Solar Cell Performance Test against Load Variations

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Abstract— Solar cell is a converter of light energy into electrical energy. This study aims to examine the characteristics of the solar cell to load variations. The research was conducted at the Semarang State Polytechnic Energy Conversion Lab. The solar cell used in the research of the monocrystalline solar cell type KTENG CP-520S. The research method is carried out by measuring the value of solar intensity, voltage and electric current from the solar cell, then calculating the value of the power and efficiency of the solar cell. The greater the intensity of sunlight, the better the characteristics of the solar cell with a note that the solar cell surface temperature must be stable at 250C. The results showed that the highest input power of the solar cell was 5293.69 watts at a lamp load of 115 watts at 833.6 W/m2 of radiation during sunny weather. The highest value of the output power of the solar cell is 191.52 watts when the lamp is loaded with 190 watts of radiation at 739.4 W/m2 during sunny weather. While the highest value of the load output power is 212.43 watts when the lamp is loaded with 200 watts of radiation at 724.4 W/m2 when the weather is sunny. The highest efficiency of the solar cell is 4.13% when the lamp is loaded with 200 watts of radiation at 724.4 W/m2 when the weather is sunny. And the highest value of Solar Power Plant efficiency is 4.61% at a 200 watt lamp loading at 724.4 W/m2 radiation when the weather is sunny.

Keywords—solar cell, intensity, electrical current, radiation.

I. INTRODUCTION

In his book, Biological Fuels, Christ Lewis predicts that natural gas will run out in 2047, oil in 2080, and coal in 2180. This is because fossil energy is explored on a large scale and is not proportional to the time the fossil energy was formed. [2]. With these facts, efforts to find alternative energy sources are increasingly being carried out. One of the efforts made is the use of solar energy to yield electrical energy. To produce electricity, a device is used to collect solar radiation energy that reaches the earth's surface and converts it into electrical energy. These devices are called solar panels or solar cells. Solar power plants are renewable energy power plants that offer great potential in global energy life for the future. Solar energy is available everywhere and can be obtained for free. The energy released by the sun's rays is actually only received by the earth's surface by 69% of the total solar energy. The supply of solar energy from sunlight received by the earth's surface is enormous, reaching 3 x 1024 joules per year, this energy is equivalent to 2 x 1017 Watts. This amount of energy is equivalent to 10,000 times the energy consumption of the entire world today. In other words, by covering only 0.1 percent of the earth's surface with a solar cell device that has an efficiency of 10 percent, it is able to cover energy needs around the world today.

II. RESEARCH METHODS

The main tool used here is a tool that already exists in the main device used, namely the KTENG CP-520S Solar Power Generation test device. These tools include:

1. Solar Panel
   This solar panel is the main equipment used for Solar Power Plants. There are 4 solar panels in total. Each of the 2 pieces is connected in series then the 2 pieces of the series are paralleled. The specifications of this solar panel are as follows:

Maximum power	200 Watt
Nominal voltage	24 Volt DC
Dimensions	1.62 m x 0.98 m x 0.05 m
Mass	19 Kg

2. Join Box
   This join box functions to combine several sources of generation. This tool has a voltage capability of 1 kV and a current of 11 Ampere.
3. Charge Controller
   This Charge Controller functions to regulate the voltage from generation to battery charging. This tool can also adjust the charging voltage for 12 V, 24 V, and 48 V DC voltages.
4. Inverters
   This inverter is used to convert DC voltage to AC. The inverter used is an inverter with a capacity of 600 W, the input voltage is 24 Volts DC, the Output voltage is 220 Volts AC.
5. Battery
   The battery used is a 12 Volt battery with a 55 Ah capacity. The number of batteries used are 2 pieces which are connected in series, so the total voltage is 24 Volts.
6. Control Panel
   This control panel functions to control the system and also manage the devices used. On this control panel there are switches, NFB, as well as a display of voltage, current, and power measuring instruments.

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The test scheme here provides an overview of the test outline. This test scheme can be seen in the following figure:

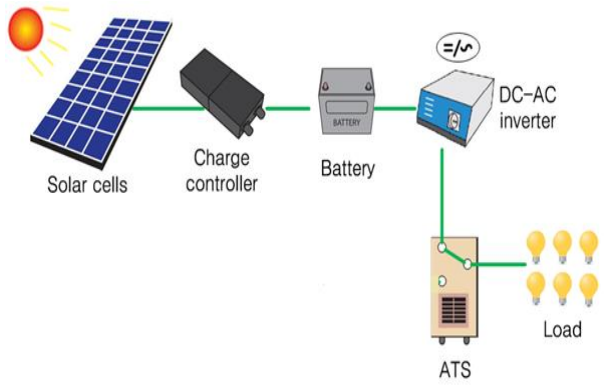

Fig. 1. Test scheme

The generation from the solar power plant is entered into the Join Box which is then connected to the charge controller. The charge controller regulates the voltage used to charge the battery. So the magnitude of the charging voltage is greater than the battery voltage. And thus the charging process can occur. In addition to charging, generation is also used to turn on the load. If the resulting power is not able to lift the load then the battery will help in supplying power for loading. The load installed is in the form of an AC load, whereas on the generating side it is in the form of DC. The inverter here converts the DC voltage into AC voltage which will later be used to turn on the load.

The wiring diagram on the control panel for testing the Analysis of Solar Cell Characteristics against Load Variations is as follows:

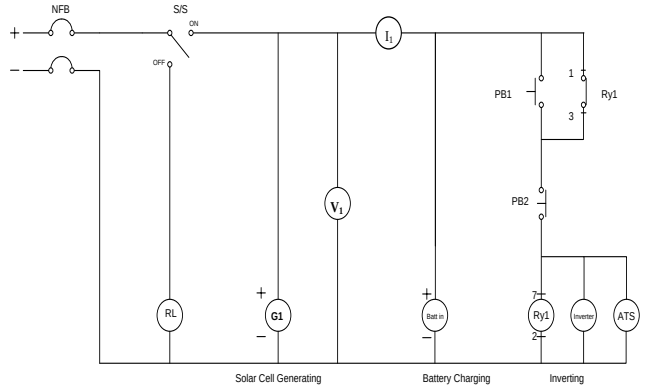

Fig. 2. Wiring diagram on control panel

Description: NFB: NO Fuse Breaker
SS : Select switch
RL : Red Lamp
G1 : Solar generator
V_1: Voltmeter before inverter
I_1 : Ampere meter before inverter
PB_1: Push button 1, PB_2: Push button 2
RY_1: Relay 1, RY_2: Relay

The load is installed separately by connecting the circuit to the ATS output. For this load circuit can be seen in the following figure:

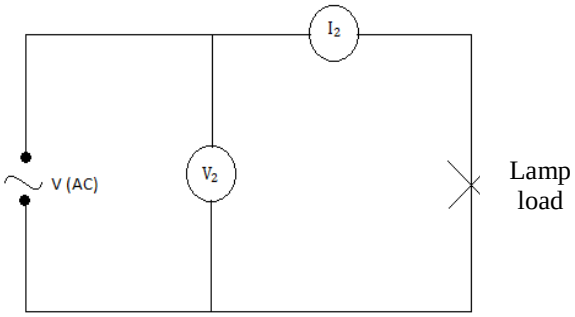

Fig. 3. Load wiring diagram

III. RESULTS AND DISCUSSION

The experimental data can be seen in the following tables 1 and 2.

Table 1. Test data in sunny weather.

No	Load (Watt)	Solar Cell			Load	
		Output Voltage (volt)	Output Current (Ampere)	Irradiation (W/m²)	V (volt)	I (A)
1.	0	38,7	1	713	198	0
2.	10	26	1,8	719,2	192	0,04
3.	15	25,7	2,3	721,5	198	0,15
4.	25	25,2	2,6	726,4	205.5	0,19
5.	30	24,9	3,1	746,7	207	0,23
6.	40	25,2	2,7	758,5	210	0,24
7.	45	24,7	3,3	762,3	210	0,24
8.	50	24,7	3,6	769,4	212.4	0,26
9.	55	24,4	4,1	776,5	216	0,33
10.	60	24,2	4,6	776,4	225	0,39
11.	65	24,4	4,4	798,4	220	0,36
12.	70	24	4,8	799,5	222	0,41
13.	80	23,3	5,8	816,4	240	0,51
14.	90	23,6	5,3	825,9	237	0,47
15.	100	23	6,4	828,4	243	0,58
16.	110	23	6,3	833,2	243	0,58
17.	115	22,8	6,6	833,6	240	0,6
18.	125	22,7	6,7	829,5	240	0,63
19.	130	22,6	7,1	824,8	237	0,68
20.	140	22,3	7,6	817,3	231	0,76
21.	150	22,5	7,3	798,4	234	0,71
22.	160	22,2	7,9	779,1	228	0,81
23.	170	22,1	8,1	768,5	225	0,84
24.	180	22,2	7,4	747,8	228	0,78
25.	190	22,8	8,4	739,4	222	0,89
26.	200	21,6	8,8	724,4	219	0,97

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Table 2. Test data on cloudy weather

No	Load (Watt)	Solar Cell			Load	
		Output Voltage (volt)	Output Current (Ampere)	Irradiation (W/m²)	V (volt)	I (A)
1.	0	32,6	0,9	437,88	189	0
2.	10	25,2	1,9	446,32	186	0,1
3.	15	24,2	1,4	452,89	186	0,09
4.	25	24,4	2,5	458,12	225	0,19
5.	30	22,7	2,1	459,12	225	0,14
6.	40	21,4	2,4	463,53	222	0,17
7.	45	21,4	2,6	464,21	189	0,22
8.	50	21,5	3,6	469,38	210	0,31
9.	55	23,4	3,2	474,93	210	0,25
10.	60	23,2	4,2	494,86	225	0,36
11.	65	21,6	4,6	530,81	234	0,39
12.	70	20,8	3,9	540,25	192	0,34
13.	80	20,5	4,1	568,33	204	0,37
14.	90	20,7	5,5	549,88	225	0,49
15.	100	19,8	5,2	472,17	231	0,41
16.	110	19,6	5,5	461,63	210	0,56
7.	115	19,7	5,8	457,01	211	0,59
18.	125	18,2	6,4	454,31	204	0,62

From the data, calculations are carried out so the results are obtained as table 3. and table 4. below:

Table 3. Calculation results of the solar cell test in sunny weather

NO.	Irradiation W/m²	Load (watt)	P output solar (watt)	P load output (watt)	E (watt)	η_{solar} (%)	η_{PLTS} (%)
1.	713	0	38,7	0	4527,83	0,85	0
2.	719,2	10	46,8	7,68	4567,21	1,02	0,16
3.	721,5	15	59,11	29,7	4581,81	1,29	0,64
4.	726,4	25	65,52	39,04	4612,93	1,42	0,84
5.	746,7	30	77,19	47,61	4741,84	1,62	1,01
6.	758,5	40	68,04	50,4	4816,77	1,41	1,04
7.	762,3	45	81,51	50,4	4840,91	1,68	1,04
8.	769,4	50	88,92	55,22	4885,99	1,82	1,13
9.	776,5	55	100,04	71,28	4931,08	2,02	1,44
10.	776,4	60	111.32	87,75	4930,45	2,25	1,77
11.	798,4	65	107,36	79,2	5070,15	2,12	1,56
12.	799,5	70	115,2	91,02	5077,14	2,26	1,79
13.	816,4	80	135,14	122,4	5184,46	2,61	2,36
14.	825,9	90	125,08	111,39	5244,79	2,38	2,12
15.	828,4	100	147,2	140,94	5260,67	2,79	2,67
16.	833,2	110	144,9	140,94	5291,15	2,73	2,66
17.	833,6	115	150,48	144	5293,69	2,84	2,72
18.	829,5	125	152,09	151,2	5267,65	2,88	2,87
19.	824,8	130	160,46	161,16	5237,81	3,06	3,07
20.	817,3	140	169,48	175,56	5190,18	3,26	3,38
21.	798,4	150	164,25	166,14	5070,15	3,24	3,27
22.	779,1	160	175,38	184,68	4947,59	3,54	3,73
23.	768,5	170	179,01	189	4880,28	3,66	3,87
24.	747,8	180	164,28	177,84	4748,82	3,45	3,74
25.	739,4	190	191,52	197,58	4695,48	4,07	4,21
26.	724,4	200	190,08	212,43	4600,22	4,13	4,61

Table 4. Calculation results of solar cell tests on cloudy weather.

NO	Irradiation W/m²	Load (watt)	P output Solar (watt)	P load output (watt)	E (watt)	η_{solar} (%)	η_{PLTS} (%)
1.	437,88	0	29,34	0	2780,71	1,05	0
2.	446,32	10	47,88	18,6	2834,31	1,68	0,65
3.	452,89	15	33,88	16,74	2876,03	1,17	0,58
4.	458,12	25	61	42,75	2909,24	2,09	1,46
5.	459,12	30	47,67	31,5	2915,59	1,63	1,08
6.	463,53	40	51,36	37,74	2943,61	1,74	1,28
7.	464,21	45	55,64	41,58	2947,91	1,88	1,41
8.	469,38	50	77,4	65,1	2980,75	2,59	2,18
9.	474,93	55	74,88	52,5	3015,99	2,48	1,74
10.	494,86	60	97,44	81	3142,55	3,11	2,57
11.	530,81	65	99,36	91,26	3370,85	2,94	2,71
12.	540,25	70	81,12	65,28	3430,81	2,36	1,91
13.	568,33	80	84,05	75,48	3609,12	2,32	2,09
14.	549,88	90	113,85	110,25	3491,95	3,26	3,15
15.	472,17	100	102,96	94,71	2998,46	3,43	3,15
16.	461,63	110	107,8	11,.6	2931,53	3,67	4,01
17.	457,01	115	114,26	124,49	2902,19	3,93	4,28
18.	454,31	125	116,48	126,48	2885,05	4,03	4,38

IV. CONCLUSION

The results obtained from this study can be concluded that the greater the solar radiation, the better the characteristics of the solar cell, with a note that the surface temperature of the solar cell must be stable at 25 degrees Celsius, an increase in temperature higher than the normal temperature in the PV cell will weaken the voltage (Voc). This current weakening causes a decrease in the output power of the solar cell. On testing the solar cell, the solar cell surface area is A = 6.3504 m2. The determination of the slope of the solar cell angle is obtained from the calculation of the declination angle of 21,01º, thus the sun's position is north of the equator. From the tests carried out, the highest value of the input power of the solar cell is 5293.69 watts at a lamp load of 115 watts at 833.6 w/m2 irradiation can be obtained in sunny weather conditions. From the tests carried out, the highest value of the solar cell output power of 191.52 watts at a lamp load of 190 watts at 739.4 w/m2 irradiation was obtained in sunny weather conditions. From the tests carried out, the highest value of the load output power of 212.43 watts at a 200 watt lamp loading at 724.4 W/m² irradiation was obtained in sunny weather conditions. From the tests carried out, the highest value of solar cell efficiency was 4.13% at the loading of 200 watt lamps at 724.4 W/m² irradiation in sunny weather conditions. 200 watt lamps at 724.4 W/m² irradiation can be obtained in sunny weather conditions.

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