Dynamic Performance of a Small Rating Photovoltaic (PV) Module

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***Abstract*—In photovoltaic power system, both photovoltaic module and switch-mode converters show non-linear and time-invariant characteristics, which is very difficult control. In this paper a small 50W photovoltaic module BP-350 is studied. The operating principle is studied and modeling of non-linear equations is done and unknown parameters like series and shunt resistance are calculated. The performance analysis of this 50W photovoltaic module is presented and simulation results are obtained. The characteristics are plotted by varying at different insolation conditions from 100 % to 20 %.**

Index terms— Photovoltaic (PV), Maximum power point (MPP), Standard test condition (STC)

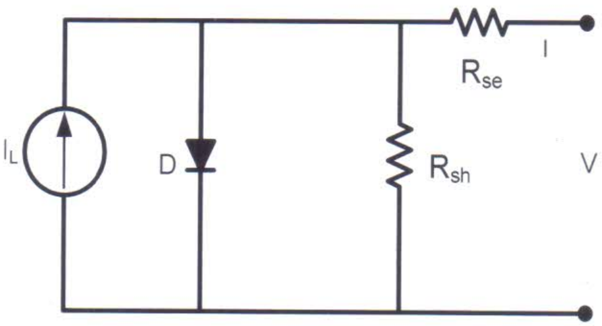

Fig.1 Equivalent circuit of the PV cell representing the model parameters.

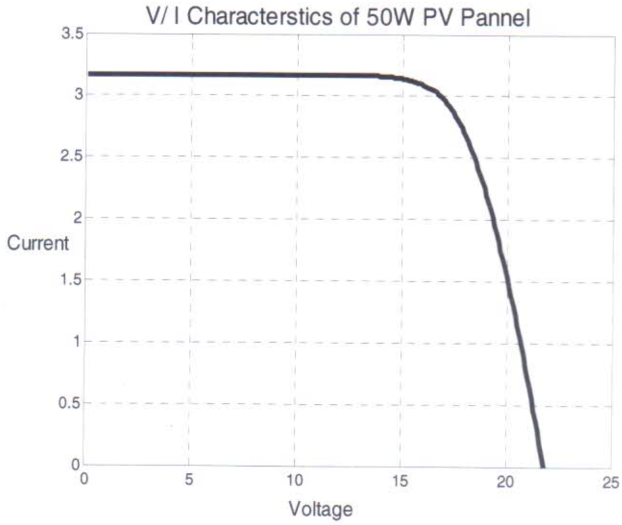

Fig. 2 Characteristics of BP 350 solar module at insolation $1000W/m^2$ at 25^0C

I. Introduction

Photovoltaic (PV) generation is gaining increased importance as a renewable source due to its advantages like absence of fuel cost, little maintenance, no noise and wear due to absence of moving parts, etc. Since the PV generator exhibits a nonlinear V-I characteristic, its maximum power (MP) point varies with the solar insolation and temperature. At a particular solar insolation, there is a unique operating point of the PV generator at which its power output power is maximum. Therefore, for maximum utilization efficiency, it is necessary to match PV generator to the load such that the equilibrium operating point coincides with the MP Point of PV source. This matching of load to PV source is possible by using an intermediate dc-dc converter, which continuously adjusts the voltage, current levels and moves the operating point. In order to understand this tracking mechanism using different dc-dc converters it is essential to have exhaustive simulation studies before being the total system experimentally implemented.

Photovoltaic (PV) cell converts part of the solar energy into electrical energy. The remaining part is converted into heat. This heat inversely affects the efficiency of the solar cell. The output power of a PV module is product of panel voltage and current. In this paper, an experiment was conducted to quantify the consequence of shading in photovoltaic power systems. Fig. 1 shows photovoltaic BP-350 module, which was installed on the frame in the direction and at the some angle on a roof, allowing them to be tested at the time and under some conditions. Each BP-350 module is comprised of 72 photovoltaic cells, as described in [10].

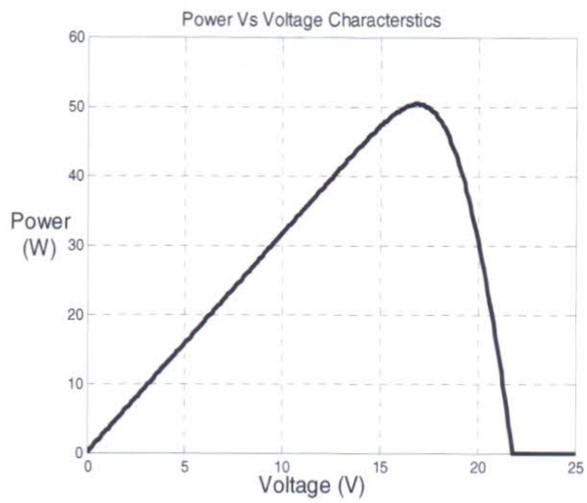

Fig.3 Characteristics of BP 350 solar module at insolation 1000W/m^2 at 25^{0}C

II. MODELING OF PHOTO VOLTAIC CELL

The electrical power output delivered by a photovoltaic panel depends on the incident solar radiation, cell temperature, solar incidence angle and load resistance. Manufacturers typically provide only few operational data for photovoltaic panels, such as the open circuit voltage (V_{oc}), the short circuit current (I_{sc}), the maximum power point voltage (V_{mpp}) and current (I_{mpp}), the temperature drift coefficients at open circuit voltage and short circuit current

$$I = I_L - I_0\left(e^{\frac{V+IR_S}{a}} - 1\right) - \frac{V + IR_S}{R_{SH}} \quad (1)$$

$$a = \frac{N_S\,\gamma KT}{q} \quad (2)$$

The electron charge q and the Boltzmann's constant k are known values, γ is the usual photovoltaic single cell ideal factor (which value varies within 1-2), Ns is the number of cells in series and T is the PV panel temperature. The five parameters appearing in Eq. (1) corresponding to operation at Standard test condition (STC), are designated: a, I_L, I_O, R_S, and R_{SH}. In general, these five parameters are functions of the solar radiation incident on the module and the module temperature. Reference values of these parameters are determined for a specified working condition, such as STC. To evaluate these five parameters in Eq. (1), a system of five independent equations is needed. Three current-voltage relations are normally available from the manufacturer at STC: the short circuit current, the open circuit voltage and the current and voltage at the maximum power point, Eqns..(3) - (5). Fourth equation results from recognizing that the derivative of the power at the maximum power point should be zero.

For short circuit:

$I = I_{sc}$ and $V = 0$

$$I_{sc} = I_L - I_0\left(e^{\frac{I_{sc}R_S}{a}} - 1\right) - \frac{I_{sc}R_S}{R_{SH}} \quad (3)$$

For open circuit :

$I = 0$ and $V = V_{oc}$

$$0 = I_L - I_0\left(e^{\frac{V_{oc}}{a}} - 1\right) - \frac{V_{oc}}{R_{SH}} \quad (4)$$

At maximum power point **A** PV cell should be operated at a specific on its I-V curves **to** maximize its efficiency over changing conditions. Cell output power at any point is given by P equal to V×I, and by taking the derivative with respect to cell voltage, **a** useful relationship is derived.

$I = I_{mpp}$ and $V = V_{mpp}$

$$I_{mpp} = I_L - I_0\left(e^{\frac{V_{mpp}+I_{mpp}R_S}{a}} - 1\right) - \frac{V_{mpp} + I_{mpp}R_S}{R_{SH}} \quad (5)$$

The derivative of output power with respect to module output voltage at maximum power point is zero

$$\left|\frac{d(VI)}{dV}\right|_{mpp} + I_{mpp} + V_{mpp}\left|\frac{dI}{dV}\right|_{mpp} = 0 \quad (6)$$

TABLE I Table showing BP-350 module specifications

Sr o.	Typical Electrical Characteristics	BP-350
1	Maximum power point (P_{max})	50 W
2	Voltage at P_{max} (V_{mp})	17.3 V
3	Current at P_{max} (I_{mp})	2.89 A
4	Short circuit current I_{sc}	3.17 A
5	Open circuit voltage V_{oc}	21.8 V

III CALCULATION OF UNKNOWN PARAMETERS

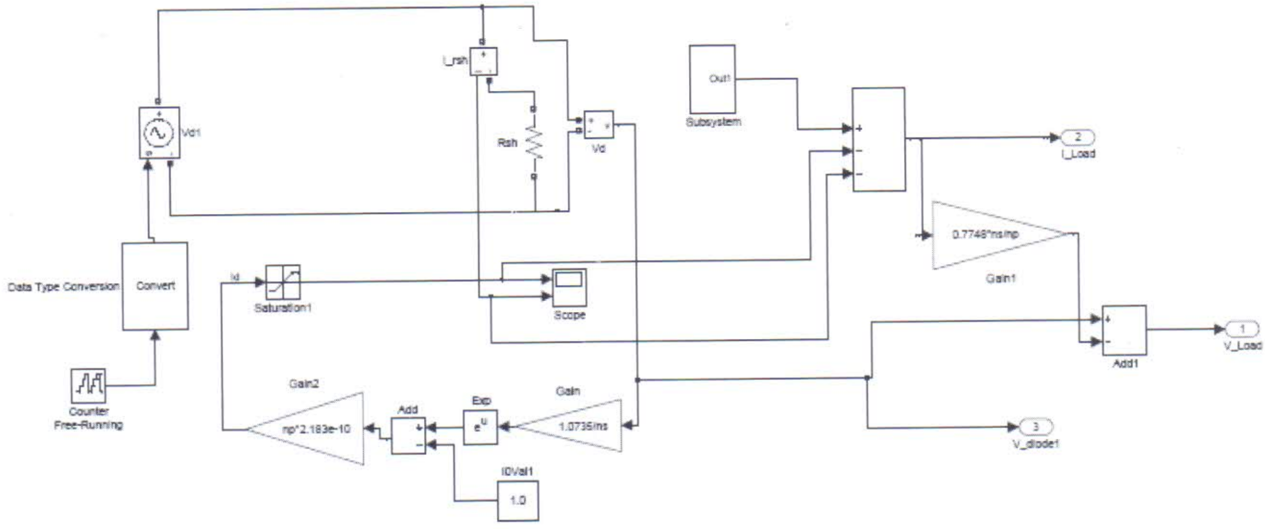

Fig. 4 Schematic diagram for simulation of control mechanism of MPPT

The unknown parameters can be calculated by solving equations 3-6 for different conditions given in table I. The first approximation is that it is assumed that the short circuit current (I_{SC}) is equal to the generated light current (I_L). The equation that relates the short circuit current and open circuit voltage becomes

$$I_{sc} = I_0\left(e^{\frac{V_{oc}}{a}} - 1\right) - \frac{V_{oc}}{R_{SH}} \qquad (7)$$

Assume that the ratio between V_{OC} and R_{SH} is negligible because of R_{SH} is typically several kilo-ohms; the diode saturation current determines the open-circuit voltage (V_{OC}) of PV module.

$$V_{oc} = a\, L_n\left(\frac{I_{sc}}{I_o} + 1\right) \qquad (8)$$

IV. SIMULATION OF BP-350 PHOTO-VOLTAIC MODULE

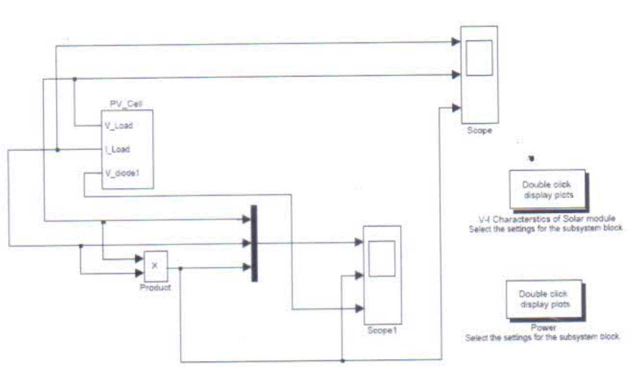

Fig. 5 Schematic diagram for simulation of photo-voltaic cell

Using MATLAB simulink software along with its SIMULINK and SIMPOWERSYSTEM toolboxes, this PV Cell is simulated. Fig.4 shows the Schematic diagram for simulation of control mechanism to track maximum power point (MPP) at different insolation conditions. The control strategy should be applied to operate the cell at MPP. Since PV-cell characteristics are non-linear it is difficult to track MPP. Fig. 5 shows the schematic diagram for simulation of BP-350 photovoltaic module

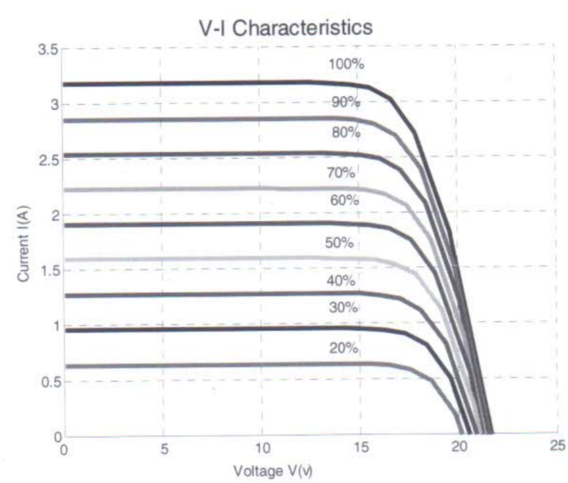

Fig.6 Simulated V-I curves of BP-350 under varying 20% to 100% insolation condition at 25^{0}C.

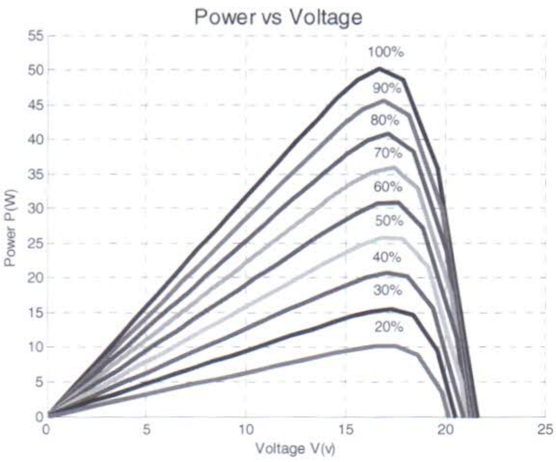

Fig.7 Simulated Power and voltage relationship curves under varying 20% to 100% insolation condition at 25^0C

V. RESULTS AND DISCUSSION

Fig. 6 has shown the V-I characteristics of BP-350 module. It shows non-linear behaviour of PV cell. Initially current is constant and equal to light generated current, with decrease in load current decreases and becomes zero at open circuit condition. Using simulation MPP is calculated for a particular current and voltage condition. Table I shows the specification of BP-350 solar module at a standard test condition of a temperature 25^0C. Fig.7 shows simulated power and voltage relationship curves under different insolation condition at constant temperature of 25^0C.

VI. CONCLUSIONS

This paper has discussed the modeling of photovoltaic cell in which analysis and modeling is done to discover the characteristics of a small photovoltaic module BP-350 at standard test condition of 25^0C. It has also presented the MPP tracking at a particular value of voltage and current.

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L Navinkumar Rao received the BE and M-Tech. degree in engineering from VNIT, Nagpur, India, in 1999 and 2002, respectively. He is currently working toward the Ph.D. degree from GB Technical University. His areas of interests are dc-dc converters and renewable energy.