NEW MODIFIED SLIDING MODE CONTROLLER FOR DC-DC BUCK CONVERTER BASED ON REACHING LAW

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Absract: *This paper represents new modified sliding mode controller with the fixed switching frequency .New proposed method using reaching law to obtain steady state response and reducing chattering phenomenon for line and load variations of DC-DC Buck converter. This paper gives a sliding mode controller accessibility condition and control equation according to the calculations. A simulation result shows that both the conventional and reaching law based sliding mode controller. It is observed that reaching law based SMC gives fast reaching to sliding manifold and high robustness against the line and load variations.*

Key words*: DC-DC Buck converter, Sliding mode control, Reaching law*

1. Introduction

The sliding mode control is derived from variable structure system. Variable structure system is analysis and design of the system. Sliding mode control very robust against to parameter variations, line variation and load variation and it's almost stable[1-2] .The sliding mode controller of buck converter has been developed strongly by use of many methods such as design of sliding mode plane take the system output voltage and inductor current are variables[3].Design a universal sliding mode plane for all kinds of dc-dc converter which consider the inductor current and output voltage are variables[4].The conventional method only analyze and design the sliding plane according to selecting two parameters on two dimensional plane[5-6]. Analyzing the buck converter with three dimension space also contrive universal design method for all kinds of dc-dc converter which is based on pulse width modulation[5].This paper propose that employing a reaching law for two dimensional space by reducing chattering [7-8] phenomenon and very easy to implement. The two parameters are voltage error and derivative of error considered.

2. Conventional buck converter operating in CCM mode

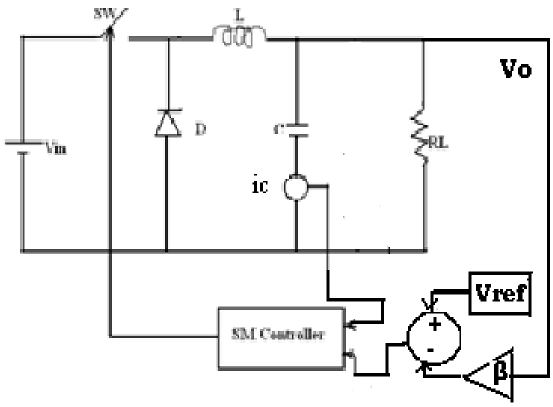

Fig1: Conventional Sliding Mode Controller Buck Converter

Conventional Sliding mode buck converter:

$$X_1 = V_{ref} - \beta V_0$$
$$X_2 = \dot{X}_1 = \beta / C\left(\frac{V_o}{R_L} - \int \frac{UV_i - V_o}{L} dt\right) \qquad (1)$$

The Conventional sliding mode buck converter is given by

$$S = \frac{1}{\beta R_L}\left(V_{ref} - \beta V_o\right) - i_C \qquad (2)$$

Where X_1 ,X_2 are the state variables, Vref. is reference voltage, β is feedback ratio,Vin is an input voltage and Vo is an output voltage

From equation (1) we get the state equations

$$X_1 = V_{ref} - \beta V_0$$
$$X_2 = \dot{X}_1 = \beta / C\left(\frac{V_o}{R_L} - \int \frac{UV_i - V_o}{L} dt\right) \quad (3)$$

3. Design of control law:

In SM control the switching function is employed that

$$S = \alpha X1 + X2 \quad (4)$$

Where α is sliding coefficient, α>0

$$U = \begin{cases} 1, S > 0 \\ 0, S < 0 \end{cases} \quad (5)$$

Table-1 Specification of Buck converter

Equation (4) determines the switching state u and directs the phase trajectories towards the sliding manifold and it must be obey the Lypunov second method

4. Proposed reaching law based S M Controller design

The derivative of equation (4)

$$\dot{S} = \alpha \dot{X}_1 + \dot{X}_2 \quad (6)$$

From equation (2) we get,

$$\dot{S} = -\varepsilon \mathrm{sgn}(S) - m(S) \quad , m>0, \epsilon>0 \quad (7)$$

Equate (6) and (7)

$$-\varepsilon \mathrm{sgn}(S) - m(S) = \alpha X2 - \frac{1}{LC} X1 - \frac{-1}{RLC} X2 - \frac{\beta Vin}{LC} u + \frac{Vref}{LC} \quad (8)$$

$$-\varepsilon \mathrm{sgn}(S) - m(S) = X2\left(\alpha - \frac{1}{RLC}\right) - \frac{1}{LC} X1 - \frac{\beta Vin}{LC} u + \frac{Vref}{LC} \quad (9)$$

Where u=d ,d is a duty ratio

$$d = \frac{LC}{\beta Vin}\left(\varepsilon \mathrm{sgn}\left(\alpha(Vref - \beta Vo) - \frac{\beta ic}{C}\right)\right) + \frac{LC}{\beta Vin} m\left(\left(\alpha(Vref - \beta Vo) - \frac{\beta ic}{C}\right)\right) - \frac{Lic}{Vin}\left(\alpha - \frac{1}{RLC}\right) - \frac{(Vref - \beta Vo)}{\beta Vin} + \frac{Vref}{\beta Vin} \quad (10)$$

d=Vc/Vramp; Vramp=βVin

Therefore

$$Vc = LC\left(\varepsilon \mathrm{sgn}\left(\alpha(Vref - \beta Vo) - \frac{\beta ic}{C}\right)\right) + LCm\left(\left(\alpha(Vref - \beta Vo) - \frac{\beta ic}{C}\right)\right) - Lic\beta\left(\alpha - \frac{1}{RLC}\right) - (Vref - \beta Vo) + Vref \quad (11)$$

We choosen a Є=m=0.001 Vin/LC ,$\alpha = 3/R_L C$[9-10,11]

5. Simulation results:

Table-1 Specification of Buck converter

Sl.No.	Parameters	Value
1	Input Voltage	24V
2	Output Voltage	12V
3	Inductance	69e-06H
4	Capacitance	220e-06F
5	Min Load Resistance	3.3Ω
6	Max Load Resistance	10Ω
7	Switching frequency	200KHz
8	Reference voltage	12V

A.Simulation results conventional sliding mode buck converter

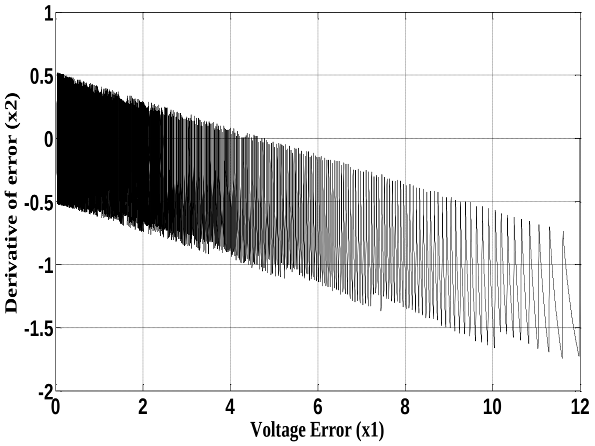

Fig. 2. Phase plane trajectory of Buck Converter

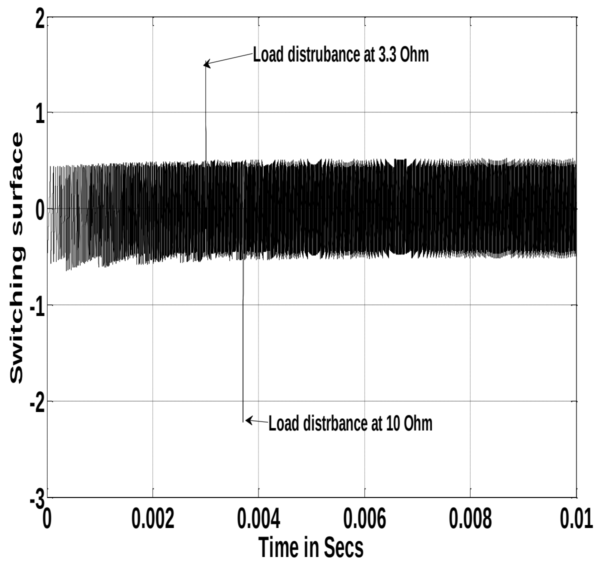

Fig.3.switching surface of Dc-DC Buck converter with load disturbance

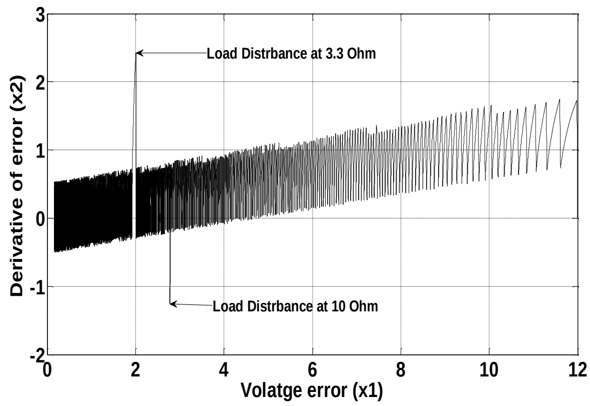

Fig.4.Phase trajectory of load variation of DC-DC buck converter

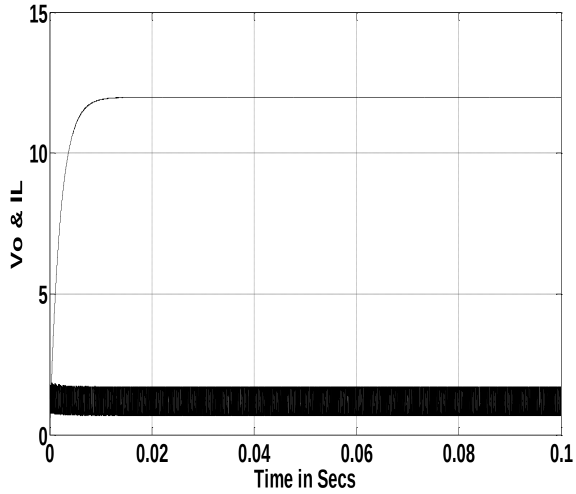

Fig.5. Output voltage and Inductor current response

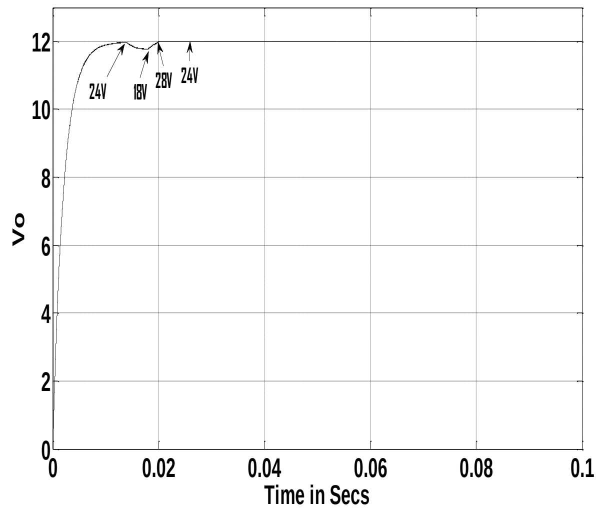

Fig.6. Input variation from 24V to 18V at 0.014Secs,18V to 28V at 0.016Secs and 28V to 24V at 0.02Secs

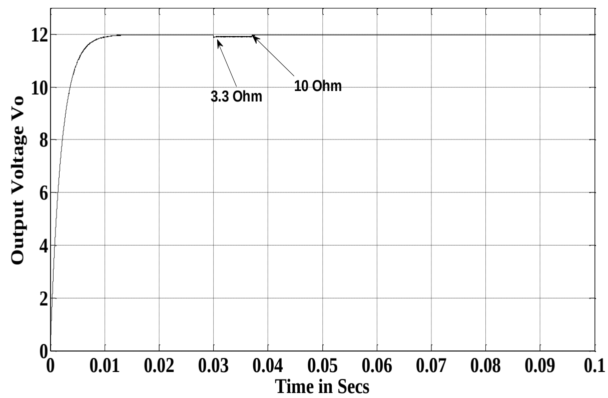

Fig. 7. Load variation from 10Ohms to 3.3 Ohms at 0.03Secs and 3.3 Ohms to 10 Ohms at 0.037Secs

By using conventional SMC buck converter has more chattering in the sliding manifold and it requires more time to reach the equilibrium as shown in fig.2.From fig .3 shows switching surface (S) with load disturbances.Fig.4. Shows phase trajectory of load disturbances takes place chattering phenomenon is also disturbs.Fig.5.Shows the simulation results obtained from the conventional controller i.e., output voltage and inductor current for the given input voltage, the output voltage has more ripple, more steady state error and inductor current has more ripple content.Fig.6.shows the line variation with different inputs.Fig.7. Shows the load variation with the different loads.

B.Simulation results of reaching law based SMC Buck converter

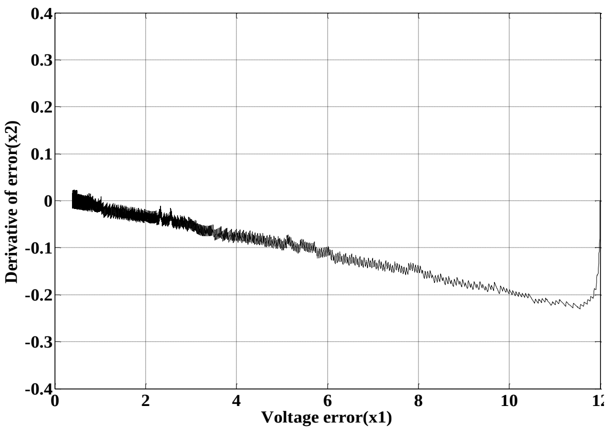

Fig.8. Phase plane trajectory of Buck Converter

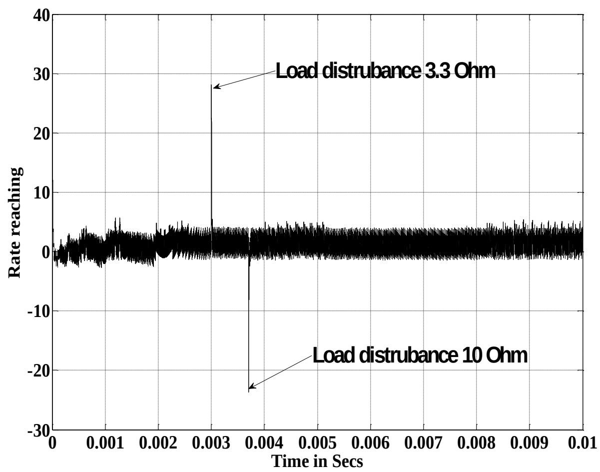

Fig.9. Switching surface of DC-DC Buck converter with load disturbances (reaching law)

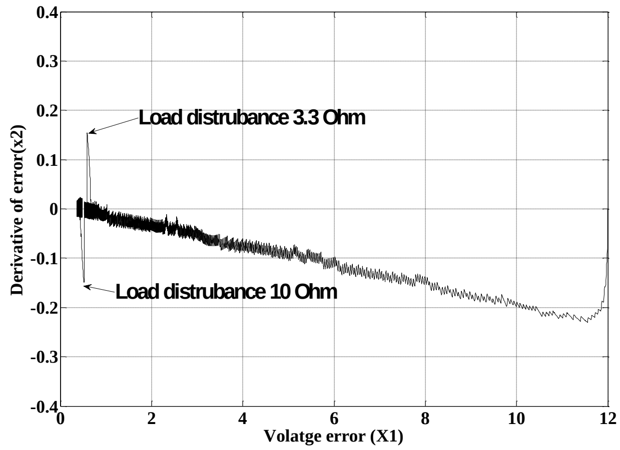

Fig.10. Phase trajectory with load variation of DC-DC buck converter (reaching law)

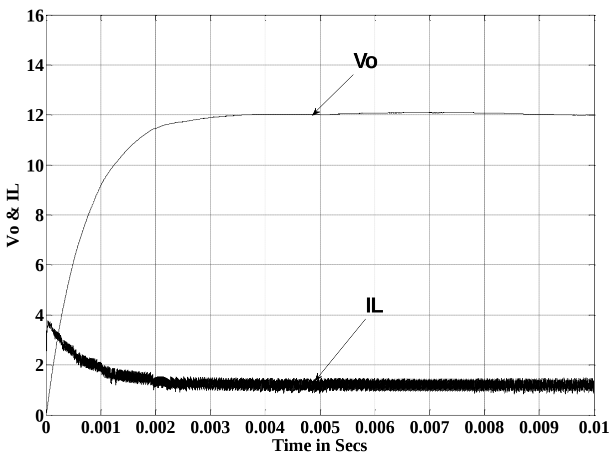

Fig.11.output voltage and inductor current response (reaching law)

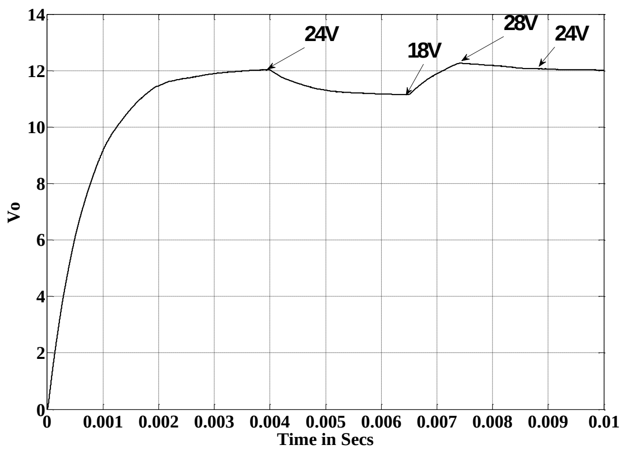

Fig .12. Input variation from 24V to 18V at 4ms, 18V to 28V at 6.4ms and 28V to 24V at7.4ms

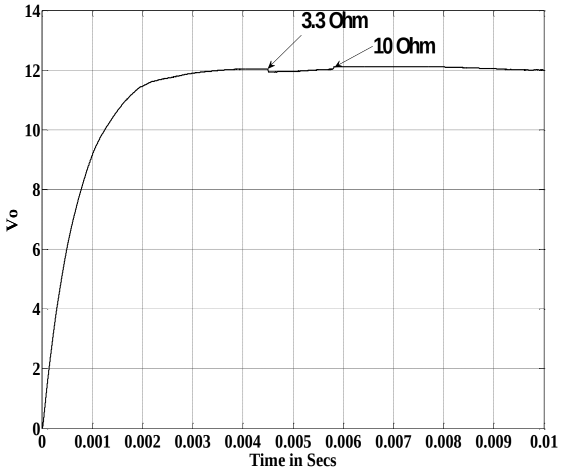

Fig.13. Load variation from 10Ω to 3.3Ω at 4.5ms and 3.3Ω to 10Ω at 5.8ms

By using reaching law for the dc-dc buck converter can reduce the chattering in the sliding manifold and reach the equilibrium very fast, as shown in fig.8.From fig.9 shows switching surface with load disturbances. Fig. 10 shows phase trajectory of load disturbances takes place, chattering phenomenon is also disturbs .Fig. 11 shows the simulation results obtained from the robust controller i.e. is output voltage and inductor current for the given input voltage. The output voltage has free from ripple, less steady state error and the inductor current has some ripple content. Fig.12 shows robustness of controller a sudden input is introduced at t=4ms, 6.4ms and 7.4ms. Step input changes from 24V to 18V, 18V to 28V and 28V to 24V respectively. Fig.13 shows the robustness of the controller a sudden load change is introduced at t=4.4ms and 6.2ms Step load changes from 10Ω to 3.3Ω and 3.3 to 10Ω respectively.

Conclusion:

A new modified scheme (reaching law) for sliding mode controller with a constant switching frequency for dc-dc buck converter is proposed. The design procedure and reaching law of SM controller for buck converter are given in detail. The proposed reaching law based SMC buck converter is compared with the conventional SMC buck converter, it is observed that the reaching law based SMC buck converter is more robustness, less chattering, less sensitivity for the line and load variations. Simulation results shows that reaching law SMC exhibits superior dynamic properties, reaching law of sliding mode controller has a shorter settling time because of the improved dynamic characteristics in the reaching phase.

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