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Design and Analysis of 100kw Maximum Power Point Tracking Based PV System in Matlab Simulink at Varying Atmospheric Conditions

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ABSTRACT: Renewable energy source such as solar energy are acquiring more significance, due to shortage and environmental impacts of conventional flues. The use of photovoltaic system for converting solar energy into electricity is generally expensive. To minimize the cost and enhance the output,the PV panel should be operated at its maximum power point for all weather conditions.

The output power of the PV panel is depends on amount of irradiation, temperature and the connected load. To extract maximum power from the PV panel, the load impedance should be equal to source impedance. Due to the mismatch between the source and load, panel is not operated at its maximum power pointMPP) resulting in lower generation of power therby decreasing the overall efficiency of the system.

The aim of this paper presantation is to design and analyze a100KW maximum power point tracking based PV system in matlabsimulink at varying atmospheric conditions". A detailed modeling of a single diode solar cell is designed and analyzed. Further using series and parallel combination of modules, a 100KW solar PV plant is designed in matlabsimulink. The output is coupled with a Perturbation and Observation(P&O) based MPPT tracker to extract maximum power from PV plant. For the detailed analysis a DSP250W PV module specification were used. To highlight the proposed system performance, irradiation and temperature variation were applied in steps, results are analyzed and compared.

I. INTRODUCTION

Due to energy crisis and environmental issues such as pollution and global warming effect, photovoltaic (PV) systems are becoming a very attractive solution. Unfortunately the actual energy conversion efficiency of PV module is rather low. So to overcome this problem and to get the maximum possible efficiency, the design of all the elements of the PV system has to be optimized. In order to increase this efficiency, MPPT controllers are used. Such controllers are becoming an essential element in PV systems. A significant number of MPPT control schemes have been elaborated since the seventies, starting with simple techniques such as voltage and current feedback based MPPT to more improved power feedback based MPPT such as the perturbation and observation (P&O) technique or the incremental conductance technique Recently intelligent based control schemes MPPT have been introduced.

II. PRINCIPLE OF MAXIMUM POWER POINT TRACKING CONTROL

The photovoltaic module operation depends strongly on the load characteristics, (Fig. 1) to which it are connected [4, 5]. Indeed, for a load, with an internal resistance Ri, the optimal adaptation occurs only at one particular operating point, called Maximum Power Point (MPP) and noted in our case Pmax .Thus, when a direct connection is carried out between the source and the load, (Fig.1.), the output of the PV module is seldom maximum and the operating point is not optimal.

To overcome this problem, it is necessary to add an adaptation device, MPPT controller with DC-DC converter, between the source and the load, (Fig. 2).

Furthermore the characteristics of a PV system vary with temperature and insulation, (Fig. 3). So, the MPPT controller is also required to track the new modified maximum power point in its corresponding curve whenever temperature and/or insulation variation occurs.

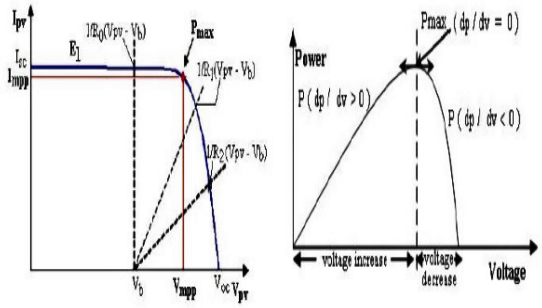


Fig.1. Current Voltage characteristics and Power-voltage Characteristic of a PV module.

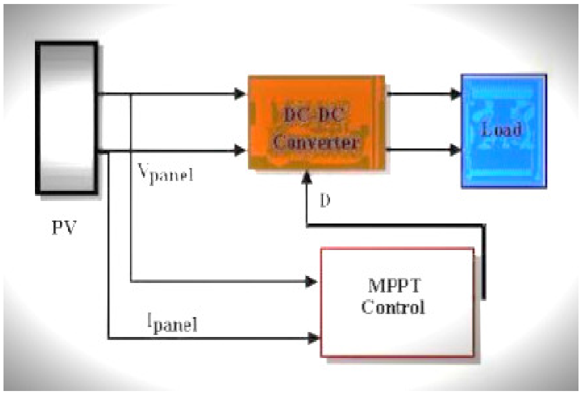


Fig. 2. Photovoltaic system.

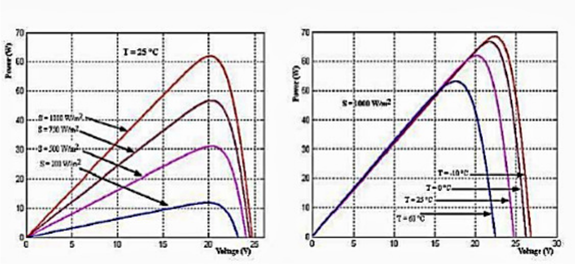


Fig. 3. Influence of the solar radiation forconstant temperature and Influence of the temperature of junction for constant insulation.

Many MPTT control techniques have been conceived for this purpose these last decades .They can be classified as:- Voltage feedback based methods which compare the PV operating voltage with a reference voltage in order to generate the PWM control signal of the DC-DC converter Current feedback based methods which use the PV module short circuit current as a feedback in order to estimate the optimal current corresponding to the maximum power .Power based methods which are based on iterative algorithms to track continuously the MPP through the current and voltage measurement of the PV module. In this category, one of the most successful and used method is perturbation and observation (P&O), which is presented in the next section.

Perturbation and Observe (P&O) Method. The perturbation and observation method has been widely used because its simple feedback structure and fewer measured parameters which are required. It operates by periodically perturbing (incrementing or decrementing) the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle. If the power is increasing the perturbation will continue in the same direction in the next cycle, otherwise the perturbation direction will be reversed. The flowchart of this method is represented by figure 4.

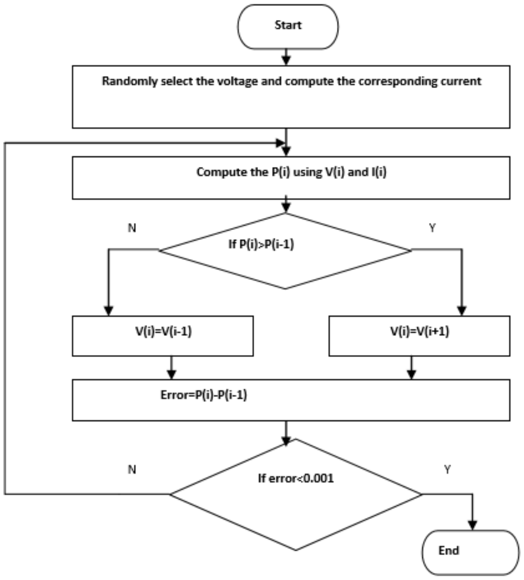


Fig.4. Flow Chart for perturbation and observe (P&O) method.

There are two well-known and widely used models, both with different levels of complexity, depending on the purpose they are used for, the single diode and the two-diodemodels. The most common version of these models is presented below as follows.

III. MODELING OF SOLAR CELL

A. The single diode model

The equivalent circuit model for a solar cell simulation with single-diode, series and equivalent shunt resistances, is shown in Figure below.

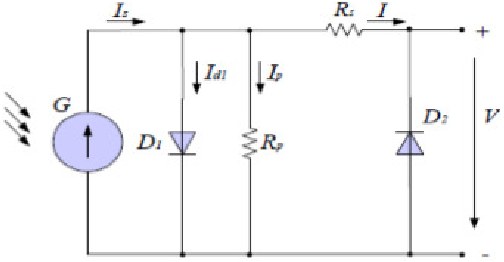


Fig. 5. The equivalent circuit model for a solar cell simulation with single-diode, series.

The equivalent circuit model can be used to simulate an individual cell, a module, an array or a panel.*G*is the solar irradiance, *Is* is the photo generated eletric current, *Id1* is the current at diode *D1*, *Ip*is the leakage current, *Rp*is the equivalent shunt resistance, *Rs* is the series resistance, *I* is the output current, *D2* is the by-pass diode and *V* is the output voltage.

$$V_{T_1} = \frac{kT_1}{q} \tag{1}$$

Where *VT1* is the thermal voltage at the cell temperature *T1* in Kelvin, *k* is the Boltzmann's constant, *q* is the electron charge. The I-V characteristic associated with the model shown in Figure 1 for the solar cell is given by:

$$I = I_s - I_{01}[e^{\frac{(V+R_sI)}{m_1V_{T_1}}} - 1] - \frac{V+R_sI}{R_p} \tag{2}$$

For constant irradiance and *p-n* junction temperature conditions, the short circuit current is the greatest value of the current at the cell terminals. The short circuit current is given
by:

$$I_{sc} = I = I_s - I_{01}(e^{\frac{R_sI_{sc}}{m_1V_{T_1}}} - 1) - \frac{R_sI_{sc}}{R_p} \tag{3}$$

For constant irradiance and *p-n* junction temperature conditions, the open circuit voltage is the greatest value of the voltage at the cell terminals. The open circuit voltage *Voc*is given by

$$V_{oc} = m_1V_{T_1} \ln(\frac{I_s}{I_{01}} + \frac{V_{oc}}{R_pI_{01}} + 1) \tag{4}$$

were:

$$R_{sho} = -\left.\frac{dV}{dI}\right|_{I=I_{sc}} \tag{5}$$

$$R_{so} = -\left.\frac{dV}{dI}\right|_{V=V_{oc}} \tag{6}$$

The diode ideality factor is given by

$$m_1 = \frac{V_m^* + R_{so}I_m^* - V_{oc}^*}{V_{T_1}[\ln(I_{sc}^* - \frac{V_m^*}{R_{sho}} - I_m^*) - \ln(I_{sc}^* - \frac{V_{oc}^*}{R_p}) + \frac{I_m^*}{I_{sc}^* - (\frac{V_{oc}^*}{R_{sho}})}]} \tag{7}$$

Where *mV is the voltage for maximum power at STC, *m I is the current for maximum power at STC, **Voc* is the open circuit voltage at STC, **Isc*is the short circuit current at STC, **mI*is the current for maximum power at STC.

The output power is given by:

$$P = V[I_{sc} - I_{01}(e^{\frac{(V+R_sI)}{m_1V_{T_1}}} - 1) - \frac{V+R_sI}{R_p}] \tag{8}$$

B. The double diode model

A simple PV cell from a modeling perspective is an ideal current source in parallel with an ideal diode as seen in Figure 6. The two parameters used to model and characterize a PV cell are: the open circuit voltage (*Voc*) and the short circuit current (*Isc*). The *Voc* is the maximum voltage which a solar cell can provide at zero current. The *Isc*is the maximum current which a solar cell can provide at zero voltage.

The output current from the PV cell can be found using the equation

$$\mathbf{I = Isc - Id} \tag{i}$$

Where *Isc*is the short circuit current that is equal to the photon generated current and *Id* is the current shunted thought the intrinsic diode.

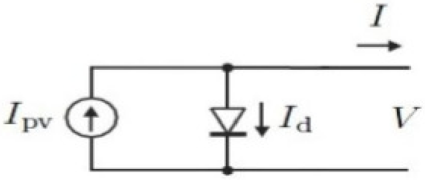


Fig. 6. Ideal PV cell.

The diode current is given by Shockley's diode equation

$$I_d = I_0 * \left(e^\wedge qVd/kT \ - 1\right) \qquad \text{(ii)}$$

1. Io is the reverse saturation current of the diode
2. *q*is the electro charge valued at 1.602x10–23 C
3. *Vd*is the diode's voltage
4. *k*is Boltzmann's constant valued at 1.381x10–23 J/K
5. T is the junction temperature in Kelvin combining Equation (i) and Equation (ii) we then obtain

$$I = I_{sc} - I_0 * \left(e^\wedge qV/kT \ - 1\right) \qquad \text{(iii)}$$

In this case *V* is the voltage that exists across the PV cell and *I* is the output current of the ideal circuit model. A single solar cell typically produces only about 0.5V so they need to be connected in series forming what is known as the PV Module. A PV panel is a collection of PV modules physically and electrically grouped together and finally a PV Array is a collection of PV panels.

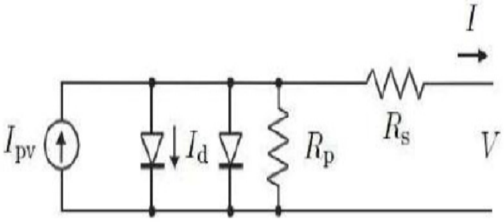


Fig. 7.

Taking into account all the additional elements mentioned the Equation (iii) changes to:

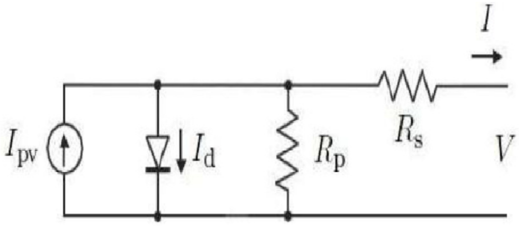


Fig. 8.

$$I_{sc@T} = I_{sc@Tref} * [1 + K_i - (T - T_{ref})] \qquad \text{(v)}$$

Isc at the reference temperature is found on the datasheet, and a refers to the temperature coefficient of Isc in percent change per degree. Both measurements are done under the standard irradiance of 1000W/m^2. Normally the reference temperature is 25 C

$$I_{pv} = (I_{sc} + K_i \ \Delta T\ )G/G_n \qquad \text{(iiv)}$$

$$I_{sc@G} = I_{sc@Gref} * [G/G_{ref}] \qquad \text{(iv)}$$

The last term of Equation (iv) is Io that is dependent on temperature described by equation:

$$I_{o@T} = I_{o@Tref} * \left(\frac{T}{Tref}\right)^{\frac{3}{n}} * e^{-\left[\frac{q*V}{n*k} * \left(\frac{1}{T} - \frac{1}{Tref}\right)\right]}$$

Now in this project we use the single diode modeling of spv module so the detailed modeling of single diode of spvmodule is as follows

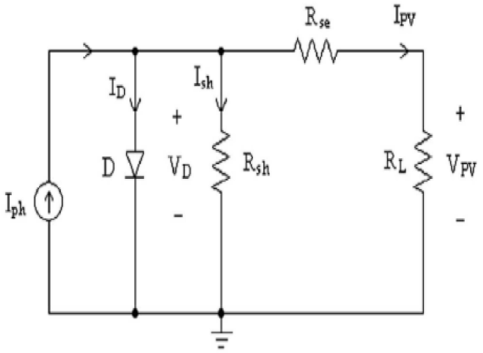


Fig. 9.

Improved model equation is used to model spv cells. The typical I-V output characteristics of PV-cell are represented as follows

$$I_{pv} = I_{ph} - I_r \left[exp\left\{\frac{V_{pv} + I_{pv}R_{se}}{V_t}\right\} - 1\right] - \left[\frac{(V_{pv} + I_{pv}R_{se})}{R_{sh}}\right] \quad (1)$$

$$I_{pv} = \{I_{ph,ref}[1 + \alpha\,(T - T_{ref})]\}\frac{G}{G_{ref}}, \qquad (2)$$

$$I_{pv,ref} = I_{sc,ref}\ , \qquad (3)$$

$$I_{ph,ref} = \frac{R_{sh} + R_{se}}{R_{sh}} \times I_{sc,ref}, \qquad (4)$$

$$I_r = I_{r,ref} \times \left[\left(\left(\frac{T}{T_{ref}}\right)^{3/n}\right) \times exp\left[\left[\frac{q \times E_g}{n \times k}\right] \times \left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right]\right], \qquad (5)$$

$$E_g = 1.16 - \left[\left((7.02 \times 10^{-4})\left[\frac{T^2}{T - 1108}\right]\right)\right], \qquad (6)$$

$$I_{r,ref} = \frac{I_{sc,ref}}{\exp\left(\frac{V_{oc,ref}}{V_{t,ref}}\right)-1} \quad (7)$$

$$V_t = V_{t,ref}\frac{T}{T_{ref}} \quad (8)$$

$$V_{t,ref} = \frac{n_{ref}kT_{ref}}{q} \quad (9)$$

$$R_{sh} = \frac{4.6}{G-0.086}\textit{(Obtained by curve fitting)} \quad (10)$$

$$I_m = I_{m,ref} \times G \quad (11)$$

and

$$V_m = V_{m,ref} + \{\beta(T - T_{ref})\} \quad (12)$$

$$n = n_{ref}\frac{T}{T_{ref}} \quad (13)$$

V. RESULTS

A. *Specifications of panel*

☐ Max output power:210W

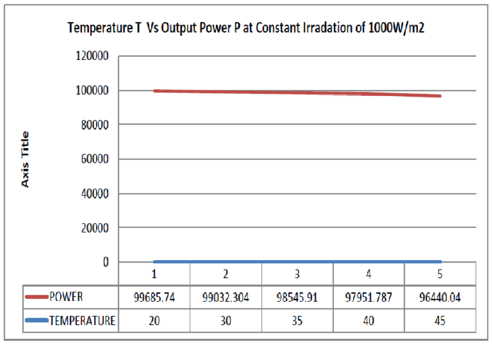
☐ Open circuit voltage:47.8V

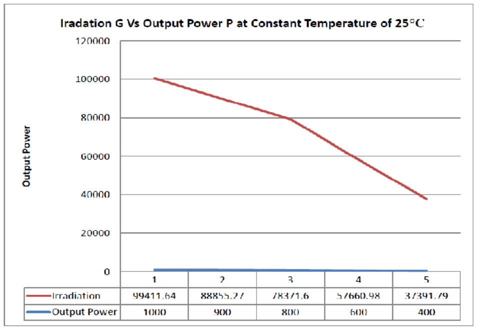
☐ Short circuit current:5.7A

☐ Temperature coefficient of open circuit voltage:0.0028 V/C0

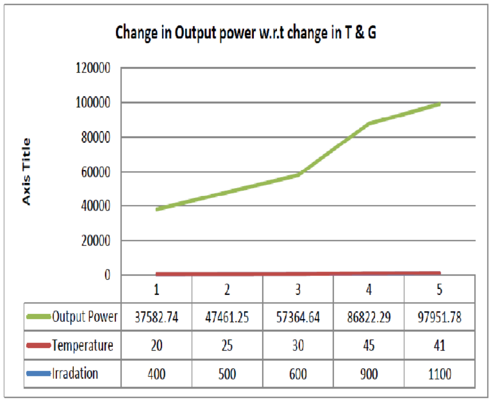
☐ No. of series connected cells:60(6*10)

Following Graph shows the simulated results of change in temperature with constant irradiation and vice versa and random variation of irradiation and temperature.





The graph shows comparison between the theoretical panel output and the optimized panel output random temperature with random irradiation



VI. CONCLUSION

A detailed modeling of a 100kW solar PV plant is done in Matlab Simulink. Solar cell is successfully modeled using single diode method and further used to create a module and array. To extract the maximum power from the plant, MPPT tracker based on P&O method is employed. The proposed MPPT is tested for different irradiations and temperatures. The results are analyzed and compared. The simulation results conclude that P&O based MPPT controller is simple for implementation, efficient and has faster convergence. Optimized results are obtained different atmospheric conditions.

VII. FUTURE SCOPE

Following are the possibilities of future modification to the model presented here,

1. Modeling of the solar cell can be done by considering the effect of partial shade condition to obtain more realistic result.
2. Modeling and analysis of a PV plant connected to grid.

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