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Discrete Sliding Mode Controller for Power Converters

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Abstract: **-- In this paper a Discrete Sliding Mode controller (DSMC) for dc-dc buck Converter is presented. The main aim is to get fast response, high efficiency, to improve Robustness. against load and input voltage variations& overcome the chattering problem, so that the overall system is efficient & economical. Results based on MATLAB simulation shows that the DSMC model is a chattering-free control, gives fast. dynamic response and shows robustness to uncertainties.**

Index Terms: **— Discrete Sliding Mode Controller, Variable Structure System, DC-DC Converter.**

I. INTRODUCTION

In recent days the application of power electronics has grown tremendously and a study predicts that by the end of the twentieth century, . more than 50% of electric. power will be from power electronic equipment. The following applications are increasingly dominated by power electronics are: (1) .switched-mode power supplies; (2) .adjustable speed drives; (3) personal computers; (4) office equipment; and (5) mobile chargers and (6) telecommunication equipments. Rapid development of.microelectronics had great impact on the evolution of power electronics.by making them technically and economically feasible.

Most commonly used application by power electronics is switched-mode power supplies and increase in use of computers and communication.equipment has high demand on switched-mode power supplies. Such converters are subjected to high load fluctuation due to increase in package density of on-board digital chips, which make the converter.performance worse. So there is a need for good controller to perform well under unpredictable load fluctuations.

In the begging PID controllers were used which require precise linear mathematical model, but the performance is poor under non-linearity and load fluctuation. The performance of DC_DC converters is non-linear because of the presence of switches, results in poor result with PID controller. Mathematical model is obtained by state space averaging method but possible only for small signals not for large signals. Modern controllers like adaptive controllers, state feedback controllers and self-tuning controllers are also require accurate mathematical model, so sensitive to parameter fluctuation.

An alternate controller which does not require accurate mathematical model is sliding mode controller (SMC) was introduced. Even though accurate mathematical model is not required, but knowledge about parameter fluctuation is required for stability. Irrespective of system order SMC is always designed for the first-order and the control law can handle worse case dynamics which results in chattering. So a boundary layer is introduced around the sliding surface to reduce chattering problem. To control variable structure systems [8] SMC was introduced which has major advantages like stability, robustness against uncertainties, flexibility in design and ease of implementation. This ensures its wide industrial application like furnace control and automotive control etc.

Power converters are highly nonlinear because of the presence of saturating inductance, switching cycle and voltage clamping etc. Introduction of resonant converter mathematical model of power converters are becoming complicated. With buck converters are considered for large signals, good voltage regulation is obtained without the requirement of complicated mathematical model even with wide range of parameter fluctuation. The use Discrete Sliding Mode Controller (DSMC) has the following advantages like [4] (1) Flexible sliding surface (2) Same controller can control other power converter with small adjustment (3) Possible to use advanced functions like digital compensator in control algorithm (4) Generation of adaptive control is possible.

II. DESIGN OF DISCRETE SLIDING MODE CONTROLLER

In this paper the control variables are sampled, so the sampled continuous systems are called discrete systems. In a discrete controller using sliding mode algorithm, .the input gains and the control law are designed based on the principles of sliding mode control. The only variables that need to be tuned are the output gain. Therefore, .the time required for tuning is greatly reduced for a discrete controller using sliding mode algorithm. The combination of the sliding mode control with the.discretization aims to improve the robustness and the performances of the controlled nonlinear systems.

Fig.1. shows the block diagram of the DSMC 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 is normally a dc source, even ac source can also be used in that case it requires a rectifier circuit to convert ac into dc. The power converter is controlled by turning on and off of the switches; the switches are normally power semiconductor devices like SCR, MOSFET, IGBT ect. In is paper for simulation MOSFET is used and control is done by controlling the gate pulse. The algorithm used for controlling gate pulse is discrete sliding mode control algorithm.

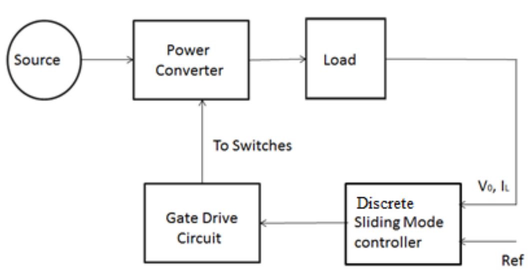

Fig.1. Block Diagram of DSMC for Power Converter.

The DSMC have the following difference with SMC [4]

- only control algorithm is implemented not the prototype
- real time application of discrete system is not possible
- DSMC does not require hysteresis limiter for commutation device
- The performance of DSMC is affected by sampling period.

III. *MATHEMATICAL MODELLING OF DC-DC BUCK CONVERTER*

The circuit diagram of buck converter is shown in fig.2. The input voltage of Vin is given to the circuit and it has diode D, switchS1, storage capacitor C, inductor L, and load resistor R. For buck converter the output voltage is less than or equal to input voltage (i.e.) V0 ≤ Vin . Let iL = x1and Vc = x2 where iL is the inductor current and Vc is the capacitor voltage which are the control variables. Then the approximate.discrete time equivalent system model for the buck converter is given by the following equations [1] & [2].

$$x_1[k+1] = x_1[k] + \frac{T}{C}\{V_{in}\ u[k] - x_2[k]\} \quad (1)$$

$$x_2[k+1] = x_2[k] + \frac{T}{C}\{x_1[k] - \frac{1}{R}x_2[k]\} \quad (2)$$

The sliding surface is given by

$$S[k] = ke_1[k] + e_2[k] \quad (3)$$

Where k is the sliding co-efficient. Let e1 be the difference between the desired value and the actual value of the output voltage,

$$e_2[k] = \dot{e_1}[k] \quad (4)$$

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

$$S[K+1] - S[K] = \left(\frac{KTRC + TRC - T^2}{RC^2}\right)X_1[K]$$
$$+ \left(\frac{T^2L - KTRCL - TRCL - T^2R^2C}{R^2C^2L}\right)X_2[K]$$
$$+ \frac{T^2}{LC}V_{in}u[k] - kr[k+1] + kr[k] \quad (5)$$

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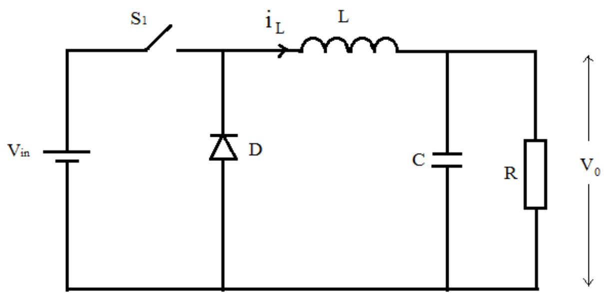

Fig.2. Circuit diagram of buck converter

A. Flowchart of buck converter

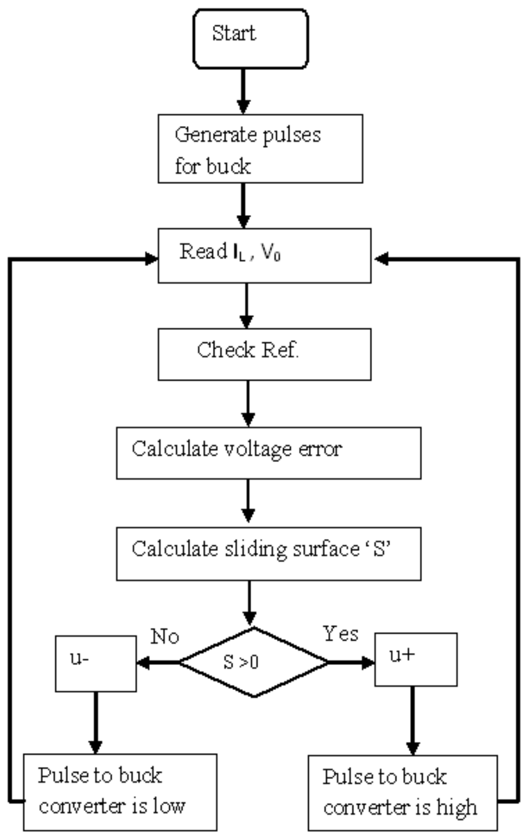

Fig.3. DSMC Flowchart for buck-converter

Fig.3. shows the flowchart of the DSMC for the buck converter. The explanation starts with the generation of pulses for the buck converter. The values of inductor current and capacitor voltage are sampled; the sampled capacitor voltage is then compared with the reference value to find the error. The next step is the calculation of sliding surface S. There are two conditions, If S>0 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.

IV. SIMULATION RESULTS

Proposed discrete sliding mode controller simulated for the buck converter with the following parameters: Vin=12V; C=3μF; L= 3mH; R=10Ω; switching frequency=10 kHz. Fig.4. shows the MATLAB SIMULINK model of DSMC buck converter. MOSFET is used here as a switch because of its high speed of response and the switching is done by controlling the gate signal by DSMC.

Fig.5. shows the MATLAB SIMULINK model of the sub-system and fig.6. shows the simulated output of control signal. Fig.7. shows simulated output waveforms of DSMC buck converter including input voltage, inductor current, and output voltage with respect to time. From the graph we can come to know that the output voltage is less than input voltage with fewer harmonic.

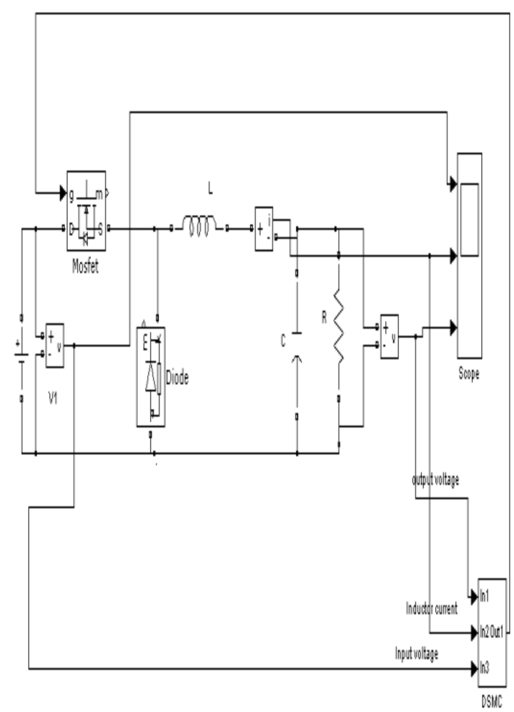

Fig.4. MATLAB simulation of DSMC buck converter

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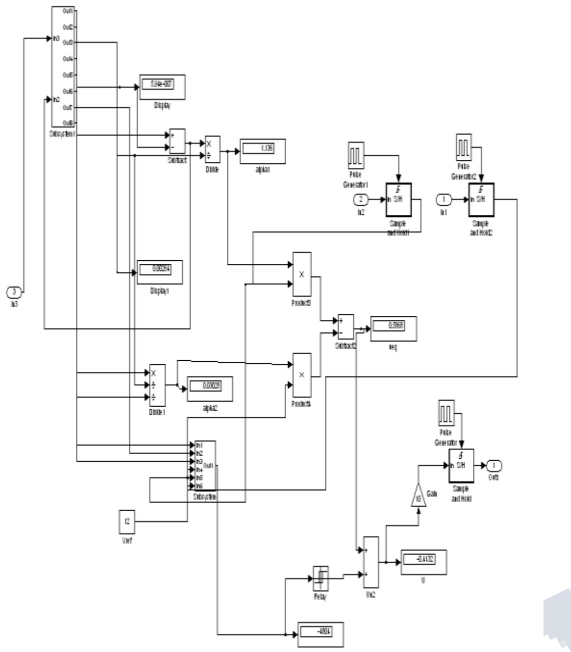

Fig.5. Matlab Simulink model of DSMC (subsystem)

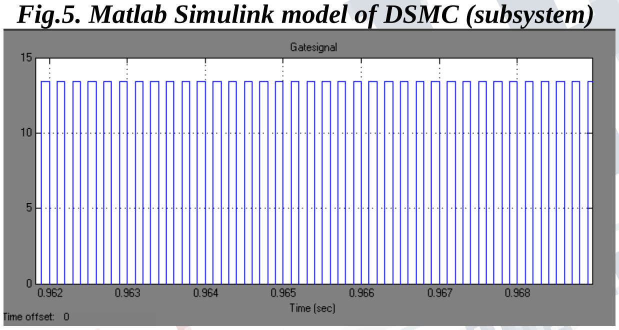

Fig.6. Simulated output of control signal

Fig.8. and fig.9. shows the input voltage and simulated output voltage with respect to time.

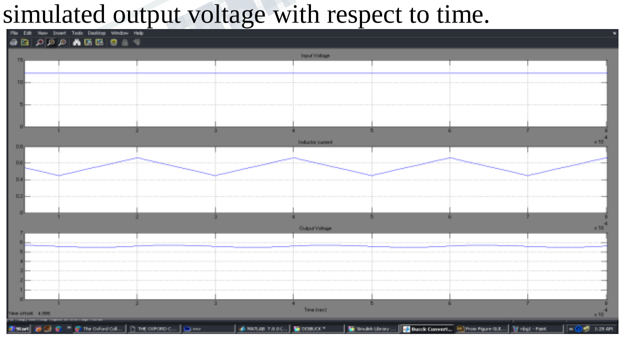

Fig.7. Simulated output waveforms of DSMC buck converter

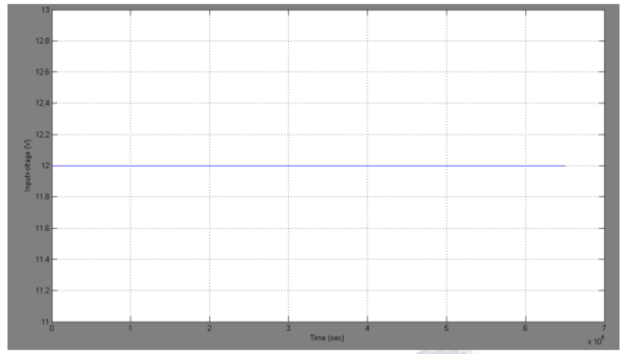

Fig.8. Input Voltage waveform of DSMC buck converter

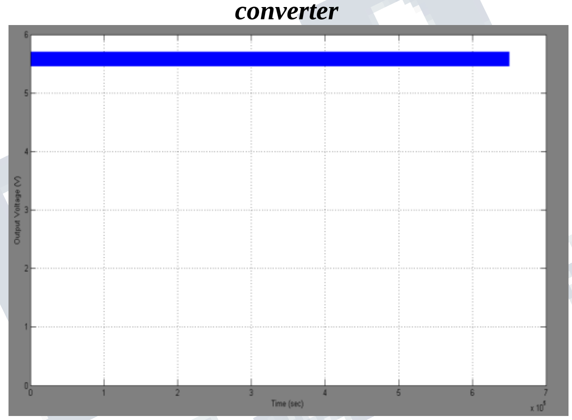

Fig.9. Simulation output waveforms of DSMC buck converter

V. CONCLUSION

In this paper DSMC for buck converter is proposed which is suitable for switched mode DC-DC converters. This control gives better result compared to sliding mode control. If we are increasing the sampling period it has more region of attraction with better performance. It also eliminates chattering problems in the controller.

REFERENCES

[1] Muhammad Attique Qamar, Jin Freg, Abbad Ur Rehman, Abid Raza, "Discrete Time Sliding Mode Control of DC-DC Buck Converter", 2015 IEEE Conference on Systems, Process and Control, Bandar Sunway, Malaysia.

[2] Kamel Ben Saad, Abdelaziz Sahbani and Mohamed Benrejeb, "Sliding Mode Control and Fuzzy

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International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
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Sliding Mode Control for DC-DC Converters", Research unit LARA, www.intechopen.com.

[3] R.Osorio, M.A. Oliver, M.Ponce, S.E.Pinto, M.Juarez, R.Katebi, M.J.Grimble, "Analysis and Design of Discrete-Sliding-Mode Control for a Square-Waveform-Ballast" Proceedings of the 44th IEEE Conference on Decision and Control, and the European Control Conference 2005, Seville, Spain, December 12-15, 2005.

[4] R.Orosco, N.Vazquez "Discrete Sliding Mode Control for DC/DC Converters", CIEP, Acapulco, MEXICO, October, 2000.

[5] G.Spiazzi, P.Mattavelli, L.Rossetto, " Sliding Mode Control of DC-DC Converters", University of Padova.

[6] Bandyopadhyay, B. & Janardhanan, B. (2005). Discrete-time sliding mode control, Springer, Berlin, 2005, ISBN-10 3-540-28140-1.

[7] El Fadil, H. ; Giri F., & Ouadi, H. (2008). Reducing Chattering Phenomenon in Sliding Mode Control of Buck-Boost Power Converters. Proceedings of the IEEE International Symposium on Industrial Electronics, Cambridge,2008.

[8] Utkin, V.I. (1977). Variable structure systems with sliding modes, IEEE Transactions on Automatic Control, Vol. AC-22, No. 2, April, pp. 212-222, 1977.