

Sliding mode Controller & Conventional Controller for Boost Converter

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Abstract— the Design and simulation of Boost converter using pulse width modulation operating in continuous conduction mode is discussed in this paper. The performance and properties of sliding mode controller of Boost Converter is compared with conventional controller i.e. Proportional Integral (PI) controller. The derived controller/converter system is feasible for step up/boosting purposes, as it is exposed to significant variations and input changes.

Index Terms: Boost converter (DC-DC), Pulse width modulation, PI Controller, sliding mode controller. (Keywords)

I. INTRODUCTION

DC-DC converter converts sources of direct current (DC) from one voltage to another voltage. There are six basic DC-DC converters. Buck, boost, buck-boost, cuk, Sepic, & zeta. DC-DC converters are nonlinear system, hence they represent a big challenge for control system. Boost converter converts an input (DC) voltage to higher output (DC) voltage by changing the duty cycle of the main switches in the Boost converter circuit. Boost converter circuits are used in battery powered devices, where the circuit requires a higher output voltage than the input voltage, e.g. laptops, mobile phones & battery powered vehicles. So, control of Boost converter is more difficult than buck converter, where output voltage is less than input voltage. Control of boost converter is difficult as control input appears in voltage as well as current equations.[1]

Although the boost converter is open-loop stable its convergence to an equilibrium point may be too slow for most practical applications. Hence, the control objectives are to increase speed of convergence and to make the system robust under load and input voltage variations. Such objectives are not easy to achieve because the circuit is a nonlinear. [4].

Pulse Width Modulation (PWM) is a modulation technique that conforms the width of a pulse, formally the pulse duration, based on a modulator signal information. The average value of voltage (or current) fed to the load is controlled by turning the switch between supply and load. The longer the switch is on compared to the off periods, the power supplied to the load is high. Advantage of PWM is that power loss in switching devices is very low, since when a switch is off practically there is no current, and when it is on, there is no voltage drop across switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM has also been used in communication systems, motor drives for fans, pumps robotic servos, electric stoves and lamp dimmers.

Sliding Mode Control or SMC is a nonlinear method of control. It alters the dynamics of any nonlinear system by application of a discontinuous control signal. State feedback control law is a discontinuous function of time. Hence it switches from one continuous structure to another. Hence sliding mode control is a variable structure control method. Discontinuous signal forces the system to slide along cross section of the system's normal behaviour. The multiple control structures are designed so that trajectories always move toward adjacent region with a different control structure so, ultimate trajectory will not exist entirely within one control structure, but it will slide along the boundaries of control structures. The motion of system that slides along the boundaries is called sliding mode and geometrical locus consisting of the boundaries is called sliding surface.

II. MATHEMATICAL MODEL OF DC-DC BOOST CONVERTER

The basic principle of a Boost converter consists of 2 distinct states (Fig. 1)

- In the On-state, the switch S (Fig. 1) is closed, resulting in an increase in the inductor current.
- In the Off-state, the switch is open and the only path offered to inductor current is through the fly back diode D, the capacitor C and the load R. This results in transferring the energy accumulated during the On-state into the capacitor.
- The input current is the same as the inductor current, So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter.

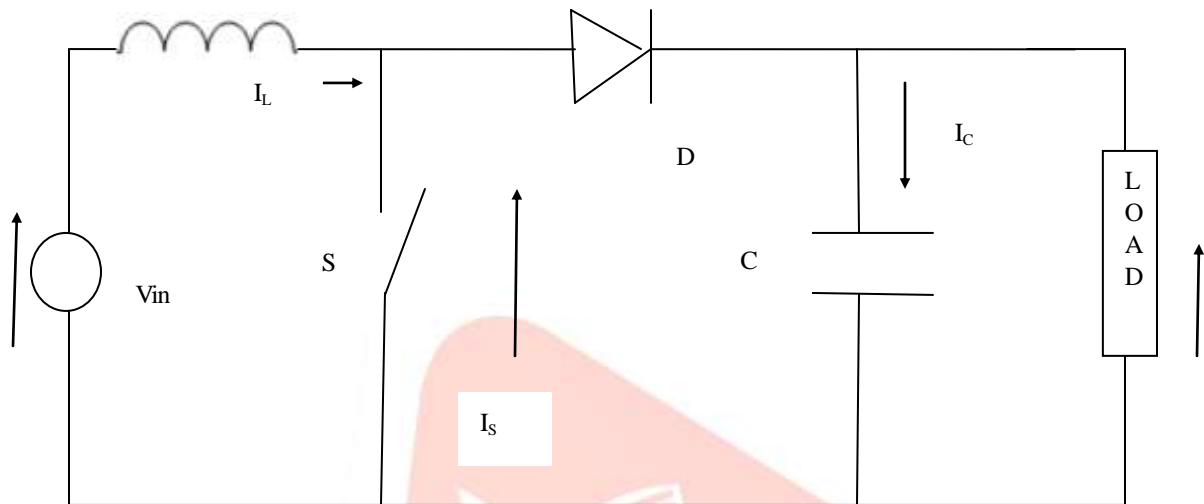


Fig.1

The duty cycle, for continuous conduction mode:

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

From the above expression it can be seen that the output voltage is always higher than the input voltage (as the duty cycle goes from 0 to 1), and that it increases with D, theoretically to infinity as D approaches 1. This is why this converter is sometimes referred to as a step-up converter.

III. MATHEMATICAL MODEL OF PULSE WIDTH MODULATOR

We know, T_{ON} is the time for which output is high and T_{OFF} is the time for which output is low. Let, T_{total} be time period of waveform, such that,

Duty cycle of a square wave is defined as,

$$D = \frac{T_{on}}{(T_{on} + T_{off})} = \frac{T_{on}}{T_{total}} \tag{3.2}$$

The output voltage varies with duty cycle as,

$$V_{out} = D \times V_{in} \tag{3.3}$$

Therefore,

$$V_{out} = \frac{T_{on}}{T_{total}} \times V_{in} \tag{3.4}$$

So, we can see from equation (3.4) the output voltage can be directly varied by varying the T_{ON} value.

If T_{on} is 0, V_{out} is also 0 and if the T_{on} is T_{total} then V_{out} is V_{in} or maximum. This was about theory behind PWM.

IV. SLIDING MODE CONTROL

In control theory, sliding mode control, or SMC, is a nonlinear control method that alters the dynamics of a nonlinear system by application of a discontinuous control signal that forces the system to "slide" along a cross-section of the system's normal behavior. The state-feedback control law is not a continuous function of time. Instead, it can switch from one continuous structure to another based on the current position in the state space. Hence, sliding mode control is a variable structure control method. The multiple control structures are designed so that trajectories always move toward an adjacent region with a different control structure, and so the ultimate trajectory will not exist entirely within one control structure. Instead, it will slide along the boundaries of the control structures.

Several systematic approaches for the synthesis of nonlinear sliding surfaces with suitable stabilizing properties have been investigated, using nonlinear control techniques. Sliding mode control via feedback linearization, extended linearization, and other nonlinear control methods is just a short list of examples. In those cases, the sliding surfaces are composed of nonlinear functions, which, in turn, depend on the input voltage, the load, and circuit parameters. [14].

There are some problems to be solved, such as chattering phenomena, non constant switching frequency, etc, when conventional SMC (CSMC) is used in the power converters. [15].

V. MODELLING AND SIMULATION RESULTS

Fig 1. Voltage measurement for SMC and PI controller :

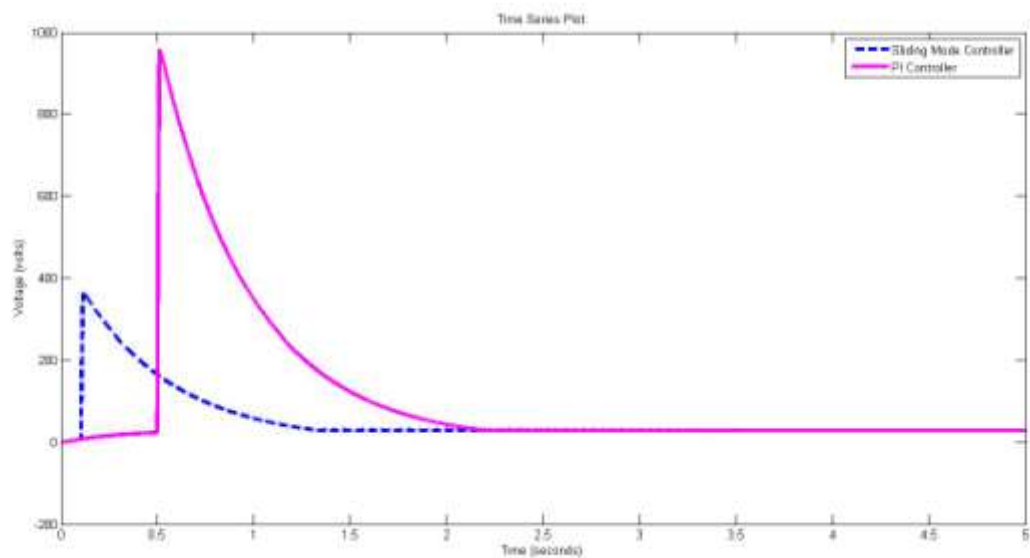


Fig 2. Current measurement for SMC and PI controller

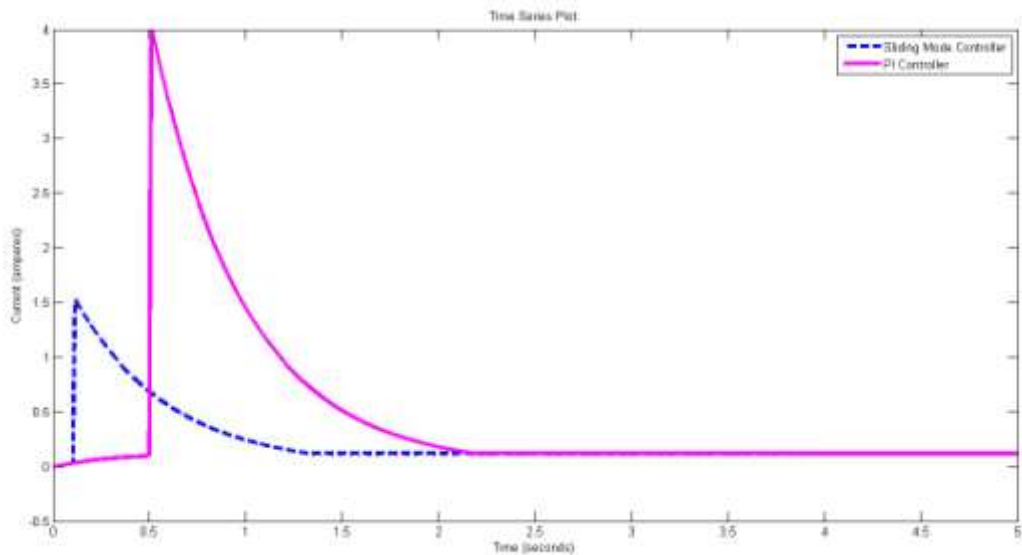


TABLE V.I: COMPARISON BETWEEN OPEN LOOP RESPONSE, SLIDING MODE CONTROLLER AND PI CONTROLLER

<i>CONTROLLER</i>	<i>VOLTAGE PROFILE</i>	<i>SETTLING TIME</i>	<i>CURRENT PROFILE</i>
Sliding mode controller	30V with linearity	0.01sec	0.1A
PI controller	31v with linearity	0.2sec	0.1A

VI. CONCLUSION

A comparison between sliding mode controller and PI controller is to be evaluated under internal losses and input voltage variation. Sliding mode controller and PI controller have same overshoot voltage but only difference is that PI controller has more voltage drop than sliding mode. PI controller has maximum settling time as compared to Sliding mode controller. In this presented work, modeling of a Boost Converter has been successfully done.

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