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Static Photovoltaic Array Partially Shaded Condition With Boost Converter Using Perturb & Observe Algorithm

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Abstract. Photovoltaic is a semiconductor component that can produce electrical energy when exposed to energy from sunlight. Electricity generation using photovoltaics require a maximum power point tracker embedded in a microcontroller to control boost converter. Boost converter is a type of dc-dc converter which functions to increase dc voltage at a certain voltage level and is kept stable. A simulation for a power generation system using photovoltaics is needed to determine the level of system success that will be realized. In this article we discuss the system simulation using PSIM to find out the maximum output power on partially shaded static photovoltaics using Perturb and Observe algorithm at the maximum power point tracker. Testing on this simulation is done for several different resistance loads. Simulation results without using the Perturb and Observe algorithm show that the maximum output power of 12.26 watts with a load resistance of 36 Ohm, while the simulation results using this algorithm obtained a maximum output power of 55.55 watts. The comparison results for partially shaded 50% showed a maximum output power smaller than partially shaded 25%.

1. Introduction

Photovoltaic (PV) is a module with semiconductor material that can convert solar energy into electrical energy. In its implementation, PVs only produce low power and change periodically. This is caused by factors of light intensity and solar temperature and geographical location (longitude and latitude). In addition, PV output power will be affected if the surface of this PV is covered by trees, buildings or passing clouds. When viewed from its characteristics, PV has nonlinear characteristics and changes to radiation and PV surface temperature [1]. So a control system is needed that can track the maximum power point of PV, the system is called the Maximum Power Point Tracker (MPPT). This is an electronic system that seeks maximum power by monitoring and controlling voltage and current. MPPT requires an algorithm to obtain and maintain a PV working point at maximum efficiency and produce the greatest output power called Maximum Power Point (MPP).

Many algorithms can be used in MPPT [2-3]. The Perturb and Observe (P&O) algorithm is one of the most common algorithms for MPPT used in research for MPP tracking techniques. This iterative-based method measures the output characteristics of a PV system and changes the work cycle of a DC - DC converter.

This paper shows the simulation results using PSIM to determine the maximum output power for partially shaded static PVs using the P&O algorithm. As a comparison, PV testing was carried out without and using the algorithm.



2. Literature Review

When PV gets input in the form of sunlight intensity and temperature can produce electric current. The amount of electric current produced by PV is directly proportional to the amount of intensity of sunlight entering the solar cell. The amount of sunlight intensity changes according to the shift in the position of the sun and weather. Weather factors such as cloudy weather and sunny weather will affect the intensity of the sun's light [4]. The mathematical models are developed to simulate the electrical characteristics of PV. Figure 1 shows the PV substitute circuit, where I and V are the current and voltage of the solar cell, then, I_L is the cell's photocurrent. R_{sh} and R_s is the shunt resistance and series resistance of solar cells [5]. The equation of the substitute circuit is shown in formula (1).

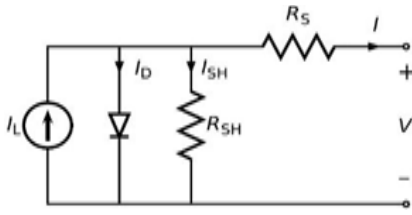


Figure 1. PV substitute circuit [5]

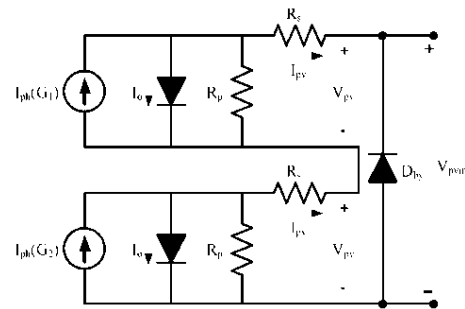


Figure 2. Partial shaded circuit module [6]

$$I = I_L - I_D = I_L - I_0 \left[e^{\frac{q(V+IR_s)}{nKT}} - 1 \right] - \frac{V+R_s I}{R_{sh}} \quad (1)$$

PVs are often shaded by interference in the form of tree branches, through clouds, poles and buildings, etc., which produce partial shadows on PV systems. In PVs configured in series will make a constant moment in which the shaded cells will operate by reverse bias and generate an inverted polarity power leading to a decrease in power and thereby reducing the net power conversion efficiency [6]. A partially shaded module can be modeled two groups of PV connected in series in the module. Each group received a different level of radiation. It can be assumed that there are bypass diodes for the cells inside the module. Figure 2 shows the circuit model for the partially shaded module. This module consists of a connected cell series r in which s shaded cells receive G_1 radiation and $(r - s)$ shaded cells receive G_2 radiation. PV parameters can be represented in formula (2):

$$I_{ph1} = I_{ph}(G_1), I_{ph2} = I_{ph}(G_2), N_{s1}, N_{s2} = (r - s)N_{s1} \quad (2)$$

where, subscripts 1 and 2 refer to the cells receiving radiation from G_1 and G_2 respectively.

In accordance with the existence of a single cut diode for a PV module not partially shaded, the output current and voltage of the PV is equal to following the following formula [6]:

$$I_{pvm} = \min(I_{pv1}, I_{pv2}) \quad (3)$$

$$V_{pvm} = \sum V_{pv} \quad (4)$$

Boost Converter is one type of DC - DC converter that works to increase the DC voltage [7-8]. Boost converter has an output voltage that is always greater than the input voltage. Boost converter generally consists of an inductor (L), a diode (D), a capacitor (C), and a switch. For the inductor and diode on the boost converter serves as a current source and voltage and to limit the ripple of the output current. Capacitors in the boost converter serve to limit the output voltage ripple. Figure 3 shows the boost converter circuit.

MPPT is an electronic system that controls the PV system so it can operate at maximum power. At the time of operation the PV will receive the intensity of the changing sunlight so that it affects the working point of the resulting current and others. Therefore the MPPT system allows the condition that the variable can be traced to its maximum power at a certain time and moment. Figure 4 shows the PV curve with different levels of light intensity.

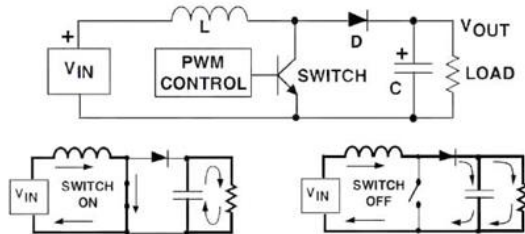


Figure 3. Boost converter circuit [9]

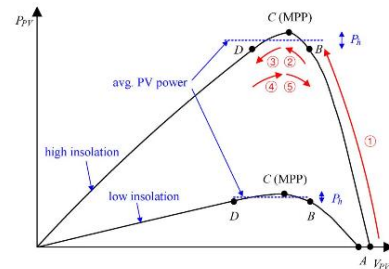


Figure 4. PV curve with different light intensity [9]

3. Method

3.1. Partially Shaded Conditioning Planning

In planning partially shaded conditions, PVs will be shaded by a quarter and a half using cardboard to compare the direction of power loss generated by PV with boost converter when partially shaded conditions.

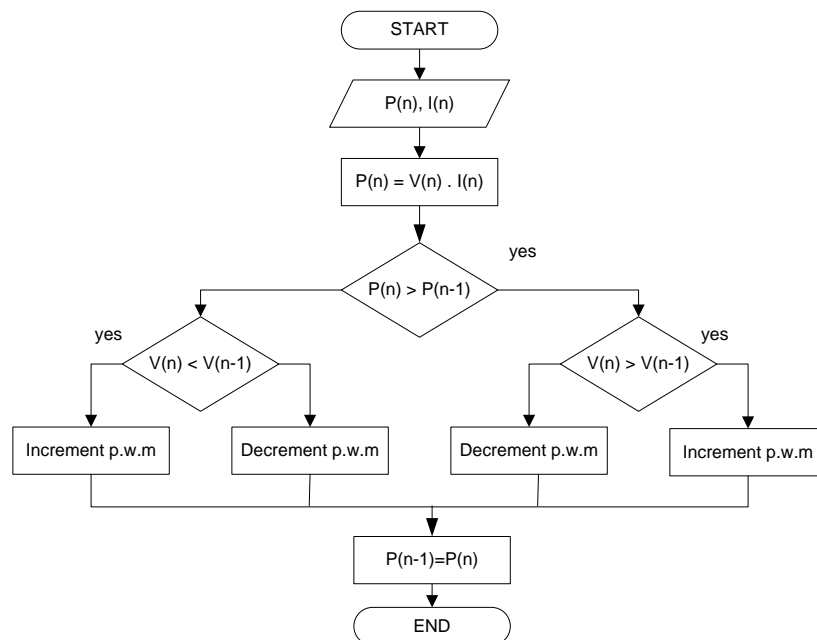


Figure 5. Flowchart of P&O algorithm

3.2. Designing the Perturb and Observe Method

The design of the P&O algorithm in the MPPT system can be interpreted to look for the maximum power value generated by PV at a time. To find the power capability that can be provided by PV at time (t) is shown in Figure 5.

4. Results and Discussion

4.1. Simulation without Perturb & Observe method

The power output testing without the P&O algorithm is that power testing using PVs directly supplies to the load. In Figure 6 shows the test circuit without P&O algorithm in PSIM simulation. In this test using the PV parameters adjusted to the actual 100Wp PV parameters, using the light intensity variables are DC voltage source with value 600 and constant as temperature 25°C, and using variable resistor (rheostat) with the load resistance value of 36 Ω . The characteristic curves are shown in Figure 7.

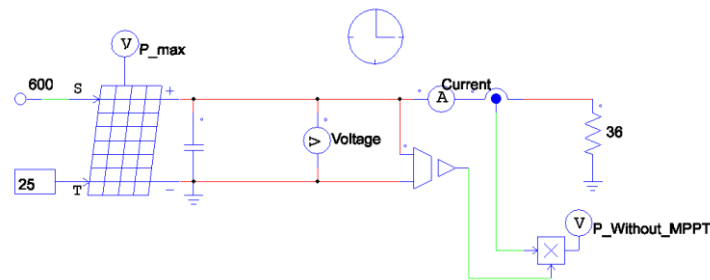


Figure 6. The simulation circuit without P&O algorithm

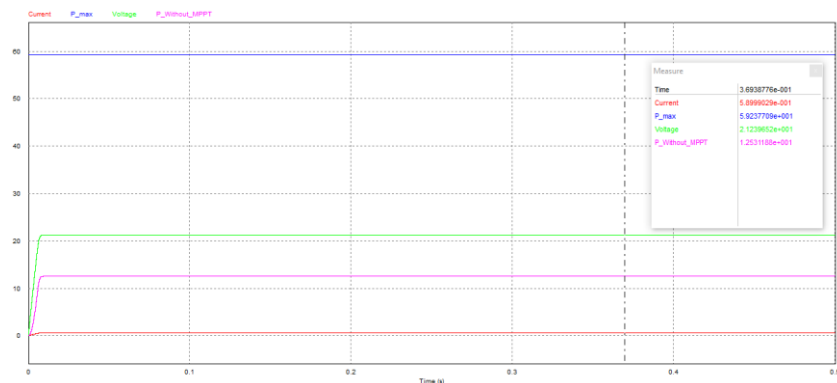


Figure 7. The simulation result without using P&O algorithm with load resistance 36 Ω

The power output value without P&O algorithm when compared to the maximum output power of PV look different. The maximum PV output power shown in Figure 7 is 59.23 watts, and the absorption power obtained is 12.26 watts at 36 Ω load resistance. For load resistance 28.8 Ω obtained the value of pmax 15.37 watt. While the load resistance of 11.3 Ω obtained a power of 36.63 watts.

4.2. Simulation using P&O algorithm

In this test using P&O algorithm, this method looks for the maximum power value by setting the modulation index value on the boost converter. This test is intended to prove that in theory P&O algorithm can indeed be used as peak power tracker on PV. Figure 8 is a simulation circuit using P&O method in PSIM simulation.

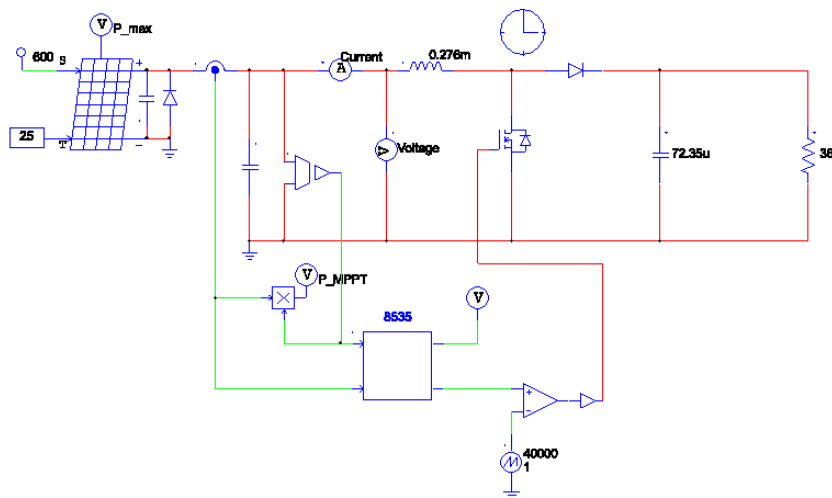


Figure 8. P&O algorithm simulation circuit

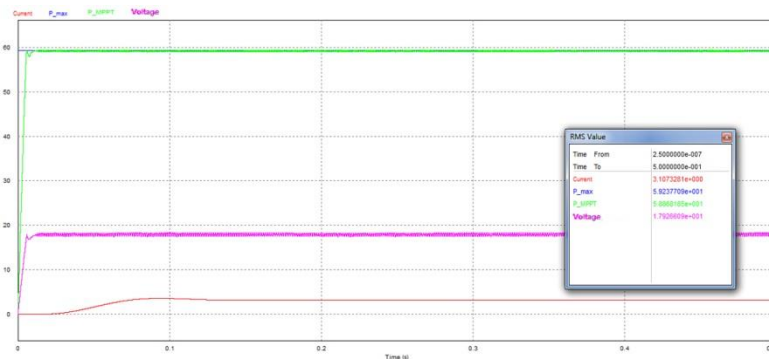


Figure 9. The simulation results using P&O algorithm with load resistance of 36 Ω

Figures 9 show the maximum PV output power of 59.23 watts and power optimized by the system at a 38 Ω weight resistance of 55.55 watts, at load resistance 28.8 Ω obtained power equal to 51.30 watt and at load resistance 11.3 Ω obtained the optimization of power of 24.92 watts.

4.3. Simulation P&O algorithm condition Partially Shaded 50% and 25%

In this simulation, a total of 12 PV units in the parallel series are shown in Figure 10. The DC source voltage of 6 is zero as a simulator that is partially shaded by 50% and the DC source voltage of 3 is zero as a simulator that is partially shaded by 25%.

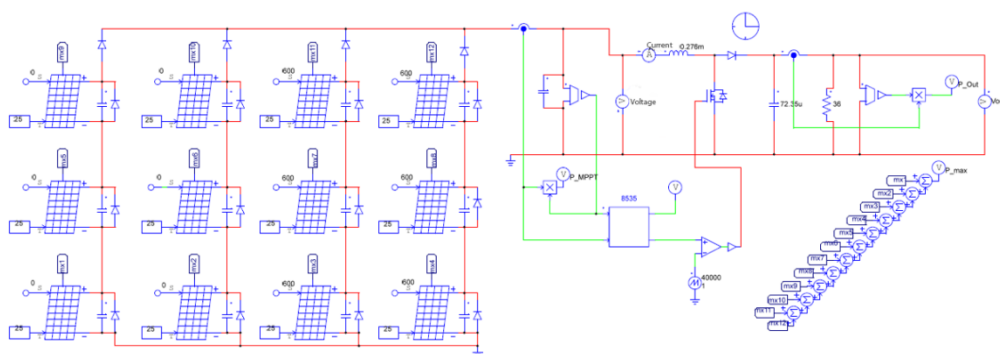


Figure 10. The P&O algorithm simulation circuit Partially Shaded condition 50%

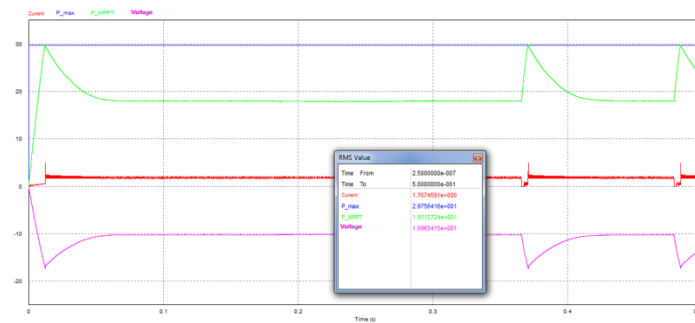


Figure 11. The simulation result using P&O algorithm of Partially Shaded 50% condition with load resistance 36 Ω

In Figure 11 the maximum PV power of 29.75 watts and the power optimized by the system at 38 beban load resistance is 19.33 watts. At a load resistance of 28.8 Ω obtained a power of 17.31 watts. While for load resistance of 11.3 Ω , the optimization of power is 10.38 watts.

Table 1. Resume Test Result of Simulation

Load (Ω)	Without P&O algorithm			With P&O algorithm		
	Voltage (V)	Current (I)	Power (P)	Voltage (V)	Current (I)	Power (P)
36	21.14	0.58	12.26	17.92	3.1	55.55
28.8	21.06	0.73	15.37	16.03	3.2	51.30
11.3	20.35	1.80	36.63	7.46	3.34	24.92

Load (Ω)	With P&O algorithm, Partially shaded 50%			With P&O algorithm, Partially shaded 25%		
	Voltage (V)	Current (I)	Power (P)	Voltage (V)	Current (I)	Power (P)
36	10.86	1.78	19.33	15.33	2.60	39.60
28.8	9.78	1.77	17.31	12.32	2.63	32.40
11.3	5.90	1.78	10.38	6.26	264	16.53

In Table 1, the power ratio measured by PSIM is shown without using the P&O algorithm until Partially Shaded. The value recorded in this simulation is the voltage and current in the input boost converter. For the sum of the power consumption values, the equation $P = V_{in} \times I_{in}$ is used.

5. Conclusions

Testing has been done by simulating using PSIM between PV systems without and using the P&O algorithm. The results for the PV system using the P&O algorithm indicate a significant power optimization. While testing PV systems using partially shaded 50% P&O algorithm lower output power than 25% partially shaded. For load 36 Ω in PV system without P&O algorithm shows output power of 12.26 watts, while using P&O algorithm the output power is 55.55 watts. For load 36 Ω in PV systems using the P&O algorithm with partially shaded 50% output power of 19.33 watts, while the system is partially shaded 25% output power of 39.60 watts. These results are as expected so that partially shaded PV designs using P&O algorithm can be realized in a hardware framework for planning PV farms.

6. References

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