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Micro-Solar Power Plant with Capacity of 900 Watt for Power Supply of Rural Village Information System

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Abstract **- Electricity is the primary energy needs of the community. Depletion in this energy led the electrical energy crisis. Thus renewable sources of energy become attractive nowadays not only in Indonesia but also worldwide. As tropical country, Indonesia has solar energy potential that can be developed for solar power plant. Indonesia receives sunlight for an average 7 to 8 hours a day. However, the potential is not yet been optimally explored. In this work, micro-scale solar power plant (PLTS) with capacity of 900 watt is tested, The plant uses solar panel 2x50 Wp, solar charger controller 12 volt, 10 ampere, and deep-cycle battery of 100 Ah. The test is conducted in the field, hence the real performance of the plant can be observed. Power output of the PLTS is used for rural village information system which consists of amplifier and loudspeaker. The existence of PLTS is important for rural village. Indonesia receives sunlight in average of 7-8 hours/day. Measured voltage, current, solar intensity at normal climate are 13.26-18.73 volt, 0.23-4.52 ampere, 25000-118500 lux, respectively. Maximum calculated power output is found to be 83.40 watt whereas average solar panel output is 371.07 watt, thus conversion efficiency is 97%. Charging power from PWM solar charger controller is an average of 227.44 watt and total discharging power is 167.96 watt means that efficiency of 89% is obtained.**

Keywords: Renewable Energy, PLTS, information system, battery

1. INTRODUCTION

Electricity, the primary needs, is very important in daily life, either for individual used or global used, such as industrial, transportation, communication-information, and agriculture. Fossil fuels experience depletion in 21st century. On the other hand, the energy of energy increases, especially in industrial country. During 2000 to 2030, it is predicted 70% fuel consumption increased. In 2015, the need of electricity reaches 19.5 till 20 trillion kWh. However, the need can be supplied only 12.4 trillion by oil fuel and natural gas fuel [1]

Solar energy, one of many renewable energies, is a potential source of energy for electricity generation. The use of solar panel in order to utilize sunlight has been explored since 1970. The solar energy is clean energy which is eco-friendly with no emission to be worried [2].

Indonesia has a huge solar energy potential, about 4.8 kWh/m^2.day. The potential is due to Indonesia as a tropical country where solar irradiation intensity is relatively higher. The value is equivalent to peak sun hour (PSH) of 4.8 hours/day. However, utilization of the potential is very low [3].

Solar panel (photovoltaic cell) is a semiconductor device that consists of p-n junction diode. The junction leads electrons transferred from n type semiconductor to p type semiconductor and vice versa for pole movement [3]. Based on the explanation, the electrons and pole movement results in photo generation as shown in Figure 1

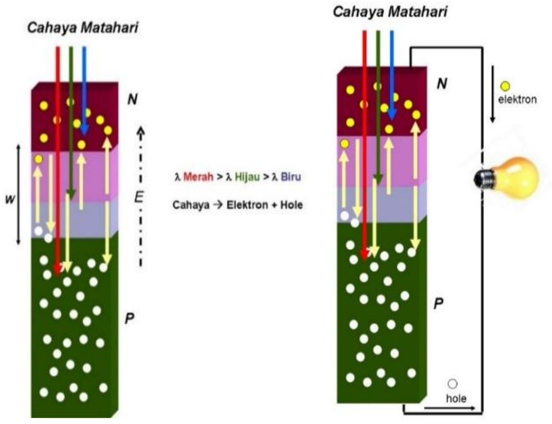

Fig. 1. Photo generation process
[www.energisurya.com]

Parameter of solar panel or photovoltaic in order to produce optimum electrical energy is affected by basic characteristic of solar panel. The parameter as a reference for being used to figure out the performance of the solar panel in generating electricity. The graph of the parameter i-V of solar panel is given in Figure 2 [5]

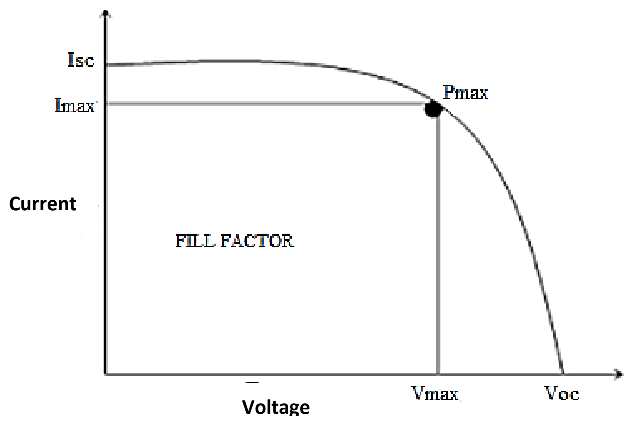

Fig. 2. The curve of I-V parameter of solar panel

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Short Circuit Current (Isc) is defined as maximum possible current output of solar panel which is released without resistance or shortcut. On the other hand, *Open Circuit Voltage* (Voc) is maximum achievable voltage by solar panel without load (no current from solar panel to load) [6]

Maximum power point (*Vmp and Imp*) on the I-V curve is optimum operation where the optimum power is generated by solar panel when loaded. The maximum power output can be calculated as :

$$P.max = V_{OC} . I_{SC} . FF_{Pmax} = Voc . Isc . FF \qquad (1)$$

where : Pmax = Maximum power (MPP)
Voc = Open circuit voltage
Isc = Open circuit current
FF = Fill Factor

Fill factor (FF) is a parameter that effects the maximum power of solar panel and also the quality. The important characteristic of FF is written as

$$\frac{Vmpp.Impp}{Voc.Isc} \; FF = \frac{Vmpp.Impp}{Voc.Isc} \qquad (2)$$

where : FF = Fill Factor
Vmpp = Maximum voltage
Impp = Maximum current

Conversion efficiency is defined as a ratio of power output of solar panel to solar power gain by solar panel. Solar energy reaches outer layer of atmospheric is approximately 136 MW/cm^2, and about 100 MW/cm2 through the earth during a daytime. The conversion efficiency is formulated in Equation 3 [7]

$$\eta = \frac{V \, x \, I}{P \, x \, A} \% \; \eta = \frac{VxI}{PxA} \% \qquad (3)$$

where : V = generated power
I = Solar panel current
P = Power density to the panel
A = Cross sectional area of the panel

Generated power can be calculated using equation 4 [8]

$$P = V \times I \qquad (4)$$

where: P = Power (Watt);
V = voltage (Volt)
I = current (Ampere)

Solar charger controller (SSC) a battery regulator circuit that consist of electronic devices. The SSC is very important during battery charging process. The equipment automatically prevents over charging and over voltage [9]

Minimal of 8 ampere is needed by the SSC. This leads for using PWM type of the CC with specification of 12 volt and 10 ampere (equivalent to 120 watt). Figure 3 presents the PWM SCC

Fig. 3. PWM Solar Charger Controller, 12V-10A

Battery has a function of energy storage that generated by solar panel. Battery convert chemical energy into electrical energy. Battery capacity in terms of Ampere Hours (Ah) is given on battery specification. Figure 4 shows the deep-cycle battery being used in this work (SHOTO 12V-100Ah).

Fig 4. Deep-cycle battery of SHOTO 12V-10A

Riset data yang digunakan berupa data penyinaran matahari di D.I.Yogyakarta yang mencakup wilayah desa singosaren, Imogiri, Bantul.Data tersebut diambil dari badan meteorologi dan geofisika (BMKG) kelas I DIY berikut Tabel 1 data lama penyinaran dan suhu

Table 1 shows sun exposures time and temperature within a year in Singosaren, Bantul, Yogyakarta which were recorded by BMKG.

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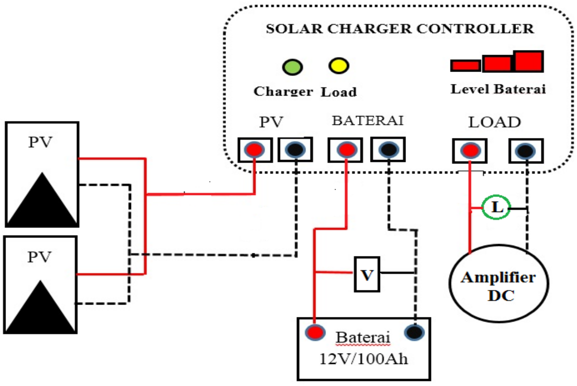
Table 1. Solar exposures time and temperature [BMKG,2015]

Month	Solar exposure (hours/day)	Temp MIN	Temp MAX
January	5,6	24	33
February	6,4	24	33
March	5,8	24	32
April	5,5	24	30
May	8	23	31
June	8,6	23	32
July	8,6	23	32
August	9,4	23	32
September	8,5	23	32
October	8,6	21	31
November	5	20	31
December	3,7	20	31
Average	7,0	22,4	26,2

According to table 1, calculation procedure for PLTS uses a minimum exposure time of 3.7 hours/day

2. METHODOLOGY

Designing wire diagram for PLTS. The wiring diagram for the PLTS is shown in Figure 5



Gambar 5. Wiring Diagram of the PLTS

The PLTS is tested with load of information system. The loads are loudspeaker TOA ZD 230 and amplifier ZH5025BM as shown in Figure 6. Total operating power of the load is 196 watt.

Fig. 6. The information system (amplifier & loudspeaker)

Based on the calculation, it is required 28.3 Wp capacity of the solar panel. Due to availability of the panel, a 50 wp solar panel is used in this work. Because not only for power supply of the information system but also for backup, two solar panel in parallel are used (2 x 50 wp). With the parallel circuit, the solar panel able to generate higher current, thus higher power output.

Table 2. Measured data

Iintensity Light (Lux)	Temp (°C)	Humidity (Rh%)	Voltage (volt)	Current (Amp)	Load (watt)
11850	36.6	49.9	18.73	4.52	84.66
11760	35.8	52.6	18.7	3.7	69.19
11410	34.8	53.4	18.66	0.65	68.11
11260	35.5	52.5	18.55	3.49	64.74
11250	34.2	53.3	18.65	1.42	26.48
11030	34.1	51.6	17.75	0.98	17.4

Table 3. Charging measurement

Line Panel Surya			Line ACCU		
Voltage (volt)	Current (Amp)	Power (watt)	Voltage (volt)	Current (Amp)	Power (watt)
18.57	4.22	86.66	10.94	4.58	47.95
18.27	3.72	79.23	11.47	3.86	44.35
18.6	3.75	68.45	12.35	3.11	39.45
18.5	3.59	69.11	13.55	3.25	35.35
18.45	2.42	65.32	13.58	1.58	26.12

Table 4. Load discharging process

Line input (ACCU)			Line Output (Load)		
Voltage (volt)	Current (Amp)	Power (watt)	Voltage (volt)	Current (Amp)	Power (watt)
13.5	0.25	3.37	13.58	0.1	0.13
13.45	6.38	85.90	13.45	6.2	82.22
13.46	0.44	5.78	13.43	0.13	1.74
13.44	6.78	91.83	13.42	6.35	83.87
13.55	6.87	86.98	13.41	6.36	67.96
Power All		273.51	Power All		236.60

The test is conducted for 6 days from 05.00 am to 05.00 pm. Average value of measured data are shown in Table 2 to Table 3

3. RESULT AND DISCUSSION

The analysis result of solar panel in terms of electrical current and voltage can be seen in Table 2. Voltage (V) and ampere (A) as a function of solar intensity, temperature, relative humidity during the day. Based on Figure 7, the graph shows initial voltage of 18.73 volt and current of 4.53 occur at solar intensity of 118500 lux and temperature of 36.6 0C. The final voltage at the end of the graph is 17.75 vold.

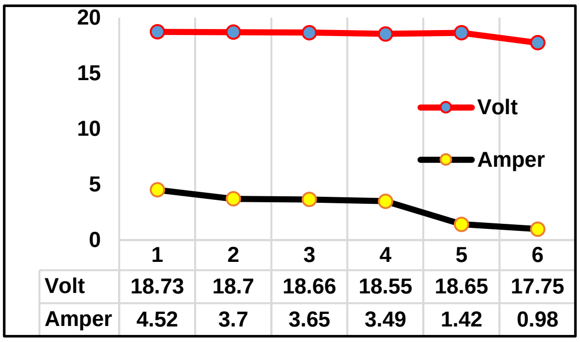


Fig. 7. Voltage and current

Discharging process is used for load with DC power source of amplifier and relay device which is used for converter activation, thus working principle of inverter follows the solar charger controller working principle as shown in Figure 8

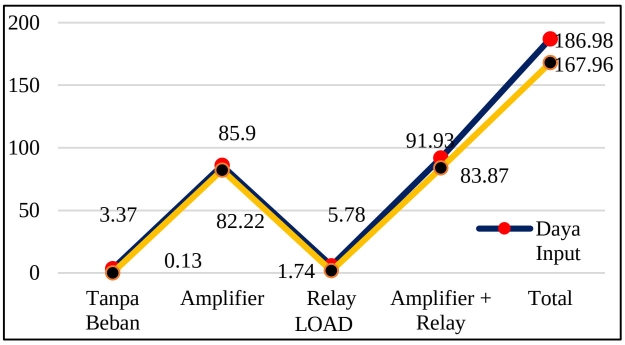


Fig. 8. Load discharging process

CONCLUSION

Voltage and electrical current are affected by solar intensity and temperature. Maximum 18.73 Volt and 4.53 Ampere are obtained at solar intensity of 118500 lux, temperature of 36.6 0C, and relative humidity of 49.9%

1. Power output of 367.77 watt is generated by solar panel where the value is over Accumulator power capacity. Total power charging battery of 273.51 is achieved per day, thus energy conversion efficiency is 97%
2. PWM solar charger controller has efficiency of 89%. The PWM unable to maintain the maximum power generated by solar panel, hence more power occurs.
3. Battery with deep-cycle characteristic has better performance than conventional battery for solar power plant. Besides, free maintenance and longer lifetime, the deep-cycle battery has no significant drop.

SUGGESTION

For optimum utilization of power output from solar panel, it is suggested for using MPPT solar charger controller instead of the PWM type. The MPPT model is equipped with temperature sensor, ampere sensor, and voltage sensor, thus maintain performance of PLTS.

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