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Maximum power point tracker of a photovoltaic system using sliding mode control

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Abstract. In this paper, a maximum power point tracker method using sliding mode control for a photovoltaic (PV) system is presented. The system includes a photovoltaic array, a DC/DC converter and a DC/AC inverter connected to a load. The designed control regulates the converter output voltage and it maximizes the power generated by the photovoltaic array. To obtain it, the sliding surface used to control the DC/DC converter is adjusted according to PV array output power. The control law designed and the results in a simulation platform will be presented.

Key words

Photovoltaic system boost converter, sliding mode control, maximum power point.

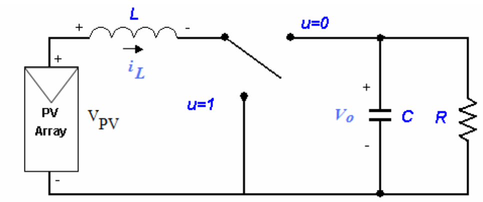
1. Introduction

This work analyse the control in an off-grid PV system, sometimes called a stand-alone system. This system consists of a PV array, a DC/DC converter, an inverter and a load. The control should guarantee that the PV array output power will be transformed with high efficiency to the load. In order to archive this maximum power point (MPP) of the PV arrays, it is necessary maintain it at their optimum points operating. This characteristic is difficult to reach because the PV array exhibit interesting dynamical properties. PV modules have nonlinear voltage-current characteristics, and there is only one unique operating point for a PV with a maximum output power under particular conditions (solar radiation and temperature). Such properties have attracted the interest of this work in the search a control that improves its dynamic performance.

Many methods have been developed to determine the MPP, [1-6]. In this analysis, a DC/DC converter is used as a maximum power point tracker. The control signal is generated to control the switch state. The control circuit adjusts the duty cycle of the switch control waveform for maximum power point tracking, as a function of the evolution of the power input at the DC/DC converter. The sliding mode controller has been designed to search maximum power point and output voltage of the converter constant.

2. System description

A real PV array with a rated power of 2.6 kW (DC) has been modelled in Matlab/Simulnik. A boost converter, figure 1, has been used to regulate the DC input voltage of the DC/AC inverter. The gain from the boost converter is directly proportional to the duty cycle (D), or the time the switch is 'on' each cycle.



$$\frac{V_o}{V_{PV}} = \frac{1}{1-D}$$

Fig. 1. Boost converter

When boost converter is used in PV applications, the voltage input change continuously with atmospheric conditions. Therefore, the duty cycle should change to track the maximum power point of photovoltaic array. This converter should support input voltages in a wide range from 100 to 325 V. Under such conditions, the duty ratio D is adjusted to regulate the output voltage at 400 V. For the given range, D is in a range of [0.76-0.20] and the output current is maximum when D = 0.33.

3. Control design

Sliding mode control is a kind of non-linear control which is robust in the presence of parameter uncertainties and disturbance. It is able to constrain the system status to follow trajectories which lie on a suitable surface in the sliding surface. Therefore, the design of the sliding mode controller starts with the design of the sliding surface [7]. In this case, the surface sliding can be designed with the error of the inductor current and the integral output error was added to achieve zero steady-state error in the boost converter. Considering the model of DC/DC converter the following sliding surface *S(.)* is proposed:

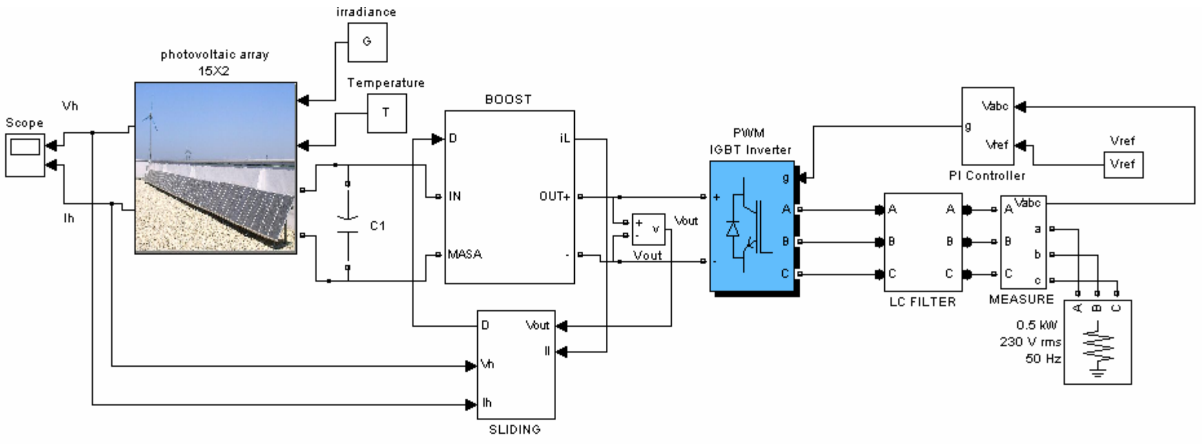


Fig. 2. Simulink block diagram of the PV system connected to AC load

$$u = \begin{cases} 1 & if \quad S(v_o, u, \xi) > 0 \\ 0 & if \quad S(v_o, u, \xi) < 0 \end{cases} \quad (2)$$

$$S(v_o, u, \xi) = i_L - i_{LREF} + K_0 \xi \quad (3)$$

$$\dot{\xi} = v_o - V_e \, , \xi(0) = 0 \quad (4)$$

Where i_L is the current across the inductor, v_0 is the voltage in the capacitor, K_0 is a positive constant and i_{REF} is reference value of inductor current and V_e is desired output voltage (400V).

This sliding surface assures that the sliding motion is reached and regulates output voltage boost converter. In this control system, it is necessary to measure the PV array output power and to change the duty cycle of the DC/DC converter control signal. So, the PV array output power is measured and compared to the previous PV array output power. Depending on the result of the comparison, the optimal reference current of sliding mode control is changed and the process is repeated until the maximum power is reached.

4. Simulation results

The proposed control of the PV system was implemented in Matlab/Simulink, figure 2. The DC output of the PV array is the DC/DC input. The 400 V obtained at boost converter are applied to an IGBT two-level inverter to generate a sinusoidal output voltage of 50 Hz. The IGBT inverter is controlled with a PI regulator in order to maintain to 230 Vrms, 50 Hz at the load terminals.

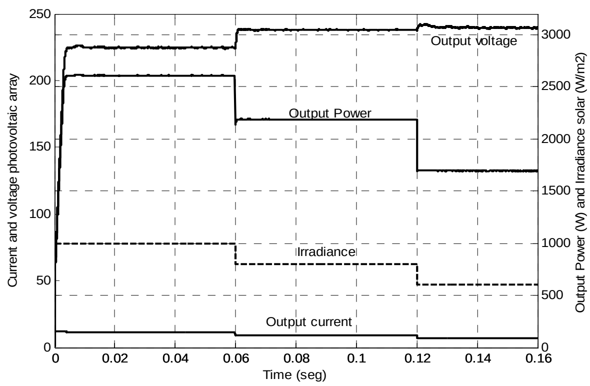


Fig. 3. $V_{PV,}$ I_{PV} and P_{PV} to difference irradiances solar

The proposed design scheme was tested connecting a load of 0.5 KW, and different radiation steps in PV array. Simulation results have been observed in each case to view the influence of the sliding mode control in PV system electrical power. Figure 3 shows the evolution of current, voltage and power of the PV array for 1000 W/m^2 and for successive irradiance steps. The system reaches the maximum power point in each step, and the time response is nearly 10 ms.

5. Conclusions

In this paper, a sliding mode integral control of a boost converter has been analyzed. The reported controller uses the output power of the PV array, the output voltage of the converter and an input signal, which in this case is the switching signal. The control law provides voltage regulation at the converter output, and guarantees the maximum power point of the PV array. The simulation results confirm the adequate performance of designed control.

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