Reduction of Switching Losses in Step Down Converter using Proposed Reaching Law

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ABSTRACT

The proposed reaching law based sliding mode control is used for chattering suppression, minimization of steady state error and reaching speed kept minimsed. With fine tuning of parameters of robust reaching law, the sliding mode reaches the equilibrium point at the earliest. The stability of the proposed reaching law is analyzed. In one hand, they guarantee the system reach the sliding surface rapidly and remain on it, in another way they deteriorate the chattering effectively, even unmatched certainties and disturbances. Such that the system response can better realize the unification of rapidity. A proposed reaching law ia analysed mathematically and applied to SMC DC-DC buck converter to lessen the chattering, because switching devices are existing in the model, it reduces the switching losses in the switching devices of the dc-dc converter. MATLAB/Simulink results gives significant decline of chattering

Keyword : - *Reaching law,Robust reaching law,Chattering,Sliding mode control ….*

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1. INTRODUCTION

Sliding Mode Control (SMC) is a nonlinear control systems design technique which is robust adjacent to parameter variations and matched uncertainties. It evolved from the Variable Structure Control (VSC) and is established in the field of nonlinear control. Details of sliding mode control can be obtained in [1] [2] [3]. In the Sliding Mode Control a reaching law takes the system states in the sliding surface at limited time interval. Once the condition of the system reaches the sliding line the switching control causes chattering. The chattering regularity is infinite and its amplitude towards zero. However, in realistic systems due to the dynamics of the Electronics sensors and actuators etc., the chattering frequency is finite and also has some amplitude [4]. In mechanical systems this can result in high bear and losses, as an effect becoming infeasible for use in such systems, on the other hand in high speed electronics it can result in enormous variations in the fixed state presentation resulting in unacceptable systems. a number of methods have been proposed in various research works for explanatory the chattering effect. In [5], VSC along with non sliding methods were used for eliminate the high frequencies by achieving the elimination of chattering. In [6], tuned sigmoid functions were implemented to weaken the chattering. In [7], power rate reaching law was implemented for the alleviation of chattering. Higher order sliding mode wakened the chattering [8] [9]. Smooth Sliding Mode [10] [11][12]Suppressed the chattering however, it was not considered robust against the parameter variations and matched uncertainties, minimization of steady sate errors, robustness explained[13][14]However, the further application of SMC is limited because of the chattering phenomenon, which can excite high frequency dynamics. Thus, some approaches have been proposed to overcome this problem. Continuation control method can solve this problem effectively. Though this method could restraint the high-frequency chattering, it also destroys the sliding mode [15]. Another method of restraining chattering is higher order sliding mode control, which can eliminate the discontinuous term in control input [16]. In this reaching law technique which is used to chattering mitigation can obtain the control law easily [17][18][19]. The problem identified that in the proposed work is chattering in SMC, due to chattering more swirtching losses in the step down converter and not obeying portion of the sliding mode.

2. MATHEMATICAL ANALYSIS OF ROBUST REACHING LAW (RRL)

A new RL, called RRL, is described in this section. The proposed RRL is described in vector format as

$$s^{\cdot} = -\rho(s,\mu,\sigma)\operatorname{sign}(s) \tag{1}$$

where σ is a positive integer, $0 < \sigma < 1$; μ is a constant, $0 < \mu < 1$

$$\rho(s,\mu,\sigma) = \left(1-\mu e^{\frac{-abs(si)}{\sigma i}}\right) \tag{2}$$

$$\dot{s}i\left(1-\mu e^{\frac{-abs(si)}{\sigma i}}\right)^{-1} = -sgn(si(t)) \tag{3}$$

Integrating with respect to time, reaching time can be calaculated as follows.

When si (t)>0, for negative values

$$t_{reach} = -\int_{0}^{-Si(0)}\left(1-\mu e^{\frac{-abs(si)}{\sigma i}}\right)^{-1} ds \tag{4}$$

When si (t) <0, positive values

$$t_{reach} = -\int_{0}^{Si(0)}\left(1-\mu e^{\frac{-abs(si)}{\sigma i}}\right)^{-1} ds \tag{5}$$

When combined both equation (5) and (6) the reaching time,

$$t_{reach} = -\int_{0}^{abs(Si(0))}\left(1-\mu e^{\frac{-abs(si)}{\sigma i}}\right)^{-1} ds \tag{6}$$

As a final point, we get

$$t_{reach} = \frac{\sigma i}{ki} \ln \left| e^{abs(si(0))/\sigma i} - \mu i / 1 - \mu i \right| \quad (7)$$

The proposed reaching laws μ bring the system on to the slidng line,by dereasing the value of μ ,causes a delay in approaching on to the sliding line, if μ value increases the speed of the system states on the trajectory path, whereever the intial conditions of states. σ makes the states to fast speed kept. If the value of σ reduces, the chattering effect can be minimized and the reaching time kept fast by appropriate selection of σ and μ values, and reduces the chattering at the orign of the slidng surface. The absolute values of the‘s’ bring the stabilty of the system on the switching surface.

2.1 SMC with Robsut Reaching Law

Slidng mode control with Robust reaching law is given by

State variable eqaution is given by

$$X_1 = V_{ref} - \beta V_o$$
$$X_2 = -\frac{\beta i_c}{C}$$
$$X_3 = \int X_1 \quad (9)$$

Where X_1 X_2 and X_3 are state variables.[20,21,22]

2.1 **The constant plus proportional rate reaching law or traditional reaching law**:

$$\dot{S} = -Q\text{sgn}(s) - Ks \quad (9)$$

Q > 0 and K> 0 are positive constants

$$s^{\cdot} = -\rho(s,\mu,\sigma)\text{sign}(s) = \dot{S} = \alpha_1\dot{X}_1 + \alpha_2\dot{X}_2 + \alpha_3\dot{X}_3 = 0 \quad (10)$$

Using equation (1) and (11), we get (Using Control Law)

$$s^{\cdot} = \mathbf{U(X)} = -\frac{\partial \mathbf{S}}{\partial X}\mathbf{B}\left[\frac{\partial \mathbf{S}}{\partial X}\mathbf{Ax} + \rho(s,\mu,\sigma)\text{sign}(s)\right] \quad (11)$$

Where A and B are matrix coefficients of the step down converter parameters.Euation (12) represents the control law,

$$-\rho(s,\mu,\sigma)\text{sign}(s) = \alpha 1\dot{X}1 + \alpha 2\dot{X}2 + \alpha 3\dot{X}3 = 0$$

$$-\rho(s,\mu,\sigma)\text{sign}(s) = \alpha 1\left(-\frac{\beta}{C}\right)ic + \alpha 2\frac{\beta ic}{RC^2} - \alpha 2\frac{UVin\beta}{LC} + \alpha 2\frac{\beta V0}{LC} + \alpha 3(Vref - \beta Vo)$$

$$Ueq = \frac{LC}{\alpha 2Vin\beta}\left[\rho(s,\mu,\sigma)\text{sign}(s) - \frac{\alpha 1ic\beta}{C} + \alpha 2\frac{\beta ic}{RC^2} + \alpha 2\frac{\beta Vo}{LC} + \alpha 3(Vref - \beta Vo)\right] \quad (12)$$

Equation (1) and eqaution (12) gives the equivalent value of the input and it’s implemented using Simulink

3. CHATTERING

The chattering is tearness and wearness of the system, it reduces the effieiciency of the step -down converter and also makes more noises and switching losses in the system. The effect of chattering in the step down converter is that more deviated in the output voltage and loss of trajectory path. Figure 2 shows the chattering in SMC. Chattering phenomena is unwanted possessions of variable structure system. The main grounds of chattering a phenomenon is the existence of sign function in control inputs.

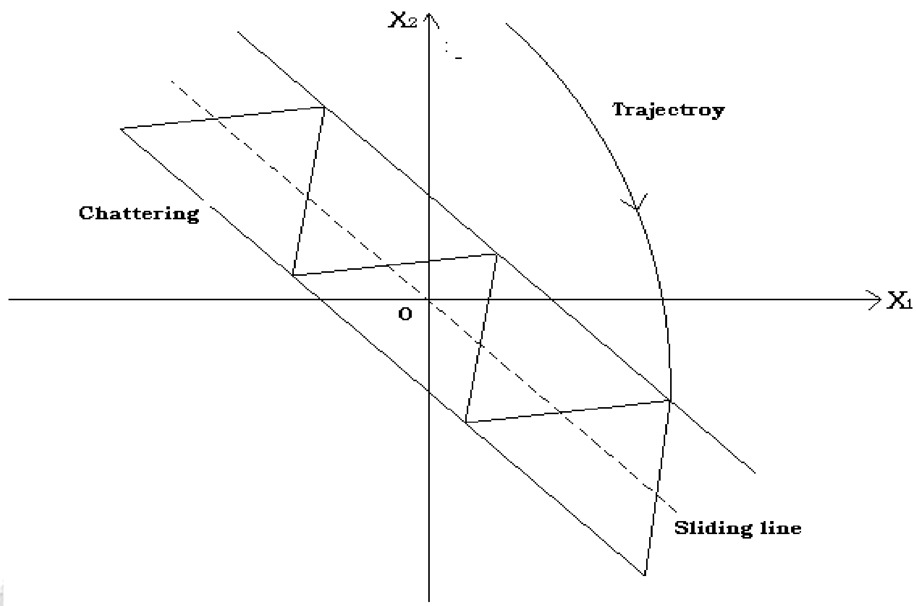

Fig: 1 Chattering

4. SIMULATION RESULTS

Table 1: Specifications of step down converter and proposed reaching law

Sl.No.	Parameter	Symbol	Value
1	Input voltage	Vi	24Volts
2	Capacitance	C	220µF
3	Inductance	L	69µH
4	Switching Frequency	fs	200KHz
5	Minimum load resistance	R_L(min)	6 Ohm
6	Maximum load resistance	R_L(max)	10 Ohm
7	Desired Output	Vod	12V

	voltage		
8	Reference voltage	Vref	12V
9	m1 &m2 (Parameters)		2,3
10	k_1 and k_2(Parameters)		1, 0.5
11	Feedback factor	β	0.99
11	sliding coefficients,	α_1	3
		α_2	25
		α3	2000
12	Duty cycle	α	0.5
13	Efficiency of the Converter	η	0.91
14	Input Power	Pi	14.2W
15	Output Power	Po	12.9W

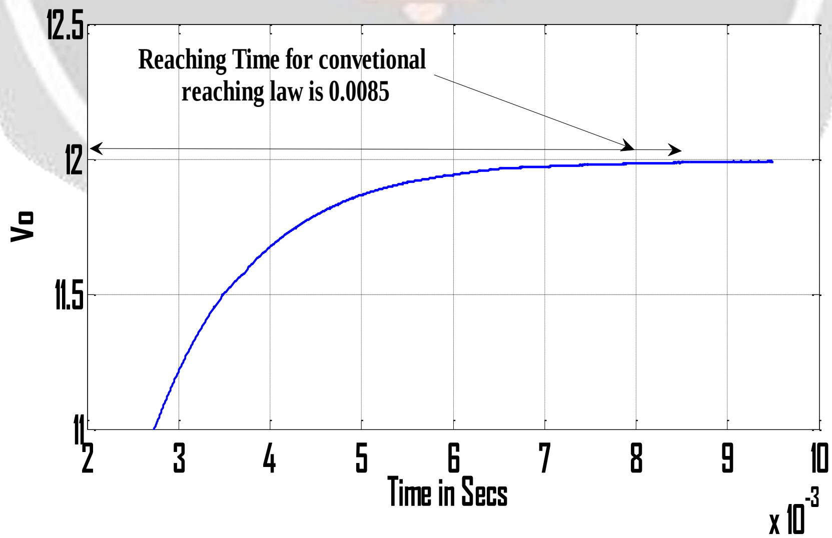

Fig: 2 Output voltage of Traditional reaching law

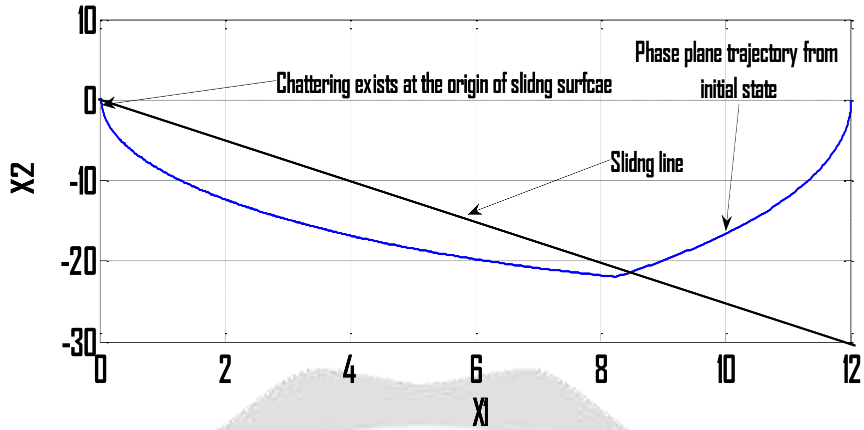

Fig: 3 Chattering of Robust reaching law

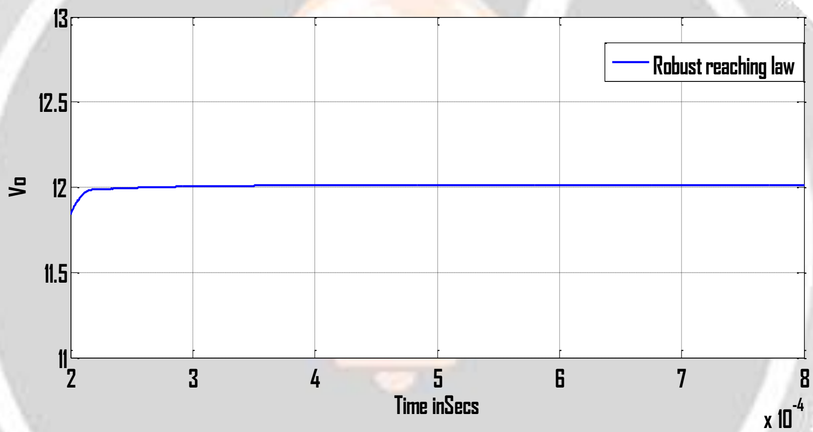

Fig: 4 Output voltage of Robust reaching law

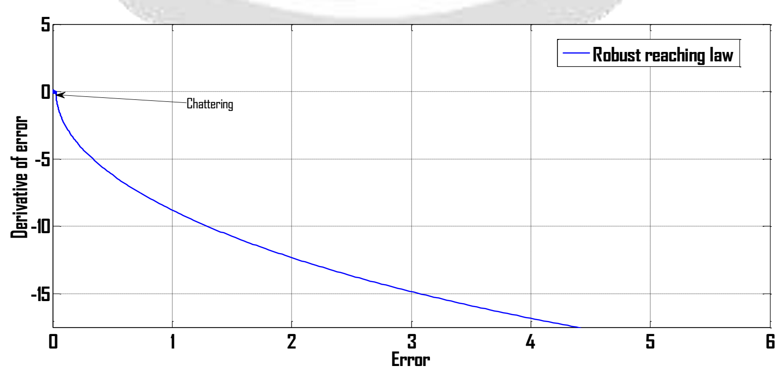

Fig: 5 Chattering of Robust reaching law.

The table 1 gives the specification of the reaching law and step down converter. Figure 2 represents the output voltage of the traditional reaching law, it takes the long time to reach the desired output voltage, due to the effect of chattering. Figure 3 represents the chattering of robust reaching law, the Robust reaching law obeys close up to the rule of the sliding surface. Figure 4. Represents the output voltage of the Robust reaching law. The proposed robust reaching law brings the output voltage nearby the origin at minimum time. Figure 5 represents the chattering at the origin of a Robust reaching law. Overall performance of the step down converter is improved. A proposed reaching law gives more dynamic in reaching time and mitigates the chattering effectively than the the traditional reaching law.

5. CONCLUSION

In this paper we discussed the robust reaching law with conventional reaching law about the chattering mitigation and newly designed robust reaching law effectively reduces the chattering and system remains on sliding surfaces. Both reaching laws are applied to DC-DC step down converter. The dynamic performance of the system can be effectively improved by changing the value of the reaching law parameters. Switching losses can be minimsed in the step down converter. The simulation results show that the proposed robust reaching law exhibits superior static and dynamic properties than the constant plus proportional rate reaching law

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