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Matlab/Simulink - Based Research on Maximum power point Tracking of Photovoltaic System

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Abstract: In order to improve the efficiency of PV system, A perturbation and observation (P&O) method is proposed to track the maximum power point of PV system. Based on the mathematical model of PV system, this method track the maximum power point by regulating the output voltage after measuring the changes of output power. A Matlab-Simulink based study of PV cell and module / PV array is carried out and presented in this paper. Basically focuses on the Photovoltaic cell five parameters consisting on a current controlled generator series diode, a shunt resistance and series resistances. The experimental results show that the method can track the maximum power point fast and exactly, which shows that adaptive P&O has better steady state and dynamic performance than the traditional P&O, and can improve the efficiency of photovoltaic power generation system effectively.

Keywords: PV panel, MPPT, modeling, simulation, experimental results.

1. INTRODUCTION

In recent years, there has been an appreciable interest in the utilization of Photovoltaic (PV) system due to concerns about envirmental issue associated with use of fossile fuels. With world development and various demand of energy, the conventional energy sources has been become linearly increasing and unable to meet the people demand for the energy. So it is important to explore more better alternate energy sources as sunlight, wind, biomass.PV energy i8s a source of energy. That's is renewable, intensively used as sources of energy in various application. Important of solar energy, it is worth say that solar energy is a unique solution for the energy crisis. That's means all these advantage of solar energy, they do not present adequate efficiency [1], [2].

The efficiency of solar cells depends on many factors such as temperature, insolation, and spectral characteristics of sunlight, dust and shading which gives of poor performance. In the addressing the poor efficiency of PV system. There are so many methods are proposed for MPPT. In PV system an maximum operating point occurs that's called maximum power point (MPP), which varies on many factor like temperature, insolation ,irradiance, and load of PV cells [3], [4]. So due to the variation of the temperature, insolation and the irradiation we use a tracker device to avoid the energy loss. A variety of MPPT is used. The method are varies in complexity, popularity, coverage and tracking and local maxima and minima and also their application [5]-[8] and [9]. Presently two type of method are used describe as indirect method and direct method .In Indirect method perturb and observation, incremental conductance , fuzzy logic are fall also another side in direct method fractional voltage, and open circuit voltage, short circuit current method are occur. INS are overcome the drawback of the P & O method and has a harse detection device and choice of threshold are also stressful [10].

For the implementation of MPPT, These techniques are used to maintain the operating point of PV system at his maximum power point so there are many maximum power point technique are in literature. These technique are very on the many aspect including hardware implementation, sensor, speed, and cost of effective for parameterization. Perturb and observation is the technique that is used in this paper [10], [11].

2. SOLAR CELL MODELING

Solar cell made of a p-n junction fabricated in thin wafer or semiconductor layers and electrical characteristics are different from a ordinary diode [1], [2], [3], [4]. Thus solar cell as like as current source in which a diode connected in parallel as shown in figure 1. The light falling on the cell is directly proportional to output current of solar cell (photocurrent **Ipv, cell**) .The modelling process of solar cell can be developed on equation(1).

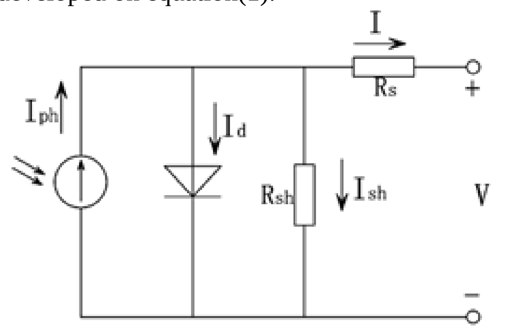

Figure 1: Equivalent circuit of PV cell

$$I = I_{ph} - I_s\left[\exp\left(\frac{q(V+IR_s)}{NKT}-1\right)\right] - \frac{(V+IR_s)}{R_{sh}} \qquad (1)$$

Where;
I_{ph} is the photo current,
Is is the reverse saturation current of diode (A)

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q is the electron charge
V is the voltage across the diode (V)
K is the Boltzmann constant
T is the junction temperature in kelvin (K)
N is the ideal factor of the diode
R_s is the series resistance of diode,
R_{sh} is shunt resistance of diode.

The basic equation (1) of the elementary PV does not represent the I-V characteristic of practical PV arrays. Practical modules are composed of several connected PV cells requires the inclusion of additional parameters Rs and Rp, with these parameters (1) becomes (2)

$$I = I_{PV} - I_0\left[EXP\left(\frac{V + R_S * I}{Vt * \alpha}\right) - 1\right] - \frac{V + R_S * I}{R_P} \qquad (2)$$

The light-generated current of the module depends linearly on solar irradiation and is also influenced by temperature according to (3).

$$I_{PV} = \left(I_{PV,n} + K_I \Delta T\right)\frac{G}{G_n} \qquad (3)$$

Where KI is the Temperature coefficient of ISC , G is the irradiance (W/m²) and Gn is the irradiance at standard operating conditions.

The diode saturation current I0 dependence on temperature can be expressed as shown in (4).

$$I_0 = I_{0,n}\left(\frac{T_n}{T}\right)^3 EXP\left[\frac{q * E_g}{\alpha * k}\left(\frac{1}{T_n} - \frac{1}{T}\right)\right] \qquad (4)$$

Eg is the band gap energy of the semiconductor and I0,n is the nominal saturation current expressed by (5)

$$I_{0,n} = \frac{I_{SC,n}}{\left[EXP\left(\frac{V_{OC,n}}{V_{t,n} * \alpha}\right) - 1\right]} \qquad (5)$$

From (4) and (5) I_0 can be expressed as shown in (6).

$$I_0 = \frac{I_{SC,n} + K_I \Delta T}{EXP\left(\frac{V_{OC,n} + K_V \Delta T}{V_t * \alpha}\right) - 1} \qquad (6)$$

Where V_{oc} is open circuit voltage ,I_{SC},*n* is the short circuit current , *Vt,n* is the thermal voltage , *Tn* is the temperature at standard operating conditions. *Vt* = Ns**kT/q* is the thermal voltage of the module.

3 The output characteristics of Photovoltaic cells

The output power of PV is the nonlinear function of ambient temperature and light intensity, the relationship between the output power and the temperature, light intensity is shown below. Figure 1 shows the output characteristic curve of photovoltaic cells at different temperature. From Figure 1 we can see that as the ambient temperature rises, the output power of photovoltaic cells decreases with the other conditions unchanged. As can be seen from Figure 2, other things being unchanged, the output power of photovoltaic cells increases as the light intensity strengthens. At particular light intensity, there is a unique maximum output power Pm for photovoltaic cell, which is called maximum power point.

The above analysis shows that the output power of photovoltaic cells, with considerable uncertainty, changes with the ambient temperature and light intensity. To this end, PV arrays must adopt maximum power point tracking control under different environmental conditions to achieve maximum power output Power.

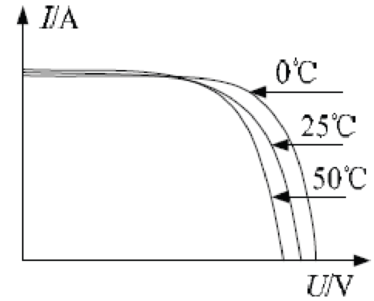

Fig. 2 U-I curve at different temperature

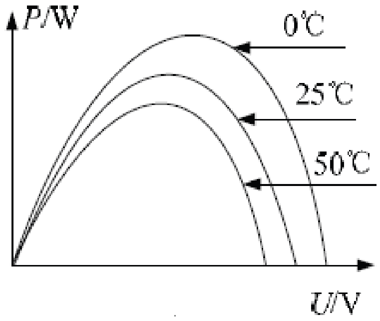

Fig. 3 P-U curve at different temperature

3. TWO COMMAN METHODS OF MAXIMUM POWER POINT TRACKING

3.1 Incremental Conductance Method

Incremental conductance method [6-7] (called IncCond for short) is one of the common used MPPT control algorithms. Incremental conductance method could estimate the relationship between the operating point voltage and the maximum power point voltage [8]. Think of the current *I* as a function of operating voltage *U* . For the formula of output power *P* =*U. I*, we can obtain *dP/dU* = *I* +*U .dI/dU* by derivative at both ends of the formula. We can see from the output characteristics of photovoltaic cells that when *dP/ dU >0* , *U* is less than the maximum power point voltage max *U* ; when *dP/ dU* < 0 , *U* is larger than the maximum power point voltage max *U* ; when *dP/ dU* = 0 , *U* equals the maximum power point voltage U_{max} . That is the following formula:

if *dI/dU* > -*I* /*U* , thus *U* <*U* max ;
if *dI/dU* < -*I* /*U* , thus *U* >*U* max ;
if *dI* /*dU* = - *I/ U* , thus *U* =*U* max ;

In this way, we can judge and adjust the operating point voltage U through the relationship between *dI dU and* – I/U to relies the maximum power point tracking. $U_{re}$is the reference voltage, the flow chart of incremental conductance method is as follows:

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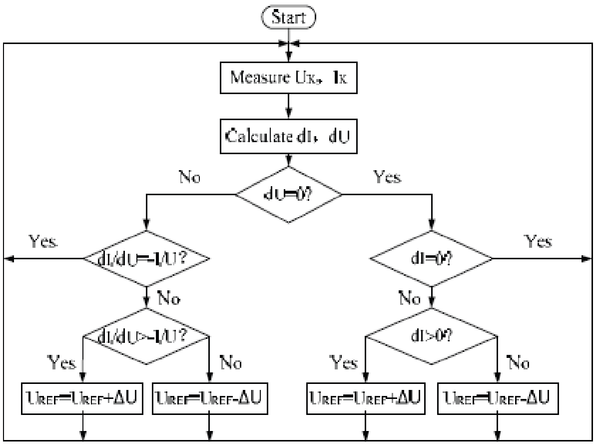

Figure 4: Method of increasing conductivity flow chart

When light intensity and outside temperature change, the incremental conductance method could control the output voltage to track the maximum power point voltage smoothly and could also reduce oscillation phenomena near the maximum power point. However, this control algorithm is very complicated, and the setting of adjusting voltage ΔU influences the maximum power point tracking accuracy greatly. If ΔU is too large, the tracking accuracy is not enough, the operating point cannot reach the maximum power point all along. If ΔU is too small, the tracking speed will slow down, the efficiency of photovoltaic power generation will also decrease.

3.2 Perturbation and Observation,P&O

Perturbation and observation method [9] (Perturbation and Observation, P & O), is also known as hill climbing method (Hill Climbing, HC). Its working principle is making a small active voltage perturbation in a certain working voltage of photovoltaic cells and observing the change direction of output power. If the output power increases then perturbation in the same direction should be kept, otherwise perturbation against the original direction should be made. The tracking diagram of perturbation and observation method is as follows.

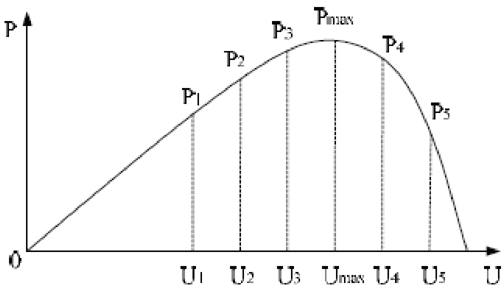

Figure 5: Taking systematic diagram of perturbation and observation method

Disturbance observation has been widely used in photovoltaic maximum power point tracking because of its simple control structure, few parameters, and easy implementation. However, due to its fixed step, the oscillation phenomenon occurs near the maximum power point, which reduces the power generation efficiency. Reducing the magnitude of each adjustment can weaken to a certain extent the oscillation near maximum power point, but the tracking to changes in the external environment will slow down, which also reduces the power efficiency. Therefore, selecting the appropriate step is the key for perturbation and observation method to achieve the desired effect.

4. VARIABLE PERTURVATION AND ABSERVATION

The perturbation and observation method with fixed step reduces the effect of tracking significantly. The perturbation and observation method with variable step is adopted in this paper; the duty cycle of voltage regulation circuit serves as the control parameter on the maximum power point tracking. The control system uses duty cycle as the control parameter, which only needs one control loop and reduces the controller design difficulty. The relationship between PV output power P with duty cycle D is shown as below [11]

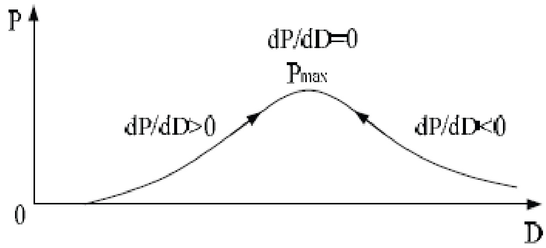

Figure 6: Schematic diagram of P-D relationship

The essence of disturbance observation method with variable step: far from the maximum power point, select a large step in order to approach the system optimal working state quickly; in the vicinity of maximum power point, select a small step to decrease or avoid system oscillation. The P-D curve of the photovoltaic cells indicates that the absolute value of the derivative power to duty cycle gradually decreases close to the maximum power point.

5. SIMULATION PRINCIPLE OF SIMULINK

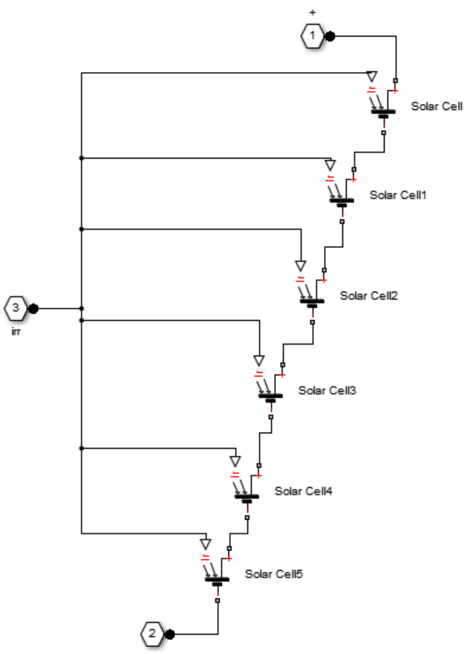

Figure 7(a): simulation model of solar cell

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As can be seen from figure 1, PV output voltage U=I*RI , RI is the equivalent load resistance. Adjusting light intensity, irradiation and resistance to change the output voltage and then achieve maximum power point tracking.

So the output power at maximum point is given as.

P=Uoc*Isc

From the above figure this is the arrangement of six solar cell here we connect irradiance port together and negative to positive terminal.

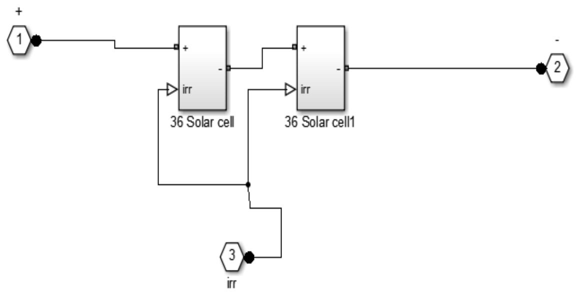

Figure 7(b): Simulation model of subsystem of 72 cell

As simulation model shown here arrangement of three group of 6 cell to 18 cell and group of two 18 cell to 36 cell and finally shown in the simulation model two group of two 36 cell make a 72 cell panel.

Solar cell panel connected to Simulink PS converter and this converted light intensity to physical signal.

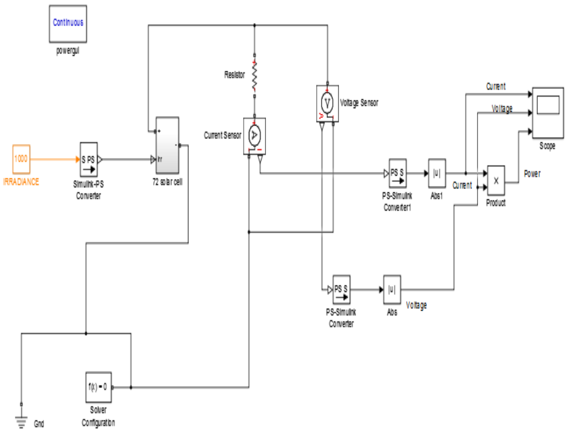

Figure 8: Structure of the simulation system

Set the ambient temperature 25°C, The light intensity from 600 W/m2 to 1000 W/m2.

In the simulation process, particular attention should be given to the cooperation of the sample time, and the initial perturbation is generated by the combination of mutual signal.

6. SIMULATION RESULT AND ANALYSIS

In Simulation model light intensity is 1000 W/m^2 and taking resistance is 5 ohm.

In below result irradiance is 1000 W/m^2 and resistance is 5 ohm. Then the current is 4.738 A and Voltage is 23.69 V. Hence the power is the product of current and voltage is obtained 112.256 W.

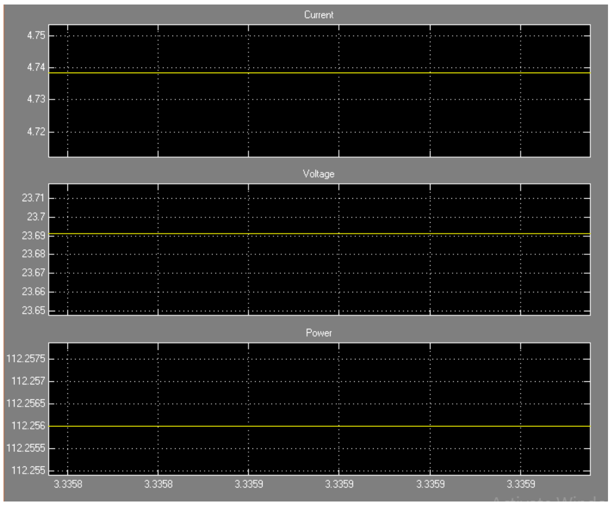

Figure 9: Output Power v/s Time axis with R=5 ohm

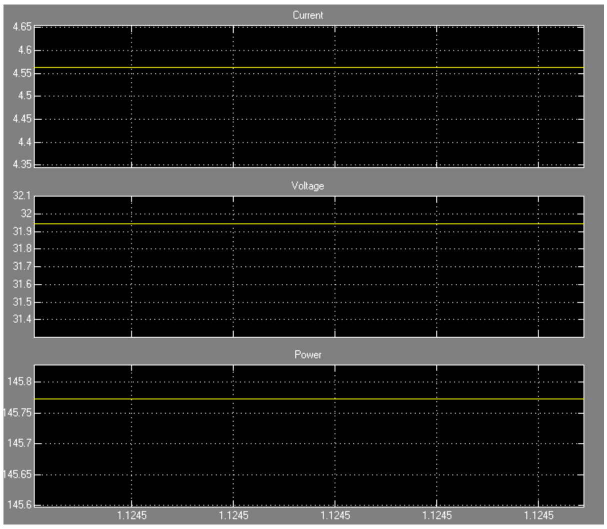

Figure 10: Output Power v/s Time with R=7 ohm

In above result irradiance is 1000 W/m^2 and resistance is 7 ohm then simulation result obtain current is 4.554 A and voltage is 31.95 V. Hence the output power is obtained as 745.755 W.

7. CONCLUSION

This article first analyzes the output characteristics of photovoltaic modules and the traditional maximum power point tracking algorithm and then proposes a MPPT algorithm. By using mathematical model of photovoltaic modules and, simulation model is built in Matlab/Simulink. The photovoltaic output characteristics are simulated under different light and temperature conditions by the simulation model.

The simulation results show that: this algorithm can overcome the shortcomings of the perturbation based on fixed step, it enable the system to track the maximum power point quickly, reduce the system's steady state error, and ensure stability. It is an effective control method to overcome the nonlinear characteristics of photovoltaic modules and improve the efficiency of photovoltaic power generation system.

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