Modeling And Estimation Of Maximum Power Point For Solar Pv Standalone Power System

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Abstract

The growing energy demand of power generation in the solar PV system, the knowledge of estimating the maximum power point is the most important key factor. The PV conversion model accomplishes the estimation of different variables such as incident irradiance on the tilted plane, temperature variants and load resistance so as to observe the maximum power produced by a PV plant. The proposed forecasting process exploits the correlations between P-V, I-V characteristics and incident global – efficiency for various environments using PV syst software.
Keywords : Photovoltaic (PV), Maximum Power Point (MPP), Grid-Connected Photovoltaic (GCPV)

1. Introduction

Power generation becomes the need of developed, developing and under developed countries to meet their increasing power requirements.Generating electrical energy conversion process from the solar energy is based on Photovoltaic (PV) Technology. The principle used behind the conversion of solar power into electrical energy is called photovoltaic effect. Solar cell is the smallest part of the device which converts solar power into electrical energy. Accumulation of semiconductor diodes form the solar cells, which are made by combining silicon substantial with different impurities.[1] The PV power conversion model accomplishes the forecast of different variants such as ambient temperature, irradiance on the tilted angle, and wind velocity in order to estimate the output power converted by a PV module. The predicted values are found with a spatio-temporal forecasting technique that comprises data from a target meteorological station and its nearby stations [2]. The powder sand of, a base material for semiconductor is generally available. The SiO_2 is collected from silicon raw materials. The solar energy can be reflected as a bunch of light particles called photons. At incidence of photon onto solar cell, the electrons are released and become free. The newly freed electrons with higher energy level become source of electrical energy. Once these electrons pass through the load, they release the additional energy gained during collision and fall into their original atomic position ready for next cycle of electricity generation. Now a day’s Grid-Connected Photovoltaic (GCPV) systems are a well-known technology to convert solar energy into electricity in renewable energy conversion.

For designing well-performing direct-coupled system, identical impedance of the electrical load is a critical part for the maximum power output of the PV array. Using spatio-temporal forecasting approach, different variables like ambient temperature, irradiance on the tilted plane, and wind velocity were found [3]. The I-V and P-V characteristics are found which proves multiple peaks under partially shaded conditions. The global peak magnitude is not only dependent on the PV array arrangement and shading pattern but also the isolation level and temperature. [3]. An actual irradiance value sampled every two minute and recommended values to be recognized with regard to the energy storage Strategy.[4,5]. The solar PV system includes different mechanisms that should be selected according to system type, site location and applications. To operate independent of the electric utility grid, stand-alone PV systems are designed and deliver to certain DC or AC electrical loads. Wherever the DC output of a PV module or array is directly associated to a DC load, a direct-coupled system is the simplest approach of stand-alone PV system. Several MPP algorithms were described in the literature, and several authors have analysed a comparison between these techniques pointing out their benefits, drawbacks, and performances. Due to ease of implementation, Perturb and Observe (P&O) method is still the most widely used technique. [6-9]. Various sensitivity studies are also discussed to examine the robustness of the design in case of variation of design parameters like variation of ambient temperature's average and variance, variation of solar irradiance, and variation of available installation area.[10]. In this paper describes simulation and performance scheme of standalone photovoltaic system using PV syst software.

2.Proposed PV system

The PV system consist of the following models

- Photovoltaic Generator Model
- Batteries and charge controllers
- Inverters

Figure 1 depicts the arrangement of standalone PV array with battery storage powering DC and AC loads.

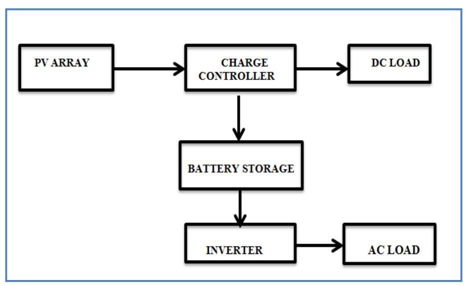

Fig. 1. PV array with battery storage powering DC and AC loads

2.1 PV array

Solar cell is the primary essential unit of a PV system. The group of Photovoltaic cells create photovoltaic modules, which are collective in parallel and series to provide the desired output power. The solar cells in a module have identical electrical characteristics, and they all experience the same insolation and temperature, then all the cells will be operating at exactly the same current and voltage. In this case, the I-V curve of the PV module has the same shape as that of the individual cells, except that the voltage and current are increased. The maximum annual incident solar radiation is obtained at an orientation of due south and at a tilt from the horizontal of 30°. Slight deviations from these optimums will not have a significant effect on the solar radiation availability. An improvement aspect is that the total annual output is of the order of 90% of maximum over an astonishingly wide range of orientations and tilts. The output of a solar PV array can be estimated by equation (1):

$$\text{Output}_{PV}(\text{kWh}) = 0.8 \times \text{kW}_P \times Z_{PV} \times S \quad (1)$$

Where:

kW_P = installed peak power
S = annual solar radiation
Z_{PV} = over shading factor

The power output of PV array module's increases with increasing irradiance and each irradiance value has a corresponding maximum power. Also the power delivered reduces with increasing resistance. The figure 6 and 7 show the Power verses Voltage characteristics with series resistance and shunt resistance respectively. The maximum power point and its relation with the irradiance received. At the maximum power point. If all the solar cells in a module have identical electrical characteristics, and they all experience the same insolation and temperature, then all the cells will be operating at exactly the same current and voltage.

$$I_{Total} = C_P \times I_{SC} \cdot C_P \times I_{SAT} \left(Exp \left(\frac{q \frac{V_{Total}}{C_S}}{I_F KT} \right) \right) \quad (2)$$

Where:
C_S = number of cells in series;
C_P = number of cells in parallel;
I_{Total} = total current from the circuit;
V_{Total} = total voltage from the circuit;
I_{SAT} = saturation current from a single solar cell;
I_{SC} = short-circuit current from a single solar cell;
I_F = ideality factor of a single solar cell
q, K, and T are constants

Inverters are used to convert solar panels output or battery to ac quantity that can be used either to be connected to the grid or used by electric devises. There are three main types of inverters, namely; stand-alone inverters, it runs the electrical devices within the system but it cannot be connected to the grid. Grid-tie inverters, it can be connected to the grid and they are designed to automatically disconnect and shut down when there is a loss of utility supply but they do not provide backup power during power outages.

1.2 Batteries and charge controllers

In stand-alone photovoltaic system, the energy produced by the PV module cannot directly used in the consumers. When it is produced because the demand for energy does not always match with its generation. The energy storage batteries are commonly used in PV system. The major functions of a storage battery in a PV system are:

- To store electrical energy, this is produced by the PV array and to supply energy to electrical loads as demand or needed.
- To supply stored energy to electrical loads at constant voltages and currents, by overpowering or smoothing out transients that may occur in PV system.

A charge controller or charge regulator restricts the rate at which electric current is added to or more drawn from electric batteries. It avoids overcharging and may prevent against overvoltage, which can decrease battery performance or lifespan, and may position a safety risk. It may also prevent totally deep discharging a battery, or perform controlled discharges, depending on the battery technology, to protect battery life.

3. Results and discussion

3.1. Effects of irradiance on MPPT

The PV module I-V and P-V performance characteristics are analysed using PV syst software. The irradiance and acquiring power are directional proportional to each other in which the electrical power delivered by the module increases with increasing irradiance. While its voltage varies slightly but the voltage of the peak power is almost fixed. However, the MPP of a PV panel is not fixed but varies with different factors such as solar irradiance, temperature and load impedance. In a PV cell, current flow depends on photons in the solar cell. The output power is constant under constant temperature, constant radiation and constant load impedance. Effects of irradiance and power conversion at constant temperature of 45° C is tabulated in table 1.

Table 1. Effects of irradiance and power conversion at constant temperature of 45° C

Temperature 45° C	
Incident irradiance	**Power Rating**
1000 Wm^2	172.3 W
800 Wm^2	138.9 W
600 Wm^2	103.9 W
400 Wm^2	66.6 W
200 Wm^2	33.2 W

The figure 2 and figure 3 show the I-V and P-V characteristics at constant temperature of 45° C with different value of incident irradiance. The current dispersed is directly proportional to irradiance intensity. The figure 4 depicts the cells temperature – efficiency at P_{max} characteristics.

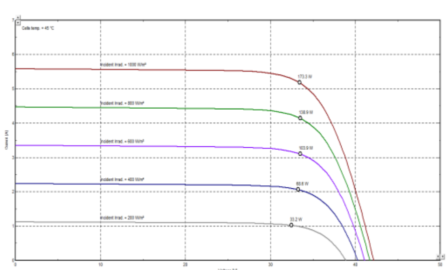

Fig. 2. Current –Voltage characteristics

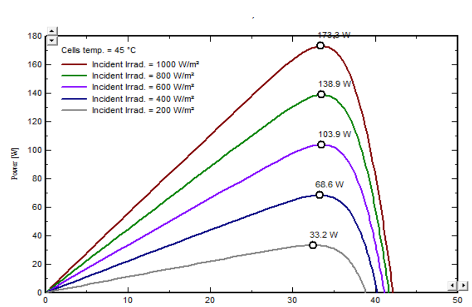

Fig 3. Power - Voltage characteristics

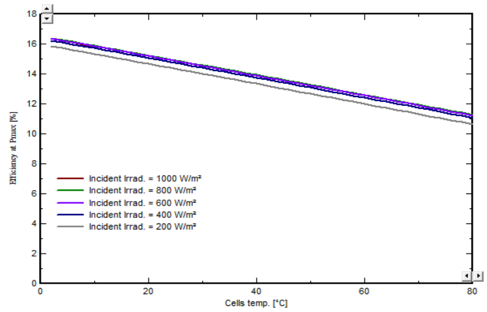

Fig 4. Cells temperature – Efficiency at P_{max} characteristics for various incident irradiance

3.2. Effects of temperature on MPPT

When the increase of temperature, the I-V and P-V characteristics of a PV cell shifts towards left and so the MPP contractions reduce with higher range of temperature. Because of the photovoltaic nature of solar panels, their current-voltage conversion and power ratio depends on temperature, irradiance load resistance. Therefore, the operating current and voltage which maximize the power output will alter with atmospheric climate conditions. The cell temperature is a function of changes in ambient temperature and changes in insolation, as given by [11].

$$\mathbf{T} = \mathbf{T}_{\mathbf{amp}} + \left(\frac{\mathbf{N}_{\mathbf{oct}} - \mathbf{20^{o}\,C}}{\mathbf{0.8}} \right) \mathbf{T}_{\mathbf{iamp}} \quad (3)$$

Where:

T_{amb} - Ambient temperature

N_{OCT} - Nominal operating cell temperature provided by the manufacturer

T_{iamp} - Solar irradiation at the ambient temperature

The figure 5 and 6 show the I-V and P-V with different climate temperature.

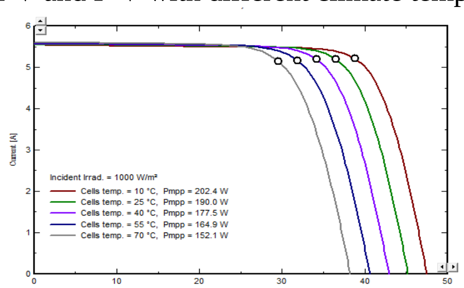

Fig.5. Current –Voltage characteristics for various temperatures

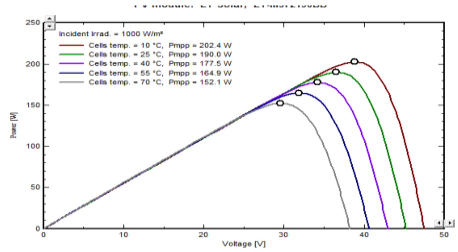

Fig.6 power – voltage characteristics for various temperatures

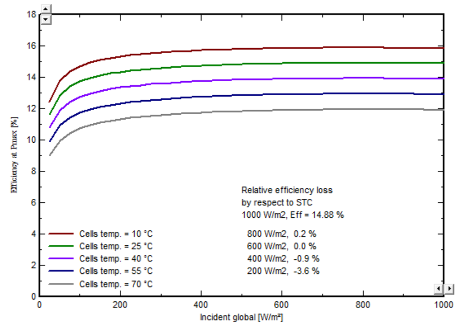

Fig 7. Efficiency –Incident global characteristics for various cells temperature

Efficiency versus incident global characteristics for different temperature is shown in figure 7. The table 2 shows the effects of temperature and power conversion at incident irradiance 1000Wm^2.

Table 2. Effects of Temperature and power conversion

Incident irradiance 1000Wm^2	
Temperature	**power Rating**
10 ^{o}C	202.4 W
25 ^{o}C	190.0 W
40 ^{o}C	177.5 W
55 ^{o}C	164.9 W
70 ^{o}C	152.1 W

3.3. Effects of Resistance on MPPT

The increase of load impedance, the I-V and P-V characteristics of a PV cell move towards left and so the MPPT contractions reduce with higher value of series and parallel load impedance. The I-V and P-V characteristics of a photovoltaic cell shown in figure 8 and figure 9. The MPP varies with the load impedance. The resistance of load directs the operating condition of the PV module. In general, this operating point is seldom at the PV module due to resistance mismatch of the connected load, thus it is not generating the maximum power at the given operating point. This mismatching between a PV module and a load requires further pre-sizing of the PV array and thus increases the total system cost.

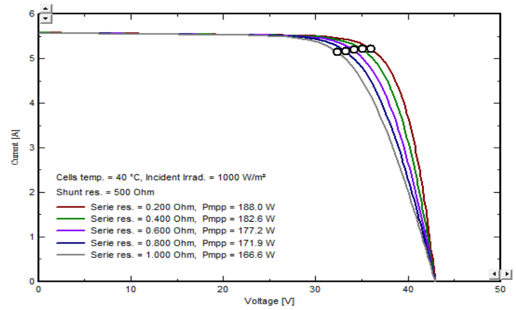

Fig. 8. Current –Voltage characteristics for various series resistance

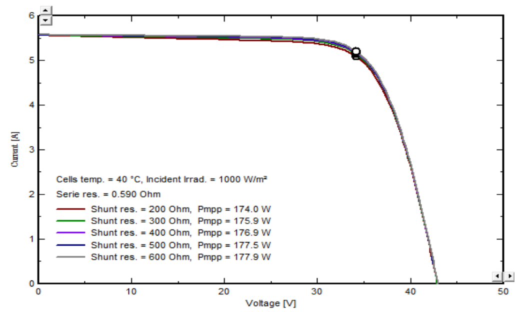

Fig. 9. Current –Voltage characteristics for various shunt resistance

Figure 10 shows Power - Voltage characteristics for constant shunt resistance for various series resistance. Figure 11 shows the power - voltage characteristics for various shunt resistance with constant series resistance.

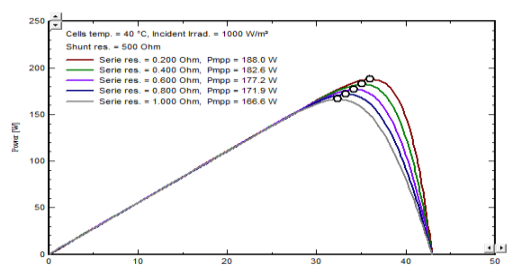

Fig 10. Power - Voltage characteristics for various series resistance

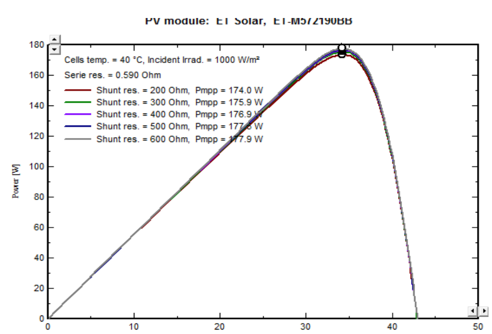

Fig 11. Power - Voltage characteristics for various shunt resistance

Figure 12 depicts the efficiency –incident global for various series resistance with constant shunt resistance.

Figure 13 depicts the efficiency –incident global for various shunt resistance with constant series resistance.

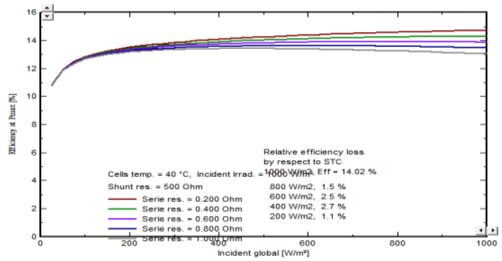

Fig 12. Efficiency –Incident global characteristics for various series resistance

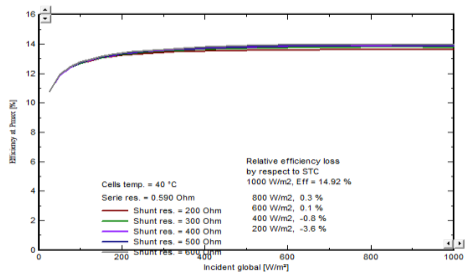

Fig 13. Efficiency –Incident global Characteristics for various shunt resistance

Table 3. Effects of series and shunt resistance - power generation

Incident irradiance 1000Wm^2			
Cell temperature 40^o C			
Shunt resistance 500 Ω		**Series resistance 0. 590 Ω**	
Series resistance (Ω)	**power Rating (W)**	**Series resistance (Ω)**	**power Rating (W)**
0.200	188.0	200	188.0
0.400	182.6	300	182.6
0.600	177.2	400	177.2
0.800	171.9	500	171.9
1.000	166.6	600	166.6

The table 3 shows the effects of series and shunt resistance and power conversion at incident irradiance 1000Wm^2.

4. Conclusion

PV syst software was used to give necessary data regarding the detailed parameter analysis to determine the maximum power generation.The MPP are estimated for various incident irradiance, temperature variation, series resistance and shunt resistance. The I-V and P-V performance characteristics studied in detail. It is found that the maximum power point and the amplitude of voltage are reduced for various incident irradiance, temperature and series load resistance. For shunt load resistance, maximum power point and the amplitude of voltage are almost constant. In this case, the PV module can be easily established and its MPP voltage and power can be estimated from the capacity of solar radiation and cell temperature.

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