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Sliding Mode Controller with Modified Sliding Function of Buck Converter Dc-Dc

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Abstract: The dc-dc buck converter is some of the most widely used power electronics circuits for its high conversion efficiency and flexible output voltage. These converter used for an electronic device are designed to regulate the output voltage against the change of the input voltage and load current. This leads to the requirement of more advanced control method to meet the real demand. The controller offers advantage such as fixed switching frequency and zero steady state error and give a better small signal performance at the designed operating point but under large parameter and load variation their performance degrades so sliding mode control technique are well suited to dc-dc converter as they are inherently variable structure system .SM controlled converter generally suffer from switching frequency variation when the input voltage and output load are varied. A comparison of the effect of PWM controller and SM control of the dc-dc buck converter response in the steady state under line variation and load variation is performed. The comparison with the PWM controller the SM control provides better steady state response, better dynamic response, and robustness against system uncertainty disturbance. The converter with conventional sliding mode results in steady state error in load voltage.

***Keywords:** SMC, PWM, MSMF, PEC, ROE.*

1. INTRODUCTION

Buck converter is also as step down converter is used to reduce the high voltage to the low voltage with required input. The modeling and control technique available in wide variety of literature [1, 2] EMS transforms electrical into mechanical. When electrical is neglected it deals with delay. When electrical is not neglected it deals with smooth. Cuk [3] the unified switching converter has two power stages start and end point. In this input and output was fixed action taken as per poles and zeros. [5] One cycle control has no steady state and dynamic error it depends on state current which is equal or proportional. The voltage regulation of pulse width modulation (PWM) based DC-DC switching converter is discussed in [6] it mainly focus on voltage regulation by using signal processing system and power processing system. The SMC is applied to the various PEC and electromechanical system [6, 7]. The analysis and experimentation of DC. AC boost converter with SMC. In this ac output, large than DC input but VSI produces AC output lower than DC output [8,9] presented design. The SMC of DC-DC available in [10] with graphical and analytical explanations maintaining current limitation and constant switching frequency and output voltage here steady state error is cancelled. Mainly [11] proposed fixed frequency hysteresis controller uses both sliding mode control and in fixed frequency. In [12] and [13] here current limit condition is used were the steady state is reduced by zero. That has described SMC based technique for control of PECS. Has a [14] suggested the adaptive terminal SMC for DC-DC buck converter the modified sliding function not only overcomes the limitation in conventional sliding mode. But it improves the performance of converter with additional tuning parameters. The proposed SMC with the two tunaing parameters proved to be better in the sense that one of them can be adjusted according to the load variations and the other is adjusted according to the required speed response of the system. The converter with modified sliding function based SMC is evaluated through analysis, Simulation, and experimentation. The analysis is carried out to prove stability in the ROE of sliding mode and to guarantee to reach mode in other the mathematical model of DC-DC buck converter is briefly explained the main contribution i.e. the modified sliding function is proposed followed by ROE and stability. The simulation and experimental result are discussed respectively.

2. MATHAMATICAL MODELLING

A Sliding Mode Voltage Controlled (SMVC) DC-DC Buck Converter model is derived using state space approach. A mathematical model of DC-DC Buck Converter in open loop can be derived using basic circuit analysis laws. The converter is with the purely resistive load whose output voltage is to be controlled with SMC. The converter is assumed to be operated in continuous current conduction mode [21]. Let $\beta = [(R2/R1) - R1]$ the voltage divider ratio. The value R1 Or R2 and are very high compared to the load resistor to avoid loading effect. If Vref is a reference voltage $\mu = \beta Vref$ is the scaled down version of reference voltage L is an inductor, C is a capacitor, D is the freewheeling diode, Vo is the output or load voltage, Vi is the input voltage rL is the load resistance. The SW is an n channel MOSFET switch turned ON or OFF with the output of SM controller which is in the form of a pulse .Nothing that u=1 means SW is closed and u=0 means SW is opened the state space model of the electrical system can be derived by defining the state

$$X1 = vu - \beta vo \qquad \ldots\ldots (1)$$

$$x2 = x1 \qquad \ldots\ldots (2)$$

From eqn (2)

$$x2 = -\beta \frac{dvo}{dt} = -\frac{\beta}{c} ic$$

Where ic is the capacitor current which can be measured.Let il and ir be the inductor current and load current respectively.
The eqn for,

$$X2 = \frac{\beta}{c}[il - i0] \qquad \ldots\ldots (3)$$

Let the voltage drop across inductor VL was given by

$$iL = (Uvi - Vo) = L\frac{dil}{dt}$$

$$iL = \int Uvl - \frac{vo}{l} dt$$

So Eqn (3)

$$x2 = x1 = \frac{\beta}{c}\{\frac{vo}{r1} - \int Uvi - \frac{vo}{l} dt\} \qquad \ldots\ldots.. (4)$$

Hence,

$$x2 = \frac{1}{LC} x1 - \frac{1}{r1c} x2 - \beta \frac{v1}{RCu} + \frac{vp}{RC} \qquad \ldots\ldots. (5)$$

From eqn (2) & (5) the state space model of the buck converter system is obtained.

2.1 Sliding mode control

Let the sliding function S which establishes linear relationship among state be defined as,

$$S = ax1 + x2 = jx \qquad \ldots\ldots\ldots\ldots\ldots..(6)$$

Where,

$$J = [\alpha, 1] \text{ state vector} \qquad \ldots\ldots\ldots\ldots.(7)$$

$X = [x1, x2]^T$ α is a scalar and it controls the first order dynamics of Eqn (7) .By reducing the value of α one can slow down the reaching mode dynamics.
The sliding mode control law can be defined as per the following rule:

$$U = \{1 = ON, S > 0 \quad 0 = OFF, S < 0\} \qquad \ldots\ldots\ldots (8)$$

The above control law Eqn (8) will trigger the switching across the sliding manifold S.

$$U = \{1 = ON, S > \varepsilon \quad 0 = OFF, S < -\varepsilon\} \qquad \ldots\ldots\ldots (9)$$

Where ε is a small positive number. The existence of sliding mode requires the following two condition to be satisfied (1) from Eqn (6), (7), (8) and (9)
Where,

$$\{B1 = jx \text{ for } 0 < s < \varepsilon \quad B2 = jx \text{ for } -\varepsilon < s < 0\} \qquad \ldots\ldots\ldots\ldots(10)$$

The region of existence (ROE) of sliding mode on the phase plane is the region where the condition $S < 0$ is satisfied.

The equation is satisfied in three lines $B1 = 0, B2 = 0, S = 0$ on the phase plane. There are two possibilities $\alpha > 1/\eta c$ and $\alpha < 1/\eta$. The slope of line $B1 = 0$, $B2 = 0$ change due to the variation in r1.This imposes a limitation on the dynamic behavior of the system as α. Determines the speed of the response.

3. PROPOSED SYSTEM

3.1Modified sliding function

Sliding mode control is well known for its good dynamic response and stability due to its insensitive for parameters change and easier in implementation, so this control technique is used extensively for the control of dc-dc buck converter. Here the state space description of the buck converter under SM voltage control, where the control parameters are the output voltage error and the voltage error dynamics is described. The steady-state switching frequency of sliding mode controlled dc-dc converters is generally affected by line and load variation. For line variation, an adaptive feed forward control that varies the hysteresis band in the hysteresis modulator of the SM controller in the event of any change of the line input voltage and for load variation.

3.2 Performance analysis

i) Stability and equivalent control law

Here the following condition must be satisfied for the sliding mode control to existing the following condition must be satisfied.

ii) Switching frequency

Practically there is physical limitation of the switching elements hence there exists upper limit in the switching frequency of the converter. Let the dead zone in the switching element be represented by small positive number ε .

iii) Steady state performance

Exact analysis of steady state error is complicated due to the presence of switching elements. The proposed control law in term of steady state performance. Hence , The proposed sliding function $E = 0$ can lead to zero steady state error compared to the case of conventional sliding function $S = 0$ which gives small but non zero steady state error.

4. IMPLEMENTATION OF DC-DC BUCK CONVERTER WITH SMC

Buck converter is a step down DC-DC converter. Due to its attractive features like compact size and high efficiency, these converters are commonly used in various control applications. The basic operation of the buck converter has the current in an inductor controlled by two switches (usually a transistor and a diode).Buck Converter is a time variable and a nonlinear switch circuit which possesses variable structure features. Sliding mode control is well known for its good dynamic response and stability due to its insensitive for parameters change and easier in implementation, so this control technique is used extensively for the control of dc-dc power converters. This section explains about the implementation to reduce steady state error based SM controller for a dc-dc buck converter. The modified sliding mode controller is well suited to reduce the steady state error in the load voltage. A typical SM controller for switching power converters has two control modes: voltage mode and current mode. Here, voltage mode control is employed, i.e. output voltage, is the parameter to be controlled. Shows the schematic diagram of an SM voltage controlled buck converter. Here the state space description of the buck converter under SM voltage control, where the control parameters are the output voltage error and the steady state error dynamics is described 0v.

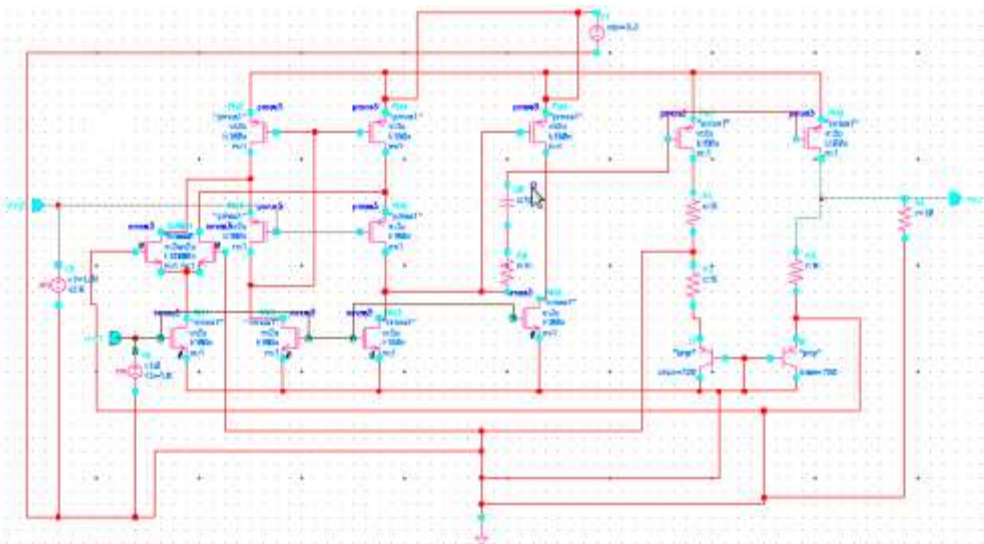

Figure 1: DC-DC buck converter

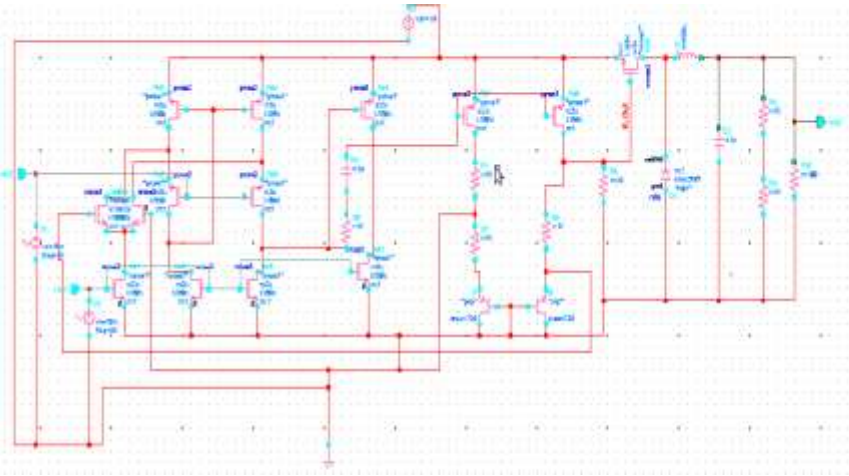

Figure 2: Dc-Dc buck converter with modified sliding function

5. RESULT AND DISCUSSION

The simulation results are presented for comparison between the different control methods that are discussed in above sections undergoing load current transient response, power, Ac and Dc transient response. The results of the comparison are explained. There are two different types of comparison study are presented. The first one is the performance comparison between PWM based mode controlled buck converter and SM controlled buck converter. The second one is the performance comparison between peak power controlled buck converters with steady state based SM controlled buck converter.

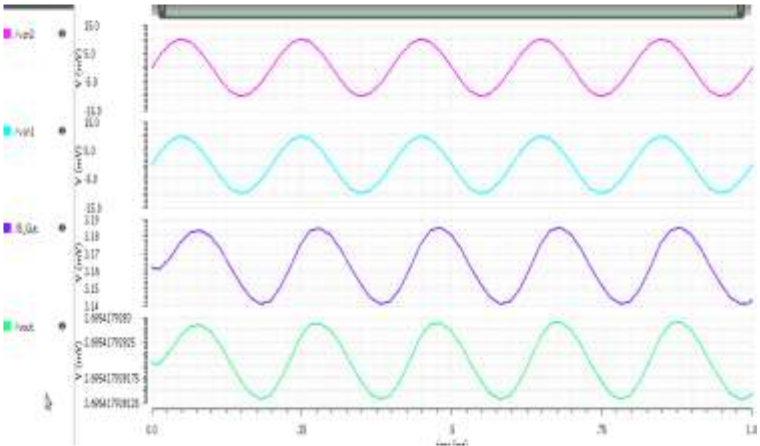

Figure 3 Output of dc-dc buck converter with sliding mode controller

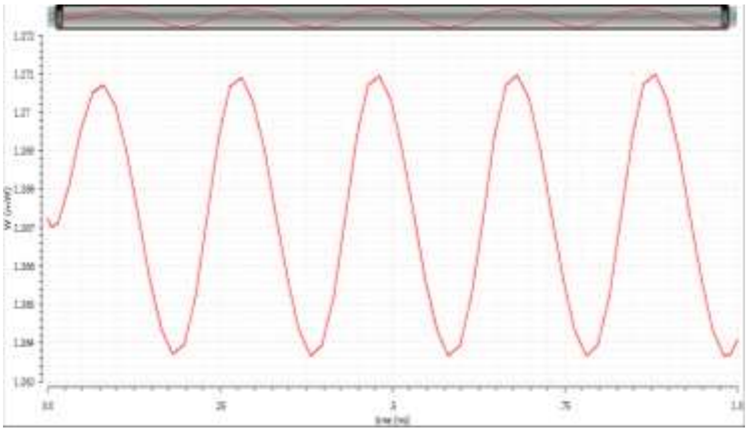

Figure 4 Output of dc-dc buck converter with power

The control methods have the same power circuit parameters and operate at the same input and output voltages. The design specifications and the circuit parameters, for simulation, are chosen as input voltage =24V, desired output voltage =5V, inductance =0.6mH, capacitance =100µF, and minimum load resistance =3.2Ω, maximum load resistance =100Ω, voltage reduction factor =0.4, proportional gain =2, and the upper and lower threshold of ramp voltage =3.8 . The sliding coefficients C1=2 and C2 =0.001. The switching frequency is set to 100 kHz.

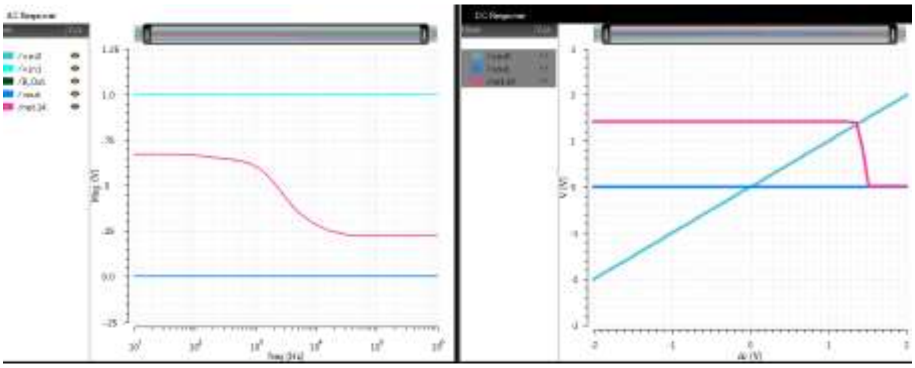

Figure 5 Output of dc-dc buck converter with AC&DC

CONCLUSION

This paper proposed the sliding surface with a sliding function for SMC. The SMC with the proposed sliding surface for a DC-DC buck convertor eliminates the steady state error in the load voltage. The proposed strategy is verified by simulation and experimentation. The steady state and the dynamic behavior of the system with proposed control strategy were studied. The proposed strategy facilitates the flexible choice of tuning parameters such that the ROE can be insensitive to load variation. The simulation as well experimental result show that the proposed control strategy is quite satisfactory in presents of abrupt load variation. It is observed that the proposed SMC improves steady state error in load voltage.

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