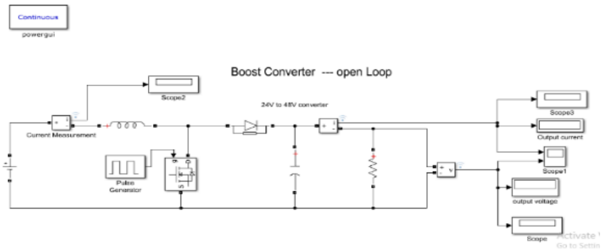

Fig. 5: MATLAB Simulink model of proposed converter

Table II: comparison between open loop and PID control close loop boost converter

	Open Loop Boost Converter		**PID Control Closed loop boost Converter**	
Input voltages	***Output voltage, V_o***	***Percentage Overshoot (%)***	***Output voltage, V_o***	***Percentage Overshoot (%)***
24	48.72	60.484	48.08	5.851
34	69.24	60.484	47.99	15.99
44	89.76	60.484	47.66	20.112

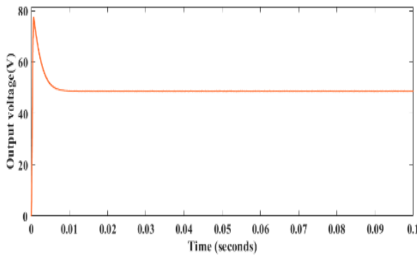

Fig. 6: Output voltage plot of proposed open loop boost converter operating at 50% duty cycle for input voltage 24 V.

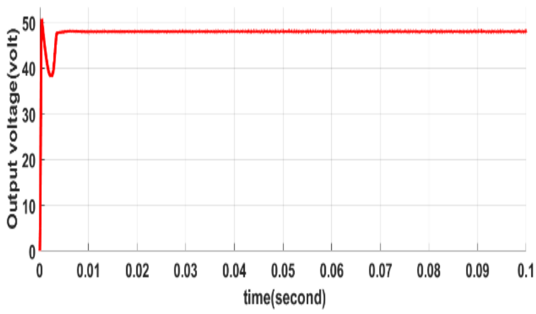

Fig. 10: Output voltage plot of boost converter with PID controller operating at 50% duty for input voltage 24V.

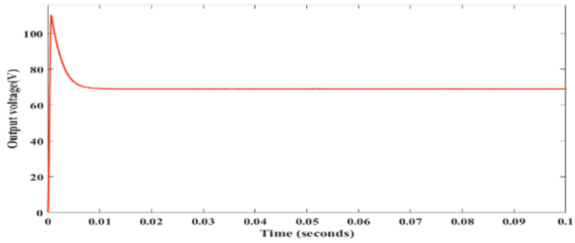

Fig. 7: Output voltage plot of proposed open loop boost converter operating at 50% duty cycle for input voltage 34 V.

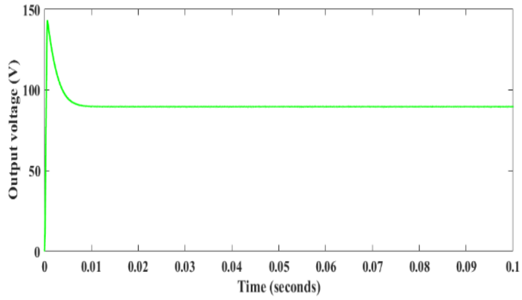

Fig. 8: Output voltage plot of proposed open loop boost converter operating at 50% duty cycle for input voltage 44 V.

Simulation data obtained as shown in Table III was plotted in MATLAB and comparison was done between proposed boost converter and PID control close loop Boost converter in terms of output voltage.

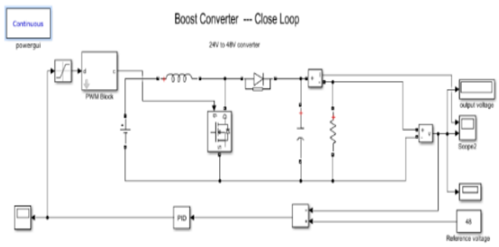

Fig. 9: MATLAB Simulink model of PID control closed loop boost converter.

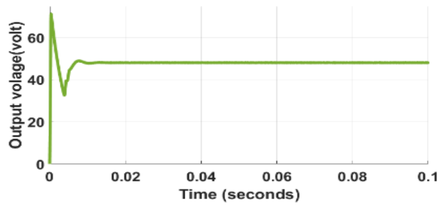

Fig. 11: Output voltage plot of boost converter with PID controller operating at 50% duty for input voltage 34V.

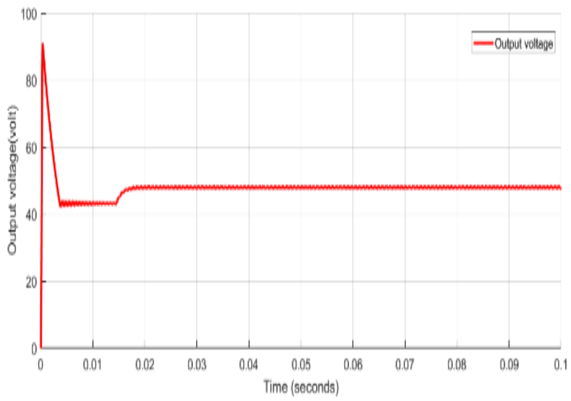

Fig. 12: Output voltage plot of boost converter with PID controller operating at 50% duty for input voltage 44V.

Fig. 9 show the PID control closed loop boost converter in MATLAB Simulink model. Simulation results show that the proposed PID controlled closed loop when used with Boost converter provides better output voltage regulation and overshoot reduction shown in fig.10, 11, 12, thereby improving the performance of the system.

V. CONCLUSION

The proposed DC to DC Boost converter with PID controller provides better voltage regulation, overshoots reduction and improves the converter performance compared to the conventional Boost converter. Where open loop boost converter percentage of overshoot was 60.484 but PID control closed loop boost converter percentage overshoot 5.851. This paper successfully provides a method to satisfy the objective of DC-DC converter to maintain a constant output voltage 48 at the load side. The proposed circuit is simple, easy to understand and can be implemented with no additional components thereby keeping size and cost of manufacturing the converter within considerable range.

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