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Implementation of Various Control Techniques in DC-DC *Convertors*

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A B S T R A C T

The widespread usage of automobiles has led to and continues to lead to major environmental and human health issues. The rapid depletion of the world's petroleum reserves, air pollution, and global warming are now major issues. Electric vehicles (Electric vehicles (evs), hybrid vehicles (Electric vehicles (evs), and fuel - cell vehicles (Fuel cell electric) are all suggested as possible alternatives for traditional automobiles in the future (FCEVs). As EV technology improves, power electronic converters become increasingly common. DC-DC converters (including buck, boost, and bidirectional) are commonly used in electric vehicles, micro - grids, and other renewables and energy storage systems. Effective operation of these converters is dependent on their switching management. A converter can be run with either an open-loop control or even a closed - loop control control. One of the main challenges in regulating the power output of a converter is sustaining an appropriate voltage output regardless of changes in the demand and parameter uncertainty. Due to the unregulated nature of the voltage and current source, these converters also have their limitations. To deal with these complications, various control mechanisms are used in combination with the converters. A few examples of common control strategies include voltage mode controls (VMC), current mode controls (CMC), proportional- integral-derivative (PID), sliding control technique (SM), and fuzzy logic control. A DC- DC converters can be designed and simulated in MATLAB/Simulink to fix these problems. Using the control algorithms yields good performance and resilience, as shown by simulation results.

Keywords:DC-DC converter, Voltage and Current mode control, Sliding mode control.

1. Introduction

One of the most fundamental pieces of power electronics hardware is the switched-mode dc-dc converter. In electrical circuits, switches are used to change the effect of one voltage level to another. These converters are becoming more used in a number of different industries. This is a result of the many applications they have, such as in office supplies, personal computer power supplies and apparatuses, communications apparatuses, DC motor drives, appliance control apparatuses, aero planes, and vehicles, among others.[1] It is essential to regulate, stabilise, and analyse switching converters. Although switching power dc-dc converters could be controlled in a number of different ways, the vast majority of industrial as well as high-performance applications that demand only the most fundamental, least expensive controller architecture. The particular control system has advantages and disadvantages depending on the constraint. Consider this control method to be a good one to apply when certain conditions are present in contrast to other control methods. Under every circumstance, persistent demand is the method of control that works the best. Dc-Dc converters frequently use pulse width modulation as a control method. A controller based on proportional integral (PI) and proportional - integral - derivative (PID) is used for both pulse width modulation (PWM) current mode control and Voltage mode control (PID). P, PI, as well as PID are still only a few examples of conventional control methods that can fail to deliver desirable results. if there is a lot of variation in a load or a parameter [2]. Therefore, nonlinear controllers are required. Image of a DC/DC converter's control panel. One of the benefits of these nonlinear systems is that they can respond rapidly to a transient situation. Many kinds of nonlinear controllers exist, including those based on hysteresis, sliding mode, boundary conditions, and others. Nonetheless, the bare bones must be in place. When attempting to regulate hysteresis, it is important to think about things like the switching frequency of the system in use and how stable it is. In order to control dc-dc converter, that are non-linear but time-variant systems that don't respond well to linear control theory, sliding-mode (SM) controlled, which would be developed from nonlinear system control systems approach, may be utilised (VSCS). [3] Systems with variable structure are those whose physical structures vary over time in accordance with the rule of structure control. The system's present state determines the circumstances in which the structure changes. Switched-mode power supply (SMPS) are often changeable structured systems since switching action is present in them. Therefore, SM controllers are employed to manage dc-dc converters.

2. NEED OF CONTROLLER

Dc-dc converters typically use a variety of control methods, including voltage mode control and current mode control with proportional (P), proportional integral (PI), but also proportional - integral - derivative (PID) controllers. When there is a large amount of volatility with in load or parameters, conventional control systems like P, PI, and PID fail to produce desirable outcomes.1] To control dc-dc converters, nonlinear controllers are thus necessary. These nonlinear controllers' capacity for quick response to changing conditions is one of their advantages. Sliding mode, boundary, and hysteresis controllers are a few examples of the several nonlinear controller types.

2.1. BOOST CONVERTER

For DC-DC voltage conversion, a "Boost Converter" is one whose output voltage is greater than its input. Capacitors as well as inductors are used in filters first at converter's output terminals to smooth out the voltage and current. [4] Two distinct states serve as the basic operational notion for the converter. When the power is on, the switch is in its closed position, which boosts the inductor's current. When one of the two is disabled as well as the switch is opened, the current through the inductor drops. The boost converter is a particular type of direct current to direct current converter. Figure.2.3 depicts the components of a standard boost converter, including the inductor, switch device, diodes, capacitors, loads, and switch device gate signal. A convertor with a controller is used in electric vehicle (EV) design to produce maximum power in varying environmental circumstances while keeping the voltage constant across the load. [5] By turning on and off a MOSFET, the inductor's stored current can be used to power a load connected to the diode. Large capacitors maintain a constant and stable voltage at the output.

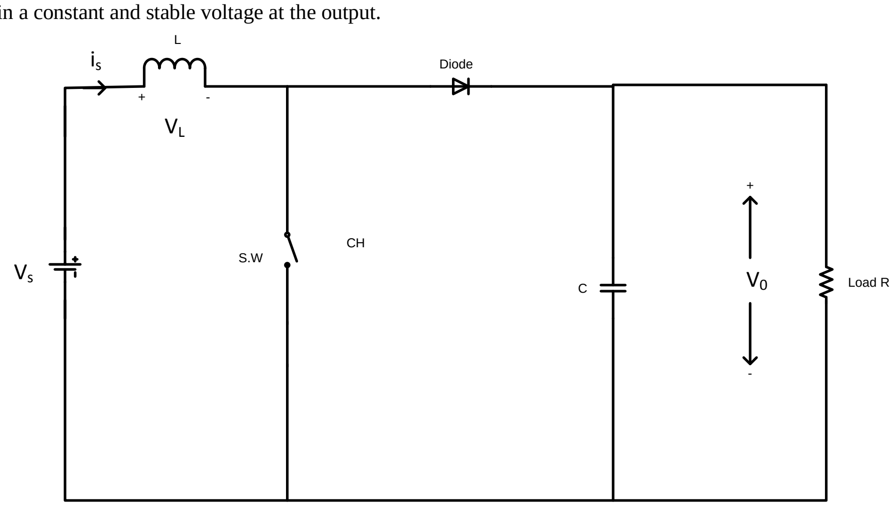


Fig. 1 - Boost DC- DC Converter

During ON condition the state equations are

$$V_{in} = V_l$$

, 0<t<DT

$$\frac{di_l}{dt} = \frac{\Delta i_l}{\Delta t} = \frac{\Delta i_l}{DT} = \frac{V_{in}}{L}$$

During OFF condition the state equations are:

$$V_l = L\frac{di_l}{dt} = V_{in} - V_o$$

$$V_{in} = V_l + V_o$$

, DT<t<T

$$\frac{di_l}{dt} = \frac{\Delta i_l}{\Delta t} = \frac{\Delta i_l}{(1-D)T} = \frac{V_{in}-V_o}{L}$$

Where 'D' stands for duty cycle of the pulses fed to the converter switch.

$$D = \frac{V_0 - V_{in}}{V_0}$$

Where, 'D' is the duty cycle of the pulse,

'ton' is the time, for which the pulse is high in (secs),

'T' is the period of the pulse in (secs).

2.2. SLIDING MODE CONTROL

First, a sliding surface is created in state space; then, using a control law, a trajectory is created that takes the system's state from some arbitrarily defined initial state to the sliding in a finite amount of time; and finally, the trajectory is brought to the phase plane's origin, where the system is in equilibrium. [1] The process can be broken down into two stages: the reaching stage and the sliding stage.

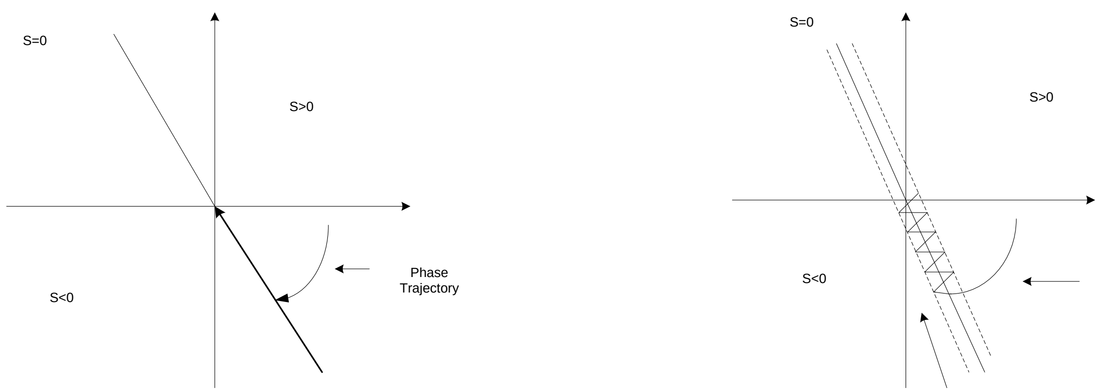


Fig 2: Sliding Phase and Reaching Phase

Due to its robust design, sliding mode control (SMC) can withstand parameter variations, nonlinear models, external disturbances, and uncertainty with relative ease. For automotive applications, it is used when the resilience requirement is of greatest priority and there are many unknowns. The reaching law technique is used on a novel nonlinear sliding surface to achieve low chattering and steady-state inaccuracy.

3. CONTROLLER DESIGN

3.1 System Modelling

The first stage in building an SM controller is to create a state-space representation of a converters model in terms of the required control variables (including such voltages and/or current, etc.). This study investigates the feasibility of Sm control for CCM-based converters. The PID SM voltage controller of second order is being studied in detail. [1] Unlike most other proposed SM voltage controllers, it reduces the steady-state dc errors of the relevant SM controlled system by including an additional voltages error integral component in the control computation. Two distinct states serve as the basic operational notion for the converter. When the power is on, the switch is in its closed position, which boosts the inductor's current. When one of the two is disabled as well as the switch is opened, the current through the inductor drops. A boosted converter is a specific kind of direct current to direct current converter. [6] Figure.2.3 depicts the components of a standard boost converter, including the inductance, switching devices, diodes, capacitors, loads, and switching device switching cycle. A convertor with a controller is used in electric vehicle (EV) design to produce maximum power in varying environmental circumstances while keepingvoltage stable across the load.

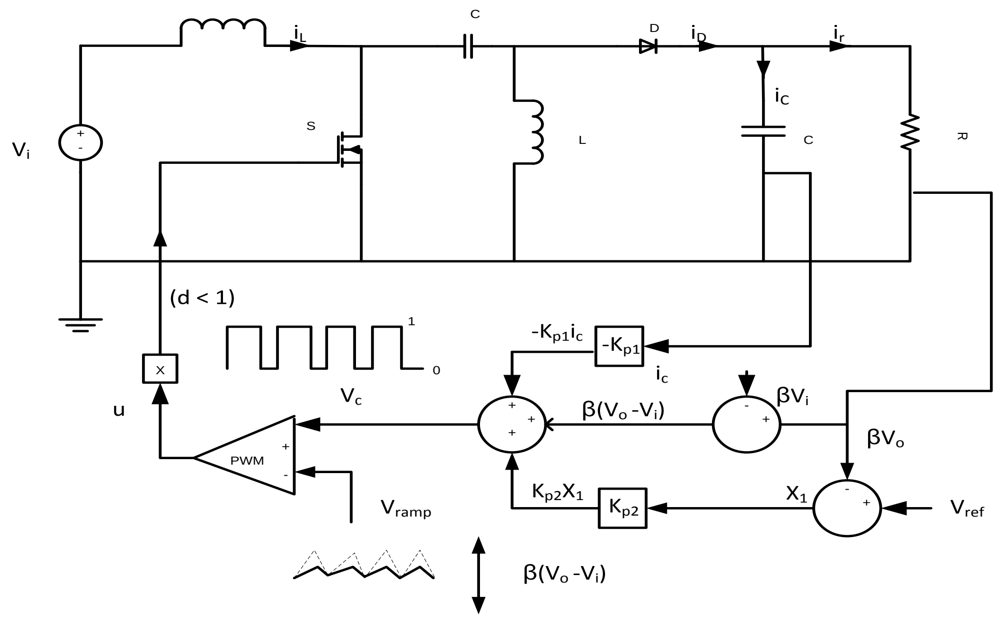


Fig 3: Sliding Mode Control of Boost Converter

In this article, we describe the boost in terms of its states in state space. This converter employs SM control with output voltage as the control parameter. The cyclical nature of errors and the cyclical nature of voltage errors are presented.[7]

Under continuous conduction mode the control variable x may be denoted by

$$x = \begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix} = \begin{bmatrix} V_{ref} - \beta v_0 \\ \dfrac{d(V_{ref} - \beta v_0)}{dt} \\ \int V_{ref} - \beta v_0 \end{bmatrix}$$

$$\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \\ \dot{x_3} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & \dfrac{-1}{r_l C} & 0 \\ 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ \dfrac{v_{0\beta}}{LC} - \dfrac{v_i \beta}{LC} \\ 0 \end{bmatrix} \bar{u}$$

Here $\bar{u} = 1 - u$ is inverse logic of u particularly designed for modelling Boost converter.

$\dot{x}$=Ax+Bv+D

Where $v = u \; or \; \bar{u}$.

3.2 Design of sliding Mode Control

After getting the state-space descriptions, the controller design can begin. Systems of this type can benefit from a standard SM control method that uses a switching function, such as

$$u = \begin{cases} 1, when\ S > 0 \\ 0, when\ S < 0 \end{cases}$$

S is an instantaneous state variable trajectory.

$$S = \alpha 1 x1 + \alpha 2 x2 + \alpha 3 x3 = J^T x$$

$$J^T = [\alpha 1 \quad \alpha 2 \quad \alpha 3]$$

where $\alpha 1$, $\alpha 2$ and $\alpha 3$ are the sliding coefficient parameters.

The reachability criterion must hold if sliding-mode operation is to exist.

$$\lim_{\mathbf{S}\to 0} \mathbf{S}.\mathbf{S}^{\cdot} < 0$$

The sliding surface controller of boost converter after all the conditions are substituted

The controlled voltage source equation

$$\boldsymbol{v_c = -K_{p1} i_c + K_{p2}\left(V_{ref} - \beta V_0\right) + \beta(V_0 - V_i)}$$

The ramp voltage equation

$\boldsymbol{V_{ramp}} = \boldsymbol{\beta(V_0 - V_i)}$

Picking the Sliding coefficients to achieve the required dynamics. For example, we show that the equation connecting the slide coefficients to the converter's dynamic response during SM operation is trivial to find. [1] This results in such a linear equation with under-damped, overdamped, and over-damped responses. The settling time s (1% criteria) of an under-damped response converter can be adjusted by varying the value of, the time constant of the system.

$$\boldsymbol{\frac{\alpha 1}{\alpha 2} = \frac{10}{T_s}}$$

$$\boldsymbol{\frac{\alpha 3}{\alpha 2} = \frac{25}{\zeta^2 T_s^2}}$$

Achieved by adjusting the aforementioned equations, and the appropriate damped ratio

$$\boldsymbol{\zeta = \sqrt{\frac{\left[Ln\left(\frac{Mp}{100}\right)\right]^2}{\pi^2 + \left[Ln\left(\frac{Mp}{100}\right)\right]^2}}}$$

By substituting the values of **L, C** and $\boldsymbol{r_l}$values, we obtain the $\boldsymbol{K_{p1}}$and $\boldsymbol{K_{p2}}$ as **0.12***$\boldsymbol{\beta}$and **2.7.**

$$\boldsymbol{K_{p1} = \beta L\left(\frac{\alpha 1}{\alpha 2} - \frac{1}{r_l C}\right)}$$

$$\boldsymbol{K_{p2} = \frac{\alpha 3}{\alpha 2} LC}$$

where the $\boldsymbol{K_{p1}}$and $\boldsymbol{K_{p2}}$are control parameters

$$\boldsymbol{\beta = \frac{V_{ref}}{V_{out}}}$$

Where $\boldsymbol{\beta}$ is feedback divider ratio in above equations.

4.Results and conclusion:

4.1. Results:

The final Sliding Mode Control for Boost Converter Simulink block is depicted in Fig. 2. This system's results for a host of parameters, including voltage and current, were acquired while the load varied across a wide range.

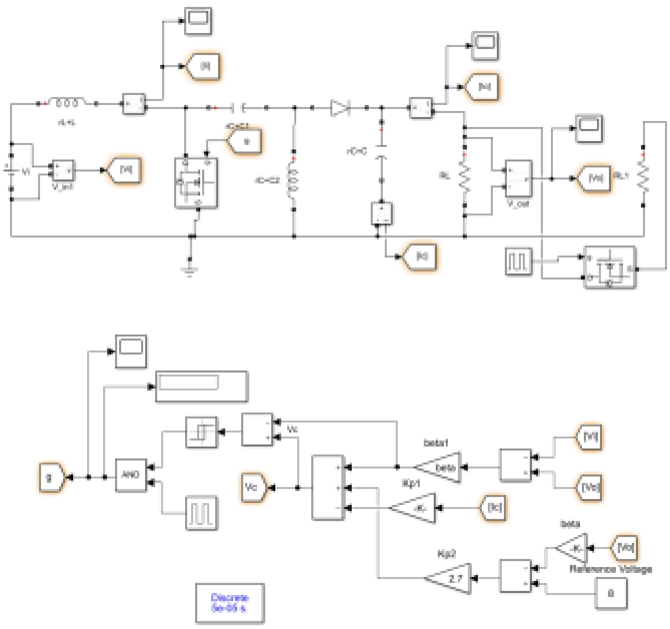
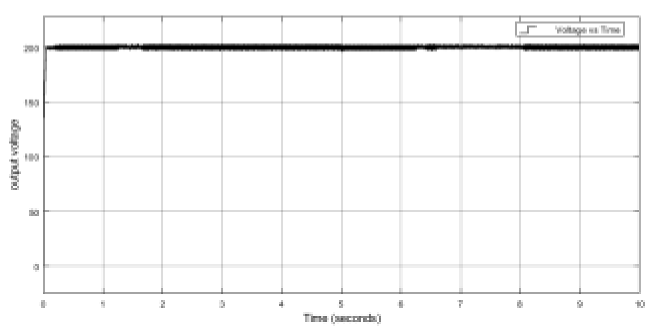


Fig 3: Simulink block of Sliding Mode Control of Boost Converter



5.2. Conclusion:

In this project, MATLAB/SIMULINK was used to model and simulate a Boost converter's control. With the suggested Boost Converter, the system's controllability over a broad spectrum can be fine-tuned with the help of a Controller and the duty ratios of the converters. The controller's stability, dependability, and good performance during load variation simulations with improved efficiency.

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