On the Output Characteristics of PV Array with Partial Shading and Different Temperature

To cite this article: Jialiangles et al 2018 J. Phys.: Conf. Ser. 1087 042053

View the article online for updates and enhancements.
On the Output Characteristics of PV Array with Partial Shading and Different Temperature

Jialiang Ling¹, Tianfa Liao², Xiaohui Wei³

¹ Department of Electronic Science, Huizhou University, Huizhou, China
² Department of Electronic Science, Huizhou University, Huizhou, China
³ Department of Electronic Science, Huizhou University, Huizhou, China

E-mail: jia@hzu.edu.cn, E-mail: liaotianfa@163.com E-mail: weixh0509@hzu.edu.cn

Abstract. The surface temperature of PV is different in the condition of the different shadings; the corresponding output characteristics will be different. This paper studies the influence of temperature and shading variation on the output P-V and I-V characteristics of photovoltaic array, and the effect of this difference on the global MPPT algorithm. In order to analyze the influence of temperature and shading on the output characteristics of photovoltaic array, the article assumes that a cloud drifts across the PV array, and simulates three kinds of situations. Simulation results show that, the output power decreased slightly under the different temperature and shading, but closer to the actual situation. The results will provide theoretical support for further optimization of global MPPT algorithm.

1. Introduction

Partial shading is one of the major reasons for power loss of photovoltaic (PV) cell, which can also cause hot spot effect and safety issue. Generally a bypass diode shall be connected with parallel at two ends of the PV cell to solve the problem. But the connection of bypass diode will change output characteristics of PV array¹², At the same time, the different light intensity will results the change of PN junction temperature, the different PN junction temperature will also affects the output characteristics of photovoltaic cells, these will affect the accuracy of tracking maximum output power.

2. PV sub-string modeling

First the paper introduced single PV cell model created by MATLAB/SIMULIN, then created two PV cell model with bypass diodes, At last created any N×M PV array model.

PV cell is a PN junction, whose basic characteristics are similar to diodes. To eliminate security risk brought by hot spot effect, a bypass diode shall be connected to PV cell in parallel. At the same time, In order to analyze the effects of partial shading on the output characteristics of PV cell, Two PV cell are connected in series to form a PV sub-string, as shown in figure 1.

![Figure 1. PV sub-string with bypass diode.](image-url)
Assuming normal PV cell is $K_1$, i.e. the shading coefficient $G_1=1$, shaded PV cells is $K_2$, i.e. the shading coefficient $G_2<1$, short-circuit current $I_{sc1}$ generated by $K_1$ shall be larger than short-circuit current $I_{sc2}$ of $K_2$. When the external load is very small, PV cells work in large electrical current, $K_1$ forces the current larger than $I_{sc2}$ through $K_2$. At the same time, open the bypass diode of $K_2$, In this case only $K_1$ output power, $K_2$ does not output power. With the increase of external load, the output current $I$ will be gradually decreased after a period of time. In the end, when the current $I$ is equal or less than short-circuit current $I_{sc2}$, bypass diode is blocked, shading PV cell $K_2$ shall has output power. Based on above analysis, piecewise function of output current can be drawn $I$ [3-4]:

$$I = \begin{cases} 
I_{sc} \left[ 1 - C_1 (e^{ \frac{U}{U_{oc} G_1} } - 1) \right] + \alpha G_2 \Delta T + (G_1 - 1) I_{sc1}, & I_{sc1} < I < I_{sc} \\
I_{sc} \left[ 1 - C_2 (e^{ \frac{U}{U_{oc} G_1} } - 1) \right] + \alpha G_2 \Delta T + (G_1 - 1) I_{sc1}, & 0 < I < I_{sc1}
\end{cases}$$

(1)

Among which:

$$C_1 = (1 - \frac{I_m}{I_{sc}}) e^{\frac{U_m}{U_{oc} G_1}}, C_2 = \frac{U_m}{U_{oc}} \ln(1 - \frac{I_m}{I_{sc}})$$

In this paper, the simulation of photovoltaic cells is BULEKEM CHN100-36W, parameters are shown in Table 1.

### Table 1. Parameters of PV Cell

| Parameter | Value                      | Parameter | Value                      |
|-----------|----------------------------|-----------|----------------------------|
| $S$       | Total light intensity $W/m^2$ | $G$       | Shading coefficient, $-S/S_{ref}$ |
| $S_{ref}$ | Reference light intensity, $1,000 W/m^2$ | $R_s$ | Series resistance of PV module, $5 \Omega$ |
| $\alpha$ | Current coefficient of temperature variation under the reference sunlight, $0.00005 A/°C$ | $\beta$ | Voltage Coefficient of temperature variation under the reference sunlight, $-0.0029 V/°C$ |
| $I_{sc}$  | Short-circuit current, $5.56A$ | $V_m$ | Maximum power voltage, $19.3A$ |
| $T_{ref}$ | Temperature for reference, $25°C$ | $I_m$ | Maximum power current, $5.18A$ |
| $U_{oc}$  | Open-circuit voltage, $22.9V$ |           |                             |

Now suppose that the shading coefficients $G_2 = 20\%$, $50\%$, or $80\%$, build the model of PV sub-string based on PV subsystem, the simulation base on MATLAB/SIMULINK can get the corresponding output $I$-$V$ characteristic curve as shown in Figure 2, $P$-$V$ curve as shown in Figure 3.
As shown in Figure 2, the output I-V characteristic curve of PV sub-string appears a knee, at the same time, the short-circuit current $I_{sc}$ of PV sub-string decreases with the increase of the shading, and the open-circuit voltage $V_{oc}$ has little changes.

As shown in Figure 3, the output P-V characteristic curve has two maximum power points, at the same time, the maximum output power decreases with the increase of the shading.

In fact, the PN junction temperature of PV cell increases with the increase of light intensity, they are approximately linear relationship. Considering temperature effect of PV cell, function for fixed output characteristics can be concluded ($U', I'$).

$$I' = I_{sc} \left[ 1 - C_e \left( e^{\frac{V'}{C_e}} - 1 \right) \right] + \Delta I$$

$$U' = U + \Delta U$$

Among which:

$$\Delta I = \alpha \frac{S}{S_{ref}} \Delta T + \left( \frac{S}{S_{ref}} - 1 \right) I_{sc}, \Delta U = -\beta \Delta T - R_i \Delta I, \Delta T = T - T_{ref}$$

The effect of PN junction temperature on the output characteristics of PV sub-string is shown in Figure 5, Figure 6.

As shown in Figure 5, the short-circuit current $I_{sc}$ of PV sub-string has slightly increases with the increase of PN junction temperature, the open-circuit voltage $V_{oc}$ of photovoltaic cells decreases with the increase of cell PN junction temperature, and the variation range is larger.

The maximum output power of the photovoltaic sub-string decreases with the increase of the PN junction temperature, and the operating voltage corresponding to the maximum power point decreases with the increase of the temperature.
3. PV arrays with different shadings and temperatures

The above PV sub-string model can be expanded to a N×M PV array model. As shown in Figure 7 is a 20×5 PV array, i.e. 20 PV cells in series form a PV sub-string, 5 PV sub-string are connected in parallel to form a photovoltaic array.

The output mathematic model of PV array can be concluded as:

\[
\begin{align*}
  I &= \sum_{i=1}^{M} I_i \\
  U &= \max\{U_i\}
\end{align*}
\]

Among them, \(I_i\) is the output current of the \(i\) column, \(U_i\) is the voltage of \(i\) column.

As mentioned above, the PN junction temperature of PV cells is different under different light intensities; the corresponding output power is also different. In order to better describe this difference, closer to the actual situation, we suppose that a cloud uniform speed drifting over the PV array from the left bottom to the right top, as is shown in Figure 6. Based on MATLAB/SIMULINK, we simulate three kinds of situations, One is the global maximum power point tracking algorithm (MPPT) under the different light intensity and temperature, We call it TS-GMPPT algorithm, the second is the global MPPT algorithm under the different light intensity [5-7], we call it S-GMPPT algorithm, the third is partial MPPT algorithm, the simulation results are shown in Figure 7.

From the output power curve of Figure 7 we can conclude that, the first, with the increases of the shading area, the output power is gradually decreased; the second, when the shading area increases to a certain extent, the local MPPT algorithm will fall into local solution, which lost part of the power; the third, compared with the S-GMPPT algorithm, the output power of the TS-GMPPT algorithm will decrease.
4. Conclusions
The surface temperature of PV is different in the condition of the different shadings; the corresponding output characteristics will be different. The paper firstly establish the PV sub-string model by using the equivalent model of PV cells, and simulate the output characteristics of PV sub-string under the different shading and different temperature, then build a 20 * 5 PV array based on the PV sub-string. In order to analyze the influence of temperature and shading on the output characteristics of photovoltaic array, we assume that a cloud drifts across the PV array, and simulate three kinds of situations. Simulation results show that, compared with the S-GMPPT algorithm, the output power of the TS-GMPPT algorithm will decrease, but closer to the actual situation. The results provide theoretical support for further optimization of global MPPT algorithm.

Fund Project:
National Natural Science Foundation of China (No. 61372064)
Science and Technology Planning Project of Huizhou (No. 2015ZX057)

References
[1] Yang H h and Xu J J 2015 Journal of Power Supply, Research of Mathematical Model for PV Array Under Partial Shaded Conditions, Vol.13 No.3
[2] LIU X Y, Qi X M and ZHENG S S 2012 Journal of System Simulation, Study on Simulation Model of PV Array under Partially Shading, Vol. 24 No. 5
[3] Chen A L , Du C S and Zhang C H 2011 Transactions of China Electro technical Society, Modelling of Photovoltaic Array Based on Support Vector Machines Under Partial Shaded Conditions, vol.26, No.3
[4] Ji S L, Yang Y and Qiu W D 2015 Power technology, Output characteristics of PV array under partial shading, Vol.39 No.1
[5] Yuan Z J 2014 Guangdong University of Technology, Maximum Power Point Tracking of PV System under Partially Shaded Condition
[6] Xiao W D 2007 IEEE Transactions on Industrial Electronics, Topology study of photovoltaic interface for maximum power point tracking, 54(3): 1696-1704
[7] Yang Y h and Zhou K L 2011 transactions of china electro technical society, Photovoltaic Cell Modelling and MPPT Control Strategies, Vol.26