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# Research on the Influence of Different Light Intensities on the Characteristics of Solar Cells

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**Abstract**

In China, there is a wide range of renewable energy resources, with solar energy resources being the most extensive. Solar cells are devices that directly convert solar energy into electrical energy through the photovoltaic effect. This energy conversion process does not produce any harmful substances that could negatively impact the environment, making solar energy a highly environmentally friendly form of new energy generation. Various external conditions, such as light intensity, light angle, spectral range, temperature, and different materials, can affect the characteristic parameters of solar cells. These parameters include open circuit voltage, short circuit current, maximum output power of solar panels, fill factor, and conversion efficiency. To enhance the longevity and efficiency of solar cells, it is crucial to determine the optimal light intensity for solar cell power generation. This study aims to investigate the patterns of variation in the characteristic parameters of solar cells and their I/V characteristic curves by manipulating light intensity and environmental temperature. The experimental results demonstrate that temperature has an inverse relationship with open circuit voltage, while its impact on fill factor is not significant. Furthermore, the influence of temperature on short circuit current is greatest at 25 ℃ and smallest at 15 ℃.

***Keywords:*** *solar cell; light intensity; ambient temperature; characterization parameters*

## 1 Introduction

As global economies advance and individuals' living standards improve, there is a concurrent degradation of the global environment. This degradation coincides with an expanding array of new energy sources and a corresponding rise in energy demands. Solar energy emerges as a prominent sustainable energy alternative due to its accessibility and lack of pollutant emissions, particularly into the atmosphere, during its acquisition[1]. Conversely, the combustion of fossil fuels emits pollutants such as carbon dioxide, nitrogen oxides, and sulfur dioxide, exacerbating environmental degradation and the greenhouse effect. Mitigating the emissions of these pollutants is crucial for counteracting the adverse effects on the environment and fostering a habitable ecological setting for human populations.

Governments worldwide are increasingly prioritizing the development of renewable energy sources, with a notable emphasis on solar power generation[2-3]. Solar power generation involves the conversion of solar radiation into electrical energy. Unlike conventional energy sources, this process necessitates only sunlight, obviating the need for additional raw materials. The potential of solar power generation is substantial; estimates suggest that harnessing just 0.1% of solar energy from the Earth's surface, even with a modest conversion efficiency of 5%, could yield a yearly solar power generation output equivalent to 40 times the current global energy consumption[4].

In China, the production cost of polycrystalline silicon for solar photovoltaics has been gradually decreasing, with raw materials now costing around 90,000 yuan per ton. The average comprehensive electricity consumption of the solar photovoltaic power generation industry is approximately 100 TWH/kg[5-6]. The continuous development and improvement of monocrystalline and polycrystalline cell technologies have led to an industrialization efficiency of twenty percent for monocrystalline silicon cells and eighteen percent for polycrystalline silicon cells. Key technologies at the forefront globally include Passivated Emitter Rear Contact (PERC), Heterojunction with Intrinsic Thin layer (HIT), rear electrodes, and high-concentration photovoltaics. In recent years, the cost of solar cell modules in China has decreased to 2.8 yuan/watt, and the investment cost of photovoltaic power generation systems has also dropped to 8 yuan/watt or even less, resulting in a cost of 0.6 to 0.9 yuan/kWh for each unit of electricity, or even less. Promoting large-scale grid-connected photovoltaic power generation projects in China is an ideal choice for changing and optimizing


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the power structure, as well as achieving sustainable power supply[7].

## 2 Experimental Principle

Solar cells are devices that convert solar energy into electrical energy through the photovoltaic effect or photochemical effect.

### 2.1 Photovoltaic effect

When P-type and N-type semiconductors exist independently, they are both electrically neutral. However, when they are connected together, diffusion occurs. This results in the formation of a P-N junction at the interface of the N-type and P-type semiconductors, as depicted in Figure 1.

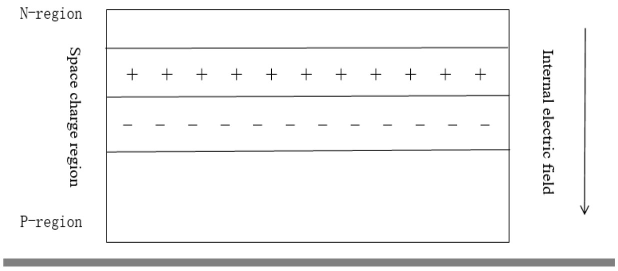


**Figure 1** Schematic diagram of P-N junction

When a semiconductor with a P-N junction is exposed to light, the number of electrons and holes within it increases. This causes the electrons in the P region to move to the N region and the holes in the N region to move to the P region under the influence of the local electric field of the P-N junction. Consequently, charge accumulation occurs at both ends of the P-N junction, resulting in the formation of a potential difference. This leads to the creation of a thin layer between the N region and the P region, which in turn generates an electromotive force known as the photovoltaic effect.

In order to efficiently capture solar radiation and separate electron-hole pairs, a potential gradient within the solar cell is necessary. As a result, the materials utilized in the solar cell must possess the capability to absorb the energy of solar photons[4]. Equation (1) describes the relationship between the energy (E) of a photon and its wavelength (1).

$$E = \frac{hc}{\lambda} \tag{1}$$

By substituting the numerical values of the constant h, which is equal to 6.62×10-34 J s, and the speed of light c, which is equal to 3×108 m/s.

Into the formula, we can calculate:

$$E = \frac{1.24}{\lambda} \tag{2}$$

The open-circuit voltage formula in the circuit is represented by equation (3).

$$V_{oc} = \frac{KT}{q}\ln\left(\frac{I_L}{I_o}+1\right) \tag{3}$$

In the formula: IL represents the photocurrent generated in the circuit, measured in amperes (A).

I0 represents the saturation current in the circuit, also measured in amperes (A).

The characteristic resistance formula (4) expresses the ratio between the open circuit voltage (Voc) and the short circuit current (Isc) as follows:

$$R_{ch} = \frac{V_{oc}}{I_{sc}} \tag{4}$$

The formula for the fill factor (FF) in circuits is shown as Equation (5).

$$FF = \frac{\mathrm{Voc} \times Isc}{\mathrm{Vm} \times Im} \tag{5}$$

In the equations provided:

Voc represents the open-circuit voltage in the circuit, measured in volts (V);

Isc represents the short-circuit current in the circuit, measured in amperes (A);

Vm represents the maximum output voltage in the circuit, measured in volts (V);

Im represents the maximum output current in the circuit, measured in amperes (A).

## 3 Experimental Process

The solar panels in this experiment are monocrystalline silicon solar panels, with a light-receiving area of 83.5 mm × 60 mm. The experiment is divided into three groups.

(1) Experimental data for solar panels were obtained by conducting experiments at a temperature of 15°C and varying the intensity of illumination, as shown in Table 1.

(2) Experimental data for solar panels were obtained by conducting experiments at a temperature of 25°C and varying the intensity of illumination, as shown in Table 2.

(3) Experimental data for solar panels were obtained by conducting experiments at a temperature of 35°C and varying the intensity of illumination, as shown in Table 3.

**Table 1** Experimental data of solar panels at 15 ℃

| Light intensity of 15°C | Open circuit voltage V | Short-circuit current mA | Maximum output powerm W | Fill factor |
|---|---|---|---|---|
| 1 | 1.87 | 10 | 13 | 0.695 |
| 1.5 | 2.02 | 12 | 14 | 0.578 |
| 2 | 2.09 | 15 | 15 | 0.478 |
| 2.5 | 2.11 | 16 | 16 | 0.474 |
| 3 | 2.14 | 18 | 16 | 0.415 |
| 3.5 | 2.15 | 19 | 16 | 0.392 |
| 4 | 2.16 | 20 | 16 | 0.37 |
| 4.5 | 2.16 | 21 | 16 | 0.353 |
| 5 | 2.16 | 21 | 16 | 0.353 |

| Light intensity of 15℃ | Open circuit voltage V | Short-circuit current mA | Maximum output powerm W | Fill factor |
|---|---|---|---|---|
| 5.5 | 2.17 | 22 | 16 | 0.33 |
| 6 | 2.17 | 22 | 16 | 0.33 |
| 6.5 | 2.17 | 22 | 16 | 0.33 |
| 7 | 2.17 | 23 | 16 | 0.32 |
| 7.5 | 2.17 | 23 | 16 | 0.32 |
| 8 | 2.17 | 23 | 16 | 0.32 |
| 8.5 | 2.17 | 23 | 16 | 0.32 |
| 9 | 2.17 | 23 | 16 | 0.32 |
| 9.5 | 2.17 | 24 | 16 | 0.307 |

**Table 2** Experimental data of solar panels at 25 ℃

| Light intensity of 25℃ | Open circuit voltage V | Short-circuit current mA | Maximum output powerm W | Fill factor |
|---|---|---|---|---|
| 1 | 1.95 | 15 | 19 | 0.649 |
| 1.5 | 1.95 | 16 | 19 | 0.601 |
| 2 | 2.01 | 19 | 19 | 0.498 |
| 2.5 | 2.05 | 21 | 20 | 0.465 |
| 3 | 2.07 | 23 | 20 | 0.42 |
| 3.5 | 2.09 | 25 | 21 | 0.402 |
| 4 | 2.1 | 26 | 21 | 0.384 |
| 4.5 | 2.11 | 27 | 21 | 0.369 |
| 5 | 2.11 | 28 | 21 | 0.355 |
| 5.5 | 2.11 | 28 | 21 | 0.353 |
| 6 | 2.12 | 28 | 21 | 0.353 |
| 6.5 | 2.12 | 28 | 21 | 0.342 |
| 7 | 2.12 | 29 | 21 | 0.33 |
| 7.5 | 2.12 | 30 | 21 | 0.33 |
| 8 | 2.12 | 30 | 21 | 0.33 |
| 8.5 | 2.12 | 30 | 21 | 0.33 |
| 9 | 2.12 | 30 | 21 | 0.33 |
| 9.5 | 2.12 | 30 | 21 | 0.33 |

**Table 3** Experimental data of solar panels at 35 ℃

| Light intensity of 35℃ | Open circuit voltage V | Short-circuit current mA | Maximum output powerm W | Fill factor |
|---|---|---|---|---|
| 1 | 1.97 | 16 | 17 | 0.539 |
| 1.5 | 1.99 | 17 | 18 | 0.532 |
| 2 | 2.02 | 19 | 18 | 0.469 |
| 2.5 | 2.04 | 21 | 19 | 0.443 |
| 3 | 2.06 | 23 | 19 | 0.401 |
| 3.5 | 2.08 | 24 | 20 | 0.4 |
| 4 | 2.08 | 25 | 20 | 0.385 |
| 4.5 | 2.09 | 26 | 20 | 0.368 |
| 5 | 2.09 | 27 | 20 | 0.354 |
| 5.5 | 2.10 | 27 | 20 | 0.352 |
| 6 | 2.10 | 28 | 20 | 0.34 |
| 6.5 | 2.10 | 28 | 20 | 0.34 |
| 7 | 2.10 | 28 | 20 | 0.34 |
| 7.5 | 2.10 | 29 | 20 | 0.328 |
| 8 | 2.10 | 29 | 20 | 0.328 |
| 8.5 | 2.10 | 29 | 20 | 0.328 |
| 9 | 2.10 | 29 | 20 | 0.328 |
| 9.5 | 2.10 | 29 | 20 | 0.328 |

## 4 Experimental Data Analysis and Conclusions

### 4.1 Under different light intensity conditions, the curve of the open-circuit voltage of the solar cell panel

The open-circuit voltage of the solar panels was observed at temperatures of 15 ℃, 25 ℃, and 35 ℃, and the results are presented in Figure 2. It was found that the open-circuit voltage increases with the intensity of light, eventually reaching a stable value. The higher the light intensity, the more photons the solar panel absorbs, and the more electrons are generated, which in turn leads to an increase in the concentration of charge carriers and ultimately increases the open circuit voltage. That is to say, the higher the intensity of light, the higher the output voltage of the photovoltaic cell.

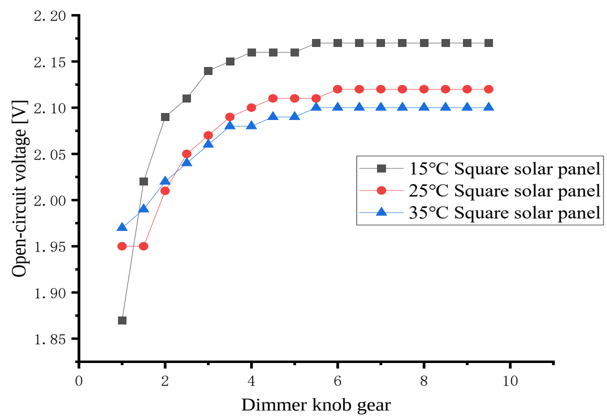


**Figure 1** Variation curve of open circuit voltage of solar panel

### 4.2 Under different light intensity conditions, the short-circuit current curve of the solar cell panel

The short-circuit current of the solar panel can be determined by observing the data at three different temperatures: 15 ℃, 25 ℃, and 35 ℃, as depicted in Figure 2. It is observed that the short-circuit current increases with the rise in light intensity, eventually reaching a stable value. Notably, the highest short-circuit current is recorded at 25 ℃, while the lowest is observed at 15 ℃. This is because the stronger the light intensity, the faster the electron hole recombination at the PN junction interface, resulting in a larger current.

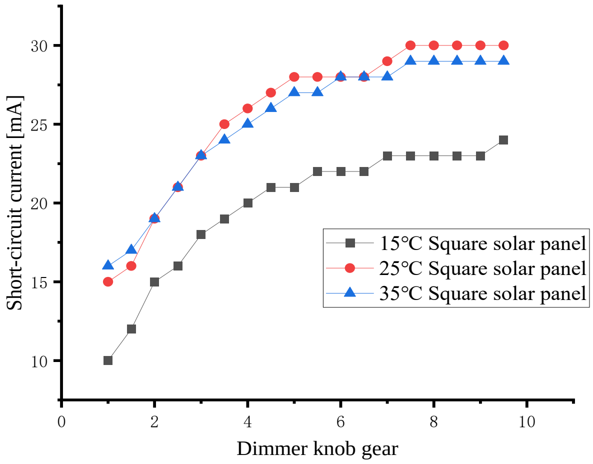


**Figure 2** Variation curve of short-circuit current of solar panel

### 4.3 Under different light intensity conditions, the fill factor curve of the solar cell panel

The observation data for the fill factor of the square solar panel at temperatures of 15 ℃, 25 ℃, and 35 ℃ is presented in Figure 3. It is observed that the fill factor decreases as the light intensity increases, eventually reaching a certain value and stabilizing thereafter. When the light intensity changes, the maximum power point of the battery output will also change accordingly, thereby affecting the size of the filling factor. Generally speaking, the higher the light intensity, the smaller the fill facto.

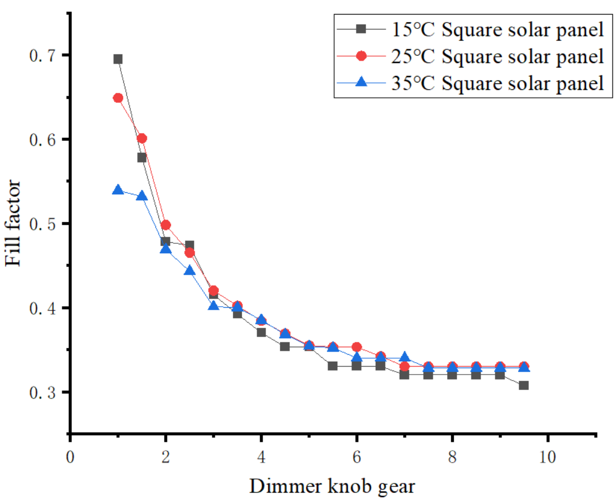


**Figure 3** Variation curve of filling factor of solar panel

## 5 Conclusion

By adjusting the light intensity, the open-circuit voltage and short-circuit current of the solar panel will incrementally rise until reaching a specific value and stabilizing, while the fill factor will gradually decrease with increasing light intensity. The temperature has an inverse proportional effect on the open-circuit voltage, with temperature changes having a less significant impact on the fill factor. Additionally, temperature has the greatest impact on the short-circuit current at 25 ℃ and the smallest impact at 15 ℃.

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