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Analysis of chattering in step down converter via sliding mode reaching law

Siddesh Kondapur Basavarajan[1], Shivarudraswamy Rudrappa[2]
[1]Department of Electronics and Communication Engineering, SJM Institute of Technology, Visvesvaraya Technological University, Karanataka, India
[2]Department of Electrical and Electronics Engineering, Manipal Institute of Technology, Karanataka, India

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ABSTRACT

The reaching law approach is broadly used for chattering repression, minimization of steady state error and reaching pace kept minimsed. The reasons of chattering, in this paper proposes sliding mode reaching law. In one hand, they assurance the scheme arrives at the sliding face swiftly and stay on it, in another way they deteriorate the chattering inefficiently, even matchless certainties and disturbances. This proposed reaching law gives uniqueness of the response. The reaching law is compared with Gao's reaching law. Sliding mode reaching laws gives the efficacy in reducing the chattering of the variable structure control (VSC). This reaching law also reduces the losses in the switching diplomacy. In turns efficiency of the step-down converter increases. Simulation results give significant decrease of chattering and extremely fewer receptive in supply and load variation.

Corresponding Author:

Siddesh Kondapur Basavarajan
Department of Electronics and Communication Engineering
SJM Institute of Technology Visvesvaraya Technological University
Jnana Sangama, VTU Main Rd, Machhe, Belagavi, Karnataka 590018, India
Email: kondapur.b@gmail.com

1. INTRODUCTION

Sliding mode control (SMC) is a control systems design practice which is vigorous beside constraint variations. and is recognized in the field of nonlinear control. Facts of sliding mode control can be obtained in [1]–[4]. In the SMC a reaching law takes the system states in the sliding face at fixed time space. Formerly the condition of the system reaches the sliding stripe the switch control cause chattering. The chattering regularity is unlimited and its amplitude towards nil though, in pragmatic system owed to the dynamics of the electrical set, the chattering frequency is restricted and also has some magnitude [4]. Several methods contain been projected in a variety of research works for extenuating the chattering consequences. Young in [5], variable structure control (VSC) beside with non sliding scheme were worn for eliminate the lofty frequencies by achieve the elimination of chattering. Moura and Olgacin [6], weakens the chattering by SMC, Camacho *et al*. in [7], power pace reaching law was implemented for the alleviation of chattering. Higher order sliding mode wakened the chattering [8], [9]. Flat sliding form [10]–[12] suppresed the chattering on the other hand, the additional purpose of SMC is incomplete because of the chattering occurrence, which be able to stimulate lofty regularity dynamics, it also destroys the sliding mode [13]. An additional method of restrictive chattering is advanced SMC, which can eliminate the alternating term in control effort [14]. In the reaching law process, which is shabby to chattering [15]–[18].

2. SLIDING MODE CONTROLLED STEP-DOWN CONVERTER

The Figure 1 shows the step-down converter, the converter has capacitor, inductor and resistor, and the function of the buck converter is used to reduce the output voltage as required and the maintaining the constant frequency. This step-down converter very largely used in electronic gadgets, satellite communication, telecommucation, medicalequipments laptops, computers, and mobile phones. One of the drawbacks of the buck converter is that switching losses in the buck converter and overcome this drawback using a proposer and suitable control technique. Vref is the reference voltage and where R_1 and R_2 are voltage dividers.

$$X1 = Vref - \beta Vo$$

$$X2 = -\frac{\beta ic}{C} \tag{1}$$

$$X3 = \int X1 \text{ [16]}$$

The derived of the states:

$$\dot{X}1 = -\beta \frac{dVo}{dt} = -\beta \frac{ic}{C} = \frac{\beta}{C}[io - iL]$$

$$\dot{X}2 = \frac{\beta}{C}\left[\frac{1}{R}\frac{dVo}{dt} - \int \frac{UVi + Vo}{L}\right]$$

$$\dot{X}2 = \frac{\beta}{C}\left[\frac{1}{R}\frac{ic}{C} - \frac{UVi + Vo}{L}\right] \tag{2}$$

$$\dot{X}3 = X1$$

The sliding face is [16], [19]:

$$S = \alpha 1 X1 + \alpha 2 X2 + \alpha 3 X3 \tag{3}$$

The derived of the sliding face is,

$$\dot{S} = \alpha 1 \dot{X}1 + \alpha 2 \dot{X}2 + \alpha 3 \dot{X}3 = 0 \tag{4}$$

where α1, α2 & α3 are coefficients.

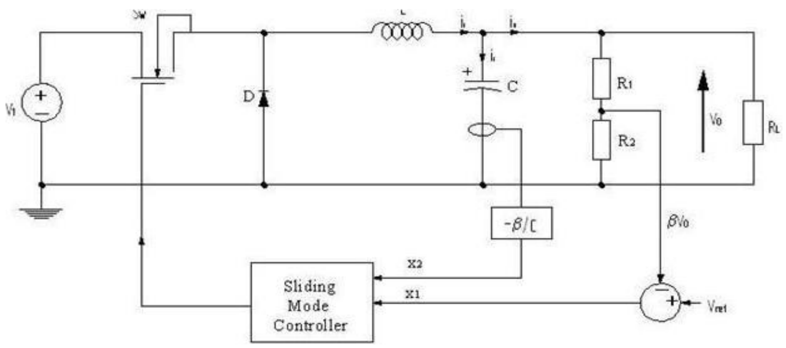

Figure 1. SMC step-down converter

3. CHATTERING

This occurrence is a disadvantage as, even if it is clean at the output of the method, it may stimulate unmodeled high frequency modes, which degrade the recital of the scheme and might yet direct to unsteadiness [12]. The chattering is tearness and wearness of the system, it reduces the effieiciency of the buck converter and also makes more noises in the system. The effect of chattering in the step-down converter is theta more deviated output voltage.

Figure 2 shows the chattering in SMC. Chattering phenomena is unwanted possessions of variable structure system. The main grounds of chattering a phenomenon are the existence of sign function in control inputs. The chattering has more oscillation at the origin, this causesa a more haet losses in the system, the sliding line should end with the origin of the system. The chattering is the main drawback of the sliding mode control systems [20], [21]. The trajectory is the path in which sliding line passed through it.

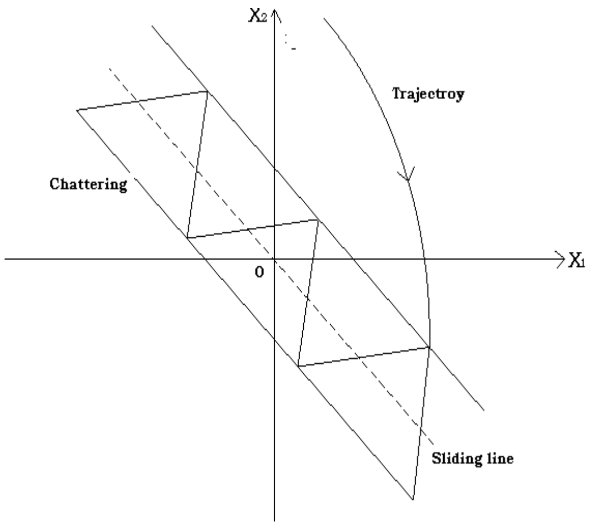

Figure 2. SMC chattering

First, transform the system model to controllable canonic form.

$$\dot{X}1 = X2$$

$$\dot{X}n - 1 = Xn \tag{5}$$

$$\dot{X}n = \sum_{i=1}^{n} = -ai + bu$$

Then the function defined is being as:

$$S(X) = C1X1 + C2X2 + \cdots Xn \tag{6}$$

The sliding surfaces,

$$C1X1 + C2X2 + \cdots Xn = 0$$

4. PROPOSED REACHING LAW

A reaching law is proposed which can reduce chattering has a quick pace either away from or move toward to the sliding face. It is indicated through scholastic analysis. its derivative can meet to a neighborhood of the starting point speedily.the proposed reaching law is more accurate and high-speed reaching time at the origin. The sliding line will reach the surface very fast and it obeys the slidng rule at the origin the effect of reaching law is that fast speed and line should be kept in sliding surface.

$$\dot{S} = \text{-m1} * |s|^{0.9}\text{sgn}(s)\text{-m2}|s|^{0.5}\, sgn(\, s) \tag{7}$$

$$\text{m1} > 0, m2 > 0,$$

Case 1: -m1 $* |s|^{0.9}\text{sgn}(s)$ (8)

By solving the nonlinear equations. Time to settle at switching surface is given by:

$S^{1-0.9}$ = -(1 - 0.9)m_1 t +S(0)$^{1-0.9}$

$t_1 = 1 - s(0)^{t-1}/m_1(0.9 - 1)$

M_1 is the parameter chosen which is superior than 1 and the power of sliding mode is 1.

Case 2: -m2$|s|^{0.5}$ $sgn(s)$ (9)

By solving the nonlinear equation to weaken the chattering at sliding face:

$S^{(1-0.5)}$ = -(1 - 0.5)m_2 t+1

$t_2 = 1/m_2(1 - 0.5)$

Total time to reach the sliding surface:

$$t = (1 - s(0)^{t-1}/(m_1(0.9 - 1) + 1/m_2(1 - 0.5)) \quad (10)$$

$$\dot{S} = -m1^*|s|^{0.9}\mathrm{sgn}(s)-m2|s|^{0.5}\, sgn(s) = \dot{S} = \alpha 1\dot{X}1 + \alpha 2\dot{X}2 + \alpha 3\dot{X}3 = 0 \quad (11)$$

$$-m1^*|s|^{0.9}\mathrm{sgn}(s)-m2|s|^{0.5}\, sgn(s) = \dot{S} = \alpha 1\dot{X}1 + \alpha 2\dot{X}2 + \alpha 3\dot{X}3 \quad (12)$$

$$-m1^*|s|^{0.9}\mathrm{sgn}(s)-m2|s|^{0.5}\, sgn(s) = \alpha 1\left(-\frac{\beta}{C}\right)ic + \alpha 2\frac{\beta ic}{RC^2} - \alpha 2\frac{UVin\beta}{LC} + \alpha 2\frac{\beta V0}{LC} + \alpha 3(Vref - \beta Vo) \quad (13)$$

$$Ueq = \frac{LC}{\alpha 2Vin\beta}\begin{bmatrix} -m1^*|s|^{0.9}\mathrm{sgn}(s)-m2|s|^{0.5}\, sgn(s) - \frac{\alpha 1ic\beta}{C} + \alpha 2\frac{\beta ic}{RC^2} + \\ \alpha 2\frac{\beta Vo}{LC} + \alpha 3(Vref - \beta Vo) \end{bmatrix} \quad (14)$$

Ueq=d; [19]

$$Ueq = \frac{LC}{\alpha 2Vin\beta}\begin{bmatrix} -m1^*|s|^{0.9}\mathrm{sgn}(s)-m2|s|^{0.5}\, sgn(s) - \frac{\alpha 1ic\beta}{C} + \alpha 2\frac{\beta ic}{RC^2} + \\ \alpha 2\frac{\beta Vo}{LC} + \alpha 3(Vref - \beta Vo) \end{bmatrix} \quad (15)$$

1) The dynamics of the switching role.

S= -Qsgn(s) - Kf(s) (16)

Three reaching laws are,

The reaching law$\dot{S} = -Qsgn(s)$ (17)

2) The constant plus proportional rate reaching law

$$\dot{S} = -Qsgn(s) - Ks \quad (18)$$

3) The power pace reaching law

$\dot{S}$=-k$|s|^{\alpha}$sgn (si)) o < α< 1 i = 1 to n [2] (19)

Reaching law approach gives the active characteristics of the system at the reaching phase [19].
4) Conventional reaching law
The reaching law is:
$\dot{S} = -\varepsilon sgn(S) - f(S)$ [16], [19], [22] (20)

Where Є >0, f(S)>0

5. RESULTS AND DISCUSSION

Figure 3 shows that chattering of robust reaching law in the phase plane trajectory, it covers entire sliding mode portion. Figure 4 chattering of traditional reaching law, here it is observed that high chattering occurs at the origin. And it causes a high quantity of switching losses. Figure 5 represents the load resistance decreased by 5 Ohm and settling time 0.45 msecs. It is observed that the recovery time to steady state of proposed reaching law is very fast.

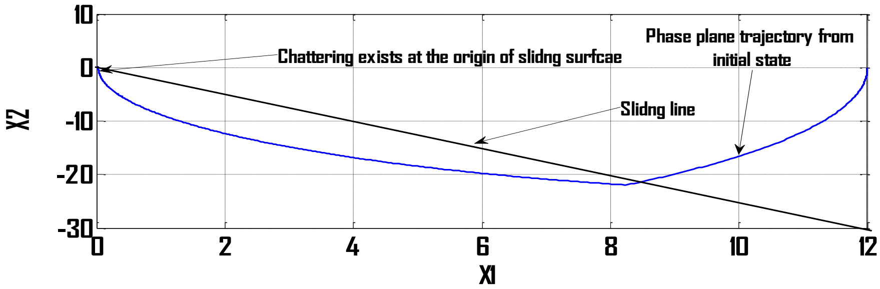

Figure 3. Chattering of proposed reaching law in sliding line path

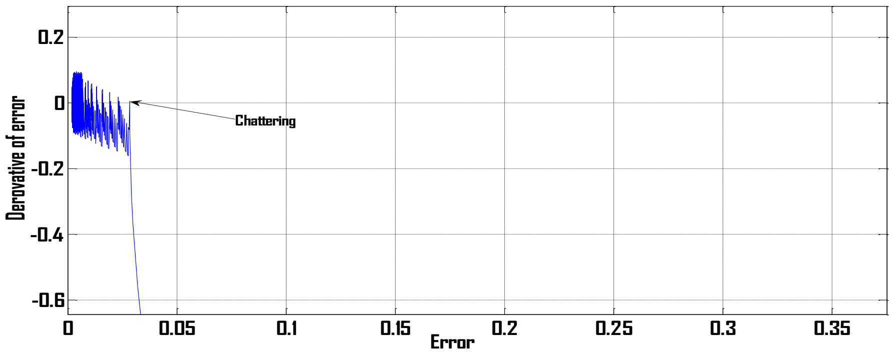

Figure 4. Chattering of proposed reaching law at origin

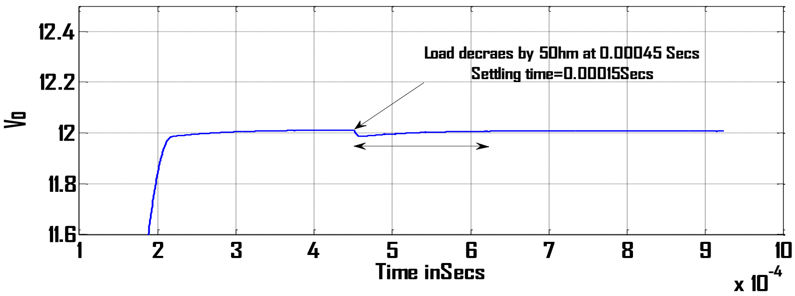

Figure 5. Load resistance decreases by 5 ohm in proposed reaching law

Figure 6 represents the line variation by 12 V from 24 V input, we can observe that, there is a decrease in output voltage by 11.8 V. It represents the small variation in the change in the output voltage. Figure 7 represents the phase plane path of the conventional reaching law, chattering exists from phase plane to origin of the sliding surface. Figure 8 output voltages of conventional reaching law and settling time of this reaching law takes 0.0085. When compared to proposed reaching law it takes more time. Figure 9 represents the output voltage of proposed reaching law with less steady state error and steady state output voltage. Figure 10 represents the chattering of the proposed reaching law; the chattering is very small at the origin by this effectively reduces the switching losses in the step-down converter. The Table 1 represents the specifications of the step-down converter. Table 2 gives chattering, settling time, ripple voltage, reaching time taken by the robust is very less, when compared conventional reaching law and switching losses details of reaching laws, it is observed that the proposed reaching law gives constant voltage even by line and load variations. The chattering effectively weakened and fast speed kept at the switching surfaces.

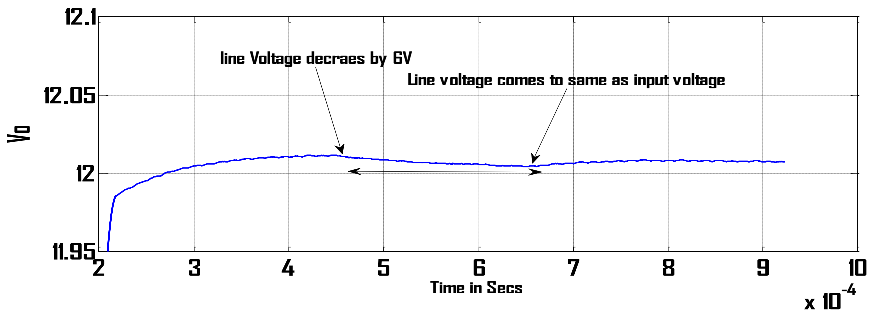

Figure 6. Line voltage decreases by 6 V from 24 Vin proposed reaching law

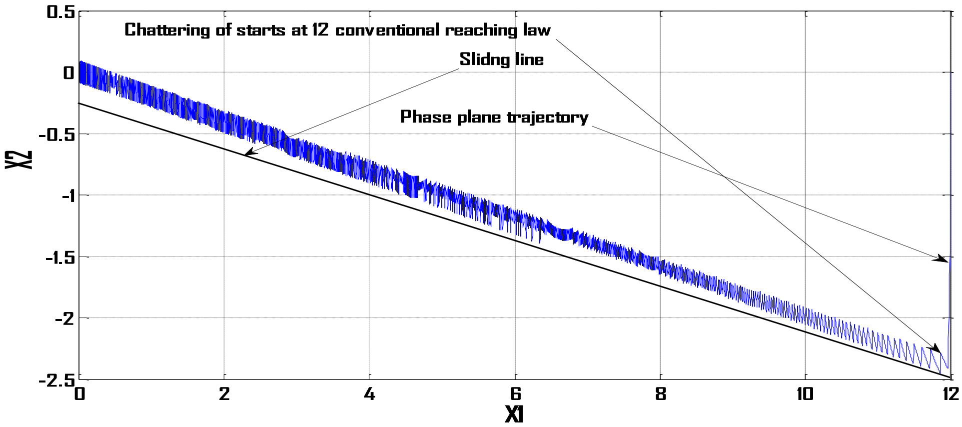

Figure 7. Chattering of conventional reaching law

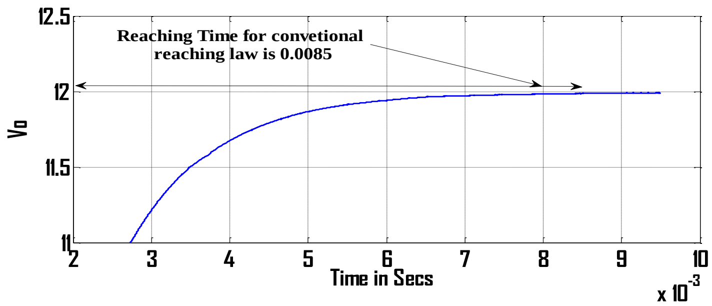

Figure 8. Output voltage of conventional reaching law

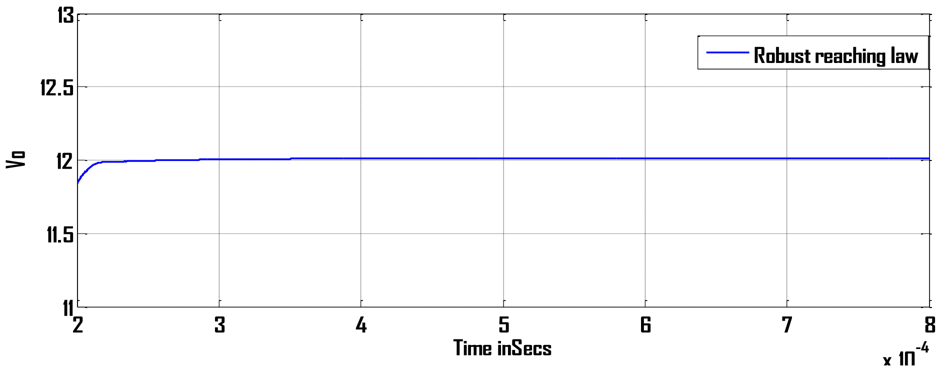

Figure 9. Vo of proposed reaching law

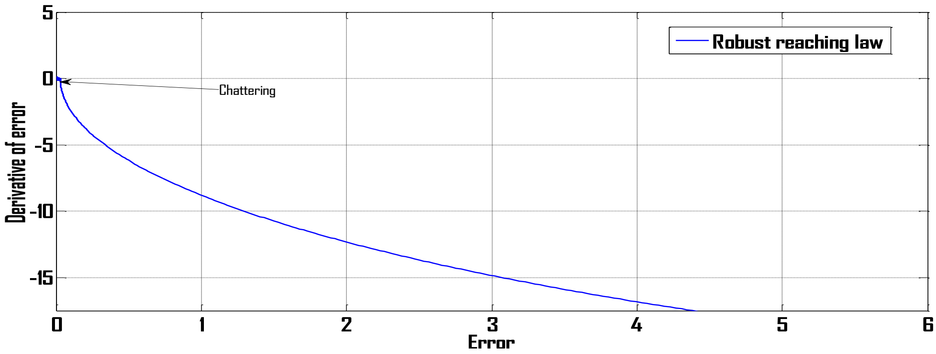

Figure 10. Chattering of proposed reaching law

Table 1. Parameters of buck converter

Sl.No.	constraint	representation	rate
1	Supply voltage	Vi	24 V
2	Capacitance	C	220 μF
3	Inductance	L	69 μH
4	Switching Frequency	fs	200 KHz
5	Min. load resistance	R_L (min)	6 Ohm
6	Max. load resistance	R_L (max)	10 Ohm
7	Vod	Vod	12 V
8	VRef	Vref	12 V
9	m1 &m2 (Parameters)		2.3
10	Feedback factor	β	0.99
11	sliding coefficients,	α_1 α_2 α3	3 25 2000
12	Duty cycle	α	0.5
13	Converter(efficiency)	η	0.91
14	Input Power	Pi	12.2 W
15	Output Power	Po	13 W

Table 2. Comparison of robust with traditional reaching laws

Parameters	Proposed reaching law	Conventional reaching law
Settling time	0.2 msecs	0.7 msecs
Chattering Amplitude	0n x-axis 0 to 0.03 On y-axis -0.08 to 0.085	0n x-axis 2.5 to 0 On y-axis -0.25 to 0.25
Vo (ripple voltage)	1 mv	10 mv
Reaching time To steady state	0.00025 Secs	0.0085 Secs
Switching losses	1 mw	10 mw

6. CONCLUSION

In this paper, discussed the reaching law and traditional reaching law for the chattering, and reaching law effectively reduce the chattering and system remains on sliding phase. Both reaching laws are applied to direct current-direct current (DC-DC) step-down converter. The simulation results show that the reaching law SMC exhibit better static and energetic properties than the traditional reaching law the proposed reaching law exhibits the fast convergence at the steady state and reduces the effects of switching losses in the step-down converter. The overall effect of sliding mode portion covered by the proposed reaching law and very effectively implemented by using this reaching law. The future work may analyze the switching losses in the switch of buck converter as further research.

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BIOGRAPHIES OF AUTHORS

Siddesh Kondapur Basavarajan is e Professor at the Department of Electronic Engineering, Visvesvaraya Technological University (VTU), received the Engineer degree in electrical Engineering from Kuvempu University in 1998, and. He received the Master degree in (Eelctrical Energy system) VTU, MCE Hassan in 2002. Completed his Ph.D. in Electrical & Electronic Engineering from the VTU, India. His research interests include slidng mode controllers, power elctronics, renewable energy, and batteries. He can be contacted at email: siddesh76@sjmit.ac.in.

Shivarudraswamy Rudrappa is Professor at the Department of Electrical Engineering, MIT, Manipal, Karnataka, India, received the Engineer degree in electrical Engineering from Bangalore University in 1992, and he received the Master degree in (Electrical Energy system) VTU, MCE Hassan in 2002. Completed his Ph.D. in Electrical & Electronic Engineering from the NIT, Surathkal. His research interests include slidng mode controllers, power elctronics, renewable energy, and batteries. He can be contacted at email: rshivarudraswamy@manipal.edu.