RESEARCHERID
THOMSON REUTERS

[IDSTM-18]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

DC-DC BOOST CONVERTER USING ADAPTIVE SLIDING MODE CONTROL

Rohit Kumar Gupta[1], Sandeep Khantwal[2], Ajay Chhillar[3]
[2]Assistant professor ECE Department, SET, Ganga Technical Campus, soldha (Haryana)
[1,3]Assistant Professor EE Department, SET Ganga Technical Campus soldha (Haryana)

ABSTRACT

This paper describes a non-linear adaptive controller using sliding mode control (SMC) technique based on system non-linear model. The proposed controller asymptotically stable and it can control the system without knowing any initial conditions. It has also the ability to adjust itself to make suitable with changing of upper bounds of uncertainty. The proposed controller is also noise insensitive.

Keywords: Adaptive sliding-mode control, dc–dc converter,pulsewidth modulation.

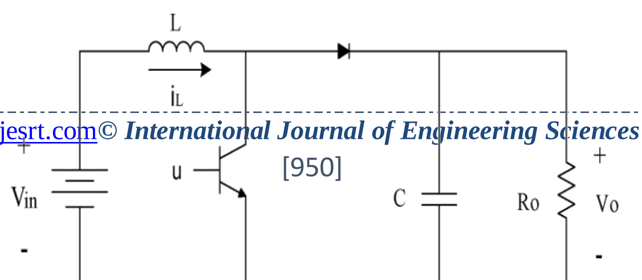
I. INTRODUCTION

Sliding-mode controllers (SMCs) most widely used for DC-DC converters due to the factor of their inherent nature of variable structure [1]. The sliding mode controlis a famous strategy for controlling of nonlinear uncertain systems having a very large frame of applications fields [12]. However with the use of the discontinuous function, its main concern are the closed-loop system robustness and the finite-time convergence.
SMCs may be depend on hysteresis modulation, or delta modulation [7]. A limitation of this method is the variation in switching frequency of operation. To eliminate the problem, extra hardware may be added to assure a constant switching frequency. A key solution is the use of an identical control (derived using sliding-mode-control methods) to modulate a pulse-width modulator (PWM), and in this the controller operates like a traditional duty cycle controller with a constant switching frequency [7].

When constant resistive loads and their values are unknown or completely uncertain as is the case in various practical conditions one may have to utilize adaptive controllers. In [14], a passivity-depend adaptive controller is implemented to handle with dc–dc converters with an unknown load resistance. In [15], back stepping technique is used in an adaptive SMC for the boost converter having unknown load resistance. In both studies [14], [15], the external input voltage must be known for the design of the controllers. In this paper, a PWM-based adaptive SMC is design for the boost converter with an unknown load resistance and external input voltage. The adaptive controller is implemented by using state estimators which guarantees that, in sliding mode, the closed-loop systems are asymptotically stable. However, the estimation for the load resistance and input voltage leads to their true values. Experimental results show that the output voltage tracks the reference voltage with very less variations in input-voltage and large resistance step variations i.e., the output voltage steady-state error is very low, and there is no requirement to add a voltage error integration term to the sliding surfaces done in sliding-mode control. The design techniques for the adaptive controller can be easily enhanced to buck and buck–boost converters.

The structure of this paper is as introduced In Section II, an adaptive SMC is implemented and experimental results are shown. Section III is the conclusion.

II. BOOST CONVERTER



ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Fig.1 Boost converter

A basic boost converter is given in Fig. 1. Under continuous mode of conduction, the averaged model of the converter is

$$\dot{x}_1 = \frac{-(1-d)}{L}x_2 + \frac{Vin}{L}$$
$$\dot{x}_2 = \frac{(1-d)}{C}x_1 - \frac{1}{RC}x_2 \qquad (1)$$

Where the state variable *x*1 indicates the average inductor current *iL*, and *x*2 indicates the average capacitor voltage *vo*. The componentsL, C, and Rindicates the inductor, capacitor and load resistor, respectively. We should point here that *R*and the external input voltage *V*in are unknown. The control input *d* to the converter is considered as the duty ratio function.

A. Estimator-Based Adaptation Law Design

Let x_1 and x_2 are accessible and $\hat{\theta}$ and $\hat{V}_{in}$ are estimates of θ and V_{in} respectively.

$$\dot{\hat{x}}_1 = -(1-d)\frac{\hat{x}_2}{L} + \frac{Vin}{L} + K_1(x_1 - \hat{x}_1)$$

$$\dot{\hat{x}}_2 = (1-d)\frac{\hat{x}_1}{C} - \frac{\hat{\theta}}{C}x_2 + K_2(x_2 - \hat{x}_2) \qquad (2)$$

Where K_1>0 and K_2>0 are known as observer gain and $\hat{x}_1$ and $\hat{x}_2$ are considered asthe estimates of x_1 and x_2 respectively.Let, $\tilde{x}_1 = x_1 - \hat{x}_1$ and $\tilde{x}_2 = x_2 - \hat{x}_2$ then by using the given above equation (1) and (2) followingEquation can be obtained as:

$$\dot{\tilde{x}}_1 = -(1-d)\frac{\tilde{x}_2}{L} + \frac{\tilde{V}_{in}}{L} - K_1\tilde{x}_1$$

$$\dot{\tilde{x}}_2 = (1-d)\frac{\tilde{x}_1}{L} - \frac{\tilde{\theta}}{C}x_2 - K_2\dot{\tilde{x}}_2 \qquad (3)$$

To produce the adaption laws, we consider the followingquadratic Lyapunov function as follows

$$V = \frac{1}{2}L\dot{\tilde{x}}_1 + \frac{1}{2}C\dot{\tilde{x}}_2^2 + \frac{1}{2\gamma_1}\tilde{\theta}^2 + \frac{1}{2\gamma_2}\tilde{V}_{in}^2 \qquad (4)$$

Where $\gamma_1 > 0$ and $\gamma_2 > 0$ are considered as design parameters. Its time derivative along the solutions is given by:

$$\dot{V} = -K_1L\tilde{x}_1^2 - K_2C\tilde{x}_2^2 - \theta\left[x_2\tilde{x}_2 + \frac{1}{\gamma_1}\dot{\hat{\theta}}\right] + \tilde{V}_{in}\left[x_1 - \frac{1}{\gamma_2}\dot{\hat{V}}_{in}\right] \qquad (5)$$

The adaptation laws are executed by canceling the terms in brackets which are given as:

$$\dot{\hat{\theta}} = -\gamma_1 x_2\tilde{x}_2 \qquad (6)$$

$$\dot{\hat{V}}_{in} = \gamma_2\tilde{x}_1 \qquad (7)$$

With the adaptation laws of (6) and (7), we have

$$\dot{V} = -K_1L\tilde{x}_1^2 - K_2C\tilde{x}_2^2 \qquad (8)$$

By using the lasalle invariant principle, we can assume that $\tilde{x}_1 \to 0$ and $\tilde{x}_2 \to 0$ asymptotically.

Adaptive Sliding mode controller design

RESEARCHERID
THOMSON REUTERS

[IDSTM-18] ISSN: 2277-9655
IC™ Value: 3.00 Impact Factor: 5.164
CODEN: IJESS7

We conclude the following switching surface:

$$\sigma = \hat{x}_1 - \frac{V_{ref}^2}{\hat{V}_{in}}\hat{\theta} \qquad (9)$$

Where Vref is referred as the desired output voltage. With the help of the invariance condition, the identical control is derived using differentiating σ with respect to time and setting $\dot{\sigma} = 0$. Using (2), (3), (4), and (9), the equivalent control is as follows:

$$d_{eq} = 1 - \frac{(\hat{V}_{in} + K_1 L\tilde{x}_1 + \frac{\gamma_1 L V_{ref}^2}{\hat{V}_{in}} x_2\tilde{x}_2 + \frac{\gamma_2 L V_{ref}^2 \hat{\theta}\tilde{x}_1}{\hat{V}_{in}^2})}{\hat{x}_2}$$

For sliding mode to locally exist [16], $\sigma\dot{\sigma}<0$ must hold, resulting
0 <$d$eq<1

$$0 < (\hat{V}_{in} + K_1 L\tilde{x}_1 + \frac{\gamma_1 L V_{ref}^2}{\hat{V}_{in}} x_2\tilde{x}_2 + \frac{\gamma_2 L V_{ref}^2 \hat{\theta}\tilde{x}_1}{\hat{V}_{in}^2}) < \hat{x}_2$$

The initial conditions of the observer is$\hat{}x1(0)$ and $\hat{}x2(0)$ and the initial conditions of the adaptation laws is$\hat{}\theta(0)$ and $\hat{}$ Vin(0) can be implemented which guaranties the sliding mode occurrence in such a way and should be selected such that the sliding mode starts at t = 0, i.e., $\sigma(0) = \hat{}x1(0) - (\hat{}\theta(0)V$ 2ref/ $\hat{}$ Vin(0)) = 0. A block diagram of the control system is given in Fig. 2.

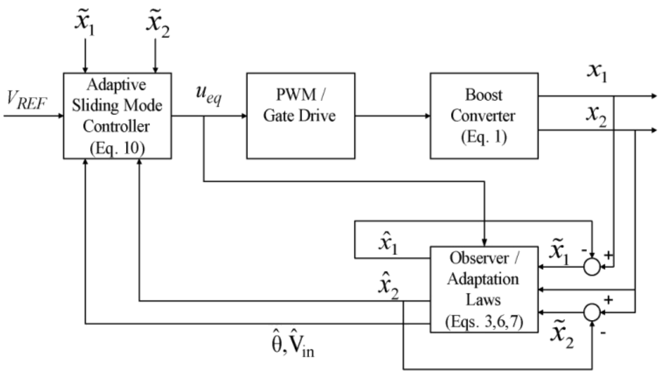


Fig. 2- block diagram of adaptive sliding mode control

III. SIMULATION AND EXPERIMENTAL RESULT

Specification for boost converter is as follows:

Description	parameter	Nominal value
Input voltage	V_i	6V
capacitance	C	0.150 mf
inductance	L	0.180 mH
Switching frequency	f_s	200kHz
Minimum load resistance	R_{Lmin}	40 ohm
Maximum load resistance	R_{Lmax}	160 ohm
Desired output voltage	V_{od}	12 V

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Values of control parameter for $K_1 = 833$ and $K_2 = 833$ with adaptation law gains $\gamma_1 = 1$ and $\gamma_2 = 250.0$.

(i) Output waveform when load is vary from 40 ohm to 160 ohm at time t=0.5 sec is shown in Fig.3

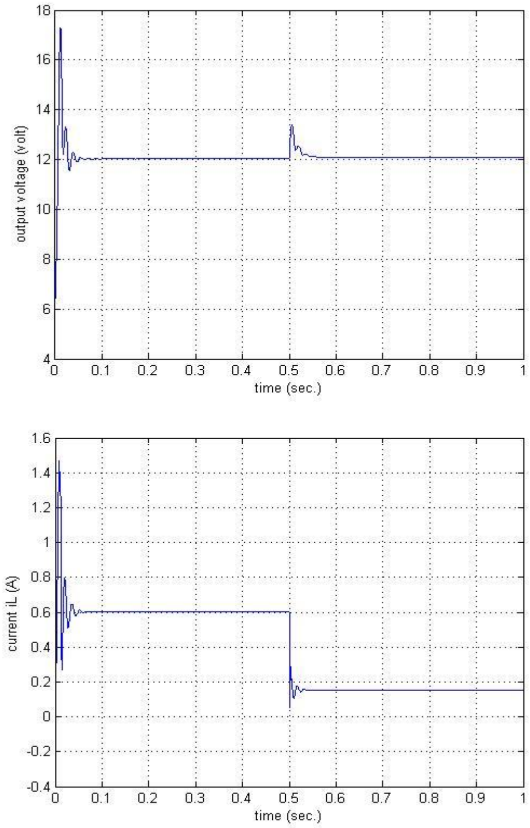
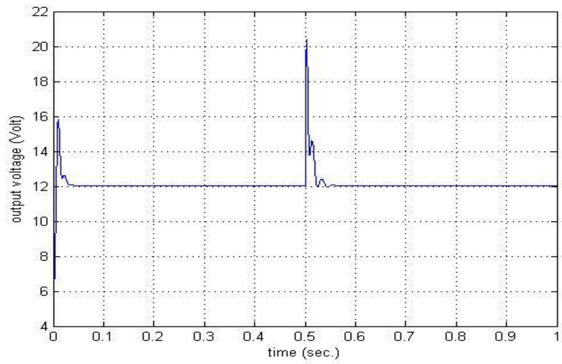


Fig.3 (A)Output voltage waveform (B) Inductor current waveform

(ii) Output waveform when input voltage is vary from 6 volt to 10 volt at time t=0.5 is shown in fig. 4



ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

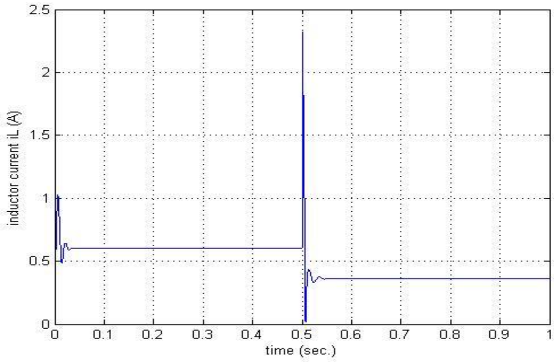


Fig. 4 (A) Output voltage waveform (B) Inductor current waveform

As shown in results we can consider that adaptive sliding mode control is accurate for uncertain load condition.

IV. CONCLUSION

In this paper we discussed about adaptive sliding mode controller for dc-dc boost converter which is simulated with uncertain conditions like undefined load and variable input voltage. In adaptive sliding mode controller it reduce chattering phenomenon and also transient time is very low. Designed controller is closed loop controller and asymptotically stable. Simulated results are verified in future and we can extended it for buck and buck-boost converter.

V. REFERENCES

[1] E. Vidal-Idiarte, C. E. Carrejo, J. Calvente, and L. Martinez-Salamero, "Two-loop digital sliding mode control of dc–dc power converters based on predictive interpolation," *IEEE Trans. Ind. Electron.*, vol. 58, no. 6,
pp. 2491–2501, Jun. 2011.
[2] R.-J. Wai and L.-C. Shih, "Design of voltage tracking control for dc–dc boost converter via total sliding-mode technique," *IEEE Trans. Ind. Elec-tron.*, vol. 58, no. 6, pp. 2502–2511, Jun. 2011.
[3] R. Cardim, M. C. M. Teixeira, E. Assuno, and M. R. Covacic, "Variable-structure control design of switched systems with an application to a dc–dc power converter," *IEEE Trans. Ind. Electron.*, vol. 56, no. 9,
pp. 3505–3513, Sep. 2009.
[4] B. J. Cardoso, A. F. Moreira, B. R. Menezes, and P. C. Cortizo, "Anal-ysis of switching frequency reduction methods applied to sliding mode controlled dc–dc converters," in *Proc. IEEE Appl. Power Electron. Conf.Expo*, Feb. 1992, pp. 403–410.
[5] L. Malesani, L. Rossetto, G. Spiazzi, and P. Tenti, "Performance opti-mization of Cuk converters by sliding mode control," *IEEE Trans. PowerElectron.*, vol. 10, no. 3, pp. 302–309, May 1995.
[6] P. Mattavelli, L. Rossetto, and G. Spiazzi, "Small-signal analysis of dc–dc converters with sliding mode control," *IEEE Trans. Power Electron.*, vol. 12, no. 1, pp. 96–102, Jan. 1997.
[7] J. Mahdavi, A. Emadi, and H. A. Toliyat, "Application of state-space averaging method to sliding mode control of PWM dc/dc converters," in *Proc. IEEE Ind. Appl. Soc. Annu. Meeting*, Oct. 1997, vol. 2, pp. 820–827.
[8] J. Mahdavi, M. R. Nasiri, A. Agah, and A. Emadi, "Application of neural networks and state-space averaging to a dc/dc PWM converter in sliding-mode operation," *IEEE/ASME Trans. Mechatronics*, vol. 10, no. 1, pp. 60– 67, Feb. 2005.
[9] S. T. Tan, Y. M. Lai, and C. K. Tse, "A unified approach to the design of PWM-based sliding-mode controllers for basic dc–dc converters in continuous conduction mode," *IEEE Trans. Circuits Syst.*, vol. 53, no. 8,
pp. 1816–1827, Aug. 2006.
[10] Y. He and F. L. Luo, "Sliding-mode control for dc–dc converters with constant switching frequency," *Inst. Elect. Eng. Proc. Control TheoryAppl.*, vol. 153, no. 1, pp. 37–45, Jan. 2006.
[11] S. T. Tan, Y. M. Lai, C. K. Tse, L. Martinez-Salamero, and C.-K. Wu, "A fast-response sliding-mode controller for boost-type converters with a wide range of operating conditions," *IEEE Trans. Ind. Electron.*, vol. 54, no. 6, pp. 3276–3286, Dec. 2007.

[13]Said Oucheriah and LipingGuo, “PWM-Based Adaptive Sliding-Mode Control for Boost DC–DC Converters,” *IEEE Trans. Ind. Electron.*, vol. 60, no. 8, pp. 3291–3294, Aug. 2013.
[14]E. M. Navarro-Lopez, D. Cortes, and C. Castro, “Design of practical sliding-mode controllers with constant switching frequency for power converters,” *Elect. Powers Syst. Res.*, vol. 79, no. 5, pp. 796–802, May 2009.
[15]H. Sira-Ramirez, R. Ortega, and M. Garcia-Esteban, “Adaptive passivity-based control of average dc-to-dc power converter models,” *Int. J. Adapt.Control Signal Process.*, vol. 12, no. 1, pp. 63–80, Feb. 1998.
[16]H. ElFadil, F. Giri, and H. Ouadi, “Adaptive sliding mode control of PWM boost dc–dc converters,” in *Proc. IEEE Int. Conf. Control Appl.*, Munich, Germany, Oct. 2006, pp. 3151–3156..