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MPPT using Perturb and Observe Algorithm and Boost Converter

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Abstract

Solar power is considered as one of the key resources in the power system. Due to massive consumption and exhaustion of fossil fuel it is considered as the best alternative to non-renewable energy sources. Thus in this paper Maximum Power Point Tracking approach is used to find out maximum power coming out of a photovoltaic panel. It provides almost constant power coming out of the panel by controlling other parameter like voltage and current. The research has been carried out on a five parameter model. Since the characteristics of PV module vary as environment changes, so considering different geographical conditions such as temperature, solar irradiance and material property, all constraints are considered to estimate characteristics of PV panel. Current - Voltage and Power - Voltage characteristics are determined at different isolation using MATLAB /SIMULINK. A Simulation has been carried out perturb and observe algorithm and Boost converter are applied to detect Maximum Power Point.

Keywords: Photovoltaic panel (PV); Maximum Power Point Tracking (MPPT); Perturb and Observe (P & O); Boost converter.

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1. Introduction

In future due to exhaustion of non- renewable energy sources such as fossil fuel and oil industry, use of renewable energy sources will rise at an increasing rate. Researchers are searching for renewable sources of energy such as solar energy, hydropower, wind and geothermal energy.

Solar energy is an important source of renewable source of energy and because of its abundant nature it is a highly appealing source of electricity. Though the conversion efficiency is low, solar energy is an abundant source of energy and there is no restriction on its uses. The consistence reduction in the cost of PV modules in the last few years has made it popular for the residential purposes and industrial applications as well. Many applications are associated with the PV panel such as solar power generation, battery charging, hybrid vehicles, satellite power and water pumping etc.

The characteristics of solar panel highly depends on the environmental conditions. The temperature and the solar irradiance changes throughout the day, so accordingly the Current - Voltage and Power – Voltage characteristics also changes, the characteristics not only depends on the outer conditions but it is highly affected by the ideality factor of material used for construction of the photovoltaic cell [1]. The operating point which lies on the Power-Voltage graph also changes according to geographical conditions, so the maximum power point tracking is required.

There are several methods by which MPPT can be done [2]. In this paper concentration is on Perturb and Observe algorithm. It is used because of its simple implementation. The perturbed output photovoltaic voltage and perturbed power are used to notice the changes in output power. Boost Converter is applied to obtain voltage level desired to battery characteristics.

This paper contributes to get better results using P & O algorithm and boost converter. The paper is organized as follow: In section 2 Modeling of photovoltaic panel is carried out. Section 3 comprises of P & O algorithm and boost converter design. Section 4 comprises of MATLAB simulation and results. Section 5 comprises of conclusion.

2. Terminology

Ipv = Solar array current (A)

Vpv = Solar array voltage (V)

Iph = Photo current (A)

Io = Diode saturation current (A)

Isc = Short circuit current (A)

Voc = Open circuit voltage (V)

Eg = Band gap voltage (V)

T = Temperature (K)

q = Electron charge (1.602 * 10^-19 C)

k = Boltzmann's constant (11.38 * 10^-23 JK^-1)

Rs = Series resistance [Ω]

Rp = Shunt resistance [Ω]

a = Diode quality factor

3. Modeling

3.1 PV Array Modeling

There are several mathematical models available for PV array modeling, but the accuracy of model is important which can represent electrical equivalent behavior of PV array precisely. A good understanding of all aspects of electrical model is required. Few models are discussed in this section depending on their behavior and real time applications [3] [4]. A simple electrical equivalent circuit of PV array can be represented by an ideal diode model. Diode model is simple to implement but because of lack of several parameters it is not efficient. Another model is four - parameter model where a diode is connected in parallel to the photovoltaic current source in series with a resistance but this model fails to represent the real time leakage occurs in a PV cell. Thus the proposed model is a five parameter model. the electrical equivalent is same as the four parameter model except one shunt resistance is connected in parallel to diode for leakage current. In this paper five-parameter model is used for photovoltaic array modeling.

A five parameter model includes almost all the constraints and gives precise results. The PV module as shown in Fig-1 includes five parameter, namely: 1) photo current; 2) A series resistor Rs; 3) A shunt resistor Rp; 4) Solar array current; 5) Solar array voltage. The relation between different parameters of model is represented by a set of mathematical equations.

The solar array current is represented by equation (*1*). It is a function of photo current and diode current. Some approximations is used considered like series resistance value should be very small and shunt resistance value should be very high. The photo current has a dependency on solar irradiance and temperature. I_{phn} is the photoelectric current at reference irradiance and temperature (1000 W/m^2 and 25˚C). I_{phn} Can be approximately equal to I_{sc}. The diode reverse saturation current can be calculated by equation (4). The accurate diode reverse saturation current depends on temperature value.

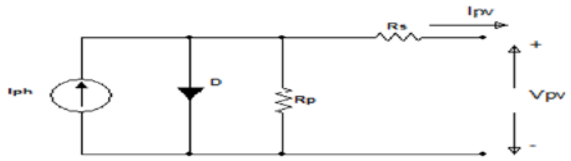

Figure 1: Electrical equivalent circuit of five- parameter model.

$$I_{pv} = I_{ph} - I_o \left(e^{\frac{V_{pv} + I_{pv} R_S}{aV_t}} - 1 \right) - \frac{V_{pv} + I_{pv} R_S}{R_p} \quad (1)$$

$$I_{ph} = \frac{G}{Gn} \left[I_{phn} + K_I \left(T - T_n \right) \right] \quad (2)$$

$$I_o = I_{on} \left(\frac{T}{Tn} \right)^3 e^{\left[\frac{qE_g}{ak} \left(\frac{1}{T_n} - \frac{1}{T} \right) \right]} \quad (3)$$

$$I_{on} = \frac{I_{sc}}{e^{(V_{oc}/aV_{tn})} - 1} \quad (4)$$

Parameter value used for simulation is given in Table.

Table 1: Parameter values used for simulation

Model parameter	Value
Open circuit voltage (Voc)	32.5V
Short circuit voltage (Isc)	8.56 A
Max power voltage(Vmpp)	30.5V
Max power voltage(Impp)	8.05A
Solar irradiance(G)	1000w/m^2
Series Resistance (Rs)	0.22Ω
Shunt Resistance (Rp)	414Ω
Photo current (Iphn)	7.29A
Ideality factor (a)	1.14
Tref	320K
Tn	298K
Eg	1.11V
Short circuit temperature coefficient(K_I)	0.00325A/°C

3.2 Maximum Power Point Tracking

It is an important factor to drag maximum amount of power out of solar panel. The operating point of the current - voltage characteristics changes according to the temperature and irradiance value [5]. Under certain conditions there is a voltage level which gives maximum power at the operating point. To always operate at this level maximum power point detection is helpful. Maximum power point varies with temperature and solar irradiance. MPPT detects maximum power point under all varying environmental conditions. MPPT works most effective under cold weather and cloudy days. There are many algorithms by which we can do maximum power point tracking [6]. In this paper our concentration is on P & O algorithm.

3.2.1 Perturb & Observe Method

Perturb & Observe is a very commonly used method of MPPT. Perturb and observe offers great controlling over the power coming out of the PV panel [7] [8]. The algorithm uses simple feedback arrangement to compare recent photovoltaic power to previous photovoltaic power. When the difference between the previous power and current power is zero, it is considered as maximum power at that point. When the difference is not zero it checks if previous voltage and current voltage is zero. If it is not zero it tries to adjust the duty cycle accordingly so that maximum power point can be extracted from the model. The detailed algorithm of P & O is given in Fig-2.

4. Simulink Model

The proposed Simulink model is given in Fig-3. The model comprises of PV array connected to MPP Tracker and Boost converter [9]. The boosted voltage is required in order to facilitate charging of battery. The duty cycle is applied to the driving switch of the Boost Converter. Switching converters are more efficient in terms of power. The circuit diagram of boost converter is implemented in the Simulink model [10]. P & O algorithm is implemented in Simulink. The detailed simulink model of MPPT algorithm (P &O) is given in Fig-4.

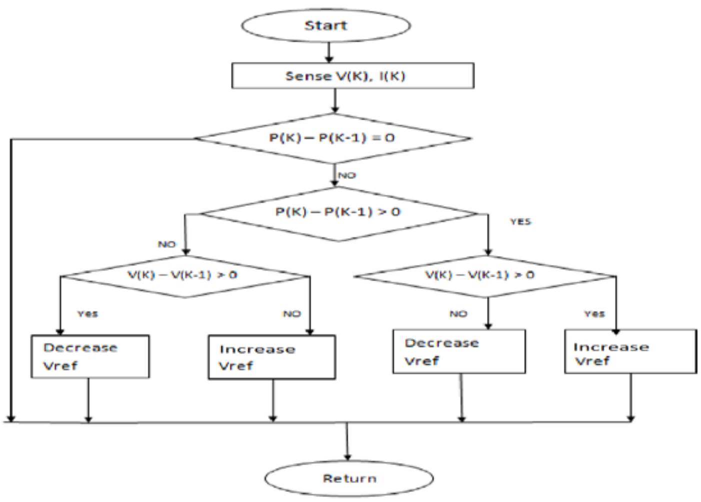

Figure 2: Algorithm of Perturb and Observe (P & O) Method

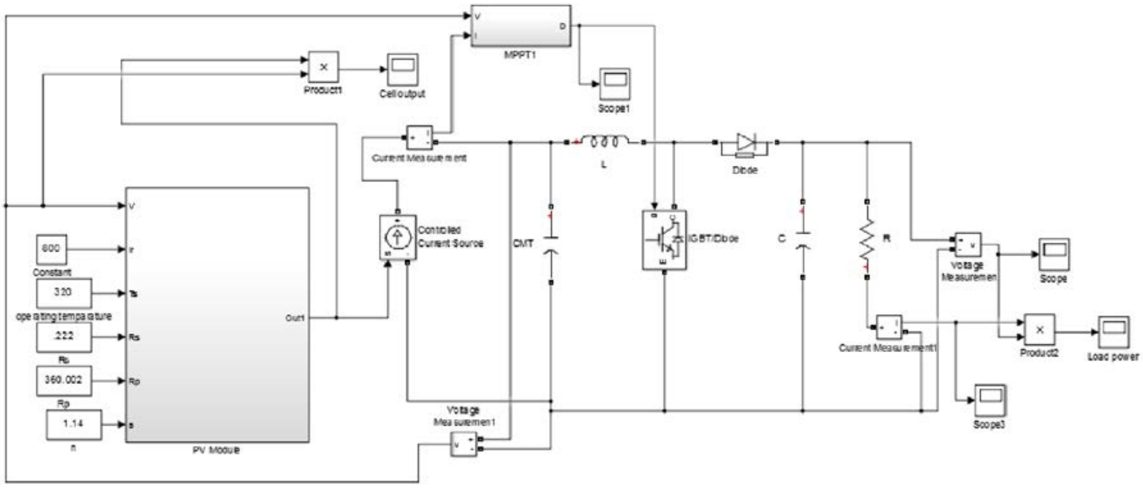

Figure 3: Proposed Simulink Model

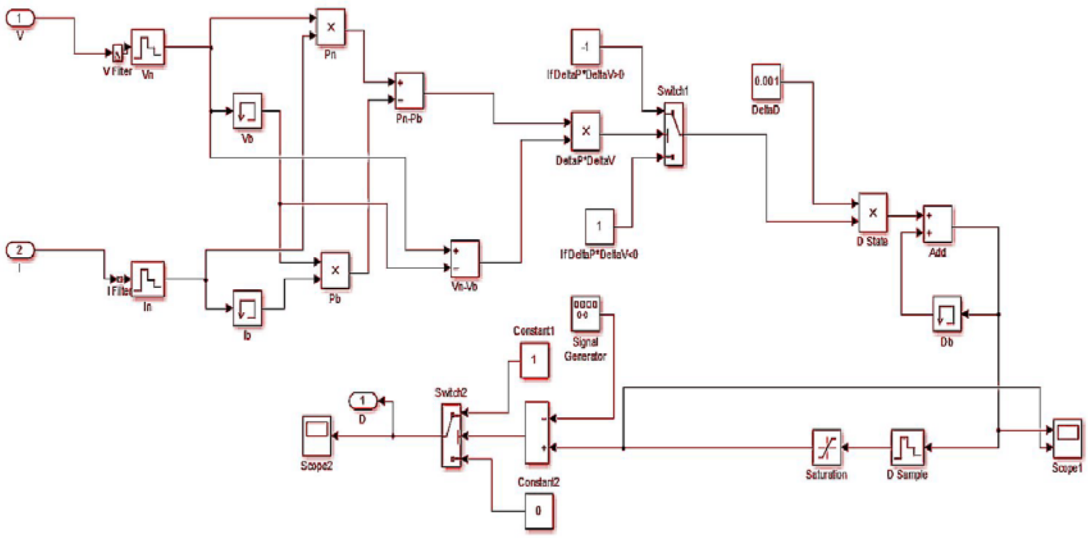

Figure 4: Perturb & Observe Algorithm Simulink

5. Results and Simulation

The simulation is done on real measured data. The model parameter has different effects on current –voltage and power - voltage relationship. The effect of different temperature and irradiance on the model output is shown.

The Resistance value has different effects on power and fill factor. The higher value of series resistance reduces the maximum power and fill factor. A higher value of resistance leads to lower voltage at the same current. Ideally the series resistance value should be as low as possible. At the same time the low shunt resistance value decreases the power and fill factor. The shunt resistance value should be high. The temperature has different effect on V_{oc} and I_{sc} and power. The lower temperature value results in an increased value of open circuit voltage and results in a reduced value of short circuit current as shown in the Fig.-5. It shows significant changes in output power, the output power decreases drastically with increase in the temperature as shown in the Fig.-6.

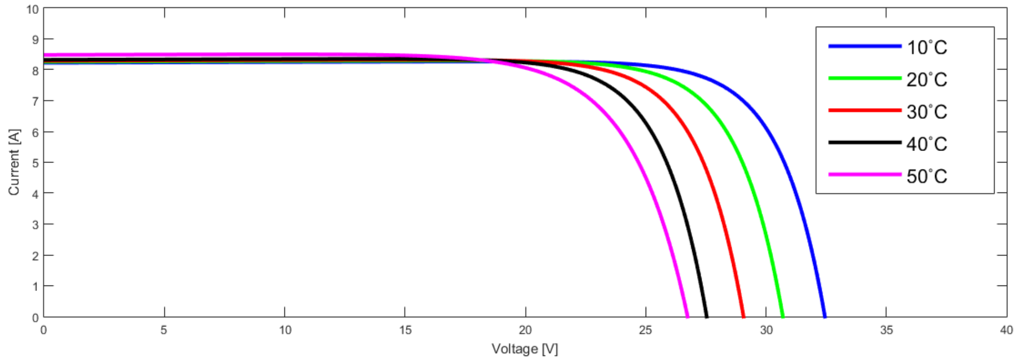

Figure 5: I-V curves with different value of Temperature [˚C]

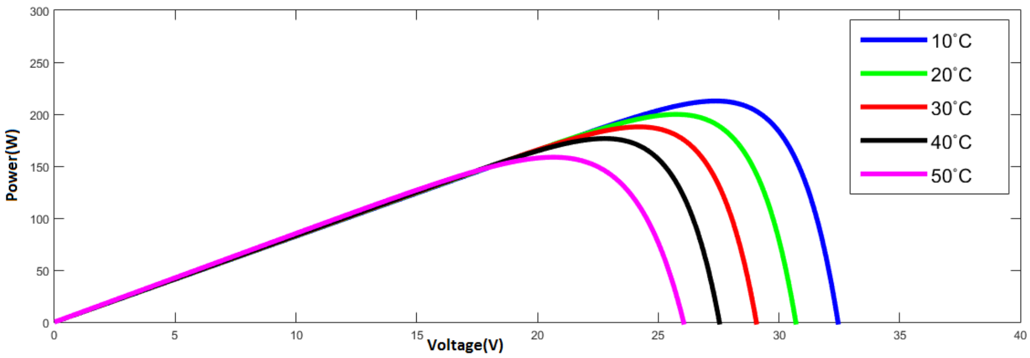

Figure 6: P-V curves with different value of Temperature [˚C]

Solar irradiance is also an important factor which affects the power and maximum power point. Increase in the solar irradiance results in an increase in the short circuit current as shown in the Fig.-7. It results in the increased power as shown in the Fig.-8.

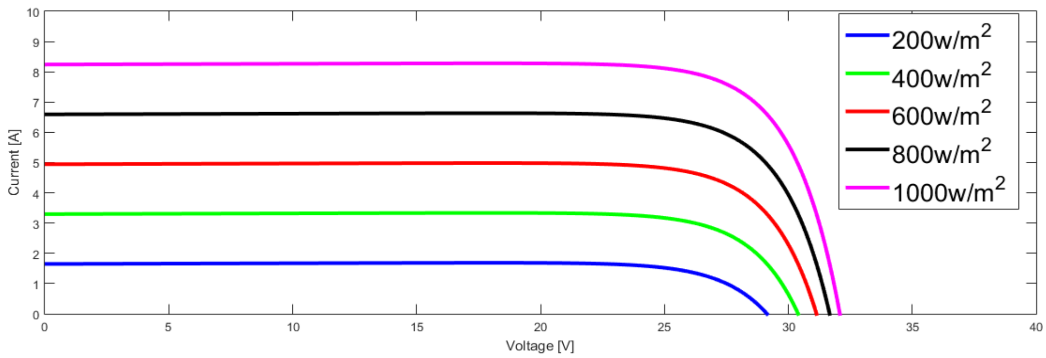

Figure 7: I-V curves with different value of Solar Irradiance [W/m^2]

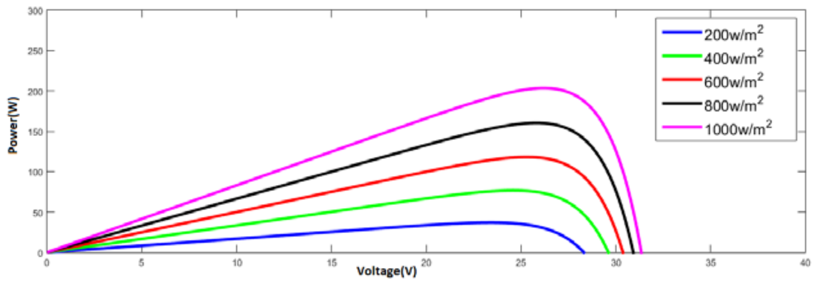

Figure 8: P-V curves with different value of Solar Irradiance [W/m^2]

The resulting output of the simulated model is given in Fig- 10. The voltage, current and power coming out of panel is given in Fig -9. The value of output power coming out of PV panel validates the model specification. In Fig-10 the voltage, current and power of boost converter is shown. The voltage gets boosted and current decreases in the case of boost Converter. The resultant output power is same in both the cases. The same value of the power of PV panel and power of the Boost converter validates MPPT algorithm.

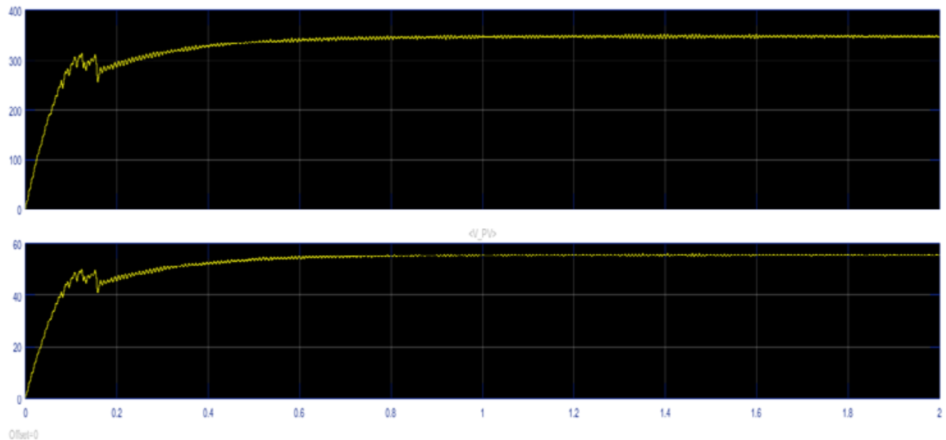

Figure 9: Voltage and Power of PV panel

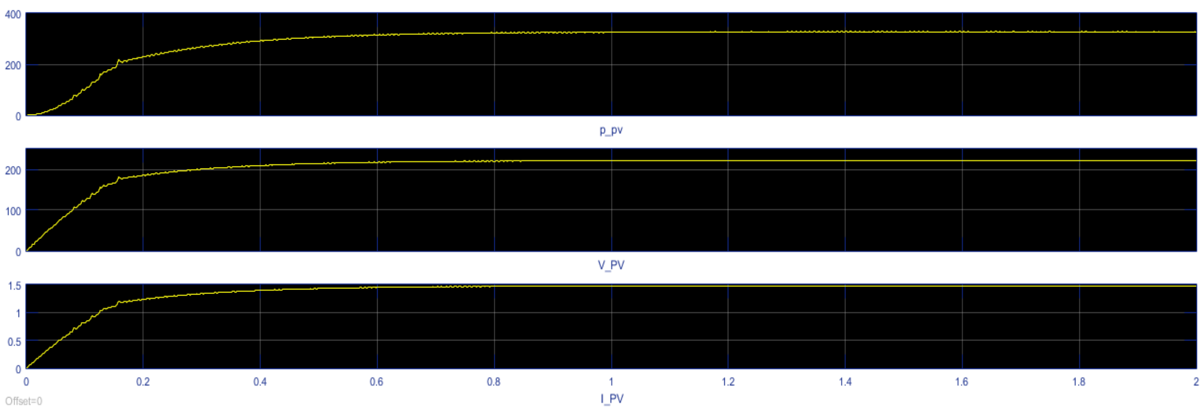

Figure 10: Voltage, Current and Power of Boost Converter

6. Conclusion

The model is designed to examine the characteristics of PV panel. Effects of different environmental conditions are shown on the PV panel. P & O algorithm and boost converter are used to extract maximum power out of the panel. At a constant value of irradiance, voltage and power coming out of the panel is compared with the resultant voltage and power of the Boost Converter. The Converter result is an increased value of voltage. The variation of power within the same range validates the working of the P & O algorithm.

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