

Study of the Maximum Power Point Tracking Method for photovoltaic system

Yali Liu^{1, a}, Yaqiu Zhang^{2, b}

¹No. 134 Fenghuang Road, Yuxi, Yunnan, China

²No. 134 Fenghuang Road, Yuxi, Yunnan, China

^aliuyali880619@163.com, ^byqzh@yxnu.net

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Abstract. In this paper, the influence of serial resistance R_s and shunt resistance R_{sh} for PV cells are studied. The series resistance R_s has a great influence on the output characteristics of the PV cells. Therefore, it is particularly important to solve the value of R_s for the model of solar cells. R_{sh} is very large, in the process of PV modular modeling, the value of R_{sh} can be neglected. Maximum power point tracking (MPPT) algorithms play an important role in the optimization of the power and the efficiency of a photovoltaic (PV) generation system. According to the contradiction of the classical Perturb and Observe (P&O) method between the corresponding speed and the tracking accuracy on steady-state, an improved MPPT method has been put forwarded in this paper. According to establishing control model and using MATLAB/Simulink to simulate the main circuit and control system, we made the comparison among P&O method and improved P&O method. In particular, this study compares the behaviors of each technique in presence of solar irradiation variations. We have also compared the output power of the system with two MPPT method.

Introduction

The application of photovoltaic (PV) system becomes more and more widely due to its highly reliable and easy to use. The main attraction of the PV system is harmless of the environment when they generate electric power. The decrease in cost and the increase in efficiency of PV arrays play important role for PV systems in the near future. A precise current-voltage (V-I) characteristic of PV cells is necessary to estimate their performance and improve the efficiency of the PV power generation system [1]. The equivalent circuit of the PV cell can be expressed as a photodiode with a large p-n junction and PV arrays. Several types of models exist to simulate the behavior of a PV cell [2], some researchers adopt simplified PV models by neglecting the serial resistance R_s and shunt resistance R_{sh} to estimate the maximum power point of PV systems [3].

In recent years, many MPPT techniques have been proposed by scholars; examples are Constant Voltage (CV) method, Perturb and Observe (P&O) method, Incremental Conductance (IC) method, Fuzzy Logic method, etc.. The IC method have a high accuracy requirements of the sensor, so the cost of hardware is higher. The P&O method has been widely used for its simple control algorithm and less measured parameters. Although the P&O method with an easy control algorithm, but it has great oscillation around MPP which will lead to a certain amount of power loss [4].

In this paper, the attention will be focused on the study of the influence of serial resistance R_s and shunt resistance R_{sh} for PV cells. Then an improved MPPT method is proposed in this paper. Control model is established by using Matlab/Simulink.

PV panel modeling

The PV cell is composed by many P-N junction semiconductor, it is possible to directly convert light to electricity. The PV cells equivalent circuit see Fig.1, it is based on a diode, adding two resistors to account for internal losses. I_{ph} is a light-generated photocurrent, R_s is the series resistance which takes into account the ohmic losses of the material, the metallization and the contact metal/semiconductor; R_{sh} represents resistance leakage current from currents between the top and bottom of the cell, by the board in particular and within the material by irregularities or

impurities[5-6]. Usually R_{sh} is very big and R_s is very small. Where, I_{ph} is internal photocurrent of photovoltaic cells and I_d is the total diffusion current through the P-N junction.

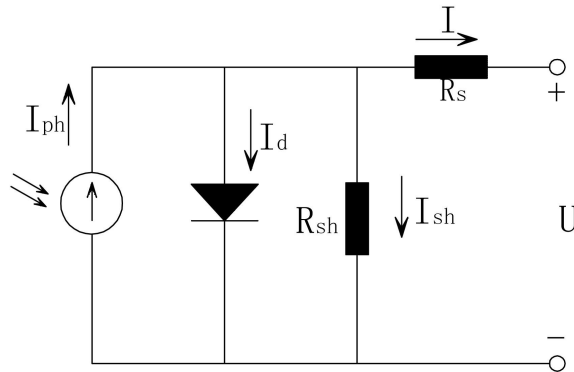


Figure 1. Equivalent circuit of PV cells

From Fig.1, The output current of the cell is given by:

$$I = I_{ph} - I_d - I_{sh} \quad (1)$$

The light current calculated as follows:

$$I_{ph} = [I_{sc} - Ki(T - T_{ref})] \frac{S}{1000} \quad (2)$$

The diode current is defined by Shockley equation:

$$I_d = I_0 \left[\exp \frac{q(U + IR_s)}{AKT} - 1 \right] \quad (3)$$

The current of shunt resistor can be expressed:

$$I_{sh} = \frac{U + IR_s}{R_{sh}} \quad (4)$$

The mathematical expression of current I for PV cell is given by:

$$I = I_{ph} - I_0 \left[\exp \frac{q(U + IR_s)}{AKT} - 1 \right] - \frac{U + IR_s}{R_{sh}} \quad (5)$$

Where, q is the electron charge equal to $1.6 \times 10^{-19}C$, A is the ideality factor of the P-N junction, K is the Boltzmann constant equal to $1.38 \times 10^{-23}J/K$.

The current–voltage characteristic of solar cells with different series resistances under constant irradiation intensity is examined. The ideality factor of the diode will be thus taken as $n=1$ in this simulation.

Under the situation of temperature $25^\circ C$, irradiation intensity $1000 W/m^2$, the influence of the series resistance R_s for the output characteristics of solar cells under different R_s values ($R_s=0, 1,2,$ and 3Ω), are depicted in Fig.2. Fig.2(a) is the I-V curves of the solar cells under different R_s values, Fig.2(b) is the P-V curves of the solar cells under different R_s values. An inspection of Fig.2(a) indicates that the open-circuit voltage (V_{oc}) of the solar cells with different R_s are almost constant at $36.8V$. The corresponding short-circuit currents (I_{sc}) of the solar cells are almost constant at $8.45A$ for $R_s=0, 1,2,$ and 3Ω .

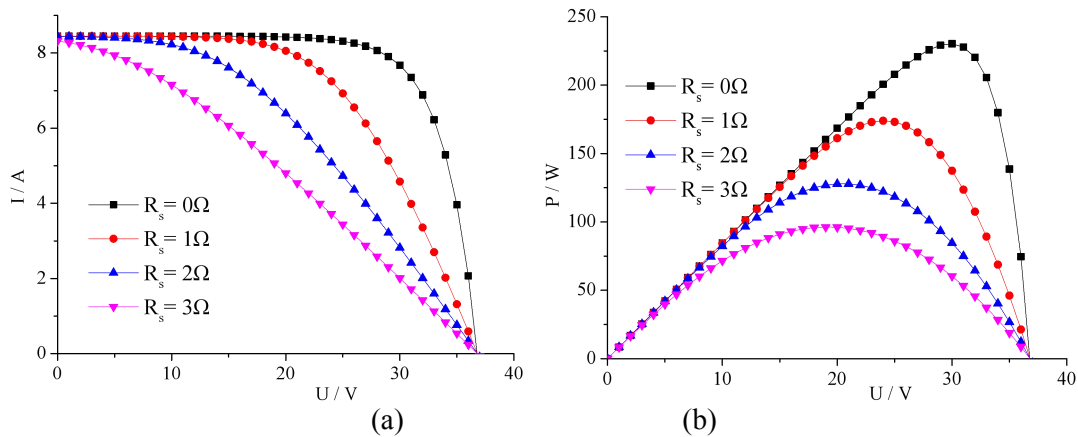


Figure 2. The influence of the series resistance R_s for the output characteristics of solar cells under different R_s values ($R_s=0, 1,2,$ and 3Ω)

The maximum power of the solar cells with different R_s values ($R_s=0, 1, 2,$ and 3Ω) are 230, 173.96, 127.82, and 96.24 W, respectively, as indicated in Fig.2(b). Clearly, the simulation results show that maximum power of the solar cells decrease from 100% to 41.8% with an increase in the series resistance R_s from 0 to 3 Ω . Thus, the series resistance R_s has a large impact on the output characteristics of the solar cells. The U_{max} , I_{max} , P_{max} with different R_s values ($R_s=0, 1, 2,$ and 3Ω) under temperature 25°C, irradiation intensity 1000 W/m² shows in table 1. The series resistance R_s has a great influence on the output characteristics of the PV cells. Therefore, it is particularly important to solve the value of R_s for the model of solar cells.

Table 1. The U_{max} , I_{max} , P_{max} with different R_s values ($R_s=0, 1, 2,$ and 3Ω) under temperature 25C, irradiation intensity 1000 W/m².

| R_s / Ω | U_{max} / V | I_{max} / A | P_{max} / W |
|----------------|---------------|---------------|---------------|
| $R_s=0$ | 30 | 7.67 | 230 |
| $R_s=1$ | 24 | 7.25 | 173.96 |
| $R_s=2$ | 21 | 6.09 | 127.82 |
| $R_s=3$ | 19 | 5.07 | 96.24 |

Under the situation of temperature 25C, irradiation intensity 1000 W/m², the influence of R_{sh} for the output characteristics of solar cells under different R_{sh} values ($R_{sh}=100, 500, 1000, 1500$ and 2000Ω) are depicted in Fig. 3.

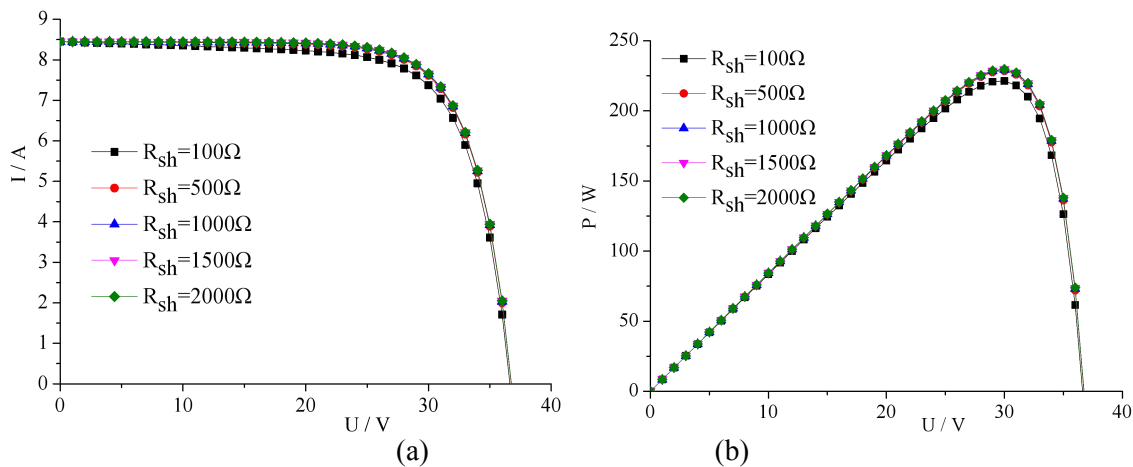


Figure 3. The influence of the series resistance R_{sh} for the output characteristics of solar cells under different R_{sh} values ($R_{sh}=100, 500, 1000, 1500$ and 2000Ω)

Fig. 3(a) is the I-V curves of the solar cells under different R_{sh} values, Fig. 3(b) is the P-V curves of the solar cells under different R_{sh} values. The simulation results show that the I-V curves and P-V curves of the solar cells almost the same under different R_{sh} values ($R_{sh}=500, 1000, 1500$ and 2000

Ω). Thus, R_{sh} has little impact on the output characteristics of solar cells when the value of R_{sh} higher than 500Ω . Effectively, R_{sh} is very large, in the process of PV modular modeling, the value of R_{sh} can be neglected.

The effect of shunt resistance R_{sh} is negligible, the mathematical expression of current I and voltage U for PV cell can be expressed:

$$I = I_{ph} - I_0 \left[\exp \frac{q(U + IR_s)}{AKT} - 1 \right] \quad (6)$$

In this paper, the Eq. 6 is used for establishing the simulation model of PV panel. The parameters of PV panel selected in this paper see Table 2.

Table 2 Electrical characteristics of PV panel

| Symbol | meaning | Value |
|-----------|-----------------------|-------|
| P_{max} | Maximum Power | 230W |
| U_m | Voltage at P_{max} | 29.5V |
| I_m | Current at P_{max} | 7.8A |
| U_{oc} | Open-Circuit Voltage | 36.8V |
| I_{sc} | Short-Circuit Current | 8.45A |

MPPT Control Algorithms

Constant voltage is a method to approximate maximum power point (MPP) by using constant voltage control algorithm[7-8].

When the temperature is constant, the maximum power point of photovoltaic cells under different irradiance distribution on a straight line approximately, that is the maximum power point of pv cells similar at a constant voltage U_m [9-11]. The relationship between U_m and U_{oc} is given by:

$$U_m = kU_{oc} \quad (7)$$

Where, the value of k is among 0.7~0.8.

The basic principle of constant voltage method as follows: sampling the open circuit voltage of a solar cell, then calculating the value of U_m according to the formula (7), through the control circuit to make the system output maximum power.

Perturb and Observe Method(P&O) is widely used due to its quite simple structure and the few measured parameters involved. The basic principle as follows: The P&O algorithms operate by periodically perturbing the array terminal voltage, then observing the changes of the PV output power, comparing the PV output power with that of the previous perturbation cycle, if the power is increased, the perturbation will be in the same direction, otherwise, it will be in the opposite direction, in the next perturbation cycle the algorithm continues in the same way. Finally the PV cells will work at the maximum power point.

This method presents the structure of a simple regulation in closed-loop where only a few controlled parameters are involved. By varying the voltage of the PV panel periodically with a very small incremental step to reduce the oscillation around the MPP, the P&O algorithm compares the power previously delivered with the one after disturbance.

To solve the contradiction of the P&O method between the tracking accuracy and tracking speed, an improved MPPT method by combination the constant voltage method and perturb and observe method is proposed. We will set the start voltage as $0.78U_{oc}$, and then use the perturb and observe method to tracking the MPP.

Simulation results and analysis

Based on the principle of the improved MPPT method mentioned above, we established the simulation model on the basis of Matlab/Simulink. The simulation model shown in Fig.4. The improved MPPT algorithm is realized by S-Function.

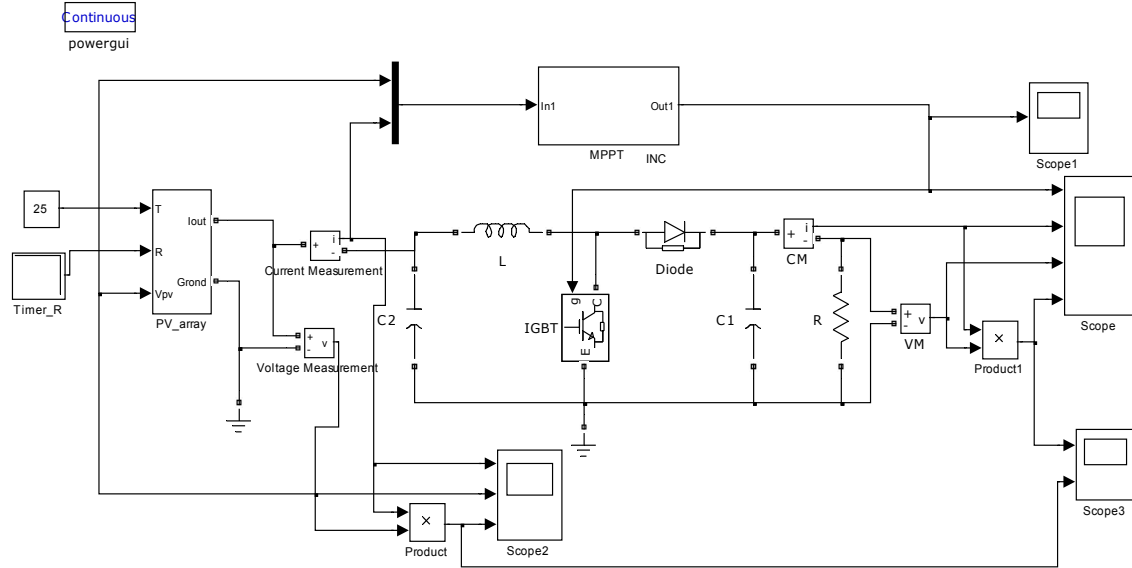


Figure 4. Simulation model of P&Ob method

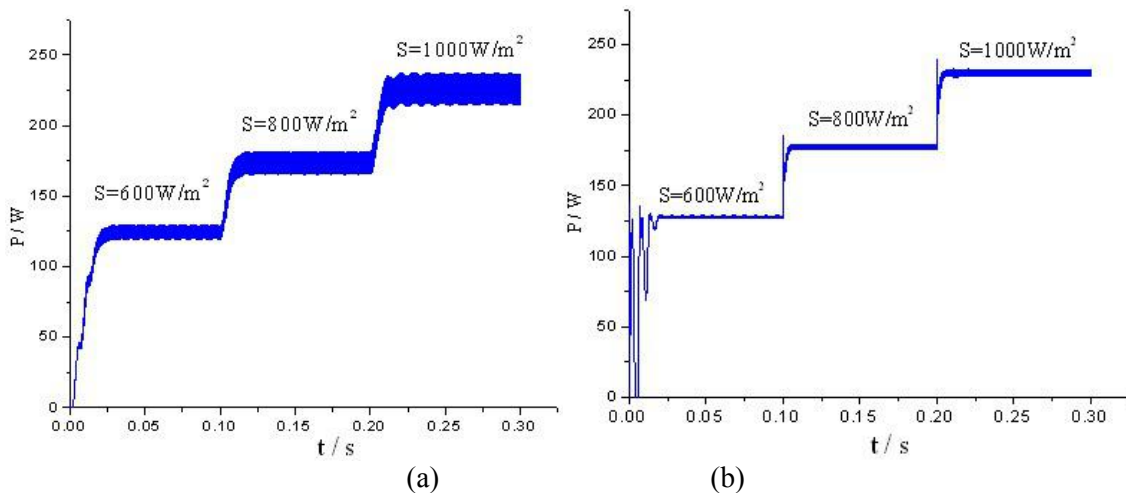


Figure 5. T=25C, the output power of PV systems for two MPPT methods under different radiation: a) P&O method, b) improved method.

To analyze and compare the performance of the MPPT algorithms presented above, we carried out a simulation study. The temperature is maintained constant (25C), under different radiation levels (600 W/m^2 , 800 W/m^2 and 1000 W/m^2). The simulation results as in Fig.5. In these figures, (a) is the power of PV systems by using the P&O method, (b) is the power of PV systems by using the improved MPPT method. Fig.5(a) shows that it presents strong oscillation when it reaches MPP and the. Fig.5(b) shows that the improved method track in right direction and present weak oscillation at MPP. The improved method presents better efficiency when the radiation changes rapidly and a better stability when the MPP is reached.

Conclusions

In this paper, the attention is focused on the study of the influence of serial resistance R_s and shunt resistance R_{sh} for PV cells. Then an improved MPPT method is proposed in this paper. Control model is established by using Matlab/Simulink. The maximum power of the solar cells with different R_s values ($R_s=0, 1, 2,$ and 3Ω) are 230, 173.96, 127.82, and 96.24 W, respectively, the simulation results show that maximum power of the solar cells decrease from 100% to 41.8% with an increase in the series resistance R_s from 0 to 3 Ω . Thus, the series resistance R_s has a large impact on the output characteristics of the solar cells. R_{sh} has little impact on the output characteristics of solar cells when the value of R_{sh} higher than 500 Ω . Effectively, R_{sh} is very large, in the process of PV modular modeling, the value of R_{sh} can be neglected.

To solve the contradiction of the P&O method between the tracking accuracy and tracking speed, an improved MPPT method by combination the constant voltage method and perturb and observe method is proposed. We will set the start voltage as 0.78 U_{oc} , and then use the perturb and observe method to tracking the MPP. The improved method track in right direction, present weak oscillation at MPP and better efficiency when the radiation changes rapidly and a better stability when the MPP is reached compared with P&O method.

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