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Qualified Analysis of DSMC over SMC for Boost Converter

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Abstract

A qualified analysis of Discrete Sliding Mode Controller (DSMC) over Sliding Mode Controller (SMC) for dc-dc boost Converter is described. The system is first designed with SMC with inner current loop and outer voltage loop control, secondly with the help of sample and hold circuit parameters are sampled and DSMC is used to regulate the output voltage. Both the cases output voltage is regulated and their response is analyzed for the step change in input to prove robustness of the controller. The main aim is to analyze the boost converter to prove its voltage regulation, to prove the robustness of the controller by giving step input, to obtain improved rate of response with better efficiency and to overcome the chattering phenomenon. The implementation of DSMC is simple which eliminates the requirement of ADC and has flexible control characteristics for parameter variation so that the overall system is efficient & cost-effective.

Keywords*: Discrete Sliding Mode Controller, Sliding Mode Controller, DC-DC Converter, Boost Converter*

1. Introduction

Now-a-Days Power electronics converters are commonly used because of its ease of implementation, high efficiency, and improved power factor, compact size, flexibility in control. The commonly used applications of power converters are variable speed AC and DC Drives, Induction heating, High Voltage Dc Transmission, Traction applications and Switched Mode Power Supply. Dc-Dc converters are one of the commonly used converters because of its simple circuit design and its ease of implementation. Boost converter is one among the DC-DC converters is used in this paper and its performance is analyzed with Sliding Mode Controller and Discrete Sliding Mode Controller, their response is compared.

The response of the power electronics converters are affected by (1) the non-linear characteristics of the switching devices like power diodes and power MOSFET what we are using in the boost converter (2) the inductance what we are using in the circuit may saturate which can cause non-linearity (3) the capacitance used for filtering purpose leads to clamping of voltage across it results in non-linear characteristics.

The non-linearity can be overcome with the help of Sliding Mode Controller, which is a part of variable structure system because the system is less sensitivity towards non-linearity [1, 2]. Even systems with unknown parameters can modeled with the help of SMC which requires only approximate equivalent design to model it, and all the higher order systems are

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reduced into first order for SMC design which results in simplicity of the design. The system shows excellent robustness against parameter fluctuations, so the non-linearity problems of power converters are overcome by this controller. The only problem what we are facing is nothing but the chattering phenomenon, which is because of the controller switches across the sliding line in order to track the path.

The DSMC is introduced which eliminates the need for ADC, has flexible control algorithm, ease of implementation, reduced ripples in the output so that the efficiency of the system is improved [3,4].

2. Block Diagram Description and Methodology

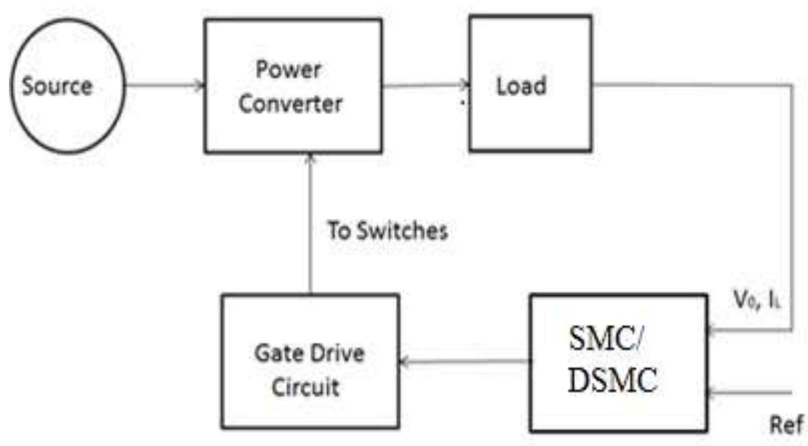

Figure 1. Block Diagram of SMC/DSMC

Figure 1 shows the block diagram description of SMC/DSMC. The power converter is the DC-DC Boost converter, so the input is the DC source which can be a battery or it can be an AC source also. In that case controlled or uncontrolled rectifier can be used. In case of controlled rectifier thyristor is used as a switch, by varying the firing angle we can control the voltage given as input to the boost converter whereas in case of un-controlled rectifier diode is used as a switch AC is converter into un-controlled DC. In boost converter power MOSFET is used as a switch, the signal is generated by the gate drive circuit after getting command from the SMC/DSMC.

The load is selected as a resistive load; the parameters to be controlled are inductor current and capacitor voltage or output voltage. These parameters are sensed and the error e_1 is measured which is the difference between the actual voltage and the reference voltage. With the help of error e_1; the current reference is calculated and then the error e_2 which is the difference between the measured value and the reference value is measured. So the system is having inner current value and outer voltage loop, using the error signals the sliding surface is calculated.

If it is the DSMC then S/H circuit is used before and after the boost converter, the variables are sampled and the sampled values are compared with the reference and the errors are calculated; the sliding surface is designed. Finally control signal is calculated which is sampled and given to the gate drive circuit then to the gate of the power MOSFET.

3. Design of SMC based Boost Converter

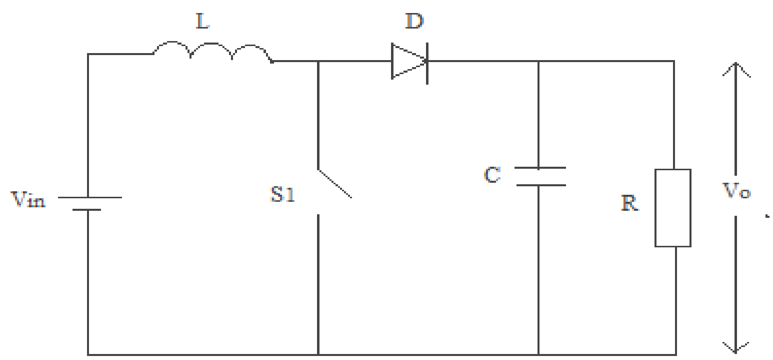

Figure 2. Circuit Diagram of Boost Converter

Figure 2 shows the circuit diagram description of the boost converter, which has input voltage V_{in}, inductor L, Diode D, capacitor C, switch S_1, load resistance R [5]. During the On state of the switch, the system is represented by the following equations (1,2)

$$\frac{di_L}{dt} = \frac{V_{in}}{L} \tag{1}$$

$$\frac{dV_o}{dt} = -\frac{V_o}{RC} \tag{2}$$

When S_1 is OFF the system is represented by the following equations (3,4)

$$\frac{di_L}{dt} = \frac{V_{in}}{L} - \frac{(1-u)}{L}V_o \tag{3}$$

$$\frac{dV_o}{dt} = \frac{1}{C}\left[(1-u)i_L - \frac{V_o}{R}\right] \tag{4}$$

Using KVL the loop equations are formed, from that we can write

$$\dot{x}_1(t) = \frac{1}{L}[V_{in} - (1-u)x_2] \tag{5}$$

$$\dot{x}_2(t) = -\frac{1}{C}\left[\frac{x_2}{R} - (1-u)x_1\right] \tag{6}$$

The sliding surface is given by

$$S = K_1 e_1 + K_2 e_2 \tag{7}$$

Where x_1 is the inductor current and x_2 is the output voltage, e_1 is the voltage error, e_2 is the current error [6,7].

4. Design of DSMC based Boost Converter

The discrete model of boost converter based SMC is represented by the following equations (8,9), equation (8) represents the discrete model when the switch is ON, equation (9) represents the discrete model when the switch is OFF.

$$x_1[k+1] = x_1[k] + \frac{T}{L}[V_{in} - (1-u)x_2] \tag{8}$$

$$x_2[k+1] = x_2[k] - \frac{T}{C}\left[\frac{x_2}{R} - (1-u)x_1\right] \tag{9}$$

$$e_1 = x_2 - V_{ref} \tag{10}$$

$$e_2 = x_1 - I_{ref} \tag{11}$$

Where $I_{ref} = \frac{V_{ref}^2}{RV_{in}}$

The sliding surface is given by the equation (12)

$$S[k] = K_1 e_1[k] + K_2 e_2[k] \tag{12}$$

The system will converge when S[k+1]<S[k] , which can be obtained from Lyapnov Stability Criteria.

5. Results and Discussion

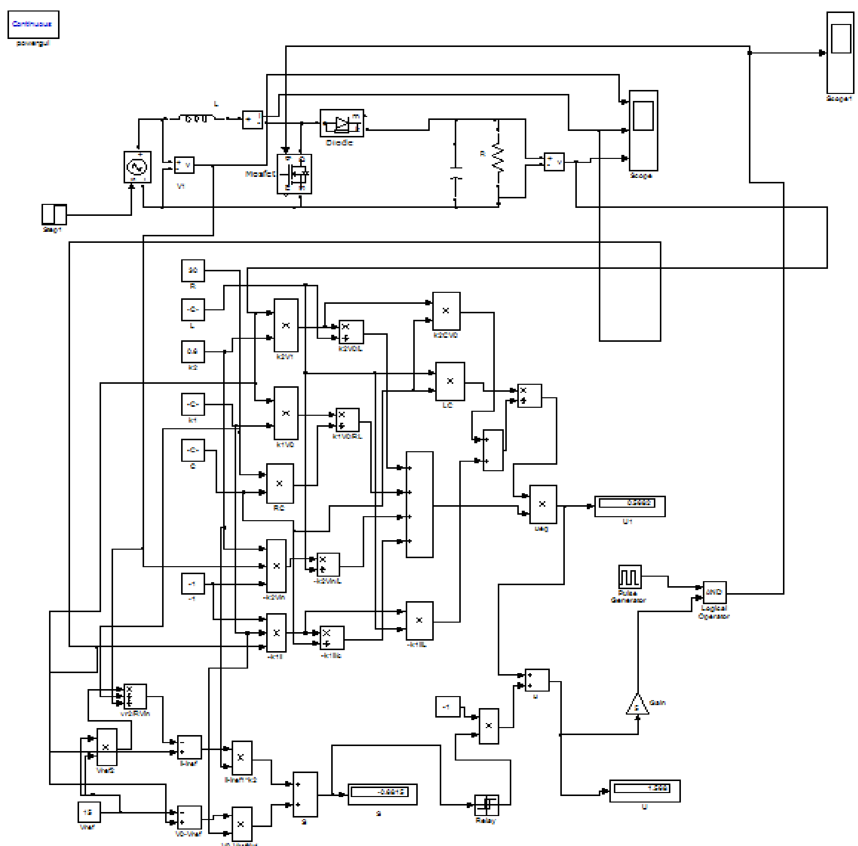

Figure 3. MATLAB SIMULINK Model of SMC for Boost Converter

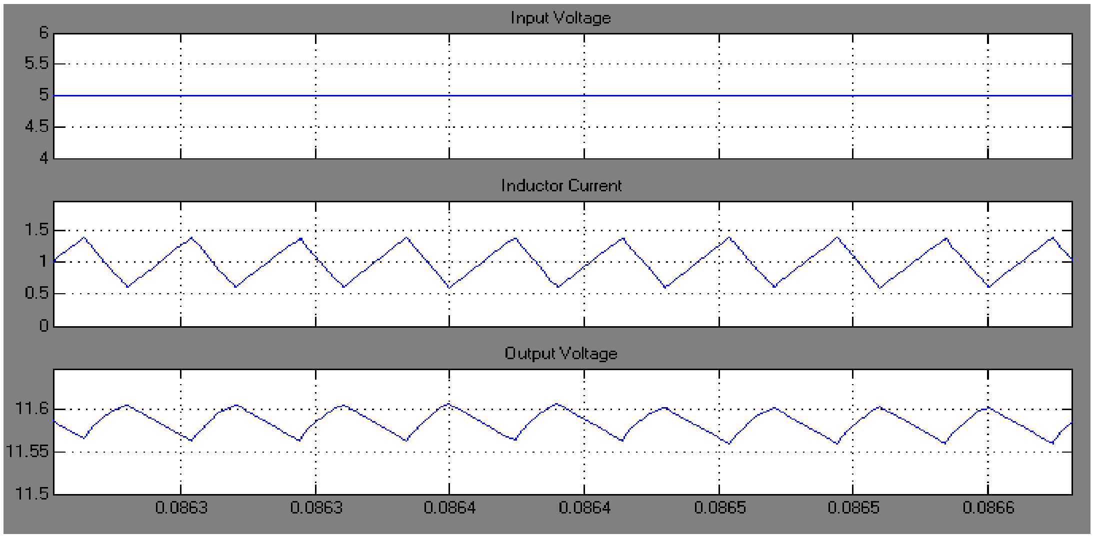

Figure 4. Simulated output of SMC based Boost Converter

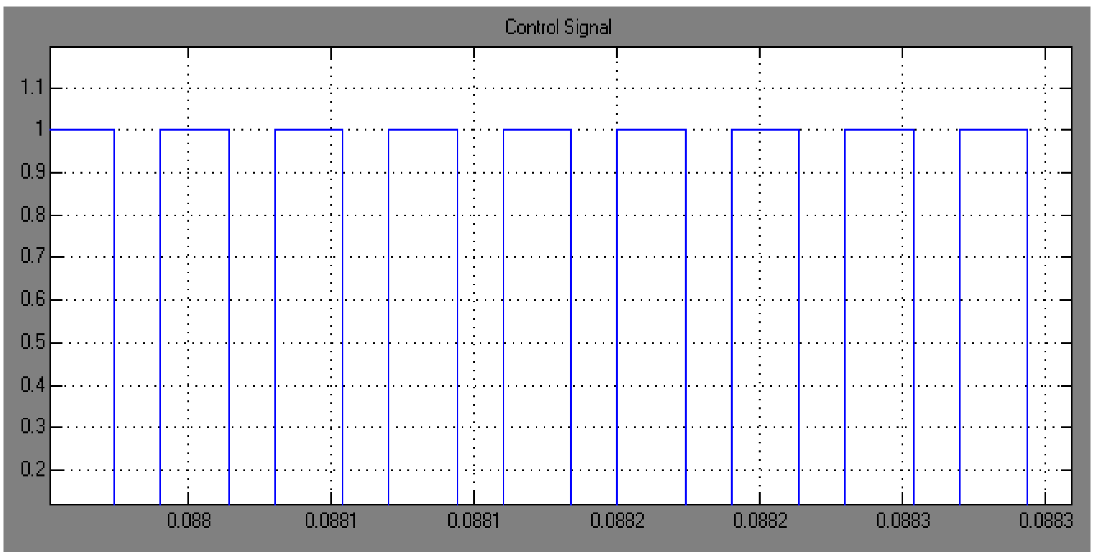

Figure 5. Control Signal for SMC based Boost Converter

Figure 3 shows MATLAB SIMULINK Model of SMC for Boost Converter, Figure 4 shows the simulated output of SMC based Boost Converter, Figure 5. Shows the control Signal for SMC based Boost Converter. Figure 6 shows the simulated output for SMC based Boost Converter with step change in input voltage from 5v to 6v, Figure 7. Shows the control Signal for SMC based Boost Converter for step change in input voltage. Figure 8 shows the MATLAB SIMULINK Model of DSMC for Boost Converter, Figure 9 shows the simulated output of DSMC based Boost Converter; Figure 10 shows the control signal for DSMC based Boost Converter. Figure 11 shows the control signal for DSMC based Boost Converter for step input voltage change from 5v to 6v. Figure 12 shows the control signal for DSMC based Boost Converter for step change in input [8, 9].

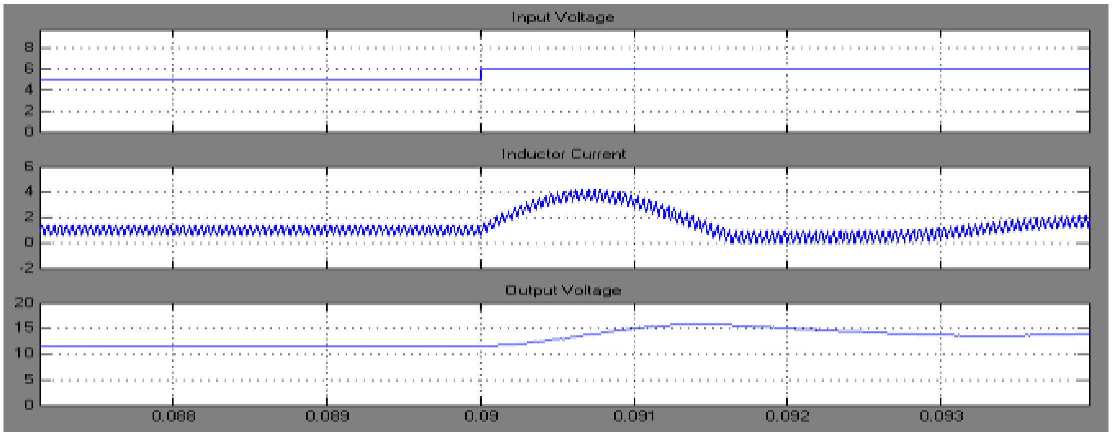

Figure 6. Simulated Output for SMC based Boost Converter with Step Change in Input

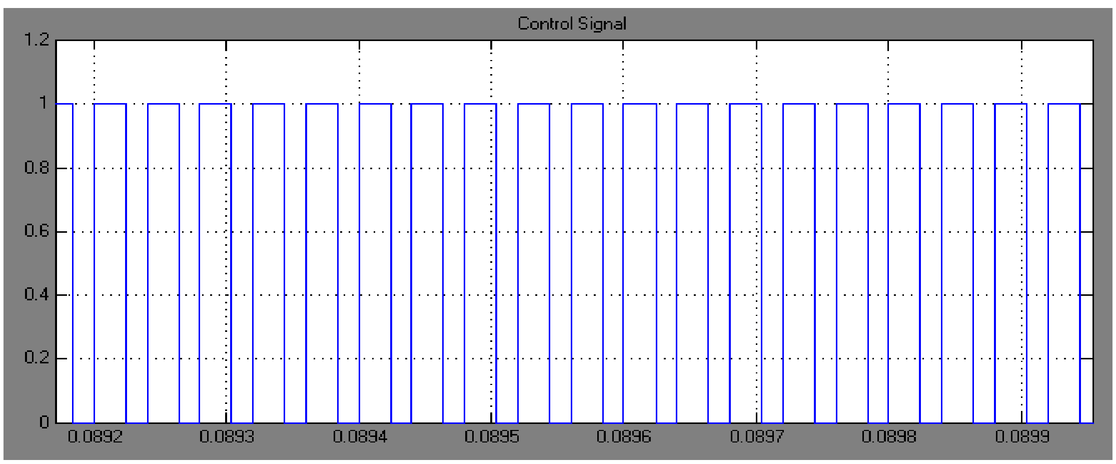

Figure 7. Control Signal for SMC based Boost Converter for Step Change in Input

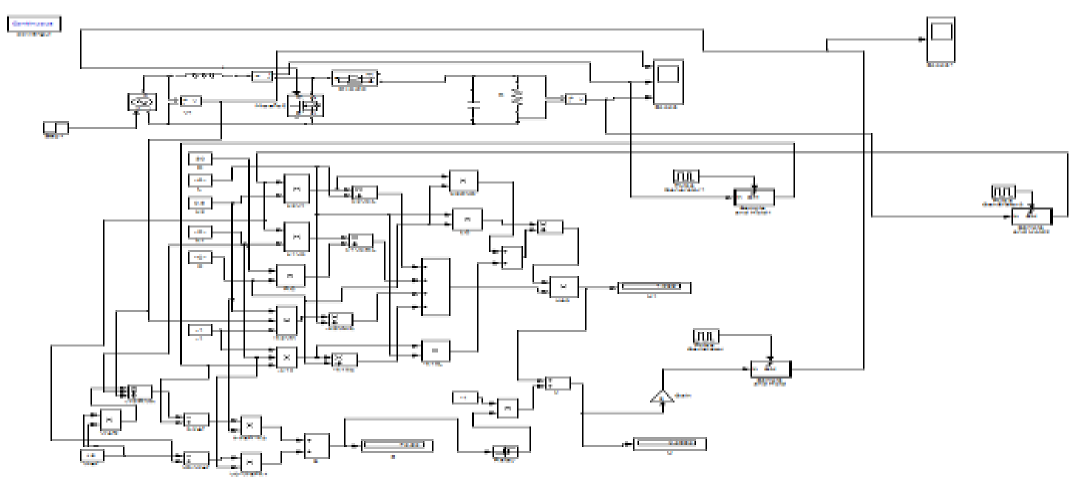

Figure 8. MATLAB SIMULINK Model of DSMC for Boost Converter

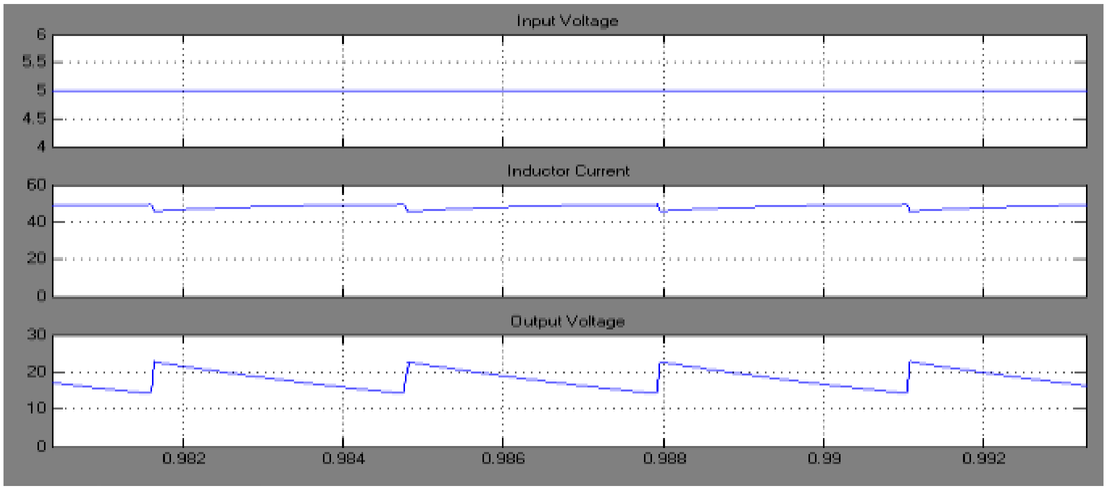

Figure 9. Simulated Output of DSMC based Boost Converter

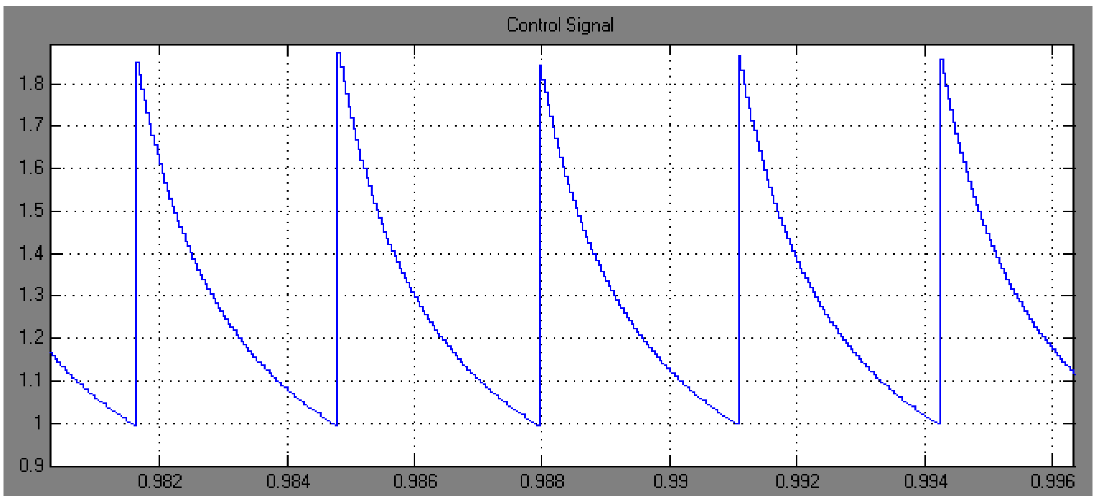

Figure 10. Control Signal for DSMC based Boost Converter

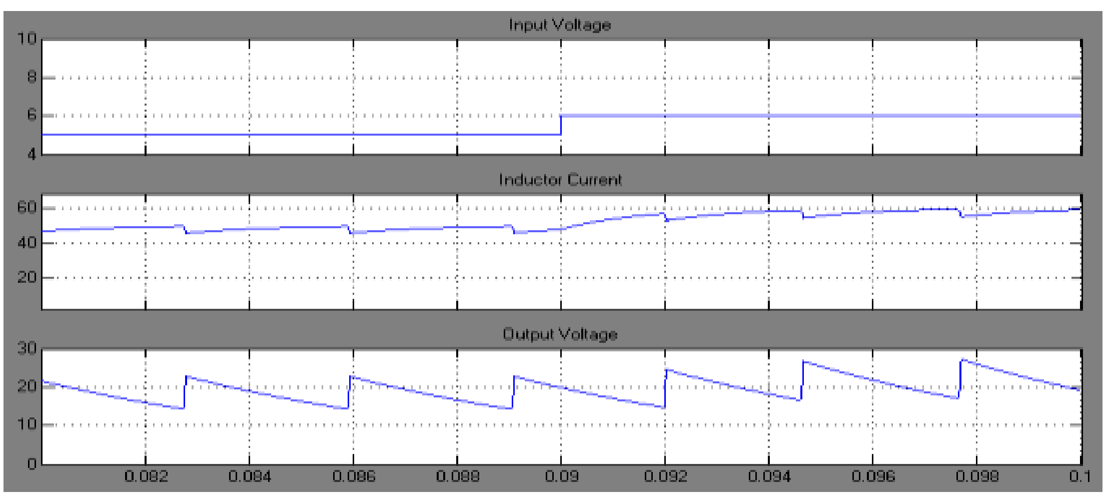

Figure 11. Control Signal for DSMC based Boost Converter for Step Input

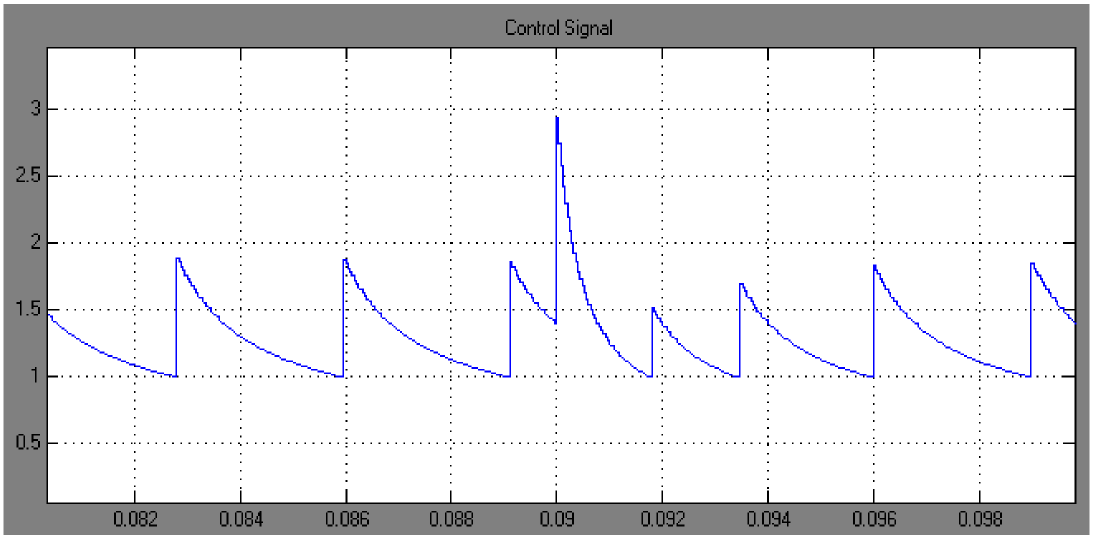

Figure 12. Control Signal for DSMC based Boost Converter for Step Change in Input

Table 1. Parameters Used for Boost Converter

Parameters	Values
R	30Ω
L	150μH
C	220μF
Sampling Frequency	30KHz

6. Conclusion

Qualified analysis of DSMC over SMC is made and the response is shown in the above figures both the cases the output is getting boosted. When there is a step change in input from 5v to 6v the system response is very fast and it stabilizes in both the controllers which show the robustness of the system under uncertainty. The parameters used are R= 30Ω, L= 150 μH, C= 220μF, K_1=0.667, K_2=0.6 and the sampling frequency is 30 KHz. The response of DSMC has more ripples compared to SMC but regulation of output voltage is good in both the cases. The performance of the controller is good for the values of K_1=0.565 to 1 and K_2=0.2 to 0.7 for both the controllers. To reduce the output ripple in DSMC sampling frequency has to be increased but at high sampling frequency discrete system will become continuous so there is a restriction for sampling frequency also. Even through ripple content is more it has other advantages like flexible control characteristics and simple digital control algorithm results in ease of implementation due to the development microcontroller and other types of digital controller. This result in overall system is cheap and economical.

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