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STUDY ON THE PHOTOVOLTAIC FACTOR OF MONOCRYSTALLINE SILICON SOLAR CELL WITH TEMPERATURE

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Abstract - *In this study, the photovoltaic factor of monocrystalline silicon solar cells was used to explain the phenomenon of cell temperature. The experiment was performed using a solar cell simulator in the range of 25-60°C with a constant light intensity of 215-515 W/m² at different battery temperatures. The results show that the battery temperature has an important influence on the photovoltaic system. Factors and conditions of solar cell quality and presentation. Open circuit voltage, peak power, duty cycle and efficiency decrease with the increase of battery temperature. The reverse current increases as the battery temperature increases, and a slight increase in short-circuit current is observed. For short circuit, temperature open circuit voltage factor, duty cycle and maximum output power are positive and negative. The relative change of photovoltaic factor with temperature is also studied. The relative change is between -0.0022/°C and -0.0 025/°C. 0.002/°C, -0.0013/°C and -0.002/°C are used for open circuit voltage, short circuit current, duty cycle and maximum output power respectively. The results are consistent with available written materials.*

Key Words: Si solar cell, Cell temperature,Photovoltaic factors,Solar cell simulator

1. INTRODUCTION

Solar energy has become one of the most important renewable energy sources due to its ease of use, cleanliness and low cost. Nowadays, many conceptual methods of solar energy have emerged. Due to the rapid development of hidden technologies and applications (to meet the energy needs of developing countries and society), solar cells have received more and more attention. It is a part of silicon solar cells and one of the first solar cells to be developed and widely used because it has many advantages, such as low maintenance cost, high reliability, noiseless and environmentally friendly, such as light intensity or illumination Intensity, tracking angle and cell temperature (Khan et al., 2010; Skoplaki and Palyvos, 2009; Chegaar et al., 2013). PV factors (such as open circuit voltage, short circuit current, maximum output power, duty cycle, and efficiency) usually depend on the battery temperature, and the maximum impact on the open circuit voltage is recorded. The battery is very sensitive to battery temperature. Open circuit voltage, duty cycle and maximum output power decrease with temperature, while short-circuit current increases with temperature. Therefore, the temperature coefficient of open circuit voltage, duty cycle and maximum output power is also negative. . As the positive electrode of the short-circuit current, Kim et al.(2013) reported the effect of using sawtooth damage etching to texture the surface of crystalline silicon solar cells. One hour after texturing, there is usually no difference between morphology and reflectivity for any surface condition. Choi et al. A crystalline silicon cell diode with cell temperature and frequency has been described. (2012).

They found that the ideality factor in the space charge range increases in the quasi-electron neutral range as the temperature decreases. (2005) used linear injection to study the dependence of the current-voltage characteristics of various solar cells on temperature and lighting, and found that the physical applicability of linear injection to temperature is based on the current-voltage characteristics of Gandia pn junction devices. And others. (2001) recommended a new method to estimate the spectral mismatch parameters as part of the photomagnet. They did not analyze, and there is no need to use similar test cells and reference cells to measure the current-voltage characteristics of solar cells. Sabri and Gitas (2008) rumored to determine the temperature factor in the series resistance of silicon solar cells, and found that the series resistance changes with changes in temperature and light.Cell temperature is a key parameter that determines the quality and performance of crystalline silicon solar cells (Dubey et al., 2013; Arjyadhara et al., 2013; Reich et al., 2009; Lammert and Schwarts, 1997; Saran et al. (2013; Coello et al., 2004). Current-voltage characteristics of crystalline silicon solar cells (Khan et al., 2010).

$$I = I_0\left[\exp\left(\frac{q\,(V - IR_s)}{nkT}\right) - 1\right] + \left(V - \frac{IR_s}{R_{Sh}}\right) - I_L. \qquad (1)$$

Nomenclature

I	Current
I_0	Reverse saturation current
q	Electron charge (1.602×10^{-19} Coulomb)
V	Voltage
R_S	Series resistance
n	Ideality factor
k	Boltzmann's constant (1.381×10^{-23} J/K)
T	Temperature
R_{sh}	Shunt resistance
I_L	Light generated current
I_{sc}	Short circuit current
V_{oc}	Open circuit voltage
P_{max}	Maximum power point
FF	Fill factor
η	Efficiency
$I_{0\,max}$	Maximum reverses saturation current
E_g	Energy band gap
V_{max}	Maximum voltage
I_{max}	Maximum current
P_{in}	Input power
$I(t)$	Light intensity or irradiance
A	Surface area of silicon solar cell

Here I0 is the reverse current, q is the electron charge, n is the ideal coefficient of the diode, k is the Boltzmann constant, T is the temperature, Rs is the series resistance, Rsh is the shunt resistance, and IL is the luminous flux produced by the silicon solar cell. In order to control quality and determine the performance of solar cells, environmental factors must be fully understood. Environmental factors have always played an important role in the performance of silicon solar cells. These factors need to be carefully checked and the gap closed. In this article, a solar cell simulator is used to study the effect of cell temperature on the photovoltaic factor of mc-Si solar cells. The battery temperature is 25 to 60°C, and the constant light intensity is 215 to 515 W/m2. The relative changes of photovoltaic parameters with temperature are also calculated.

Status	Light magnitude (W/m2)
Without any glass/filter	515
With clear glass	400
With frosted glass	280
With filter (First)	215

Table 1 The variation of light magnitude of two Halogen lamps with different glass plates and filters.

2. Experimental details

Use a single crystal silicon solar cell with an area of (4×4) cm 2 and experiment with a simulated solar cell. The cell temperature of the solar cell is in the range of 25 to 60°C, and the light intensity is constant 215-515 W / m^2. Two quartz halogen lamps (50 W each OS-RAM, 230 V) were simulated. Use a solar meter to measure the amount of light or brightness of the halogen lamp. A glass plate and several gray filters are installed between the lamp assembly and the lower chamber of the solar cell simulator. Table 1 shows the light intensity of halogen lamps with various glass plates and filters. The frosted glass plate helps to scatter and make the light uniform, especially when using a perforated metal plate as a light attenuator to reduce the light intensity. Use an extractor to cool the simulator. The temperature control unit includes a heater and a temperature sensor to stabilize the temperature required by the mc-Si solar cell and adjust the temperature from room temperature to 80°C. The properties of power supply, voltage and power supply voltage are considered and the photoelectric factor is calculated. The relative change of photovoltaic factor with battery temperature is also calculated.

3. Results and discussion

The graph shows the current-voltage and current-voltage characteristics of an mc-Si solar cell with cell temperature and constant light intensity. Observations were performed at constant light intensities of 215, 280, 400 and 515 W/m 2 at battery temperatures of 25°, 40°, 50° and 60°C. Figure 1(a)-(d) clearly shows that the current-voltage and current-voltage characteristics depend on the temperature of the component. According to the characteristics, the current in the lower voltage range is the largest and almost constant, and changes in the range of 100-120 mA, 125-140 mA, 170-190 mA and 220-240 mA according to the battery temperature, and the constant light intensity is 215 W/ m2, 280 W./m2, 400 W/m2 or 515 W/m2. The performance is evaluated in order of battery temperature, because the higher numbers below underestimate the lower numbers. The trend is opposite. Overvoltage 0.3V, 0.375V, 0.385V and 0.The intensity is 4 V at 515 W/m2, 400 W/m2, 280 W/m2, or 215 W/m2. After that, the current decreases rapidly and is the smallest in the range of 6 to 8 mA at a voltage of 0.5 to 0.58 V Compared with the higher battery temperature, the characteristic of sequentially lowering the battery temperature exists. Likewise, the evaluation of the current-voltage characteristics follows the same trend as the current-voltage characteristics. For all temperatures and constant light intensity, the power starts in the range of 2 to 8 mW. It can be observed that in the low voltage range, it increases with the increase of battery temperature, almost linearly with battery temperature, and its peak value is in the range of 35 to 90 mW at all constant light intensities. As reported by Arjyadhara et al., it was found that in a higher voltage range, the rate of photon generation decreases rapidly with the increase of battery temperature, resulting in a rapid increase in reverse current. (2013). Display the maximum power point, the voltage at this point will be less than the open circuit voltage. The current at this time is also less than the short-circuit current. At this time, the changes in current and voltage are almost the same for different temperatures of the battery. These results are similar to previously published work (Fesharaki et al., 2011; Sabry and Ghitas, 2008).

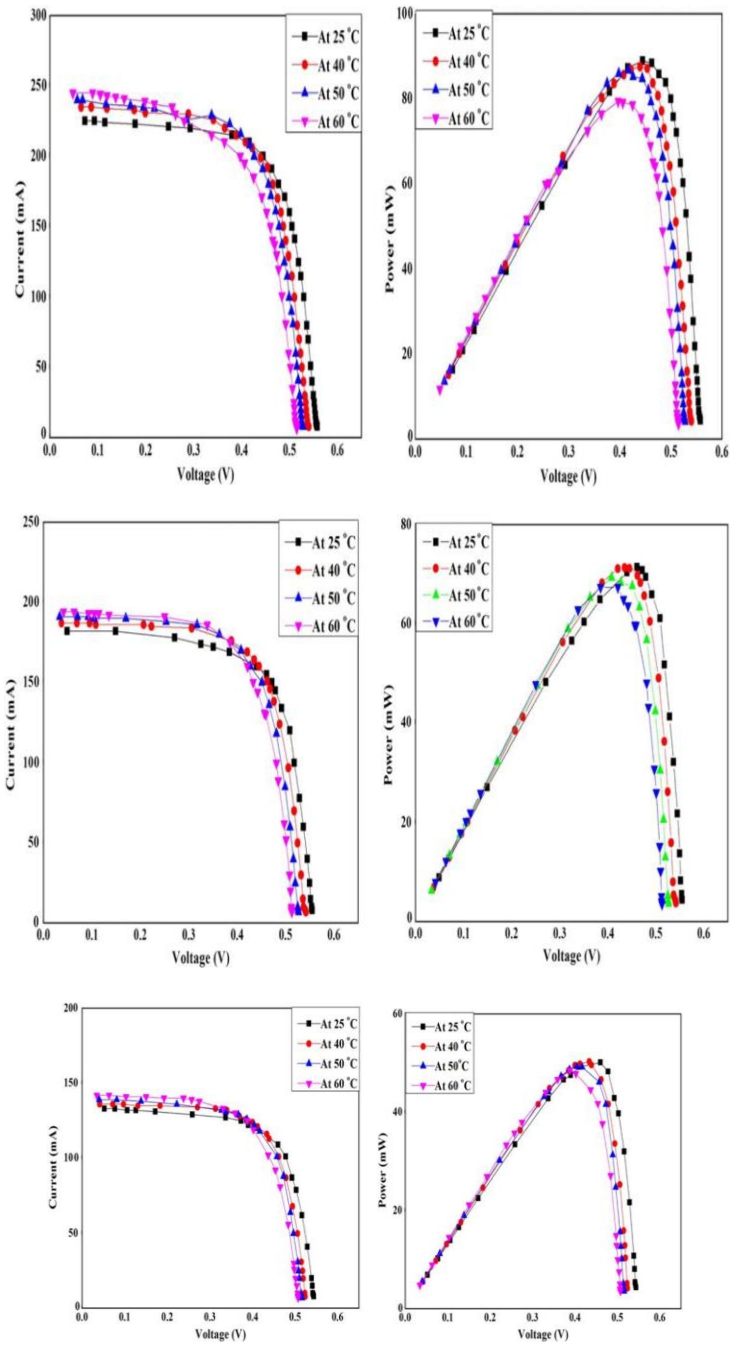


Fig. 1. The current–voltage and power–voltage characteristics of mc-Si solar cell with cell temperature at constant light intensities (a) 515 W/m2, (b) 400 W/m2, (c) 280 W/m2 and (d) 215 W/m2.

At a battery temperature of 25°C to 60°C and a constant light intensity of 215, 280, 400, and 515 W/m2, the temperature dependence has an effect on photovoltaic factors (such as open circuit voltage, short circuit current, and duty cycle)) Is displayed in the numbers. Figure 2 shows that the open circuit voltage (Voc) and duty cycle (FF) decrease as the battery temperature increases, while the short-circuit current (Isc) increases slightly. For all constant light intensities, they vary from 0.495–0.558 V, 112–245 mA, or 0.651–0.704 depending on the battery temperature. These results are consistent with the literature (Fesharaki et al., 2011; Arora and Hauser, 1982; Emery and Osterwald, 1987) and are explained using equations.(2) and (3) were described in earlier work (Cai et al., 2012; Singh and Ravindra, 2012; Lammert and Schwarts, 1997). By checking the relative changes of open circuit voltage, short circuit current and duty cycle, the maximum power can also be calculated and determined by the relational equations (4)-(6). The open circuit voltage (Voc) that depends on the battery temperature is determined by the relationship considered (Cai et al., 2012).

$$V_{oc} = \frac{E_g}{q} - \frac{nkT}{q}\left(\ln \frac{I_{0\,\max}}{I_{sc}}\right). \qquad (2)$$

For example, here is the energy band gap, and I0 max is the maximum current in the inversion state. The fill factor (FF) is determined by the relationship considered (Singh and Ravindra, 2012).

$$FF = \frac{P_{\max}}{V_{oc} \times I_{sc}} = \frac{V_{\max} \times I_{\max}}{V_{oc} \times I_{sc}}. \qquad (3)$$

Here, Vmax and Imax are voltage and current, respectively, which correspond to the maximum output power. The relationship of short-circuit current can be found in the literature (Lammert and Schwarts, 1997). Calculate the relative change of open circuit voltage (Voc), short circuit current (Isc) and duty cycle (FF) with battery temperature, and use the relationship (4)-(6) to obtain.

$$\frac{1}{V_{oc}}\frac{dV_{oc}}{dT} \approx -(0.0022 \text{ to } 0.0025) \text{ per } ^\circ\text{C} \qquad (4)$$

$$\frac{1}{I_{sc}}\frac{dI_{sc}}{dT} \approx 0.002 \text{ per } ^\circ\text{C} \qquad (5)$$

$$\frac{1}{FF}\frac{d(FF)}{dT} \approx -0.0013 \text{ per } ^\circ\text{C} \qquad (6)$$

The temperature decreases, so the open circuit voltage decreases. The short-circuit current (Isc) is directly proportional to the number of charge carriers generated and their mobility. This largely depends on the generation rate and diffusion length of charge carriers. Carriers increase with the increase of battery temperature and cause an increase in short-circuit current, as reported by Arora and Hauser (Lammert and Schwarts, 1997). Equation (3) draws the conclusion that due to the corresponding change in open circuit voltage, the duty cycle decreases with battery temperature. And short-circuit current. Table 2-3 shows the maximum output power (Pmax) and efficiency changes of mc-Si solar cells with battery temperature under constant light intensity of 215, 280, 400 and 515 W/m2. Use the corresponding ratio to calculate the maximum output change with temperature.

$$\frac{1}{P_{max}}\frac{dP_{max}}{dT} \approx -0.002 \text{ per } ^{\circ}\text{C}. \quad (7)$$

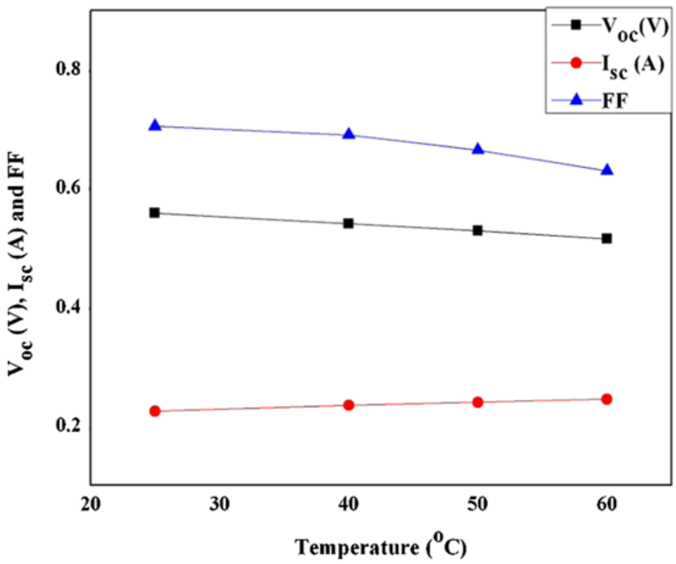
The efficiency of solar cell is given (Singh and Ravindra, 2012)

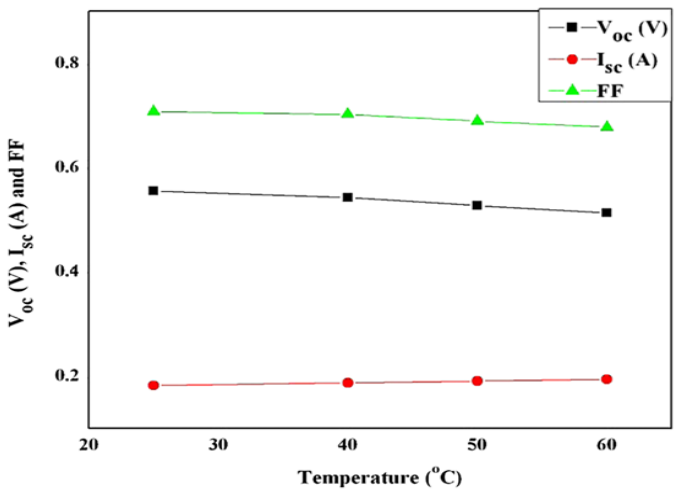
$$\eta = \frac{P_{max}}{P_{in}} = \frac{V_{max} \times I_{max}}{I(t) \times A} = \frac{FF \times V_{oc} \times I_{sc}}{I(t) \times A}. \quad (8)$$

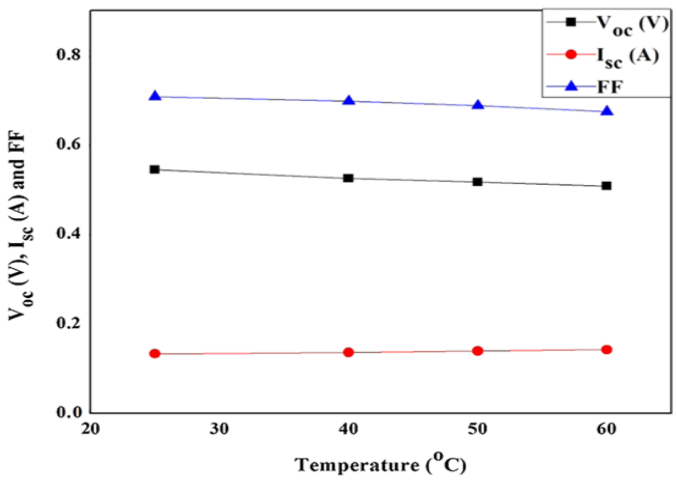
Here Pin is the input power, I(t) is the amount of light that can be defined as irradiance (E), that is, the power of electromagnetic radiation per unit area incident on the surface, and A is the surface cell of the silicon solar cell. It can be seen that under all constant light intensity, the maximum output power decreases with the increase of battery temperature, as shown in Table 2, which shows that the voltage decreases with the decrease of battery temperature. It can be clearly seen from Table 3 that the efficiency decreases as the battery temperature increases. Due to the corresponding decrease in open circuit voltage and duty cycle, all temperatures under constant light intensity. The temperature-dependent battery efficiency is defined as (Dubey et al., 2013):

$$\eta_c = \eta_{Tref}[1 - \beta_0 (T_c - T_{ref})]. \quad (9)$$

Here, ηc and ηTref are efficiencies of solar cell at cell temperature and room temperature respectively, β0 is the efficiency temperature coefficient (0.004 K−1), Tc and Tref are the cell temperature and reference temperature of solar cell respectively. The quantity (Tc − Tref) increases with cell temperature and consequently efficiency decreases. The calculated efficiency is similar to the earlier reported work (Radziemska, 2003; Dubey et al., 2013).







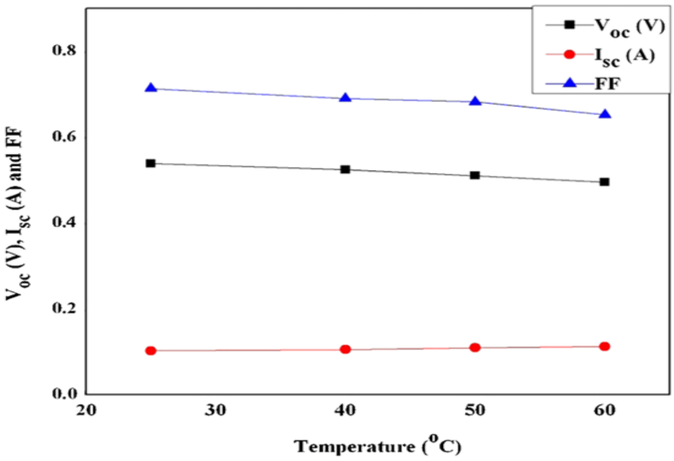


Fig. 2. The variation of open circuit voltage (Voc), short circuit current (Isc) and fill factor (FF) of mc-Si solar cell with cell temperature in the range 25–60 °C at constant light intensities (a) 515 W/m2 , (b) 400 W/m2 , (c) 280 W/m2 and (d) 215 W/m2.

4. Conclusion

This article reports the influence of cell temperature on the photovoltaic factor of mc-Si solar cells. Experiments were performed using a solar cell simulator. The battery temperature was 215, 280, 400, and 515 W/m 2 at a constant light intensity, and the battery temperature was in the range of 25 to 60°C. The results show that the battery temperature has an important influence on the photovoltaic factor and controls the quality and performance of the mc-Si solar cell. Open circuit voltage (Voc), maximum power point (Pmax), duty cycle (FF) and battery efficiency (η) decrease with the increase of battery temperature, while the short-circuit current increases slightly due to the increase of power generation rate. The number of load carriers. ... temperature. For short-circuit current, circuit voltage, duty cycle and maximum output power are negative and positive values. The relative change of PV factor with temperature was also calculated, ranging from -0.0022/°C to -0.002 5/°C, 0.002/°C, -0.0013/°C and -0.002/°C means open circuit voltage, short circuit current, duty cycle or maximum output power. The results are consistent with the existing literature.

Temperature (°C)	Maximum output power P_{max} (mW)			
	At 515 W/m^2	At 400 W/m^2	At 280 W/m^2	At 215 W/m^2
25	88.43	71.455	51.15	39.15
40	87.56	71.149	50.344	37.944
50	84.192	69.36	49.288	37.904
60	79.40	67.375	48.5	36.127

Table 3
The efficiency (η) of mc-Si solar cell with cell temperature at different constant light intensity.

Temperature (°C)	Efficiency (η%)			
	At 515 W/m^2	At 400 W/m^2	At 280 W/m^2	At 215 W/m^2
25	10.049	11.165	11.417	11.381
40	9.95	11.117	11.238	11.03
50	9.856	10.837	11.002	11.019
60	9.023	10.527	10.826	10.502

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