Maximum Power Point Tracking Simulation for a Photovoltaic System

by Susatyo Handoko

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***Abstract*—This paper presents maximum power point tracking (MPPT) simulation for a photovoltaic (PV) system. The MPPT is used to find and maintain operation at the maximum power point. Algorithm used is perturb and observe (PO). There are four blocks in this simulation i.e. PV, boost converter, hysteresis PWM, and PO algorithm. The output of PO algorithm block is reference voltage. Hysteresis PWM block generates switching pulse for IGBT in boost converter that regulate PV output voltage tracks reference voltage. The simulation is carried out by PSIM. Simulation result show that PO algorithm can find and maintain operation of PV at maximum power point. The increase in irradiation causes PV power generated will be increased. But the increase in temperature will cause the generated PV power decreased slightly.**

***Keywords*—PV; boost converter; MPPT; perturb & observe**

I. INTRODUCTION

The increasing of world energy demand, air pollution, global warming, and extinction of fossil fuels have made it necessary to look towards renewable sources as a future energy solution. Various renewable sources such as solar energy, wind energy, geothermal etc. are harnessed for electric power generation. Among those, solar power is a strong candidate in many countries where the solar power density is relatively high. The solar energy is directly converted into electrical energy by solar photovoltaic module. The term photovoltaic refers to a phenomenon that describes conversion of sunlight into electricity energy in a solar cell [1].

Photovoltaic system still have relatively low conversion efficiency; therefore, maximum power point tracking (MPPT) of the solar cell is essential as far as the system efficiency is concerned. The nonlinear nature of PV system in addition to the fact that the maximum power operating point varies with the irradiation level and temperature complicates the tracking control of the maximum power point.

The many different techniques for maximum power point tracking of photovoltaic (PV) arrays were discussed i.e. hill climbing/ P & O, incremental conductance, fractional open-circuit voltage, fractional short-circuit current, fuzzy logic control, neural network, RCC, current sweep, DC-link capacitor droop control, load current or load voltage maximization, dP/dV or dP/dI feedback control, and other MPPT techniques [2]. For maintaining photovoltaic (PV) generation system at maximum power point, it is necessary to calculate the parameters of PV cell model precisely. The modified expressions for the single diode equivalent circuit parameters of PV cell model were derived based on the exclusive four basic electrical parameters provided by manufacturer [3]. Conversely, the MPPT algorithm based on the application of the “ripple correlation control’’ did not require knowledge of the model of the PV panels [4]. The principle of active decoupling presented could be combined with different MPPT methods in order to optimize the maximum power tracking process [5].

This paper presents effect of irradiation and temperature on the PV power, voltage, and current. The simulation of MPPT was performed using perturb & observe algorithm due to it is simple in implementation.

II. SYSTEM CONFIGURATION

It is important to model the solar cell in order to predict the power extracted from the solar modules and the module current-voltage (I-V) characteristics. Once the I-V characteristics of a single solar cell is determined using the model, one must then expand that model to determine the behavior of a PV array or module.

A. Solar Module (Physical Model)

Fig. 1 shows the solar module (physical model) used in PSIM. The nodes with the "+" and "-" signs are the positive and negative terminals. The node with the letter "S" refers to the light intensity input (in W/m^2), and the node with the letter "T" refers to the ambient temperature input (in °C). The node on the top is for the theoretical maximum power giving the operating conditions. While the positive and negative terminal nodes are power circuit nodes, the other nodes are all control circuit nodes.

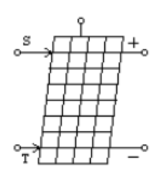


Fig. 1. Solar module (physical model) in PSIM

The equations that describe the physical model of a solar cell are:

$$i = i_{ph} - i_d - i_r \tag{1}$$

$$i_{ph} = i_{sc0}.\frac{S}{S_0} + C_t.(T - T_{ref}) \tag{2}$$

$$i_d = i_0.\left(e^{\frac{qV_d}{AkT}} - 1\right) \tag{3}$$

$$i_0 = i_{s0}.\left(\frac{T}{T_{ref}}\right)^3.e^{\frac{qE_g}{Ak}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)} \tag{4}$$

$$i_r = \frac{V_d}{R_{sh}} \tag{5}$$

$$T = T_s + K_s.S \tag{6}$$

where:

- S_0 : Standard light intensity (W/m^2)
- T_{ref} : Reference temperature (°C)
- R_s : Series resistance (Ω)
- R_{sh} : Shunt resistance (Ω)
- i_{sc0} : Short circuit current (A)
- i_{s0} : Saturation current (A)
- E_g : Band energy (eV)
- A : Ideality factor
- C_t : Temperature coefficient (A/C or A/K)
- K_s : Coefficient
- k : Boltzman constant (k = 1.3806505 x 10^{-23})
- q : Electron charge (q = 1.6 x 10^{-19})
- S : Light intensity input (W/m^2)
- T : Ambient temperature (°C)

B. Boost converter

Boost type dc-dc converter is used in this research. By using boost converter, the output voltage is higher than the input voltage. Fig. 2 shows a circuit of boost converter.

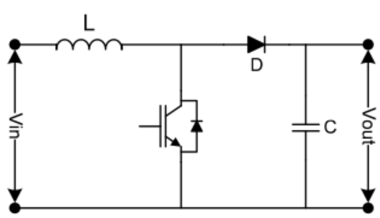


Fig. 2. Boost converter circuit

C. Control of PV-Boost converter

Fig. 3 shows the control structure for PV-boost converter circuit. The inputs for perturb & observe (PO) block are voltage and current of PV.

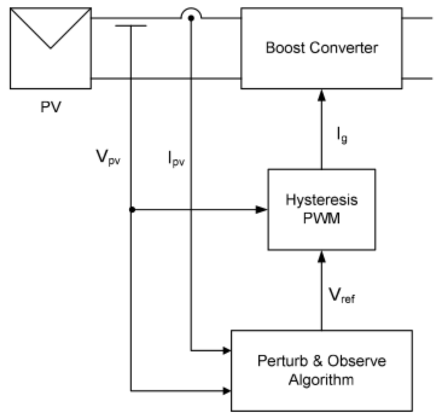


Fig. 3. Control structure of PV-boost converter

III. PERTURB AND OBSERVE ALGORITHM

Maximum power point tracking (MPPT) is used to track the maximum power output of PV. The algorithm used is perturb & observe (PO). Fig. 3 shows a flowchart of the perturb & observe algorithm.

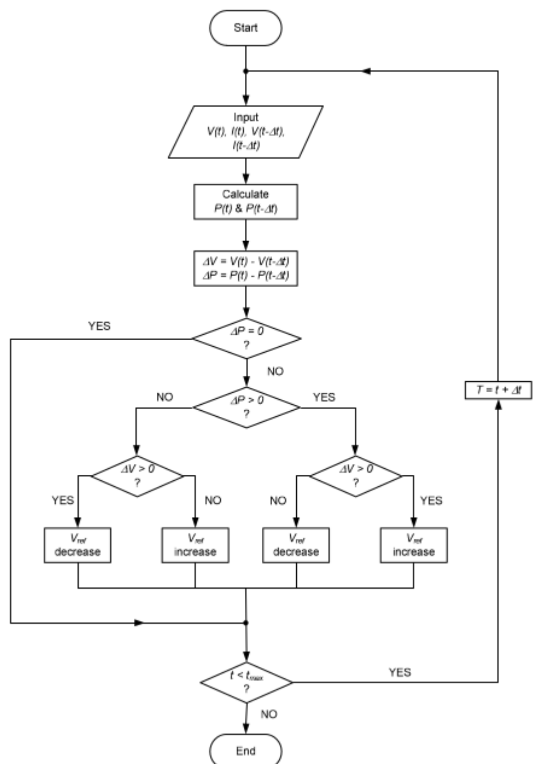


Fig. 4. Perturb and observe algorithm

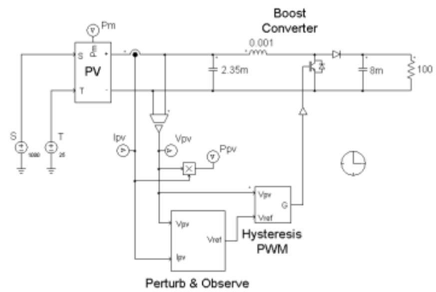


Fig. 5. The simulation circuit of PV-boost converter

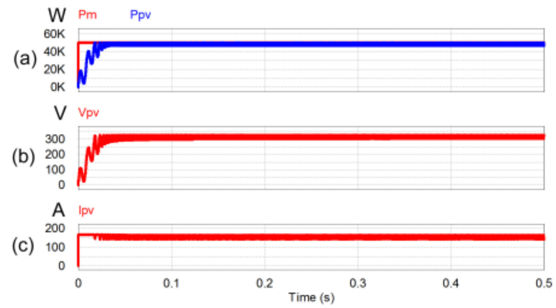


Fig. 7. Outputs of the PV when S = 1000 W/m² and T = 25°C

IV. Simulation Results

Fig. 5 shows the PV-boost converter simulation blocks. The simulation is carried out by PSIM 9.0.3.

Table I shows the electrical characteristics of PV modules used for simulation when the Standard Test Condition (STC). This PV module parameters obtained from the technical data of PV modules. The number of PV modules used is 200 units (10 series and 20 parallel)

A. *Irradiation Variation*

For this case, solar irradiation (S) varies between 200 - 1000 W/m². The temperature (T) remains constant at 25°C.

Fig. 6 shows the output of the PV when irradiation 200 W/m² and temperature 25°C. It is shown in Fig. 6(a) that the power output of the PV can track the maximum available power at t = 0.15 s. The power of the PV is 10.6 kW. Fig. 6(b) and Fig. 6(c) show voltage and current of the PV at maximum power are 328.5 V and 32.3 A.

TABLE I. The Electrical Characteristics of PV Modules at STC

Maximum power	P_{MAX}	250 Wp
Open circuit voltage	V_{OC}	37,8 V
Voltage at maximum power	V_{MPP}	31,1 V
Short circuit current	I_{SC}	8,28 A
Current at maximum power	I_{MPP}	8,05 A

***STC : 1000 W/m², 25°C, AM 1.5**

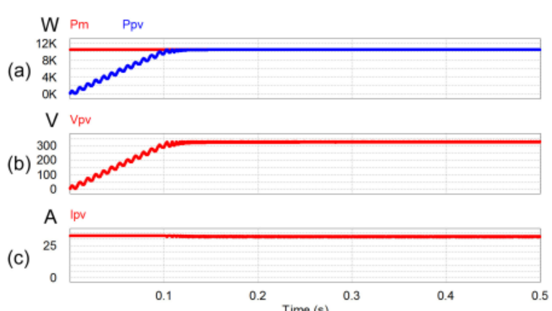
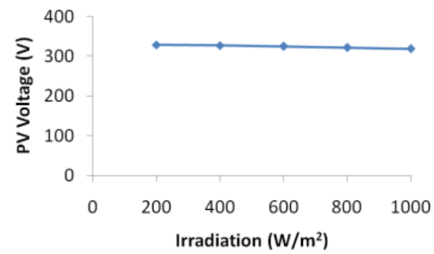
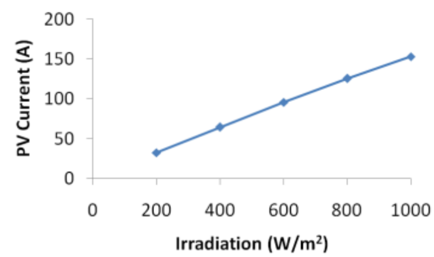


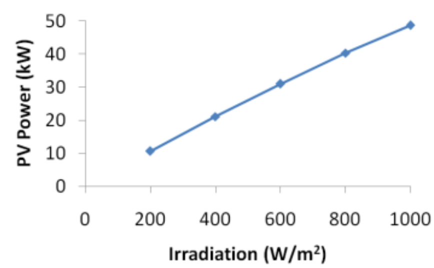
Fig. 6. Outputs of the PV when S = 200 W/m² and T = 25°C



(a)



(b)



(c)

Fig. 8. Voltage, current, and power of the PV versus irradiation

It is shown in Fig. 7(a) that output power of the PV can track maximum available power at t = 0.03 s when irradiation 1000 W/m^2 and temperature 25°C. The power of the PV is 48.7 kW. Fig. 7(b) and Fig. 7(c) show voltage and current of the PV at maximum power are 318.8 V and 152.9 A.

Fig. 8 shows effect of irradiation on power, voltage, and current of the PV. It is shown that the increase in irradiation cause power and current also higher. While voltage of the PV slightly decreased for higher irradiation.

B. Temperature Variation

For this case, the temperature varies between 15-35°C. Solar irradiation remains constant at 1000 W/m^2.

Fig. 9 shows the outputs of the PV when irradiation 1000 W/m^2 and temperature of 15°C. It is shown in Fig. 9(a) that the maximum power 50.5 kW is achieved after 0.03 s. Fig. 9(b) and Fig. 9(c) show that voltage and current at this maximum power point are 329.5 V and 153.5 A.

Outputs of the PV when irradiation 1000 W/m^2 and temperature 25°C is shown in Fig. 10. The PV maximum power 48.7 kW is achieved after 0.03 s when voltage is 318.8 V and current is 152.9 A.

Fig. 11(a) shows that the maximum power 46.8 kW is achieved after 0.03 s when irradiation 1000 W/m^2 and temperature 35°C. At this maximum power point, Fig. 11(b) and Fig. 11(c) show that PV voltage is 308.1 V and PV current is 152.3 A.

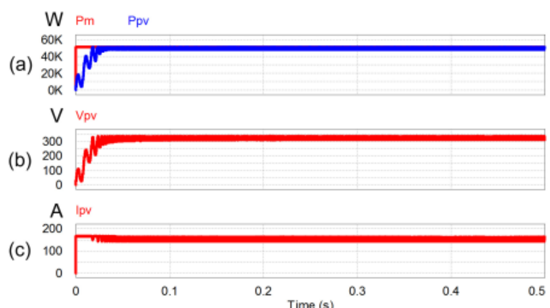


Fig. 9. Outputs of the PV when S = 1000 W/m^2 and T = 15°C

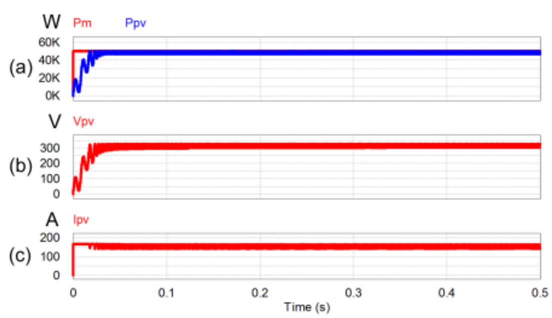


Fig. 10. Outputs of the PV when S=1000 W/m^2 and T=25°C.

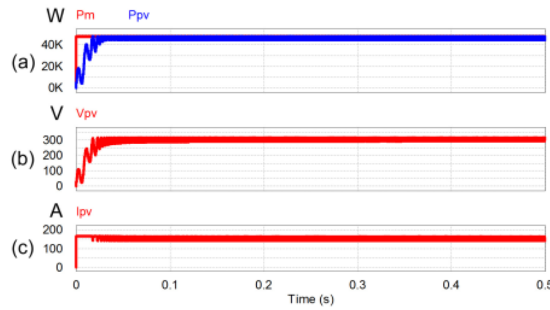


Fig. 11. Outputs of the PV when S = 1000 W/m^2 and T = 35°C

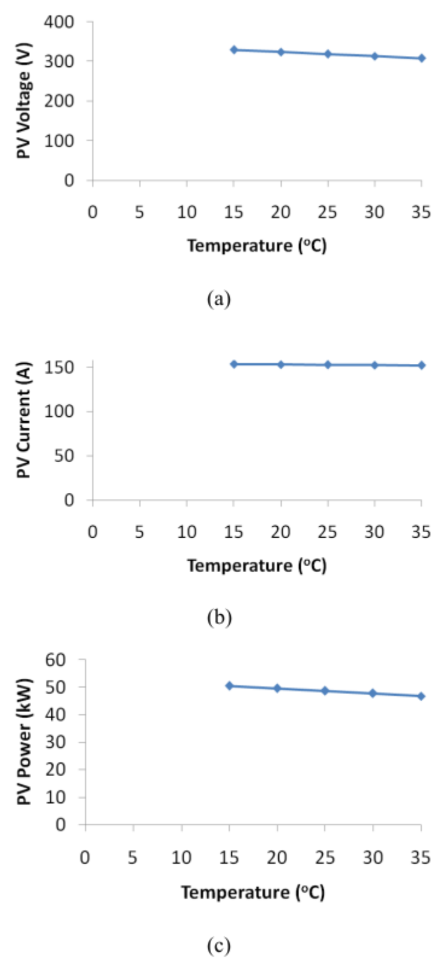


Fig. 12. Voltage, current, and power of the PV versus temperature

Fig. 12 shows effect of temperature on voltage, current, and power of the PV. For temperature 15-35°C, it is shown that higher temperatures will cause the PV power and voltage will experience a slight decrease while the PV current is almost the same.

V. Conclusion

Perturb and observe (PO) algorithm can be used as the maximum power point tracking (MPPT) for photovoltaic system to find and maintain operation at the maximum power point. The increase in irradiation causes PV power generated will be increased. But the increase in temperature will cause the generated PV power decreased slightly.

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