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THE DESIGN OF STANDALONE PV SYSTEM USING P&O ALGORITHM FOR MAXIMUM POWER POINT TRACKING

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ABSTRACT. This paper presents the simulation of output power control of photovoltaic panel using Maximum Power Point Tracking (MPPT) controller of boost converter. Due to the stochastic behavior of temperature and irradiation condition, integrating a MPPT algorithm to DC-DC converter is important for extracting the maximum power from photovoltaic system. The Perturb and Observe (P&O) algorithm has been preferred due to its lower complexity and easy implementation. The main aim of this study is to track the maximum operation point of photovoltaic system and to control the output power with respect to the changing irradiation and temperature. The simulation results demonstrate that MPPT controller prevents the power deviation and provide to extract maximum possible power from solar array.

1. INTRODUCTION

The increasing demand for energy raises concerns about environmental pollution and energy crisis. The usage of alternative energy sources is considered the most effective solution to overcome these concerns. Recently, these energy sources have become increasingly important due to the depletion of fossil fuel reserves. Amongst them, solar energy is one of the most eminent energy sources owing to inexhaustible nature and free of use [1, 2].

Photovoltaic (PV) cells are devices that convert solar energy directly into electrical energy. However, the electrical power output of the PV cells is significantly affected by changing atmospheric conditions [3]. As seen in Fig. 1, the current-voltage (I-V) characteristics of PV cells are influenced by solar irradiance and temperature. The bending point of I-V characteristic curve of PV cell points out an operation point

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called MPPT. At this point, PV cells deliver maximum power, working with highest efficiency [4]. Hence, it is important to track this point for extracting maximum possible power from PV system under various conditions.

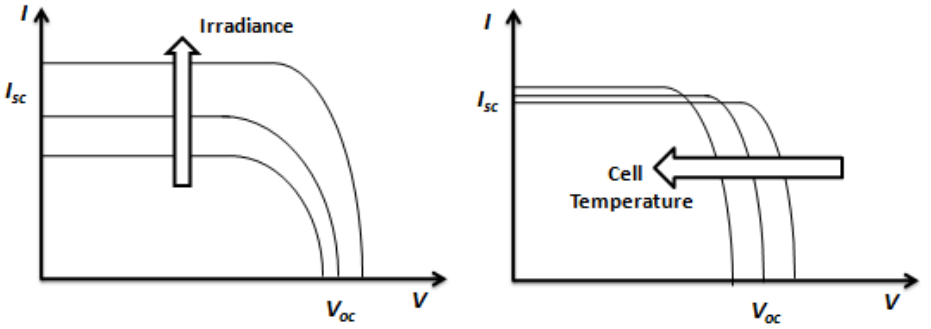

FIGURE 1. I-V characteristics of PV cell with (a) irradiation and (b) temperature effect.

This study is generally divided into 5 sections. The first is the modeling of the PV cell. Section 2 relates to the operation of the boost converter to be used in the simulation. Section 3 presents the review of the MPPT and P&O Algorithm. In section 4, the simulation of the independent PV system in MATLAB / Simulink is given and the results are listed in section 5.

2. THE MODELING OF PHOTOVOLTAIC (PV) CELL

The equivalent circuit model of a PV cell is shown in Fig. 2. This circuit model called single diode model comprises two resistances which are series R_s and parallel R_{sh}. It is desirable for an ideal PV cell to have a low R_s and high R_{sh} value. Open circuit voltage (V_{oc}), short circuit current (I_{sc}) is related with R_{sh} and R_s, respectively [5].

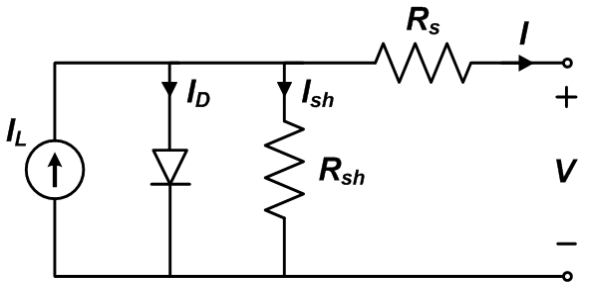

FIGURE 2. Single diode equivalent circuit model of PV cell.

Solar modules consist of a number of solar cells connected series. Similarly, solar arrays are made up of solar modules connected in series and in parallel. The module used in this work consists of N_s=96 of series connected solar cells and array is made up of 5 series and 66 parallel connected modules.

Generally, PV systems are classified into two main categories, which are grid-connected and standalone mode. In our case, we have worked on standalone system. Fig. 3 displays the basic block diagram of a standalone solar system [6]. In this system, electrical power produced by solar module is fed to the load, passing through DC-DC converter. Conventional Perturb and Observe (P&O) MPPT algorithm can be applied to a DC-DC Boost converter to provide the maximum power output of the PV module.

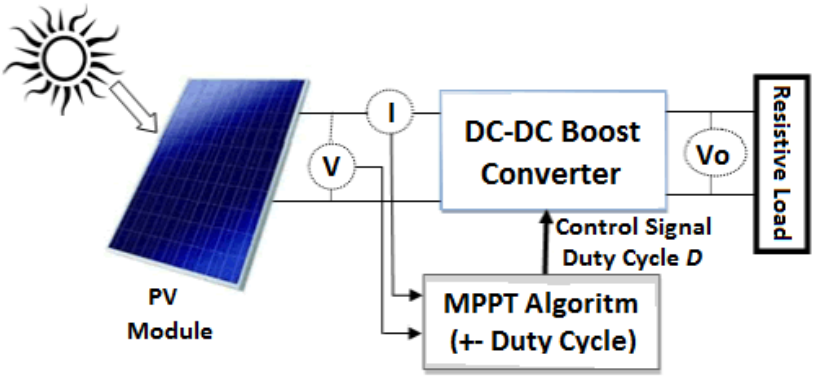

FIGURE 3. Block diagram of PV system with MPPT controller.

3. THE TOPOLOGY OF DC-DC BOOST CONVERTER

Circuit diagram of a DC-DC Boost converter is shown in Fig. 4. The circuit consists of an input capacitor, an output capacitor, an inductor, a switching device (IGBT or MOSFET), a diode and a load. This type of converter is also named as boost converter due to the larger output than the input. [7, 13]. The output voltage is adjusted by switching device which is either on or off depending on the duty cycle D coming from MPPT controller. Output voltage is given by the following equations:

$$V_{in} * t_{on} + (V_{in} - V_0) * t_{off} = 0 \tag{1}$$

$$t_{on} + t_{off} = t_s \tag{2}$$

According to the given equations (1-2), the relation between input and output voltage is obtained depending on the duty cycle given as in Equation (3).

$$\frac{V_0}{V_i} = \frac{t_s}{t_{off}} = \frac{1}{1-D} \tag{3}$$

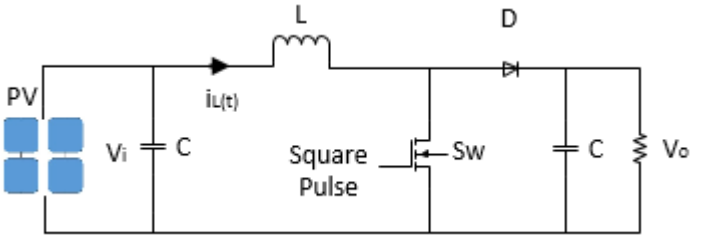

FIGURE 4. Circuit diagram of DC-DC Boost converter

Herein, D (duty cycle) is given as the ratio of the elapsed time when switch is off, to the total period of switching time. The dc-dc boost converter is operated in two

different modes depending on the switching conditions. If the switch is on-state mode, two parts of the circuit can be given as in Fig. 5 (a). First part is related to the inductor and switch. In this condition, inductor stores energy. The other part is regarding to capacitor. Stored energy in the capacitor discharges through the load. If the switch is off-state mode, stored energy in the inductor is transferred to the capacitor and load via the diode. Thus, the capacitor is recharged by the inductor, which is shown in Fig. 5 (b).

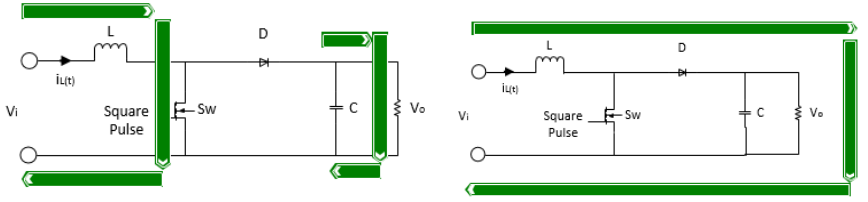

FIGURE 5. Conduction states of boost converter: (a) On-mode condition, (b) Off-mode condition.

4. PERTURB AND OBSERVE ALGORITHM (P&O)

This algorithm has been preferred due to its lower complexity and easy implementation [8]. This technique is based on the inserting slight perturbation to the system and the observation of system response [9]. In order to trace maximum operation point, output voltage of PV system is decreased or increased in accordance with the changes in power ΔP. If the power changes are positive, then we are on the right MPP track and maintain the perturbation in the same direction. Just for the opposite case, perturbation direction has to be changed [10]. Fig. 6 depicts the flowchart of P&O algorithm.

P&O algorithm is started by perturbing the PV array's voltage periodically. Then, PV output power is computed and compared with previous power values [11]. PV power and voltage value are increased or decreased by a perturbation step. According to the difference between calculated and last power/voltage value before perturbation, duty cycle (D) will be collected or differentiated with a finite increment (ΔD), to determine the next perturbation step size. This process will be executed continuously to attain a specific point at which maximum power can be extracted from PV system [12].

5. Simulation of the Standalone PV System in MATLAB/Simulink

Standalone PV system is constructed with MATLAB/Simulink software. By using this simulation, it can be evaluated the performance of the system. In the simulation, perturb and observe algorithm based MPPT controller are used to generate the switching signal which is the input of switching device of the DC-DC Boost converter. Also, PV current generated by the PV array is fed to the load through DC-DC Boost converter. The simulation model of standalone PV system built in MATLAB/Simulink is represented in Fig. 7. As can be understood, MPPT controller is the heart of the system, determining the output characteristics. Fig. 8 illustrates the subsystem representing the MPPT controller based on the perturb and observe algorithm depicted in Fig. 5.

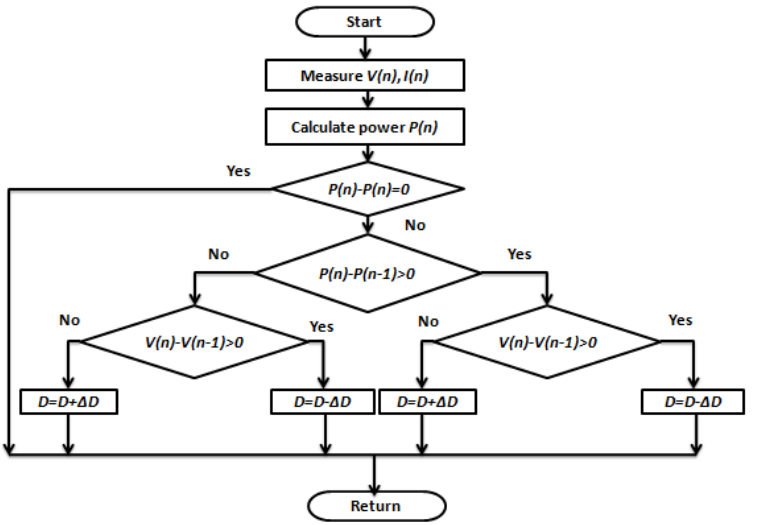

Figure 6. Flowchart of Perturb and Observation algorithm

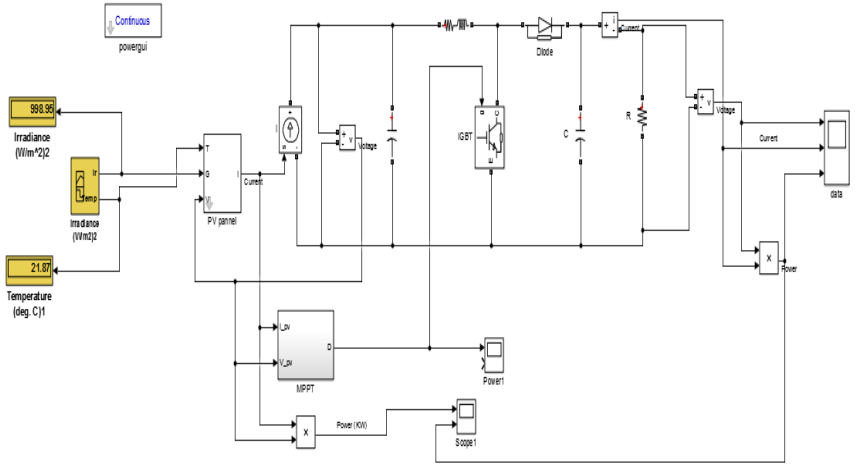

FIGURE 7. Standalone PV system built in Matlab/Simulink

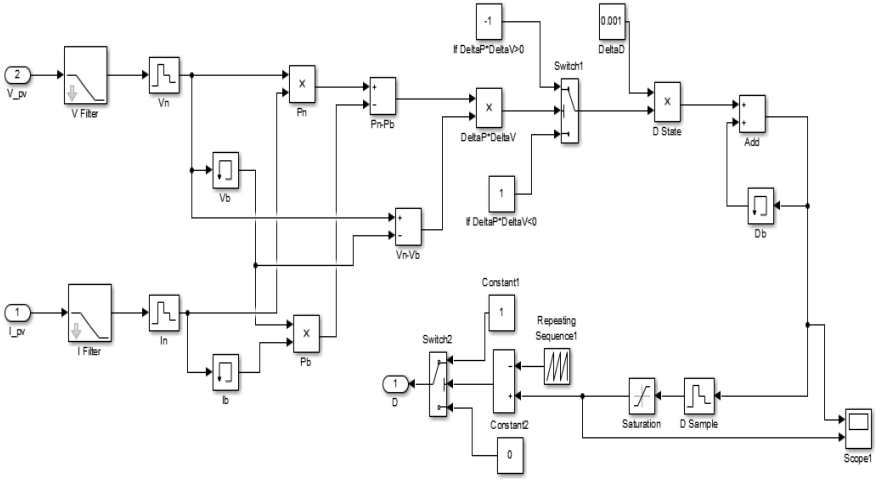

FIGURE 8. Subsystem representing the MPPT controller

In this study, a simulation is conducted to investigate the effect of changes in radiation and temperature. Time-varying input irradiation and temperature signals

are shown in Fig. 9. These changing inputs determine the output photoelectrical parameters of PV panel. Because of the non-linear properties of these inputs, it is required the use of the MPPT controller to obtain the maximum possible power from the PV panel. Fig. 10 represents the plot of switching signal assigned by the MPPT algorithm. This switching signal is used to determine the working condition of switching device.

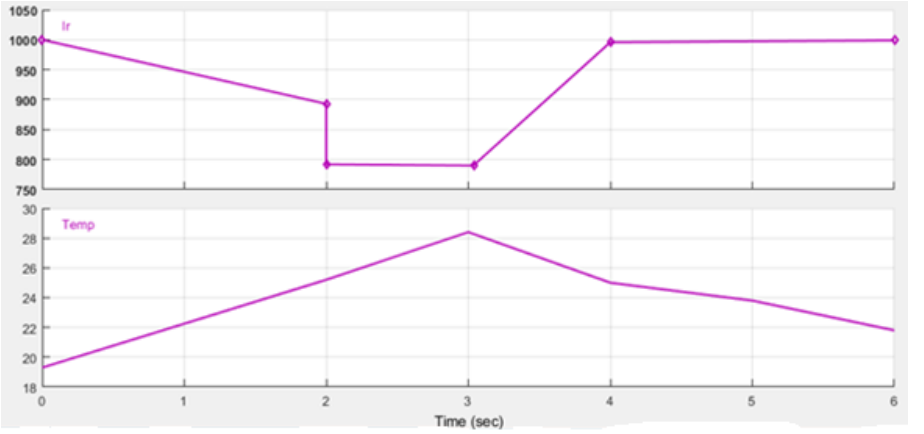

FIGURE 9. Time-varying input irradiation and temperature signals

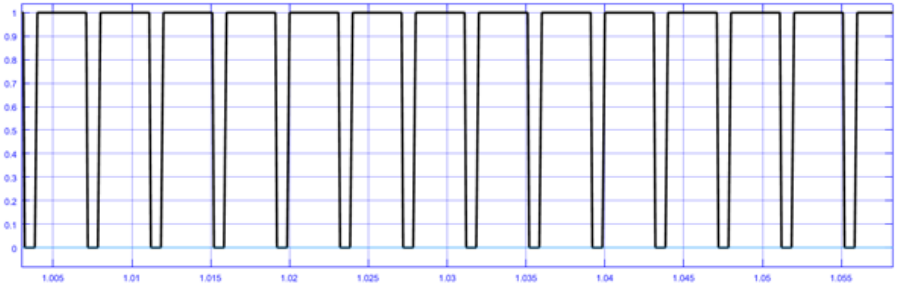

FIGURE 10. Plot of the switching signal

Fig. 11 shows the load voltage, current and power. The initial irradiation level is of 1000 W/m^2 and starts to decrease with time. At t=2 s, it begins to fall to 800 W/m^2 and stays this level during an interval of 1s. At t=3 s, it begins to rise at the same

level initial condition. Considering temperature variation, initial temperature value is of unnecessary 19.6ºC and begins to rise to 28ºC at t=3 s. Then, the temperature is subject to variation by decreasing back towards 21.8 ºC. The MPPT technique is used to track the maximum power point of PV array depending on the instantaneous current and voltage values. At any circumstances, MPPT will be tracking the MPP of the PV array by adjusting the duty cycle of the converter. As implied by the name, boost converter amplifies the output voltage of PV array. Irradiance and temperature inputs have opposite effect on output current. Fig. 11 displays the load voltage, current and power.

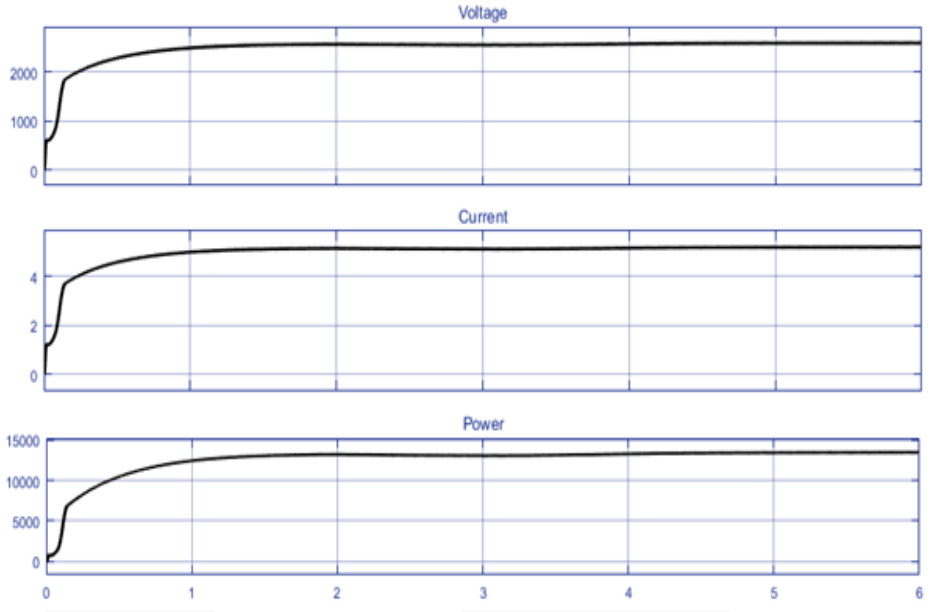

FIGURE 11. Simulation results of the converter with Perturb and Observation algorithm

Fig. 12 depicts the PV system output power in presence of irradiation and temperature variation. Without MPPT controller, the output power of system oscillates at the simulation time and it is affected with varying atmospheric conditions. This output power can be fixed using MPPT controller.

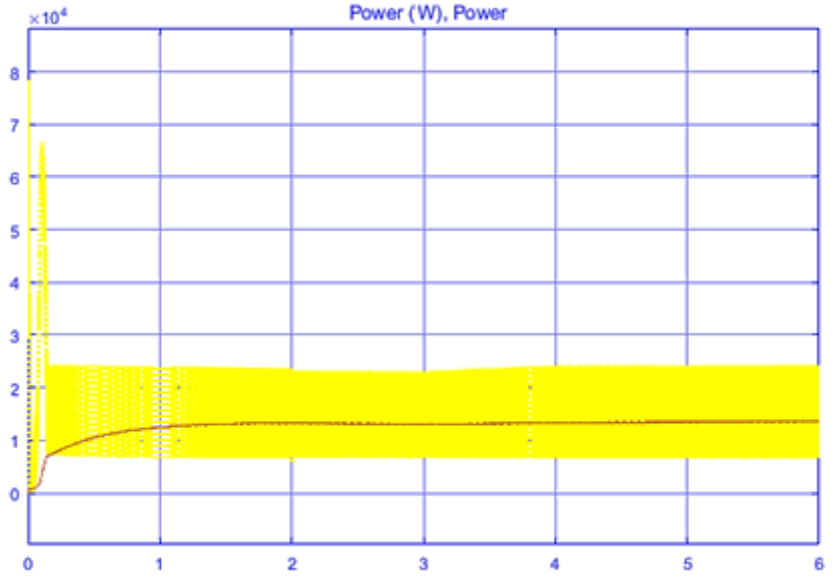

FIGURE 12. System power result in presence of irradiation and temperature variations.

6. CONCLUSION

This paper deals with designing of a standalone PV system using P&O algorithm for MPPT in MATLAB/Simulink environment. The focus of this work is to investigate the effect of MPPT controller on the output power of PV system. As seen from the results, nearly stable power output was achieved by inserting perturb and observe algorithm to the DC-DC Boost converter. It was observed that MPPT is not deviated from the tracking of varying maximum power point owing to the irradiation and temperature variations.

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