H K . N C C P
International Journal of Intelligent Information and Management Science
ISSN: 2307-0692 *Volume 4, Issue 2, April 2015*

EXPERIMENTS ON PHOVOLTAIC EFFICIENCY IN DIFFERENT CONFIGURATION PARAMETERS AND IRRADIATION LEVELS

Liwei FANG
Wenzhou Vocational & Technical College, Wenzhou, 325035, CHINA

Abstract: On account of the limited non-renewable energy and enlarging energy consumption, solar seems to be an alternative, because it is free, clean and extensive, and can be changed into different energy forms. In this case, photovoltaic (PV) system is utilized to convert sunlight into electricity directly and is widely applied all around the world. This report is based on a PV laboratory and provides an opportunity for people to acquire a comprehensive understanding of characteristics of PV system, especially the influencing elements on electricity generation of PV system. A series of tests would control variables, such as the circuit load, the irradiation and connection type, to investigate the behavior of PV modules. The data presented in the following content reveals the specifying links between them. For the efficiency part, factors would be raised to analyze the distance between the results and normal data.

Keywords: Phovoltaic Efficiency; Irradiation; Solar Panel

1. Introduction

A number of environmental factors and systemic variables could have impacts on the PV efficiency. This experiment is mainly aimed at finding the specific influences due to distinct connections, for example series and parallel connected panels, discovering the general relationship between the quantity of circuit load and the amount of electricity generation by PV cells through changing the resistance, and bringing out that the incident light intensity affects panel efficiency by testing with the shading plates. Six groups of data would be collected to create the current voltage curves and the power voltage curves for maximum power point (MPP) prediction and to calculate the panel efficiency for comparison with common published data.

Since the electricity produced by PV cells in this system is entirely used to generate heat, the basic theory is that power equals current multiplied by voltage, i.e. W=VI, and that light power received on the module surface multiplied by the irradiation, together leading to the final efficiency, i.e. η=W/AI*100%. For estimation, the smooth trend curves are roughly drawn on the scattered diagram by the Excel Software. The MPP should be the peak of power voltage curves and the efficiency for these particular modules varies with different levels of irradiation.

2. Method

The experiment is primarily concentrated on six tests:

1. Series connected panels under full insolation;
2. Parallel connected panels under full insolation;
3. Single panel under full irradiation;
4. Single panel under 70% irradiation;
5. Single panel under 50% irradiation;
6. Single panel under 10% irradiation.

The information is obtained by following operation process:

1. Switch on the light source, which is regarded as sunlight in real world.
2. The measurement point of light intensity is located in the middle of the two panels. After the number shown on the screen of the Pyranometer becomes stable, record the reading, which can used to determine irradiation within the known calibration factor $19.25*10^{-6}$V/ (m^{-2}W). Note the unit for reading is mV.
3. Turn on or off the switches to make sure the modules are series connected correctly.
4. Change the rheostat to Position 1, i.e. the short circuit position. Select a proper setting for the ammeter in order to achieve a full-scale deflection a little

larger than the reading. Record the magnitude of current and voltage after the numbers are stable. Then move the rheostat from Position 1 to Position 11 step by step, which increases the load gradually and note down the data on the sheet orderly. At last turn on the open circuit switch to get the zero current and maximum voltage, and then turn off the open circuit switch.

5. Note: when it is short circuit, most voltages fail to reach zero as expected originally for the unavoidable inherent resistance of wire and PV cells.
6. Repeat Step 3 to Step 4 for parallel connection and single panel, and record the statistics.
7. Take notes of the reading of Pyranometer after selecting shading plates with different quantities of holes for various levels of irradiation (70%, 50% and 10%) under the single panel condition and repeat Step 4.

Compute the panel efficiency with the total area 0.09m2 of the two identical panels and 0.045m2 for single panel.

The following figures illustrate the structure of PV system.

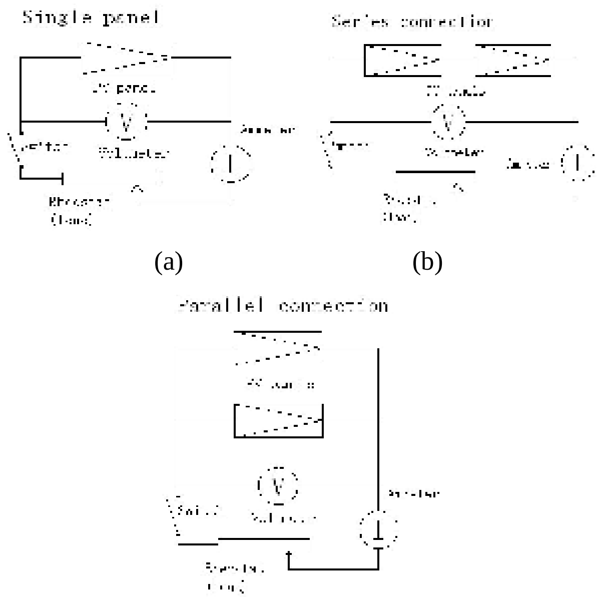

Figure 1. Three connections of PV modules. ***(Note: the place of ammeter in diagrams is different from that on instruction sheet. The ammeter under this condition would be working for longer time since the switches can control the ammeters. If the ammeter is located on the position displayed on instruction sheet, it would probably need maintenance more frequently since it works all the time.)***

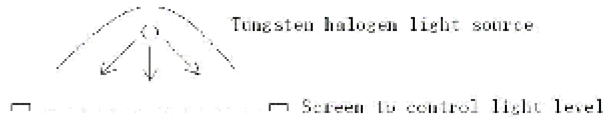

Figure 2. The light source.

There is a table of the equipment and apparatus applied shown as Table 1.

Table 1. Equipment and their functions

Equipment	Function
Ammeter	Measure current
Voltmeter	Measure voltage
Rheostat	Control the load on the circuit
PV modules	Provide electricity as the power source
Wire	Connect devices
Tungsten halogen lamp	Act as sunlight in this case
Pyranometer	Measure the strength of light source

3. Results

The raw data as well as the further gained data by calculation was used to figure out the approximate trend line below.

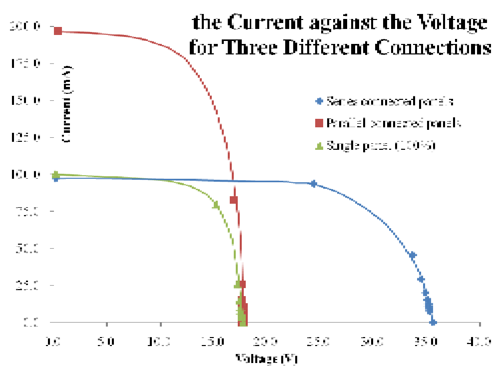

Figure 3. The current against the voltage for three different connections.

According to Figure 3, there are some transparent consequences. First of all, when the circuit is open, all the currents are zero and the voltages are the maximum in their own group of data. The voltage of series connection circuit is nearly as twice large as that of parallel connection circuit or single panel circuit (voltages of parallel connection circuit and single panel circuit are identical). And under short circuit situation, the currents and voltages are more or less same, and closely half amount for parallel connection circuit respectively. From Position 2 to Position 11 (i.e. increasing the load in a gradual manner), the currents and voltages changes to be nearly identical for parallel connection and single panel circuit and becomes half of that for series connection circuit at the same position.

ISSN: 2307-0692 Volume 4, Issue 2, April 2015

Consulting Figure 4, the MPP of series connection is obviously the largest one, and is followed by that of parallel connection and finally single panel. In other words, the series connection seems to perform best in this experiment. The data for the two lower power voltage curves are very similar to each other even though the curve shows that the MPPs are not so close. At Position 2, the power under series connected panels is once bigger than that under parallel connected panels or single panel, while at Position 3 to Position 11, it is three times bigger correspondingly. However, at Position 1 the power under parallel connected panels is three times larger than that under series connected panels or single panel.

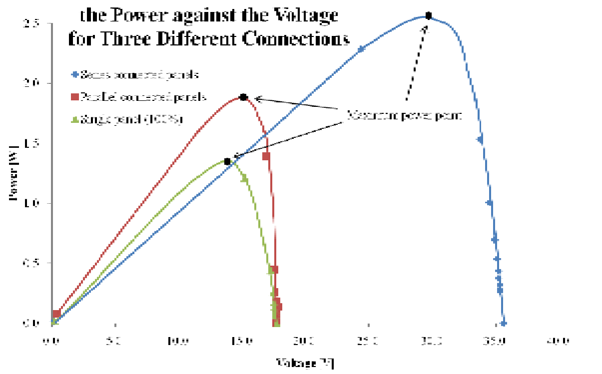

Figure 4. The power against the voltage for three different connections.

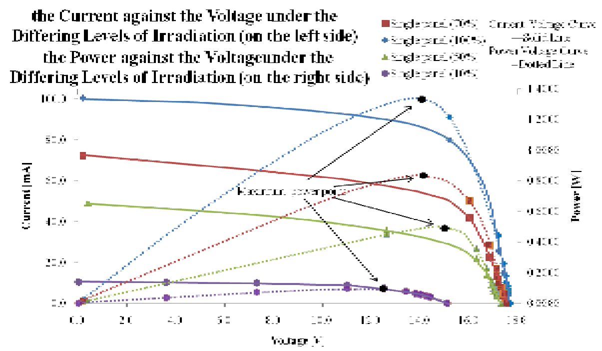

Figure 5. Combined current voltage curve and power voltage curve.

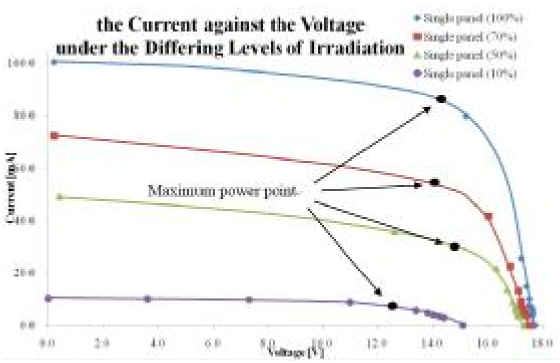

Figure 6. The current against the voltage under the differing levels of irradiation

Transparently, the full insolation allows the highest maximum power and the maximum power would drop with the reduction of irradiation. At the view of quantity of load, i.e. for each curve, nearly all MPP would occur at Position 2, namely that when the load increases, most maximum power would decrease, except for the column of single panel of 10% irradiation. Thus the load is indeed needed to be accurately assumed and play a significant role during the design, installation and future operation. According to the previous comments, Rational hypothesis can be made that the relatively lower load can affect the PV modules to gain more power and when the irradiation is lower, the load for maximum power grows (with the evidence in the column of 10% single panel).

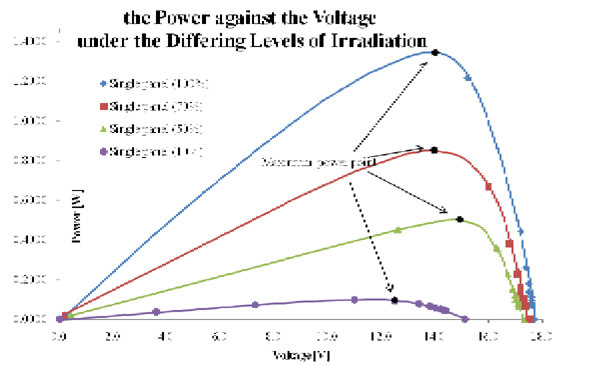

Figure 7. The power against the voltage under the differing levels of irradiation

Based on the data collected, the curves link up most scattered points. Even though it is not precise, observing the peak points on Figure 6 and Figure 7 is still be an appropriate approach to attain the MPP, which are estimated in the table below.

Table 2: the irradiation and maximum power

	Single (100%)	Single (70%)	Single (50%)	Single (10%)
Irradiation [W/m2]	662.86	474.29	299.22	60.78
Maximum power [W]	1.36	0.80	0.50	0.10

Seemingly, on Figure 8 the equation worked by Excel Program best fits the curve through the points, which is $y=6*10^{-9}x^3-5*10^{-6}x^2+0.0027x-0.0486$.

Here, it might give the opportunity for maximum power at different levels of irradiation, which is very useful in design and installation of PV products actually.

Shown on Figure 9, the efficiency voltage curve is created by the same method mentioned before. This curve performs more like the power voltage curve. And the highest efficiency takes place when the power is relatively large or the load is relatively small.

When comparing with the normal efficiency of PV module, which is around 12% to 15% [1], the result is much lower.

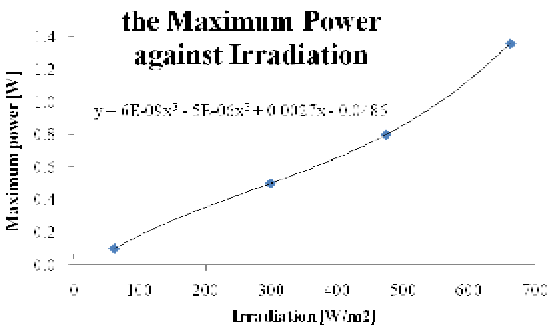

Figure 8. The maximum power against irradiation

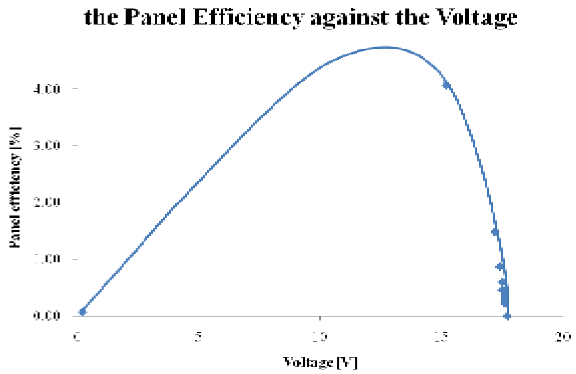

Figure 9. The panel efficiency against the voltage

4. Discussion

The experiment almost follows the original instruction and the variation tendency goes as expected.

The data from first three tests (except short circuit) are quiet match the regulation. The voltage of the two same power sources (PV modules) under parallel connection equivalents to that of a single power source. And the total voltage of series connection is the sum of every separate voltage. Therefore when the amounts of rheostat movement are same, the current calculated by Ohm Law turns out to have the identical relationship.

However, the experiment has intrinsic problems, operating mistakes and limitations, such as the reading errors in common cases. And in this specified situation, if the MPP requires to be more accurate, the times of testing should be enhanced. In addition, the MPP for different irradiation is merely assessed by eyes. Thus, the curve of maximum power against irradiation is all based on the rough statistics, leading to the low level of accuracy for characteristic function. Another might be the equipment, especially the light source. The tungsten halogen light is regarded as the sunlight, but in fact, the spectrum could not be same with the sunlight. And the absorption ability of PV cells probably varies with the light wavelength, which could importantly have effects on the final efficiency.

Despite these above, the panel efficiency obtained in this case largely differs from the real system. Several factors affecting PV output are raised here to explain these phenomenons.

Firstly, the dirt covered on the panel surface can lower the efficiency. Accordingly, the PV panels need periodically maintenance to ensure the surface is sufficiently clean for light absorption.

Then the temperature also affects the panel efficiency. It is noted that "the performance of PV modules decreases with increasing temperature" [2]. Hence, to some extent, it is inappropriate to compare the data with the normal statistics, because of lack of thermometer in the lab.

Last but not least, mismatch losses is another serious problem in PV system. It usually takes place if solar cells or modules do not reach the same properties or some experience different conditions. For instance, under series connection, the current is determined by the module with poorest performance.

5. Conclusion

There are two major working parts of this system, one is the PV modules, acting as the power source for the circuit and also is the main subject of study, and the other is the electricity consumption section, rheostat, used to testing the panel efficiency. The existence of difference between the experiment and experience is very common since it is impossible for testing at first time perfectly matching expectation. Although the numerical relationship basically matches the performance principles of different connected circuit, the panel efficiency seems much lower than empirical information. Three reasonable points, dust, temperature and mismatch, can explain the disparity. The appearance of any above factor can reduce the power output and the panel efficiency as well. As mentioned before, for apparatus, the light source should be selected more similar with sunlight. In order to achieve higher accuracy of MPP, the more testing times are taken, the closer to truth for function. Additional future work such as devices checking and maintenance should be done frequently to guarantee them functioning well.

References

[1] CIBSE TM25: Understanding Building Integrated Photovoltaics, 2000.

[2] DTI: Photovoltaics in Building – A Design Guide, Report No. ETSU S/P2/00282/REP, 1999. www.berr.gov.uk/file16811.pdf