

Analysis of light intensity effect on Photovoltaic cells

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Abstract. Effects of solar panels must be taken into account by the light intensity of its output characteristics in practical application, especially solar panels placed outdoor. So the light intensity coefficient is an important parameter to be considered. In this paper, we took the light intensity characteristics of single crystal silicon solar cell as the research object. Also, through transforming the illumination intensity which changes from 580W/m^2 to 1225W/m^2 , we would finish researching the characteristics of the cell sheet, which included battery plate volt ampere characteristic, open circuit voltage, short circuit current and maximum output power. Also, we've got the relationship of U_{oc} -T, I_{sc} -T and P_m -T, respectively and put forward the better intensity theory. It would lay a solid foundation of practice for the further study on how to improve the rate of light conversion.

Introduction

With the development of social economy, the importance of the energy problem has become increasingly prominent[1]. Demand for energy is more and more intensified. Experts estimate that the current consumption of annual energy is equivalent to 200 tons of standard coal. However, about 90% of this is relying on non-renewable fossil energy to maintain. In the current situation, the amount of fossil energy reserves can only last about 100 years. Solar energy for its clean, long-term has become the main way for the sustainable development[2].

At present, application of solar energy is also full of challenges and problems. At present, limitations of the solar cell mainly exist in its dispersion, instability and high cost. We know its dispersion and instability are determined by the geographical features, and the high cost is determined by the technological level[3,4]. Based on this, through the different amounts of sunlight, this paper takes the light characteristics of solar battery as the research object. We have started to study on its characteristics and analyzed the effects of light intensity on the output voltage, electric current, power, etc. and provided researchers with a sound theoretical and practical basis for later study.

(1)

Light Characteristics of Solar Battery

The solar battery is a large area of the PN junction with a shallow junction depth[5]. The photoelectric conversion process which solar battery has been able to complete relies mainly on the photovoltaic effect. Note that light could cause the height of potential barrier to decrease or even disappear. Its effect is completely equivalent to the PN junction loaded forward voltage that applied to both ends. The PN junction mentioned above is a solar energy battery[6].

Usually, solar illumination performance refers to the output of volt ampere characteristics which is in the condition of light. This paper takes crystalline silicon as the research object. The promising properties parameters are: open circuit voltage, short circuit current, maximum output power.

1.1 Characteristics of Volt Ampere.

The output curve of volt-ampere characteristic is shown in Figure.1. Rectangular that means maximum power is formed of I_m and V_m . The physical meaning of the maximum power rectangle is

the maximum output power of solar cell, which is the maximum product by horizontal and vertical coordinates of the I-V curve[7].

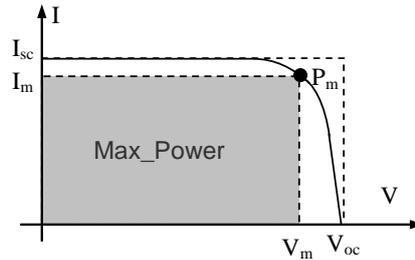


Figure.1 output volt ampere curve of solar battery

Ideally, the equivalent load circuit is shown as Figure 2. The light of the PN junction is regarded as an ideal diode and a constant current source in parallel. Constant current source is generated by light. I_F is from the junction silicon diode. R_L is the external load.

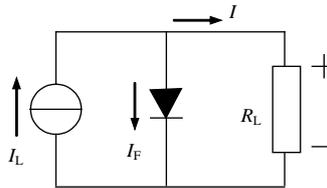


Figure.2 equivalent load circuit of solar battery

The physical meaning of the equivalent circuit: the solar cell shined by light could generate current which express by I_L . part of I_L is used to counteract the junction current. The other part is provided to the external load[8]. The equivalent circuit diagram is shown as Eq. 1.

$$I = I_L - I_F = I_L - I_s \left[\exp\left(\frac{qV}{k_0T}\right) - 1 \right] \quad (1)$$

However, There are two extreme cases which must be considered in the analysis of the characteristics of solar battery. The first is $R_L = 0$. In this case, the voltage of the load resistor ends is zero and the PN junction is in short circuit[9]. The output current I_{sc} is called short current shown as Eq. 1.

$$I_{sc} = I_L \quad (2)$$

It means that the short circuit current is equal to the photocurrent. So, the strength of the current is then proportional to the intensity of the light named E_e and the effective area of the panel named A [10]. The second is the load resistance. When $R_L \rightarrow \infty$, the external circuit would be open. At this time, current that flowing through the load is zero, that is, $I = 0$. According to the equivalent circuit, The photocurrent is neutralized by forward current. The voltage (U_{oc}) between the two poles of the battery is the so-called open circuit voltage. Clearly, the relationship expresses as Eq. 3.

$$I = I_L - I_s \left[\exp\left(\frac{qU_{oc}}{k_0T}\right) - 1 \right] = 0 \quad (3)$$

So, the open circuit voltage (U_{oc}) shown as Eq. 4 could be obtained by the formula mentioned above.

$$U_{oc} = \frac{k_0T}{q} \ln\left(\frac{I_L}{I_s} + 1\right) \quad (4)$$

In conclusion, the open circuit voltage (U_{oc}) is proportional to the amount of incident light intensity, also, related with the series of cell sheet, but, regardless of the area of photovoltaic panel[11].

Characteristic Tests of Solar Illumination

The characteristic tests of solar illumination based on single crystal silicon, polycrystalline silicon and amorphous silicon refer to the output characteristic curve of I-V, which is in different temperatures and different light intensities. Then, its consequences of the open circuit voltage, short circuit current, the maximum output power, the conversion efficiency could be calculated.

3.1 Tests of Single Crystal Silicon Solar Cell

High pressure Xe flash lamp source for its spectral distribution characteristics similar to the sun was used as light source[12]. The power of the light source is 750W and its aperture is 50mm. Through transforming the light intensity which changes from 580W/m² to 1225 W/m², we would get the output of the illumination parameters. The steps are as follows.

Step1: keeping the temperature at 25 degrees, arranging Xenon lamp in the 2 file, we could get the light intensity by the detector.

Step2: putting single crystal silicon cells, starting to do the experiment, we should record the data which includes I-V characteristic, open circuit voltage, Short circuit current and maximum output power.

Step3: adjust the light intensity to 1 and 4 file, sequentially. repeat the above steps until getting the ideal result.

Through the experimental steps, characteristic parameters were shown in Table. 1.

Table.1 characteristic parameters

Light Intensity: 1225 W/m²

NO.	Voltage (V)	Current (A)	Power(W)	NO.	Voltage (V)	Current (A)	Power(W)
1	1.01	1.770	1.79	11	11.00	1.755	19.31
2	2.02	1.770	3.58	12	12.00	1.750	21.00
3	3.01	1.770	5.33	13	13.02	1.740	22.65
4	4.02	1.767	7.10	14	14.01	1.740	24.38
5	5.00	1.765	8.83	15	15.01	1.738	26.09
6	6.02	1.763	10.61	16	16.02	1.730	27.71
7	7.02	1.760	12.36	17	17.02	1.503	25.58
8	8.00	1.760	14.08	18	18.01	0.975	17.56
9	9.02	1.760	15.88	19	19.01	0.170	3.23
10	10.00	1.758	17.58	20	19.20	0.000	0.00

Light Intensity: 910 W/m²

NO.	Volta ge (V)	Curr ent (A)	Pow er(W)	NO.	Volt age (V)	Curre nt (A)	Pow er(W)
1	1.00	1.525	1.53	11	11.0 2	1.476	16.2 7
2	2.01	1.523	3.06	12	12.0 3	1.470	17.6 8
3	3.01	1.521	4.58	13	13.0 0	1.455	18.9 2
4	4.00	1.520	6.08	14	14.0 0	1.450	20.3 0
5	5.00	1.517	7.59	15	15.0 3	1.450	21.7 9
6	6.02	1.513	9.11	16	16.0 1	1.440	23.0 5
7	7.00	1.510	10.5 7	17	17.0 3	1.310	22.3 1
8	8.00	1.505	12.0 4	18	18.0 1	0.888	15.9 9
9	9.00	1.500	13.5 0	19	19.0 0	0.230	4.37
10	10.00	1.480	14.8 0	20	19.2 8	0.000	0.00

Light Intensity: 760W/m²

NO.	Volta ge (V)	Curre nt (A)	Pow er(W)	NO.	Volta ge (V)	Curre nt (A)	Pow er(W)
1	1.01	1.345	1.36	11	11.0 1	1.302	14.3 4
2	2.00	1.342	2.68	12	12.0 0	1.300	15.6 0
3	3.01	1.342	4.04	13	13.0 0	1.300	16.9 0
4	4.03	1.343	5.41	14	14.0 0	1.295	18.1 3
5	5.01	1.343	6.73	15	15.0 2	1.282	19.2 6
6	6.01	1.335	8.02	16	16.0 1	1.275	20.4 1
7	7.00	1.335	9.35	17	17.0 0	1.182	20.0 9
8	8.01	1.330	10.6 5	18	18.0 2	0.830	14.9 6
9	9.02	1.315	11.8 6	19	19.0 0	0.253	4.81
10	10.01	1.310	13.1 1	20	19.3 4	0.000	0.00

Light Intensity: 580 W/m²

NO.	Volta ge (V)	Curr ent (A)	Pow er(W)	NO.	Volta ge (V)	Curre nt (A)	Pow er(W)
1	1.01	1.105	1.12	11	11.0 2	1.083	11.9 3
2	2.01	1.104	2.22	12	12.0 2	1.083	13.0 2
3	3.02	1.103	3.33	13	13.0 0	1.080	15.1 2
4	4.02	1.103	4.43	14	14.0 0	1.295	18.1 3
5	5.01	1.098	5.50	15	15.0 2	1.075	16.1 5
6	6.00	1.096	6.58	16	16.0 2	1.062	17.0 1
7	7.00	1.095	7.67	17	17.0 1	0.963	16.3 8
8	8.02	1.095	8.78	18	18.0 0	0.703	12.6 5
9	9.01	1.095	9.87	19	19.0 0	0.234	4.45
10	10.02	1.090	10.9 2	20	19.3 6	0.000	0.00

4 Analysis

According to the data in Table 1, we could get the curves such as short circuit current and light intensity, the maximum output power and the short circuit current.

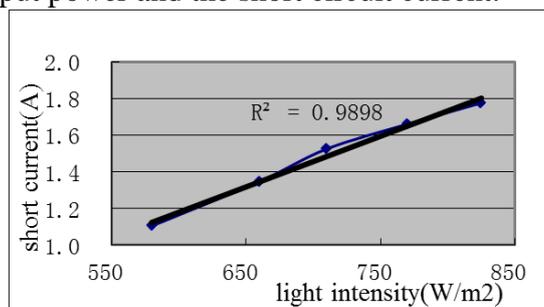


Figure.3curves of short current and light intensity

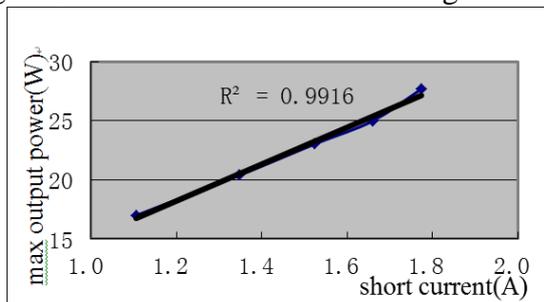


Figure.4curves of maxoutput power and short current.

From the Figure.3 and Figure.4, we got the results of the experiment.

i) Under different light intensity, the shape of output volt ampere characteristic curves are similar, but different: Short circuit current increases with the increase of light intensity and the open circuit voltage changes little.

ii) The relationship between short circuit current and light intensity is approximately linear. So is the maximum output power and the short circuit current.

Through the experimental data acquisition, we've drawn its relationship curve by Matlab shown in Figure. 5 and Figure.6

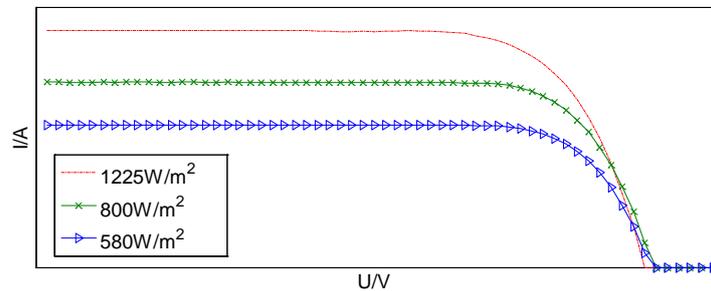


Figure.5 U - I relationship curve

Seen from the Figure.5 and Figure.6, at a certain temperature, with the increase of light intensity, the short circuit current named I_{sc} , the open circuit voltage named U_{oc} and max_output power named P will increase along with together. When the light intensity is lower than $996\text{W}/\text{m}^2$, I_{sc} , U_{oc} and P grew faster. When it is higher than $1225\text{W}/\text{m}^2$, the curve grew slower until saturation.

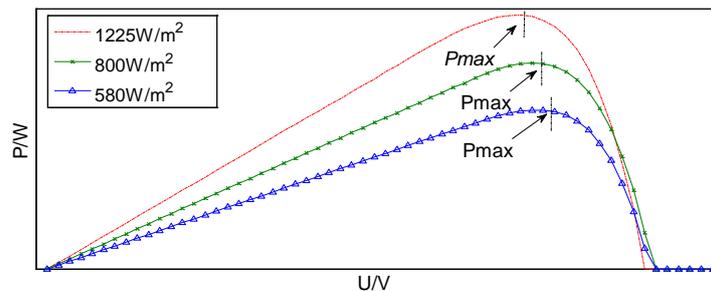


Figure.6 U - P relationship curve

But the two parameters show different variety laws: I_{sc} is proportional to the incident intensity named E_e . U_{oc} increases along with the amount of E_e . However, U_{oc} won't increase unlimitedly.

Conclusions

This paper compared output characteristics of the solar battery under different light intensity.

- i) The light intensity nearly $1225\text{W}/\text{m}^2$ is reasonable, the conversion rate of current and voltage amplitude grew higher.
- ii) When the temperature is increased by 1°C , the light intensity would be increased nearly $10\text{W}/\text{m}^2$. So, we must pay attention to ventilation.
- iii) The maximum value of voltage amplitude is to make the height of PN junction barrier be zero. So, researching on solar battery, we should not only choose the reasonable illumination intensity, but consider other influence such as material, etc.

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