

EFFECT OF TILT ANGLE ON CURRENT AND POWER CHARACTERISTICS IN PHOTOVOLTAIC MODULE MODEL ET-250

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ABSTRACT

Solar cells or also often called *photovoltaics* are device with two terminals or connections capable of converting direct sunlight into electricity, which can then be distributed and used for the needs of electrical loads. Solar systems typically use batteries to store excess energy captured during the day for further use at night when there is no sunlight or is used during the day when sunlight radiation is very small, for example when it is dark. or not enough light works like a diode, and when illuminated with sunlight can produce voltage. When illuminated, generally one commercial solar cell produces a dc voltage of 0.5 to 1 volt, and a short-circuit current in milliamperes scale per cm^2 . This large voltage and current is not enough for various applications, so generally a number of solar cells are arranged in series to form solar modules. One solar module typically consists of 28-36 solar cells, and the total produces a dc voltage of 12 V under standard illumination conditions.

The current-voltage curve is nonlinear. The greater the load resistance, the closer the load voltage will be to the value of the open connect voltage (V_{oc}) of the solar panel. While the smaller the load resistance, the current flowing into the load will get closer to the short circuit current (I_{sc}) of the solar panel. The power-voltage curve is nonlinear. Solar panel power will be maximum if at the load flows the maximum current (I_m) and has a maximum voltage (V_m). The addition of a load that has resistance (R) is smaller than the maximum load resistance, then the power will increase close to the maximum power value (P_m) of the solar panel. While the increase in the load that has resistance (R) is greater than the maximum load resistance, the power will decrease from the maximum power of the solar panel. The longer the cable is used, the maximum power of the solar panels will decrease. The tilt of the solar panels towards the angle comes sunlight affecting the maximum power generated by solar panels.

Keywords : Photovoltaic Module, Array, Diode, Nonlinear, Solar Panel Tilt

INTRODUCTION

Most of the world's energy needs are adequacy with energy derived from the burning of fossil fuels. Natural resources such as fossils are un renewable natural resources. With continuous use, those resources will run out. The sun is one of the main components of life. The sun emits light radiation with various wavelengths, ranging from ultraviolet, visible light, to infrared from the electromagnetic spectrum. This radiation arises as a result of the sun's surface having a temperature of about 5800 K (~ 5500 C) so that the spectrum emitted by the sun is the same as the spectrum of the blackbody at the same temperature. Solar cells or also often called photovoltaics are device with two terminals or connections capable of converting direct sunlight into electricity, which can then be distributed and used for the needs of electrical loads. When

illuminated, generally one commercial solar cell produces a dc voltage of 0.5 to 1 volt, and a short-circuit current in milliampere scale per cm^2 .

This large voltage and current is not enough for various applications, so generally a number of solar cells are arranged in series to form solar modules. One solar module typically consists of 28-36 solar cells, and the total produces a dc voltage of 12 V under standard illumination conditions [Air Mass 1.5]. Multiple modules can be connected together to form an array, the larger the region of the module or array, the more electricity it will generate. Photovoltaic modules and arrays generate direct current electricity (dc). These modules and arrays can be electrically connected both in series and parallel to produce the required combination of voltage and current. The performance of solar panels can be seen from the characteristics of solar panels, which consist of current-voltage curves and power-voltage curves that are connected series and parallel based on the intensity of sunlight. Based on the problems as mentioned above, it is necessary to research the Effect of Angle tilt light intensity on current-voltage characteristics, power-voltage connected series and parallel by using photovoltaic module Model ET 250. The final results of this study are measurements of current-voltage and power-voltage as well as factors that affect the performance of photovoltaic modules.

METHODS

1. Series Design

The series design in this lamp uses model ET 250.01 which contains typical system components of photovoltaic solar modules in grid-connection operation. The basic structure and network of equipment for ET 250 can be shown in Figure 2.1.

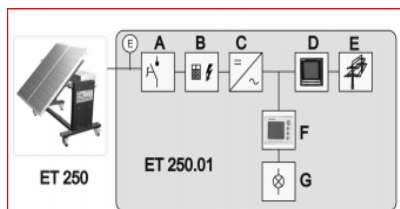


Image Caption :

- a. DC Switch Disconnector
- b. Voltage Protection
- c. Grid Inverter
- d. Grid feed-in bi-directional meter
- e. Grid feed-in
- f. Own consumption energy meter
- g. Halogen lamp with dimmer

Fig 2.1. Block Diagram

The component is attached to the front of the equipment. The electrical line diagram is shown in Figure 2.2. The front panel of the unit below. The measurement terminal (El1) of electricity and voltage measurement is available on the input circuit. Measurements can be given by conventional instruments or with ET 250 units of measurement.



Image Caption :

- 1. Connector socket for PV Module
- 2. Measuring point El1
- 3. DC circuit breaker
- 4. Voltage surge protection
- 5. Grid inverter
- 6. Halogen lamps as electric load
- 7. Dimmer
- 8. Fuse
- 9. Energy meter
- 10. Bi-directional meter on the grid
- 11. Grid feed-in

Fig 2.2. Panel unit

2.1 Solar Panel Current and Voltage Measurement

❖ *Series Connected*

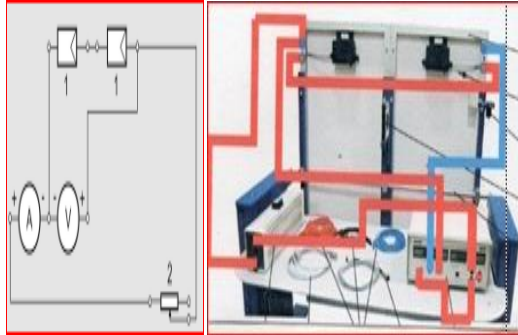


Image Caption :
1. Solar Modul
2. Slide resistor
A. Ammeter
B. Voltmeter

Fig 2.3 The circuit of measuring modules is connected in series

❖ *Parallel Connected Circuit*

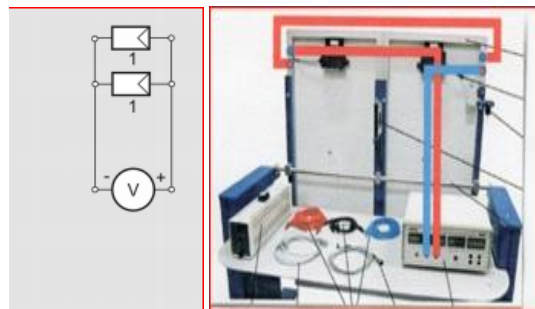


Fig 2.4 Measurement of open-circuit voltage

DISCUSSIONS

3.1 Current and Voltage Measurement Results Linked Series

Table 3.1 Solar module measurement with Slope angle 50° in the series

V (Volt)	I (Ampere)	P = V.I (Watt)
0	1.6	0
42	0	0
5	1.6	8
10	1.5	15
20.3	1.5	30.45
35.5	1.4	49.7
36.7	1.2	44.04

From Table 3.1 the measurement results with a slope angle of 50° , the characteristics of the module can be seen in Figure 4.6 below. At a voltage of 0 Volts, a large current of 1.5 Ampere, the power generated is 0 Watts. When the voltage is 35 Volts, the current is 1.4 Amper and the resulting power is 49.7 Watts.

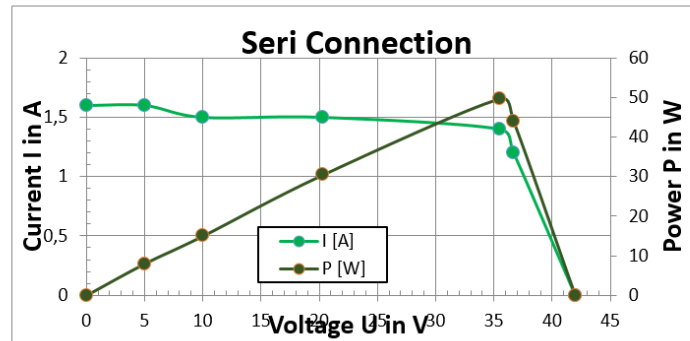


Fig 3.1 Characteristics of the Model ET 250 Photovoltaic Module Connected Series with a slope angle of 50°

Table 3.2 Solar module measurement with tilt angle 55° in the series

V (Volt)	I (Ampere)	P = V.I (Watt)
0	1.4	0
20.6	0	0
1.8	3.1	5.58
7.2	3.0	21.6
18.3	2.8	51.24
19.2	2.1	40.32
19.5	1.6	31.2
19.6	1.4	27.44
19.7	1.1	21.67
19.8	0.7	13.93

From Table 3.2 the measurement results with a slope angle of 55° , the characteristics of the module can be seen in Figure 4.7 below. At a voltage of 18.3 Volts, a large current of 2.8 Ampere, the power generated is 51 Watts. When the voltage is 19.2 Volts, the current is 2.1 Amper and the resulting power is 40.32 Watts.

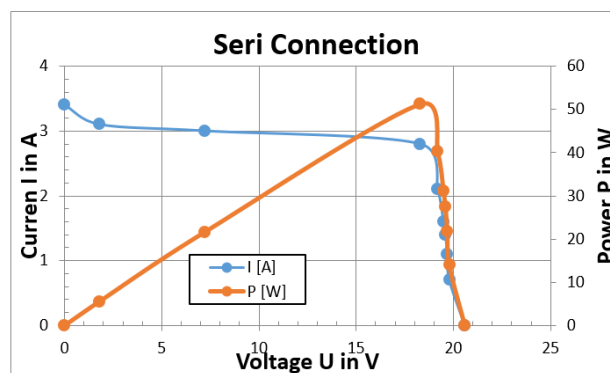


Fig 3.2 Characteristics of the ET 250 Model Photovoltaic Module Connected Series with a slope angle of 55°

Table 3.3 Solar module measurement Slant angle 62.5° in the series

V (Volt)	I (Ampere)	P = V.I (Watt)
0	2.6	0
38	0	0
19.7	2.5	9.85
19.8	0.6	11.88
20	0.7	14

From Table 3.3 the measurement results with a slope angle of 62.5° , the characteristics of the module can be seen in Figure 4.8 below. At a voltage of 19.7 Volts, a large current of 2.5 Ampere, the power generated is 9.85 Watts. When the voltage is 19.8 Volts, the current is 0.6 Amper and the resulting power is 11.88 Watts.

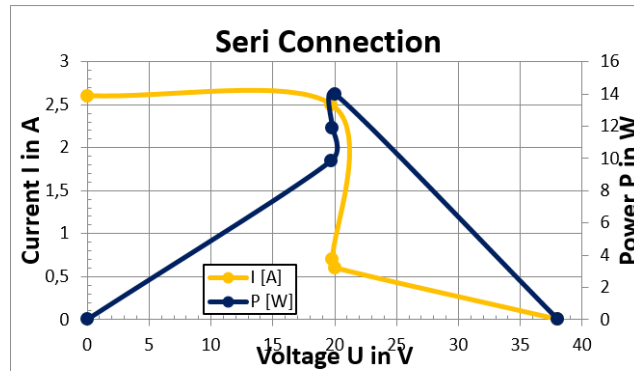


Fig 3.3 Characteristics of the Model ET 250 Photovoltaic Module Connected Series with a slope angle of 62.5°

Table 3.4 Solar module measuring with Tilt angle 70.3° in series

V (Volt)	I (Ampere)	P = V.I (Watt)
0	1.1	0
42	0	0
3.2	1	3.2
17.3	0.9	15.6
17.7	0.8	14.1
20.8	0.7	14.5
37.6	0.6	22.6
38	0.5	19
38.1	0.4	15.2

From Table 3.4 the measurement results with a slope angle of 70.3° , the characteristics of the module can be seen in Figure 4.9 below. At a voltage of 37.6 Volts, a large current of 0.6 Ampere, the resulting power is 22.6 Watts. When the voltage is 38 Volts, the current is 0.5 Amper and the resulting power is 19 Watts.

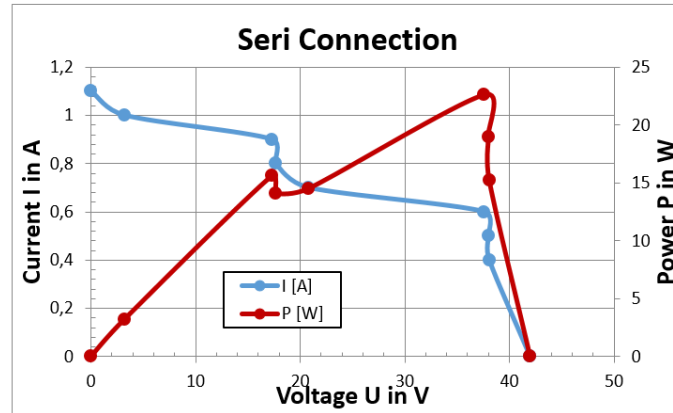


Fig 3.4 Characteristics of the Model ET 250 Photovoltaic Module Connected Series with a slope angle of 70.3°

Table 3.5 Solar measurement module with Slope angle 88° in the series

V (Volt)	I (Ampere)	P = V.I (Watt)
0	1.5	0
39.3	0	0
38.2	0.8	30.56
38.5	0.7	26.95
38.6	0.6	23.16
38.8	0.5	19.4

From Table 3.5 of the measurement results with a slope angle of 88°, the characteristics of the module can be seen in Figure 4.10 below. At a voltage of 19.7 Volts, a large current of 2.5 Ampere, the power generated is 9.85 Watts. When the voltage is 19.8 Volts, the current is 0.6 Amper and the resulting power is 11.88 Watts.

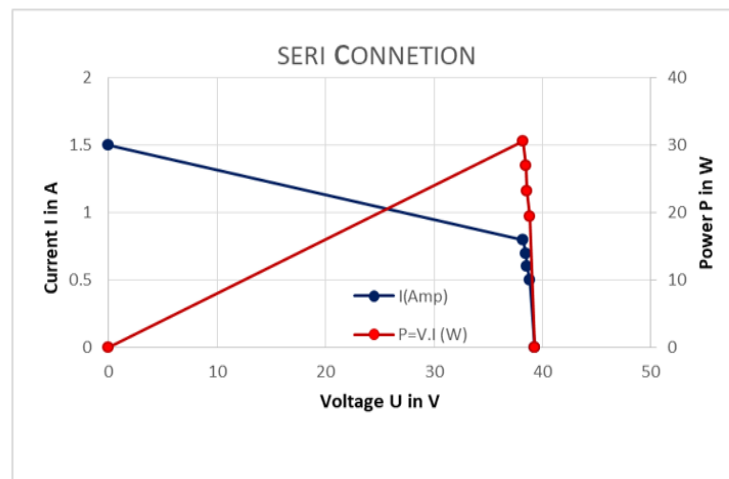


Fig 3.5 Characteristics of the Model ET 250 Photovoltaic Module Connected Series with a slope angle of 88°

3.2 Parallel Connected Current and Voltage Measurement Results

Table 3.6 Solar module measurement with Slope angle 50° in parallel connect

V (Volt)	I (Ampere)	P = V.I (Watt)
0	3.2	0
20.5	0	0
5.7	3.0	17.1
10.6	3.0	31.8
15	3.0	45
20	1.3	26
20.3	0.6	12.18

From Table 3.6 the measurement results with a slope angle of 50°, the characteristics of the module can be seen in Figure 4.11 below. At a voltage of 10.6 Volts, a large current of 3.0 Ampere, the resulting power is 31.8 Watts. When the voltage is 15 Volts, the current is 3.0 Ampere and the resulting power is 45 Watts.

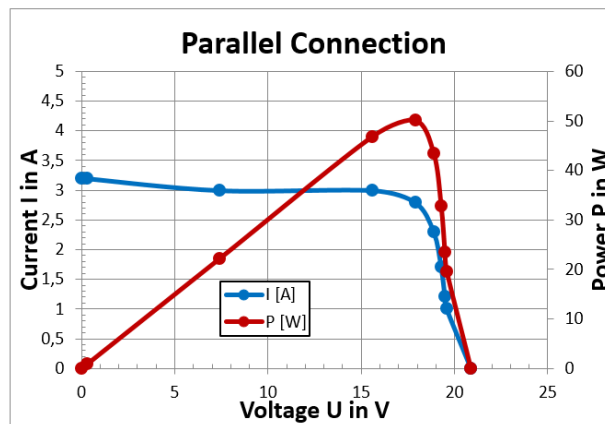


Fig 3.6 Characteristics of the Model ET 250 Photovoltaic Module Connected Parallel with a slope angle of 50°

Table 3.7 Solar module measurement with Tilt angle 55° in parallel

V (Volt)	I (Ampere)	P = V.I (Watt)
0	3.2	0
20.9	0	0
0.3	3.2	0.96
7.4	3.0	22.2
15.6	3.0	46.8
17.9	2.8	50.12
18.9	2.3	43.47
19.3	1.7	32.81
19.5	1.2	23.4
19.6	1.0	19.6
10.7	0.8	15.76

From Table 3.7 the measurement results with a slope angle of 55° , the characteristics of the module can be seen in Figure 4.12 below. At a voltage of 15.6 Volts, a large current of 3.0 Ampere, the resulting power is 46.8Watts. When the voltage is 17.9 Volts, the current is 2.8 Amper and the resulting power is 50.12 Watts.

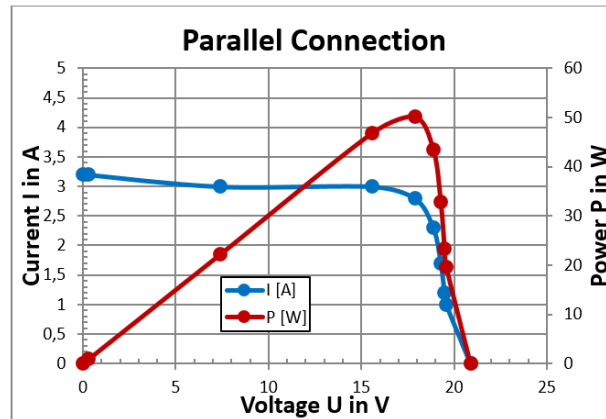


Fig 3.7 Characteristics of the Model ET 250 Photovoltaic Module Connected Parallel with a slope angle of 55°

Table 3.8 Solar module measurement Slant angle 62.5° in parallel

V (Volt)	I (Ampere)	P = V.I (Watt)
0	4.2	0
21.5	0	0
6.7	4.0	26.8
11.6	4.0	46.4
16	4.0	64
21	2.3	48.3
21.3	1.6	34.08

From Table 3.8 the measurement results with a slope angle of 62.5° , the characteristics of the module can be seen in Figure 4.13 below. At a voltage of 16 Volts, a large current of 4.0 Ampere, the power generated is 64 Watts. When the voltage is 21 Volts, the current is 2.3 Amper and the resulting power is 48.3 Watts.

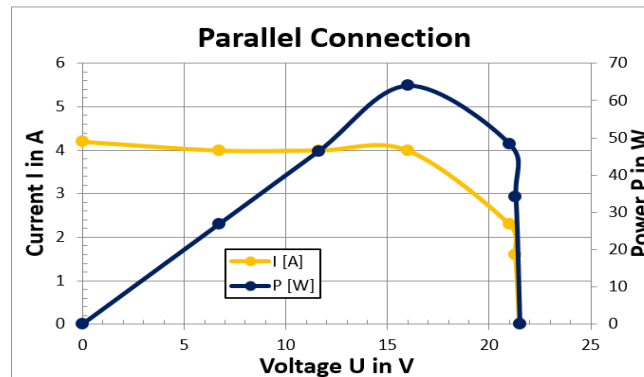


Fig 3.8 Characteristics of the Model ET 250 Photovoltaic Module Connected Parallel with a slope angle of $62,5^\circ$

Table 3.9 Solar module measurement Slant angle 70.3° in parallel

V (Volt)	I (Ampere)	P = V.I (Watt)
0	2.0	0
20.1	0	0
19.7	0.2	3.9
19.5	0.3	5.9
19.4	0.4	7.8
19.2	0.5	9.6
19.1	0.6	11.5
19	0.7	13.3
18.9	0.8	15.1
18.8	0.9	16.9
18.7	1	18.7
18.6	1.1	20.5
18.5	1.2	22.2
18.4	1.3	23.9
18.3	1.4	25.6
18.2	1.5	27.3
18.1	1.6	28.9
17.8	1.7	30.3

From Table 3.9 the measurement results with a slope angle of 70.3°, the characteristics of the module can be seen in Figure 4.14 below. At a voltage of 18.1 Volts, a large current of 1.6 Ampere, the power generated is 28.9 Watts. When the voltage is 17.8 Volts, the current is 1.7 Amper and the resulting power is 30.3 Watts.

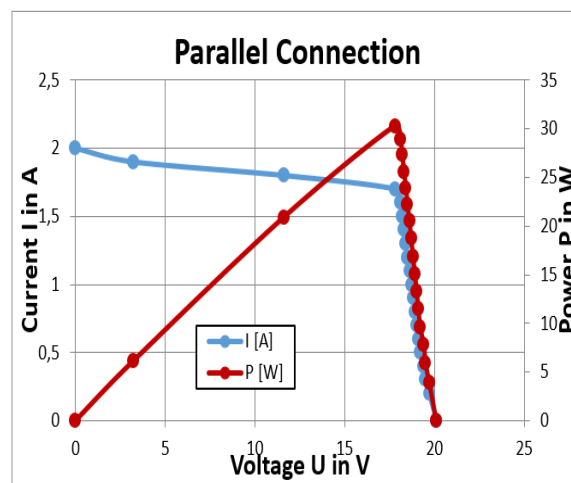


Figure 3.9 Characteristics of the Model ET 250 Photovoltaic Module Connected Parallel to a slope angle of 70.3°

Table 3.10 Solar module measurement Slant angle 88° in parallel connect

V (Volt)	I (Ampere)	P = V.I (Watt)
0	2.5	0
21.3	0	0
4.9	2.4	11.76
9.4	2.3	21.62
19.5	2.1	40.95
19.7	1.9	37.43
19.8	1.8	35.64
20	1.4	28
20.3	1.0	20.3
20.4	0.8	16.32

From Table 3.10 of measurement results with a slope angle of 88° , the characteristics of the module can be seen in Figure 4.14 below. At a voltage of 19.5 Volts, a large current of 2.1 Ampere, the power generated is 40.95 Watts. When the voltage is 19.7 Volts, the current is 1.9 Amper and the resulting power is 37.43 Watts

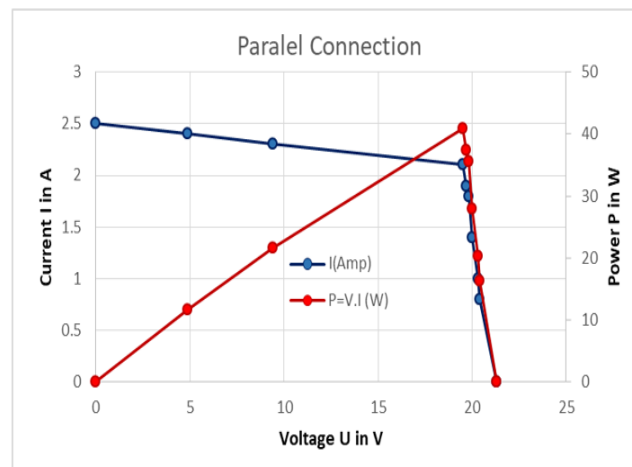


Figure 3.9 Characteristics of the Model ET 250 Photovoltaic Module Connected Parallel to a slope angle of 88°

CONCLUSION

The current-voltage curve is nonlinear. The greater the load resistance, the closer the load voltage will be to the value of the open connect voltage (V_{oc}) of the solar panel. While the smaller the load resistance, the current flowing into the load will get closer to the short circuit current (I_{sc}) of the solar panel while the power-voltage curve is nonlinear. Solar panel power will be maximum if at the load flows the maximum current (I_m) and has a maximum voltage (V_m). The addition of a load that has resistance (R) is smaller than the maximum load resistance, then the power will increase close to the maximum power value (P_m) of the solar panel. While the increase in the load that has resistance (R) is greater than the maximum load resistance, the power will decrease from the maximum power of the solar panel.

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