Design of Boost Converter of Sliding Mode Control Powered by PV Array

Tamal Biswas[1], Prof. G K Panda[2], Prof. P K Saha[3]

PG Scholar, Dept. of EE, Jalpaiguri Government Engineering College, Jalpaiguri, West Bengal, India[1]

HOD and Professor, Dept of EE, JGEC, Jalpaiguri, West Bengal, India[2]

Professor, Dept of EE, JGEC, Jalpaiguri, West Bengal, India[3]

ABSTRACT: This Paper gives you a brief idea of the Design and simulation of DC/DC Boost converter operating in continuous conduction mode using sliding mode controller with PV source. The performance and properties of sliding mode controller is compared with Proportional Integral Derivative (PID) controller and Proportional Integral (PI) controller. Simulation results shows that the sliding mode control scheme provides good voltage regulation and is suitable for boost DC-to-DC conversion purposes. The derived controller/converter system is suitable for any changes on line voltage and parameters at input keeping load as a constant.

KEYWORDS: Boost converter, Sliding mode control, PV array, PID controller, PWM, MPPT, MATLAB, Simulink.

I.INTRODUCTION

The switch mode DC-DC converters are some of the simplest circuit which converts power level of DC power effectively. It has wide application in modern computer, DC motor drive, power system, automotive, aircrafts etc. the commonly used control methods are pulse width modulation (PWM), voltage mode control, PWM current mode control with proportional (P), proportional integral (PI), and proportional integral derivative (PID) controller. But this control method cannot perform satisfactory under large load variation so non liner control technique is in picture. The dc-dc converters, which are non-linear and time variant system, and do not lend themselves to the application of linear control theory, can be controlled by means of sliding-mode (SM) control, Which is derived from the variable structure control system theory (VSCS). Variable structure systems are systems the physical structures of which are changed during time with respect to the structure control law. Photovoltaics (PVs) are arrays (combination of cells) that contain a solar voltaic material that converts solar energy into electrical energy. PV cell is a basic device for Photovoltaic Systems. Such systems include multiple components like mechanical and electrical connections and mountings and various means of regulating and (if required) modifying the electrical output. In order to extract maximum amount of power from PV array we have to model converters so that it can track Maximum Power Point (MPP).

II.BASIC PRINCIPLE

In a boost regulator the output voltage is greater than the input voltage- the name "boost". A boost regulator using apower MOSFET, the circuit operation can be divided into two modes. Mode 1 beings when transistor M1 switched on at t=0. The input current, which rises, flow through inductor L and transistor Q1.
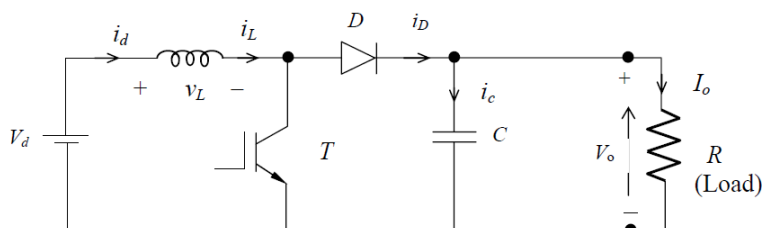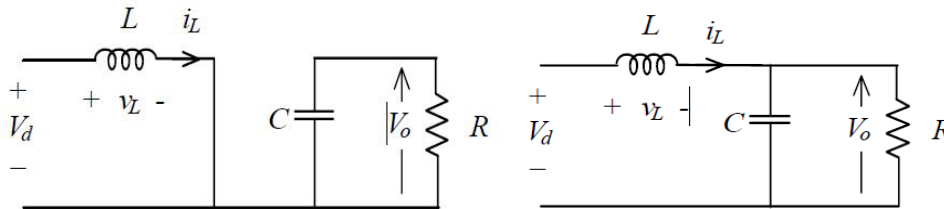

Figure 1: Dc-Dc Boost Converter Topology

Figure 2: Mode 1 and Mode 2 operation of boost converter

Mode2 beings when transistor M1 is switched off at t=t1. The current that was flowing through the transistor would now flow through L, C, load, and diode Dm. The inductor current falls until transistor M1 is turned on again in next cycle. The energy stored in inductor L is transferred to the load. The equivalent circuits for the modes of operation are shown in Fig:3 The waveforms for voltage and currents are shown in fig:5 For load current, assuming that the current rises or falls linearly.
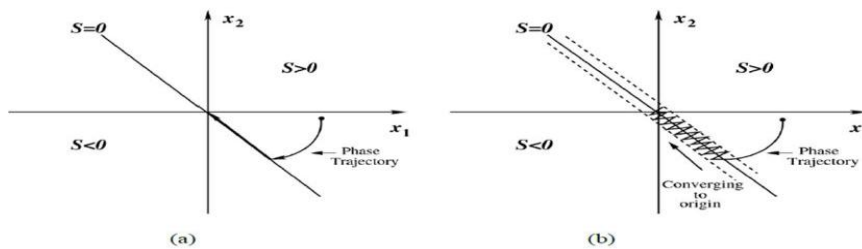

Figure 3: Phase Plot for (a) ideal SM Control (b) actual SM control

The basic idea of SM control is to design first a sliding surface in state space and then the second is to design a control law direct the system state trajectory starting from any arbitrary initial state to reach the sliding surface in finite time, and finally it should come to a point where the system equilibrium state exists that is in the origin point of the phase plane. The existence, stability and hitting condition are the three factors for the stability of sliding mode control. SM control principle is graphically represented in Figure 4, where, represent the sliding surface and $x1$ and $x2$ are the voltage error variable and voltage error dynamics respectively. The sliding line (when it is a two variable SM control system in two-dimensional plane) divides the phase plane into two regions. Each region is specified with a switching state and when the trajectory arrives at the system equilibrium point, the system is considered as stable.

III. CONTROL TECHNIQUES FOR BOOST CONVERTER

3.0 Photovoltaic cell: A photovoltaic cell or photoelectric cell is a semiconductor device that converts light to electrical energy by photovoltaic effect. If the energy of photon of light is greater than the band gap then the electron is emitted and the flow of electrons creates current.

A PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array. Typically a solar cell can be modeled by a current source and an inverted diode connected in parallel to it. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n to p junction and parallel resistance is due to the leakage current.
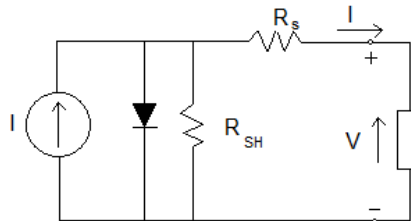
Figure 4: Single diode model of a PV cell

In this model we consider a current source (I) along with a diode and series resistance (Rs). The shunt resistance (RSH) in parallel is very high, has a negligible effect and can be neglected. The output current from the photovoltaic array is

$$I = I_{SC} - I_d$$

$$I_d = I_o(e^{\frac{qV_d}{KT}} - 1)$$

where Io is the reverse saturation current of the diode, q is the electron charge, Vd is the voltage across the diode, k is Boltzmann constant (1.38 * 10-19 J/K) and T is the junction temperature in Kelvin (K).

$$I = I_{SC} - I_o(e^{\frac{qV_d}{KT}} - 1)$$

Using suitable approximations,

$$I = I_{SC} - I_o(e^{q\left(\frac{V+IRs}{nKT}\right)} - 1)$$

where, I is the photovoltaic cell current, V is the PV cell voltage, T is the temperature (in Kelvin) and n is the diode ideality factor In order to model the solar panel accurately.

3.1 Maximum Power Point Tracking :

Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power.

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel.

3.2 System Design:

The first step to the design of an SM controller is to develop a state-space description of the converter model in terms of the desired control variables (i.e., voltage and/or current etc,). Our focus in this paper is the application of SM control to converters operating in CCM. The controller under study is a second-order proportional integral derivative (PID) SM voltage controller. Unlike most previously proposed SM voltage controllers, it takes into account an additional voltage error integral term in the control computation to reduce the steady-state dc error of the practical SM controlled system.

A second-order PID type of SM voltage controller is adopted. Fig.5 shows the schematic description of the proposed

SMVC boost converters, where C,L, and r_L are the capacitance, inductance, and load resistance of the converters,

respectively i_c ,i_L ,and i_r are the capacitor, inductor, and load currents, respectively;V_{ref}, v_i, and βvo are the reference,

input, and sensed output voltage, respectively; and $u = 0$ or 1is the switching state of power switch S w.
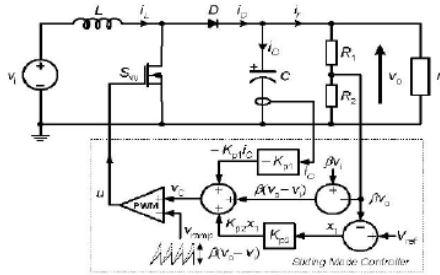
Figure 5: System modelling of sliding mode controller

lets consider, voltage error be X, rate of change of voltage error be Y & integral of voltage error be Z. Under continuous conduction mode, derived in can be expressed as,

$$X = (V_{ref} - \beta_{V0})$$

$$Y = \dot{X} = \frac{\beta}{c}[\frac{v0}{RL} - \int 1\frac{uVi - V0}{RL}dt]$$

$$Z = \int X1dt$$

$$X_{Boost} = \begin{bmatrix} V_{ref} - \beta_{V0} \\ \frac{\beta}{C}[\frac{v0}{RL} - \int 1\frac{uVi - V0}{RL}dt] \\ \int V_{ref} - \beta_{V0} \end{bmatrix}$$

$$X_{Boost} = AX_{Boost} + Bu$$

$$A = \begin{bmatrix} 0 & \cdots 1 & 0 \\ 0 \vdots & \ddots \frac{1}{RLC} & \vdots 0 \\ 1 & \cdots 0 & 0 \end{bmatrix}$$

$$B = \begin{bmatrix} 0 \\ \frac{\beta V0}{LC} - \frac{\beta Vi}{LC} \\ 0 \end{bmatrix}$$

For this system, it is appropriate to have a general SM control law that adopts a switching function such as,
u=1 When S>0,
u=0 When S<0

$$u = \frac{1}{2(1 + sign\,S)}$$

Where S is the instantaneous state variable's trajectory and is described as,

$$S = \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 = J^T X$$

With, $J^T = \begin{bmatrix} \alpha_1 & \alpha_2 & \alpha_3 \end{bmatrix}$

where, α_1, α_2 and α_3 are representing control parameter termed as sliding coefficients. A sliding surface can be obtained by enforcing, $S = 0$. Finally, the mapping of the equivalent control function onto the duty ratio control d,

where, $0 < d = \dfrac{V_c}{V_{ramp}} < 1$

gives the following relationship for the control signal V_c and V_{ramp} signal , where

$$V_C = U_{equ} = -\beta L \left[\left(\frac{\alpha_1}{\alpha_2} \right) - \left(\frac{1}{RLC} \right) \right] i_C + LC \left(\frac{\alpha_3}{\alpha_2} \right) \left(V_{ref} - \beta V_0 \right) + \beta (V_0 - V_i)$$

$$V_C = -K_{p1} i_C + K_{p2} \left(V_{ref} - \beta V_0 \right) + \beta (V_0 - V_i)$$

$$K_{p1} = \left(\frac{\alpha_1}{\alpha_2} \right) - \left(\frac{1}{RLC} \right) \text{ and } K_{p2} = LC \left(\frac{\alpha_3}{\alpha_2} \right)$$

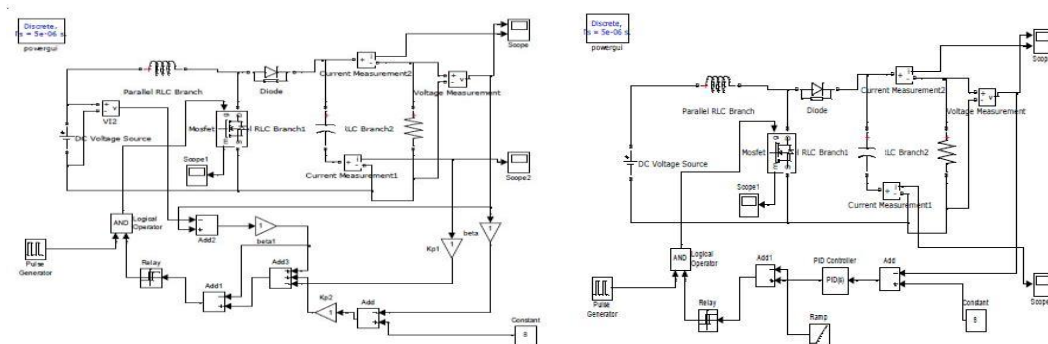$$V_{ramp} = \beta (V_0 - V_i)$$

IV. SIMULINK MODEL

Figure 6: Simulated block diagram for boost converter using (a)SM and (b)PID Controller
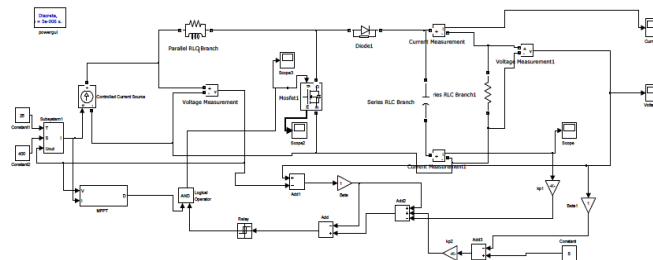

Figure 7: Simulated block diagram of boost converter using PV cell with MPPT
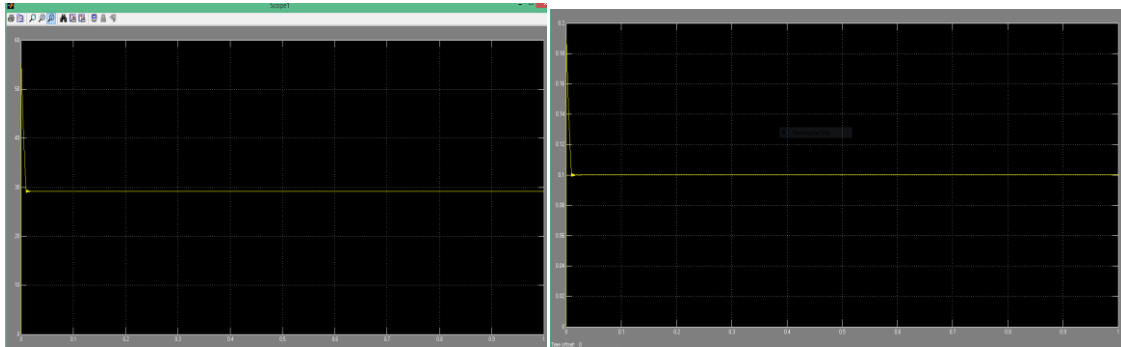
V. RESULT AND DISCUSSION

Figure 8: Simulation result for boost converter using sliding mode controller (a) voltage (b) current.
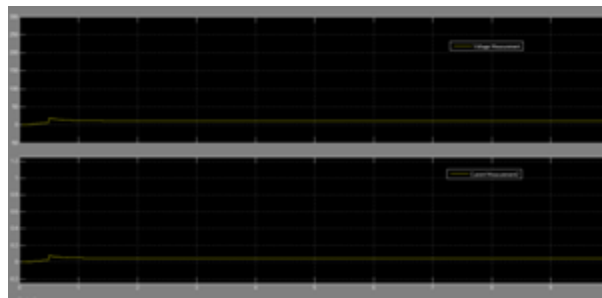

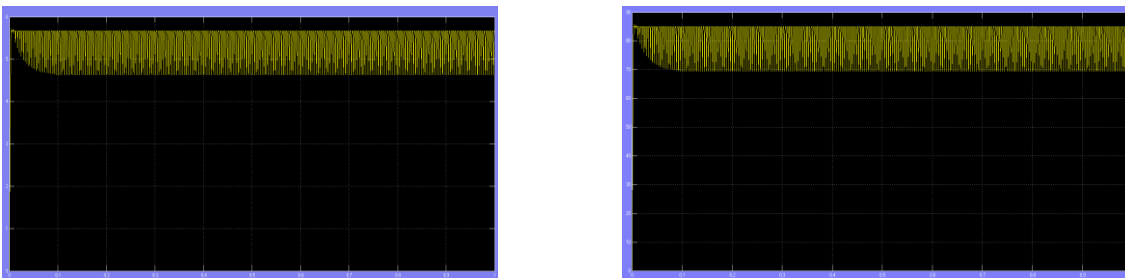**Figure 9: Simulation result for boost converter using PID controller**

Figure 10:simulation result for boost converter using PV cell with MPPT (a) current (b) voltage

VI.CONCLUSION

Maximum power point tracking (MPPT) use for maximum possible power from one or more photovoltaic devices. The simulation was first run with the switch on no MPPT mode, bypassing the MPPT algorithm block in the circuit. It was seen that when we do not use an MPPT algorithm, the power obtained at the load side was very low value. Therefore, the conversion efficiency came out to be very low.

The simulation was then run with the switch on MPPT mode. This included the MPPT block in the circuit and the PI controller was fed the Vref as calculated by the P&O algorithm. In this case, however, the power obtained at the load side was found to be around 350 Watts, thus increasing the conversion efficiency of the photovoltaic system as a whole.

REFERENCES

[1] M. H. RASHID, POWER ELECTRONICS: CIRCUITS, DEVICES AND APPLICATIONS (3RD EDITION), PRENTICE HALL, 2003.

[2] Utkin V., Guldner J., and Shi J.X., *Sliding Mode Control in Electromechanical Systems.* London, U.K.: Taylor and Francis, 1999.

[3] Tan S.C., Lai Y.M., Cheung M.K.H. and Tse C.K., \A Fixed-Frequency Pulse-Width-Modulation Based Quasi Sliding Mode Controller for Buck Converters," *IEEETransactions on Power Electronics*, vol. 20 no. 6, pp. 1379-1392, Nov. 2005.

[4] P. Mattavelli, L. Rossetto, G. Spiazzi, and P. Tenti, "General-purpose sliding-mode controller for dc/dc converter applications," in *Rec. IEEE Electron. Specialists Conf. (PESC'93)*, Jun. 1993, pp. 609–615.

[5] S. C. Tan, Y. M. Lai, and C. K. Tse, "Adaptive feedforward and feedback control schemes for sliding mode controlled power converters," *IEEE Trans. Power Electron.*, vol. 21, no. 1, pp. 182–192, Jan. 2006.

[6] H. Sira-Ramirez, "A geometric approach to pulse-width modulated control in nolinear dynamical systems," *IEEE Trans. Automat. Contr.*, vol.34, no. 3, pp. 184–187, Feb. 1989.

[7] Assad Abu-Jasser, "A Stand-Alone Photovoltaic System, Case Study: A Residence in Gaza", Journal of Applied Sciences in Environmental Sanitation, Vol.5, No.1, pp.81-91, 2010 .

[8] R. Hosseini, N. Hosseini and H. Khorasanizadeh, "An experimental study of combining a photovoltaic system with a heating system", World Renewable Energy Congress, Vol.8, pp.2993-3000, 2011

[9] Mohamed Azab, "A New Maximum Power Point Tracking for Photovoltaic Systems", International Journal of Electrical and Electronics Engineering, Vol.3, No.11, pp.702-705, 2009

[10] M. Gohul, T. Jayachandran, A. Mohamed Syed Ali, T.G. Raju, N. Santhosh Kumar and M.R. Saravanan, "A New Design of Grid Tie Inverter for a Grid Interactive Solar Photovoltaic Power Generation – An Innovative Option for Energy Conservation & Security", International Journal of Electronics & Communication Technology, Vol.2, No.3, pp.161-166, 2011

[11] Klimis Ch. Karasavvas, "Modular simulation of a hybrid power system with diesel, photovoltaic inverter and wind turbine generation", Journal of Engineering Science and Technology Review, Vol.1, pp.38-40, 2008

BIOGRAPHY

Tamal Biswas was born in West Bengal, India on july 19, 1988. He has received his B.Tech degree in Electrical Engineering from Birbhum Institute of Engineering and echnology,Suri, Birbhum, West Bengal in 2012. Currently he is persuing hisM.Tech degree in Power Electronics and Drives from Jalpaiguri Govt. Engineering College, Jalpaiguri, West Bengal.

Prof.Gautam Kumar Panda, Professor and Head, Department of Electrical Engineering, Department of Electrical Engineering, Jalpaiguri Government Engineering College, Jalpaiguri,WB- 735102,BE (Electrical) from J.G.E. College, Jalpaiguri, M.E.E(Electrical) Specialization: Electrical Machines & drives from JadavpurUniversity.PhD from University of North Bengal. FIE, MISTE, Certified Energy Auditor.

Prof.Pradip Kumar Saha, Professor, Jalpaiguri Government Engineering College, Jalpaiguri,WB- 735102. BE (Electrical) from B.E. College, Shibpore. M.Tech((Electrical) Specialization: Machine Drives & Power Electronics from IIT- Kharagpur.PhD from University of North Bengal. FIE, MISTE, Certified Energy Auditor.