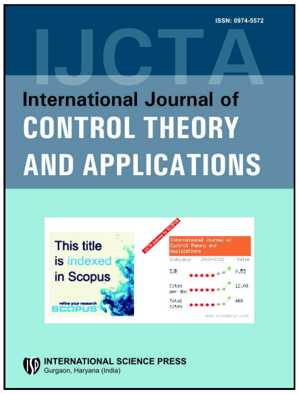

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Enhanced Discrete Fuzzy Sliding Mode Control for Buck Converter

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Abstract: In this paper a Discrete Fuzzy Sliding Mode controller (DFSMC) for dc-dc buck Converter is presented. The main aim is to increase the rate of response, develop efficiency, to get excellent Robustness & chattering phenomenon inhibition. This method is easy to implement and the overall system is efficient & cost-effective. Results based on MATLAB simulation shows that the DFSMC model is a chattering free control, gives fast dynamic response and shows robustness to uncertainties.

Keywords: Discrete Sliding Mode Controller, Discrete Fuzzy Sliding Mode Controller, Fuzzy logic controllers, Sliding Mode Controller, DC-DC Converter.

1. INTRODUCTION

The performance of Dc-Dc converters are exaggerated by the non-linear individuality of switching devices, saturation of inductance, voltage clamping. In dc-dc converters the buck converters are most universally used because of its trouble-free mathematical model and superior regulation of voltage even with constraint deviation. The universally worn closed loop control methods are closed loop voltage control and closed loop current control with PWM method. Even hysteresis control techniques are worn because of its effortlessness.

Former PID controllers were used universally which necessitate exact mathematical model, but their performance was reduced under load fluctuations and non linearity. To advance the performance and to ease the necessity of distinct mathematical model sliding mode controllers (SMC) introduced. SMC requires only fairly accurate mathematical model and provide superior response in constraint fluctuations. The design of SMC is for first-order irrespective of system order and the control law can competent to grip worst case of dynamics. These characteristics of SMC fallout in chattering problem and performance can be enhanced by the introduction of boundary layer. The difficulty with the SMC is that while designing, the local non linearity is not taken into description. The main reward of using SMC is it ensures stability, flexibility in design, ease of implementation and robust against uncertainties.

Now-a-days fuzzy logic controllers (FLC) are most commonly used because it is more robust than other non-linear controllers, it requires only fairly accurate mathematical model, can able to work with inexact inputs, consider restricted non-linearity. So the chattering problem introduced by SMC can be overcome by introducing FLC along with SMC.

Power Electronic converters are extremely non linear for the reason that of its dissimilarity in a single switching cycle, use of inductance saturation, voltage clamp. With the opening of resonant converter, power converters are being paid complicated because of the constraint of composite mathematical model. Introduction of Fuzzy Sliding Mode Controller (FSMC) overcomes these troubles and it is trouble-free to put into practice also. The DSMC has the following dissimilarity with SMC (1) only control algorithm is implemented not the prototype (2) actual time appliance of discrete system is not feasible (3) DSMC does not necessitate hysteresis limiter for commutation appliance (4) The act of DSMC is exaggerated by sampling time.

2. DESIGN OF DISCRETE FUZZY SLIDING MODE CONTROLLER

2.1. Block Diagram Description

In this paper the output voltage of dc-dc buck converter is controlled with the help of DFSMC , the control variables are sampled, and the sampled continuous systems are called discrete time systems. Based on sliding mode algorithm fuzzy rule tables are shaped and the gains are tuned. Now the parameter to be tuned is output gain. With the use of discrete controller along with sliding mode algorithm the tuning time has reduced. The main aim of the DFSMC design is to improve robustness and to get better output of nonlinear systems.

Figure.1. shows the block diagram of the DFSMC for power converters. The power converter can be buck, boost, buck-boost or resonant converters. For ease of implementation buck converter is considered in this paper and its performance is analyzed. The source normally used here is a dc source or a battery. We can use ac source also in that case it requires a controlled or un-controlled rectifier circuit to convert input ac into required dc. The power converter is controlled by adjusting gate signal of the switch by comparing the actual output voltage with the reference value. The switches normally used are power semiconductor devices like SCR, GTO, TRIAC, MOSFET, IGBT ect, In is paper for simulation MOSFET is used. The algorithm used for tuning the gate pulse is discrete fuzzy sliding mode control algorithm.

The utilize of Discrete Sliding Mode Controller (DSMC) has the subsequent rewards like (1) flexible sliding surface (2) identical controller can manage other power converter with fine-tuning (3) feasible to use superior function in control algorithm (4) invention of adaptive control is feasible.

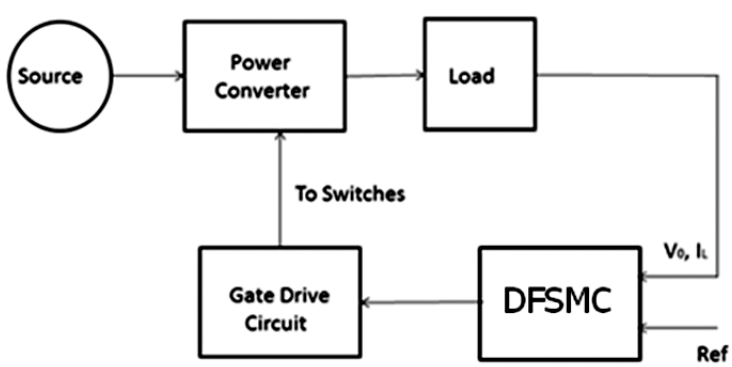

Figure 1: Block Diagram of DFSMC for Power Converter

2.2. Discrete Sliding Mode Controller Design

The circuit diagram of dc-dc buck converter is shown in figure.2. The components used in the circuit are DC supply Vin , diode D, switch S1, storage capacitor C, inductor L, and load resistor R. For the buck converters the output voltage is less than or equal to input voltage (i.e.) $V_0 \le V_{in}$.

Let $i_L = x_1$ and $V_c = x_2$ where i_L is the inductor current and V_c is the capacitor voltage and x_1, x_2 are the control variables. Then the discrete time equivalent system model for the dc-dc buck converter is given by the following equations [1] . This paper is the continuation of the reference paper [1].

$$x_1[k+1] = x_1[k] + \frac{1}{C}\{V_{in}u[k] - x_2[k]\} \tag{1}$$

$$x_2[k+1] = x_2[k] + \frac{1}{C}\left\{x_1[k] - \frac{1}{R}x_2[k]\right\} \tag{2}$$

The sliding surface S[k] is given by

$$S[k] = ke_1[k] + e_2[k] \tag{3}$$

Where k is the sliding co-efficient, e_1 is the difference between the reference value and the actual value of the output voltage,

$$e_2[k] = e'_1[k] \tag{4}$$

According to discrete sliding mode control theorem for the dc-dc buck converter the condition for stability is [1] from Lyapunov continuous condition, (i.e.) |S[k+1]| < |S[k]

2.3. Discrete Fuzzy Sliding Mode Controller Design

The DFSMC uses the surface S[k] and its derivative S[k+1] to define changes on the control signal , the main aim is to ensure Lyapunov stability condition |S[k+1]| < |S[k]. Let the sliding surface be S[k] , the proposed DFSMC makes the derivative of the Lyapunov function as negative in sign. The rule based table is developed to suit this condition. The conditions are (1) if S[k] > 0 and S[k+1] > 0 then duty cycle has to increase (2) if S[k] < 0 and S[k+1] < 0 then duty cycle has to decrease . Thus the surface S and its derivatives are the input to the DFSMC, the output is the control increment “u(k) such that the control law is reorganized.

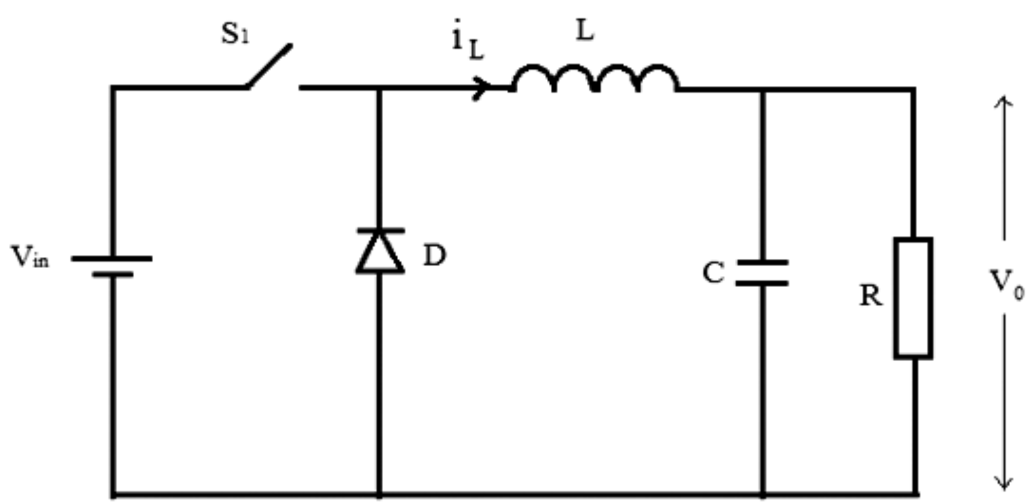

Figure 2: Circuit Diagram of Buck Converter

The proposed DFSMC uses Mamdani fuzzy inference system. For the input signal triangular and trapezoidal membership functions were used for the surface and change in surface with the limit [-1 1] , for the output triangular membership functions were used with limit [-1 1] . The membership functions are represented by N (Negative), Z (Zero), P (positive) for input signals and NB (Negative big) , NM (Negative Minimum), Z (zero), PM (Positive Minimum), PB (Positive Big) for the output signal. The rule base table is given in Table-1 , which is the developed table to implement the DFSMC in the converter circuit. Control signal is given in eqn(5)

$$u(k) = \Delta u(k) + \Delta u(k-1) \tag{5}$$

Table 1
Rule base table for DFSMC

S[K+1] \ S[K]	*N*	*Z*	*P*
P	Z	PM	PB
Z	NM	Z	PM
N	NB	NM	Z

2.4. Flow chart of Discrete Fuzzy Sliding Mode Controller Design

Fig.3. shows the flowchart of the DFSMC for the buck converter. First gate pulse is generated for the buck converter. The values of inductor current and output voltage are sampled. The sampled output voltage is then

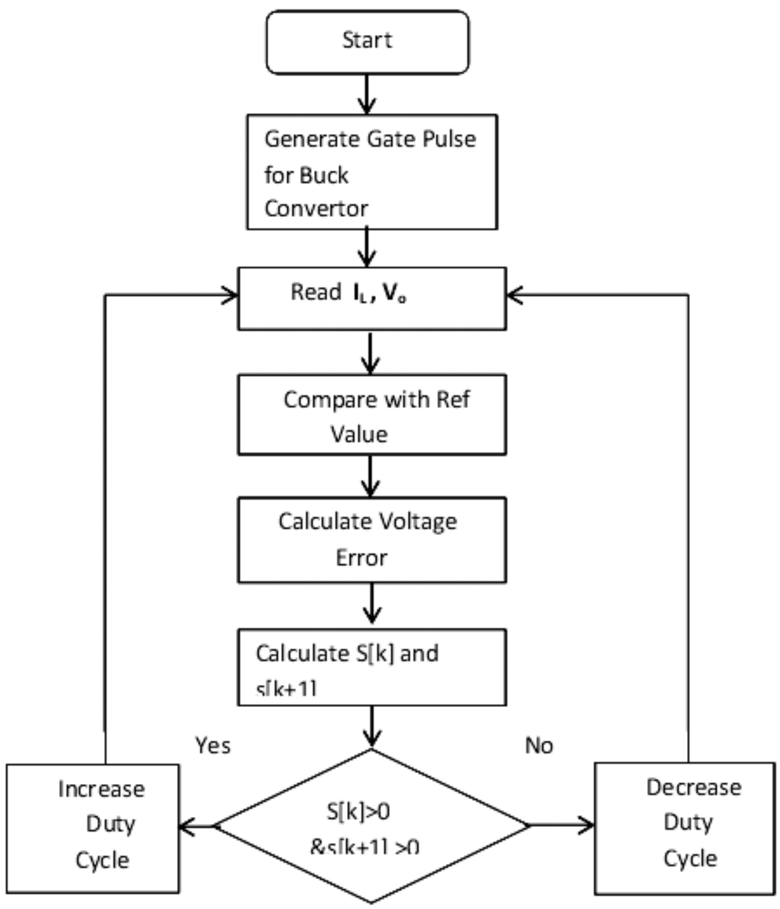

Figure 3: Flow chart for DFSMC for Buck Converter

compared with the reference the error is calculated. Then sliding surface S and change in sliding surface is calculated. There are two conditions, If S>0 and then u is positive so that the pulse to the converter is set high else u is negative and the pulse to the converter is set low. The loop is getting closed by reading the control variables.

3. SIMULATION RESULTS AND DISCUSSION

The parameters used for the proposed converter is given in Table-II. The DFSMC of Buck converter is simulated in MATLAB SIMULINK and the developed model is given in Figure.4. MOSFET is used in this converter which has great speed of reaction and the switching is through controlling the gate signal by DFSMC. Figure.5. shows the Mamdani fuzzy inference system collected by a fuzzification block, a rule base block and a defuzzification block. This is done with the help of rule editor where input and output variables are defined with the help of membership functions. Then the rules are formed by selecting proper membership function from each input variables and

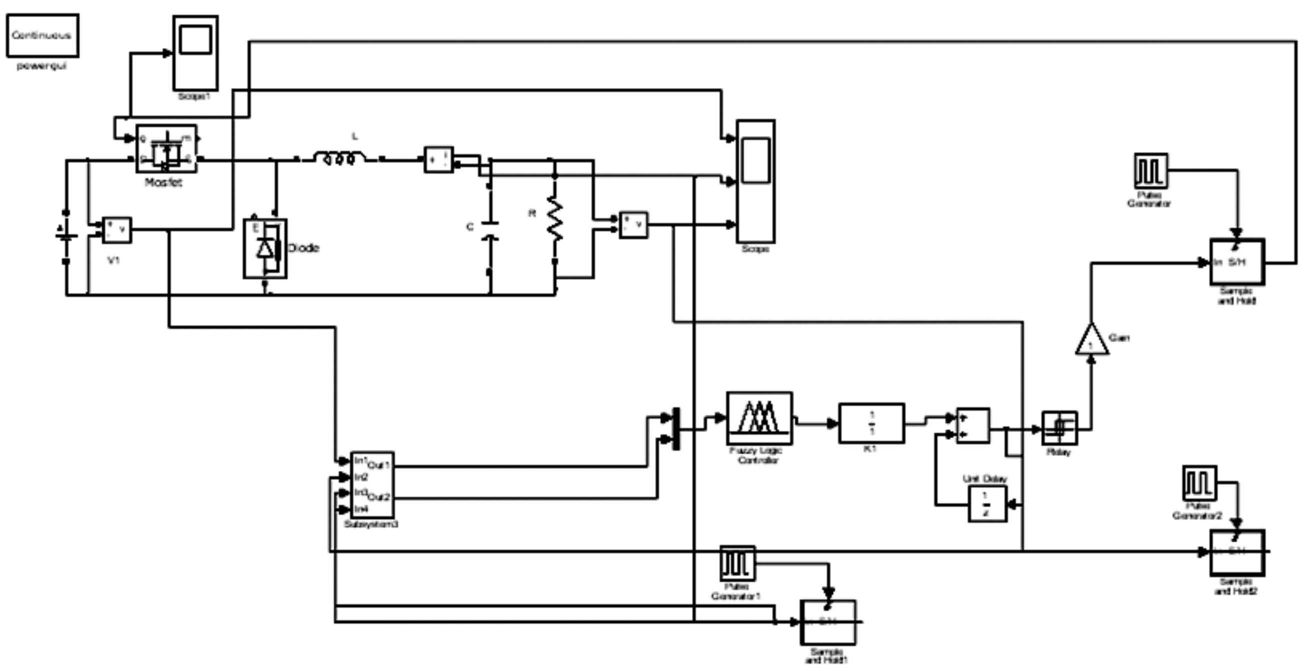

Figure 4: MATLAB SIMULINK model of Buck Converter

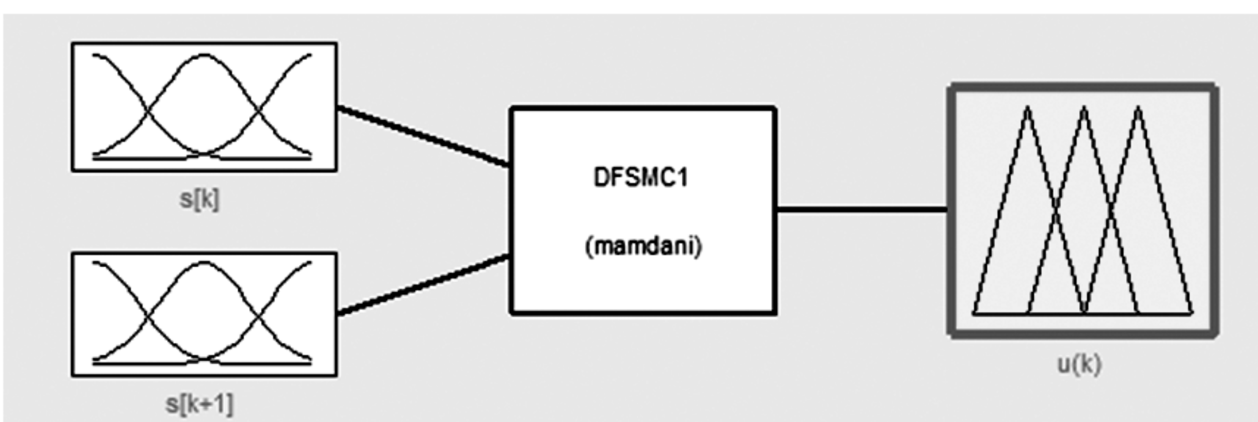

Figure 5: Mamdani fuzzy inference system model for Buck Converter

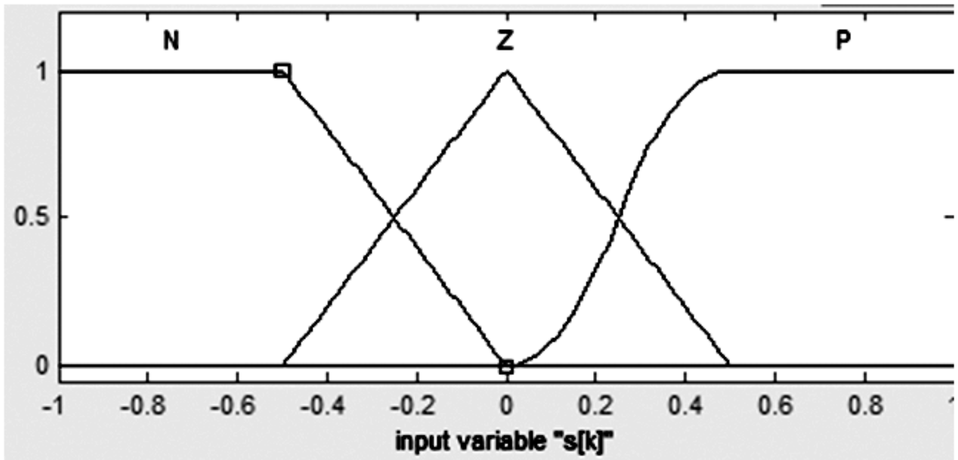

Figure 6: Membership functions of sliding surface S[k]

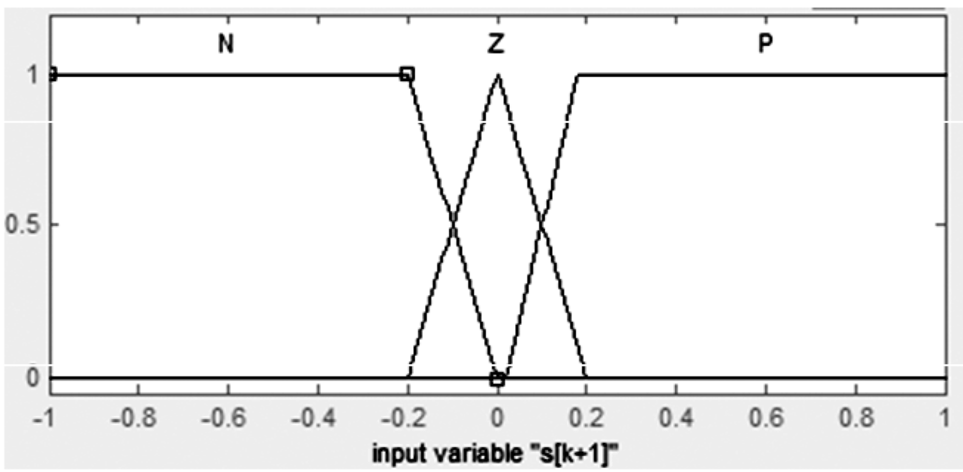

Figure 7: Membership functions of change in sliding surface S[k+1]

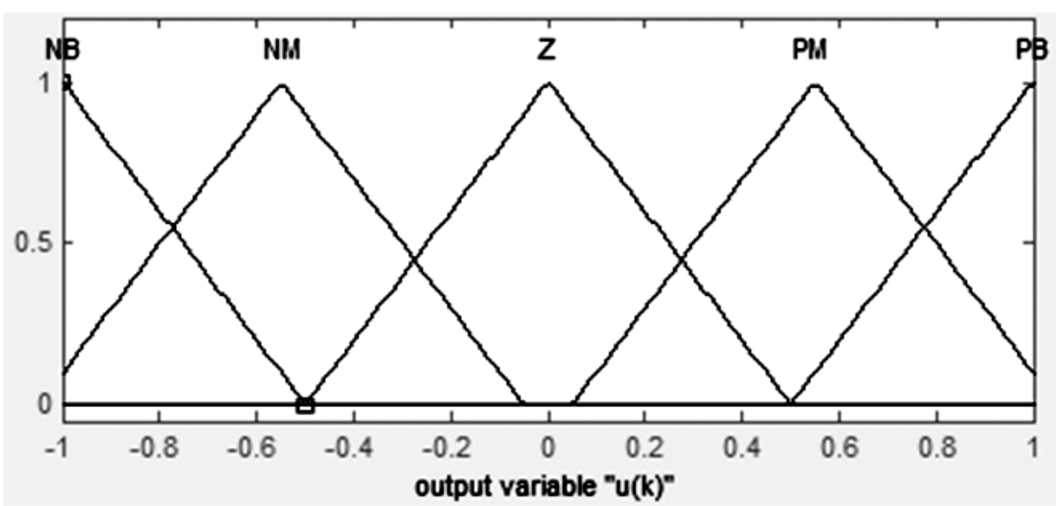

Figure 8: Membership functions of output variable u[k]

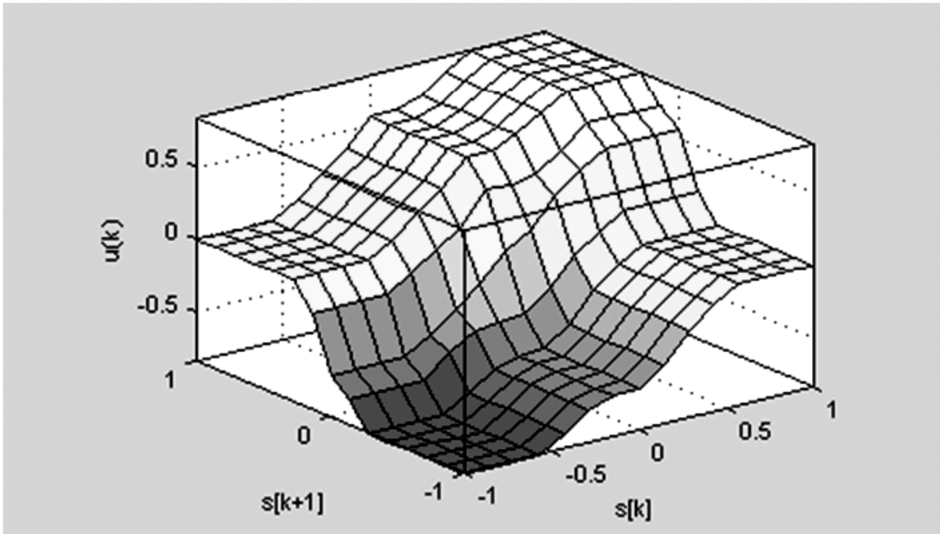

Figure 9: DFSMC control surface

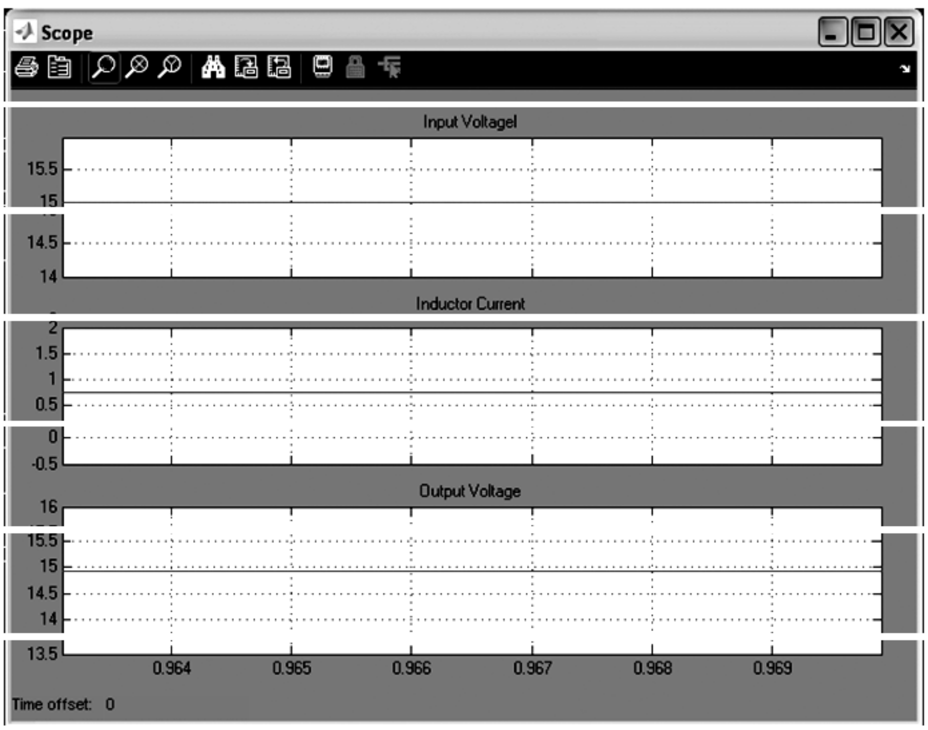

Figure 10: MATLAB SIMULINK Simulated response of Input voltage, Inductor current and output voltage

selecting membership function from output variable. One of the input variable is S[k] and its membership functions are shown in figure.6. and the other input variable is S[k+1] and its defined membership functions are shown in figure.7. The output variable is the control signal given by U[k] and its defined membership function is given in figure.8. With the help of rule edit viewer we can able to see the control surface shown in figure.9.

The DFSMC MATLAB SIMULINK model was simulated with the specified parameters and the response of input voltage , Inductor current and output voltage responses were taken which is shown in Figure.10. From

Table 2
Parameters used for Buck converter

Parameters	*Values*
R	10Ω
L	10mH
C	100μF
Switching Frequency	30KHz

the response we can make out that output voltage is less than the input voltage and it is working in continuous current mode.

4. CONCLUSION

In this paper DFSMC for buck converter is proposed which will suit for power converters like switched mode DC-DC converters. If we are comparing the result of DSMC [1] with this controller output we can able see the improvement in its performance and it is chattering free also. If we are growing the sampling period it has extra area of attraction with enhanced performance. It also removes chattering problems in the controller.

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