Sliding Mode MPPT Based Control For a Solar Photovoltaic system

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Abstract –*This paper proposes the controlling of the photovoltaic (PV) system by sliding mode control(SMC). Here, open circuit voltage MPPT technique is used to track maximum power point. There is a difficulty in tracking the maximum power point of the photovoltaic system due to nonlinearity of the I-V characteristics which is dependent of the temperature and irradiation conditions. The system involves a PV panel, dc/dc boost converter, a load and a control that generates PWM signal that goes to the boost converter. The open circuit voltage based MPPT uses open circuit voltage to calculate maximum power output voltage. The input to the sliding mode controller is the change in reference voltage and PV voltage and the output of the SMC is the change in duty ratio. The SMC is used to track the maximum power point by changing the duty cycle of the boost converter. Using this method, the output power of PV array directly controls the dc/dc converter, hence reduces the complexity of the system. The advantages of this method are high efficiency, best accuracy, good convergence speed, and is robust to weather condition changes. The effectiveness of proposed sliding mode control can be validated using simulation*

Key Words: **photovoltaic system; boost converter; sliding mode control; maximum power point tracking.**

1.INTRODUCTION

Nowadays, the photovoltaic systems are playing a major role to meet the increasing growth on the energy demand. The photovoltaic power systems are becoming increasingly important. It can be used for reducing emission of the carbondioxide and to achieve renewable energy goals. the demand of PV generation systems seems to be increased for both standalone and grid-connected modes of PV systems. Therefore, an efficient maximum power point tracking (MPPT) technique is necessary that is expected to track the MPP at all environmental conditions and then force the PV system to operate at that MPP point. MPPT is an essential component of PV systems[1]. PV module is the main building block to construct the PV systems The output power delivered by the PV system of one or more photovoltaic cells dependent on irradiance, temperature. Maximum power point tracking (MPPT) is used to obtain maximum power from these systems. There are several techniques of MPPT, here considering the open circuit voltage MPPT[2]. The sliding mode control(SMC) has its major advantages including stability, robustness against parameter variations, fast dynamic response and simplicity in its implementation. Depending on the end application and the dynamics of the irradiance, the power conversion engineer needs to evaluate the various options. This paper represents the design of sliding mode control to track directly the MPP by changing the duty ratio of the boost converter. Due to the aforesaid benefits, SMC-MPPT is being chosen widely for controlling nonlinear systems including dc/dc converters for MPP tracking in PV systems [2], [3]. The photovoltaic array is shown in figure 1.

Fig.1 photovoltaic array

2.SYSTEM DESCRIPTION

Fig .2 describes the topology of the photovoltaic system. It consists of PV panel, a dc/dc boost converter, a load and a control circuit that generates

PWM signal that goes to the boost converter for MPPT operation. MPPT function controls DC-DC converter that accepts a DC input voltage and outputs a DC voltage higher, lower or same as the input voltage. For a boost converter, the output of the DC voltage will be higher than that of the input voltage. These converters uses intermediate energy storage components which includes inductors and capacitors which control the energy flow from the PV module to the load by continuously opening and closing of switch. The switch is an electronic device which operates in two states: on or off state. The input to the SMC-MPPT is the tracking error term i.e, the change in the reference voltage and PV voltage and the output to the SMC is the change in the duty ratio which will be given to the PWM generator.

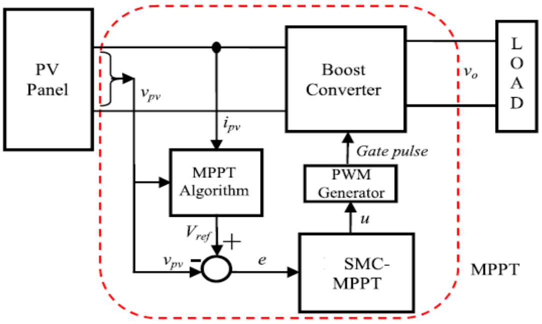

Fig. 2 Block diagram of simple PV system with SMC-MPPT

2.1 Photovoltaic Operation

The output PV current i_{pv} can be expressed as [4],

$$i_{pv} = I_{pv} - I_0 \left[exp\left(\frac{v_{pv}+i_{pv}}{N_s V_t}\right) - 1\right] - \frac{v_{pv}+i_{pv}R_{se}}{R_{sh}} \qquad (1)$$

With,

$$I_{pv} = \left(I_{sc} + K_1(T-298)\right)\frac{G}{1000} \qquad (2)$$

$$V_t = \frac{ak_b}{e}T \qquad (3)$$

$$I_0 = I_{0,ref}\left(\frac{T}{298}\right)^3 exp\left(\frac{eE_g}{k_b N_s V_t}\left(\frac{1}{298} - \frac{1}{T}\right)\right) \qquad (4)$$

Where, I_{pv}=photo –generated current, I_0 =dark saturation current, V_t =thermal voltage, R_{se} =series resistance, N_s =number of series cells in a PV panel, R_{sh}=shunt resistance, I_{sc} =short circuit current, K_1 =short circuit coefficient of temperature, G =solarradiation,T =temperature k_b =Boltzmann's constant, i_{pv} =output current of PV panel, v_{pv} =output voltage of PV panel, $I_{0,ref}$ =reference dark saturation current, e =charge of an electron, E_g =energy of a photon constant. The figure shows the equivalent circuit of the DC-DC boost converter.

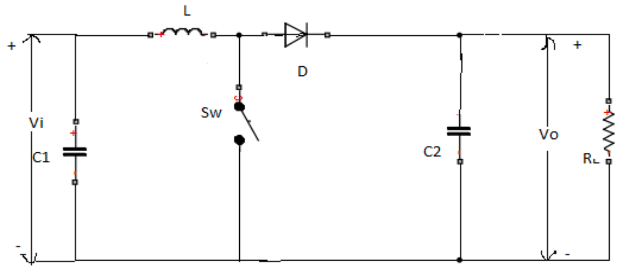

Fig.3 Equivalent circuit of boost converter

Referring to figure 3, when the switch is OFF , then

$$\dot{v}_{pv} = \frac{1}{C_1}i_L - \frac{1}{C_1 r_{pv}}v_{pv} \qquad (5)$$

$$i_L = \frac{1}{L}v_{pv} - \frac{1}{L}v_0 \qquad (6)$$

Where v_0 is the load voltage, and r_{pv} is the dynamic resistance of PV panel.

When the switch is ON, then

$$i_L = \frac{1}{L}v_{pv} \qquad (7)$$

It is necessary to design a MPPT algorithm for generating reference operating voltage (V_{ref}). A dc/dc boost converter and a control circuit are used to provide control signal to the boost converter so that it forces operating point of the PV system close to the reference voltage. Figure 4 shows the typical current versus voltage curve for photovoltaic modules.

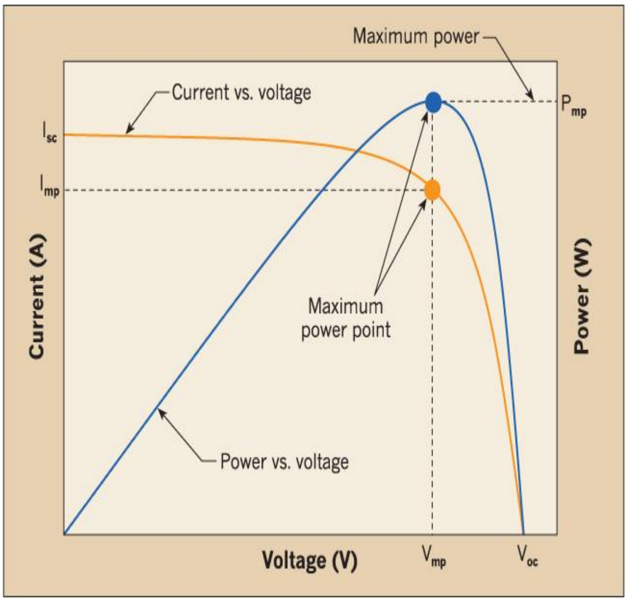

Fig 4 current versus voltage curve for a PV module

2.1 Proposed SMC AND MPPT

The MPPT used here is the open circuit voltage MPPT, this method uses V_{oc} to calculate V_{mp}.

The open circuit voltage can be calculated by [5]:

$$V_{oc} = N_s V_t ln\left(\frac{I_{pv}+I_0}{I_0}\right) \quad (8)$$

When the system obtains the V_{oc} value , V_{mp} is calculated by :

$$V_{mp} = k * V_{oc} \quad (9)$$

Where k is the material coefficient of PV module which depends on structure and material of the PV module. The k value is between 0.70 to 0.80. It is necessary to update V_{oc} occasionally to compensate for any temperature change.

The basic idea of the SMC is attracts the state of the system in a selected area of the state space, which is known as the sliding surface and in conceiving the control law in a finished time and to maintain the system towards this area.

Consider the system as an example [6],

$$x^0 = f(x,t) + g(x,t)u \quad (10)$$

Let $S(x,t)$ be the sliding surface and its derivative is given by:

$$S^o = \frac{ds(x,t)}{dt} = \frac{1}{dt}\left(\frac{\partial s}{\partial x}dx + \frac{\partial s}{\partial t}dt\right) = \frac{\partial s}{\partial x}x^o + \frac{\partial s}{\partial t} \quad (11)$$

G is the gradient of S, then:

$$S^o = Gf(x,t) + Gg(x,t)u + \frac{\partial s}{\partial t} \quad (12)$$

The sliding mode control composes of the terms including the discontinuous control in function of the sign of the sliding surface u_n, an equivalent control u_{eq} characterising the dynamic of the system on the sliding surface.

$$u = u_{eq} + u_n \quad (13)$$

u_n corresponds to the non-linear component and is determined to ensure the attractiveness of the control variable to the sliding surface and satisfies the convergence condition

$$S(x).S^o(x) < 0 \quad (14)$$

The value of u_n can be calculated by:

$$u_n = k_{eq}S(x) \quad (15)$$

The sliding mode control function is to track the maximum power point by changing the duty cycle of the boost converter.

$$\frac{dP_{pv}}{dV_{pv}} = I_{pv} + \frac{dI_{pv}}{dV_{pv}}V_{pv} = 0 \quad (16)$$

The switch function can be selected as,

$$S(x) = \frac{dP_{pv}}{dV_{pv}} = I_{pv} + \frac{dI_{pv}}{dV_{pv}} \quad (17)$$

Imposing the invariance condition,

$$S(x) = 0 \; and \; \frac{ds(x)}{dt} = 0 \qquad (18)$$

Thus the equivalent control can be written as,

$$u_{eq} = 1 - \frac{V_{pv}}{V_0} \qquad (19)$$

That is by taking the values of load voltage and PV panel voltage, the duty ratio for the boost converter can be estimated.

Hence,

$$u = u_{eq} + k_{eq} * S \qquad (20)$$

The input to the controller is the change in PV voltage and the reference voltage,(e) output of the sliding mode control will be change in the duty cycle

3. SIMULATIONS AND RESULTS

This paper presents a new technique for the maximum power point tracking of the photovoltaic systems. The approach is based on the sliding mode based control technique. The photovoltaic system is dependent on the temperature and irradiation conditions. Here, the system consists of DC-DC converter and is connected to the resistive load. The simulation is made for 0.5second, the response of the PV system for the SMC-MPPT is illustrated.

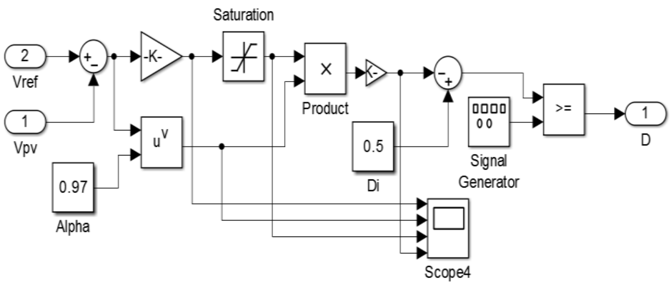

Fig 5. Simulation diagram of SMC

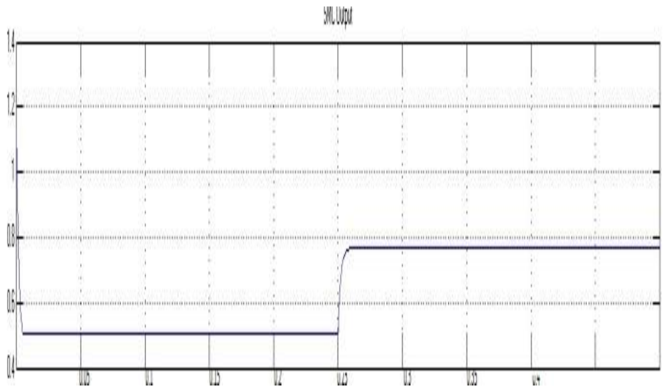

Fig 6.simulation result of SMC

Fig 5 shows the simulation result of sliding mode controller. After designing the sliding surface, and then maintaining the system towards the area.The input to the sliding mode controller is the change in the PV voltage and the reference voltage and the output is the duty ratio.

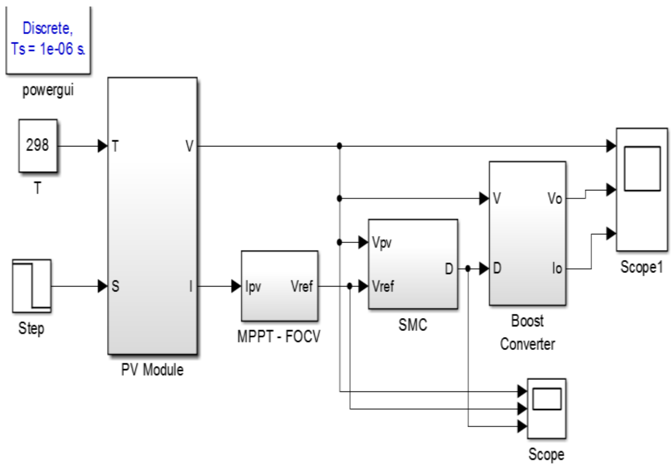

Fig 7. Simulation diagram of SMC-MPPT

The simulation results shown below are the PV output voltage, the boost converter voltage and the boost converter current.

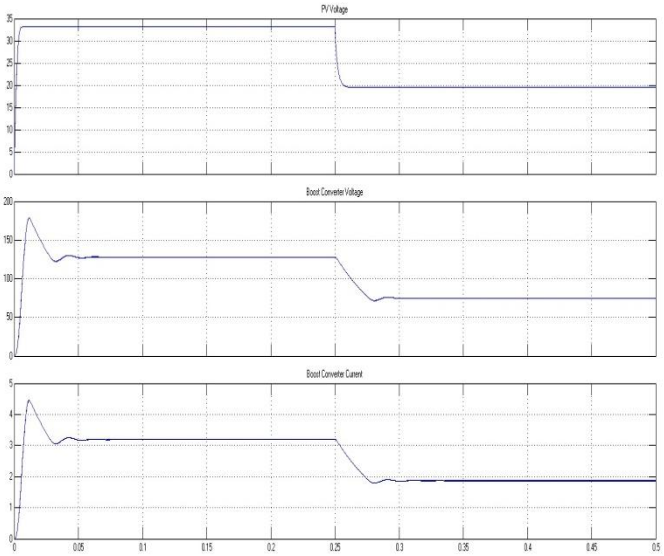

Fig .8 PV output voltage, boost converter voltage and boost converter current

4. CONCLUSION

The SMC based MPPT is proposed on this brief. The MPPT estimates maximum power point of PV system using SMC-MPPT algorithm. The model proposed to simulate the characteristics of solar PV cell, as the PV system is dependent of the temperature and irradiation conditions. Using the sliding mode controller, superior performance of tracking is achieved. The simulation is presented to validate the efficiency of MPPT.

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