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Hybrid Power Plant Prototype (Solar and Microhydro) Stand Alone System

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ABSTRACT: Electrical energy generated by solar power and micro hydro power plants can be combined to serve the electrical needs of a load. The combination of two or more generators is known as a Hybrid Power Generation System. Both generators are designed to work alternately depending on the output voltage generated. The problem found is how to design a battery charging control to choose which power plant will distribute electrical energy to the battery automatically. This paper presents a miniature design of an automatic battery charging system in a hybrid power plant between a solar power plant and a micro hydro power plant using a voltage sensor. Miniature solar power plants use solar panels with a capacity of 20 W type GH20M-36, while micro hydro power plants use 18 DC generators, 1750 rpm type D63 DC MOTOR VP3312D. The result is that the switch can work to distribute electrical energy from one generator when the other generator is not active or when the generator output voltage value is at a lower value than other power plants.

KEYWORDS: Hybrid Power Plant, PLTS, PLTMH, Automatic Switch.

I. INTRODUCTION

[1].National electricity production is still dominated by fossil-fuel power plants (coal, gas, fuel), around 66% to s.d. 80%. In 2025, the share of NRE in primary energy power plants is around 34% (249 million BOE), increasing to 43% in 2050, and reducing the dominance of fossil energy. The NRE share has taken into account the co-firing of coal-fired power plants, nuclear power plants, and biofuels for diesel power plant (in Indonesia it is called PLTD).

[2].According to the Director-General of Electricity, the Electrification Ratio has currently reached 99.45 percent of the 2021 target of 100 percent. This electrification ratio has increased by 0.25 percent from 2020 which was 99.20 percent..This means that there is still 0.55% of the total population of Indonesia who still cannot enjoy electrical energy.

[3].Development of New and Renewable Energy (EBT) such as solar energy, wind, water, geothermal, sea waves are the main choices for renewable energy. replacing the role of fossil energy use in meeting national electricity needs.

[4].Renewable energy can be combined to work together to serve electricity needs in rural areas that are far from the reach of main power plants.

[5],[6], [7].Solar energy is environmentally friendly energy that does not cause pollution. It has enormous potential to be developed in the tropics to meet the needs of household electricity, transportation and street lighting.

[8].Until now, research related to solar energy continues to be developed. Petru A. Cotfas, made a solar energy generator using a lens as a concentrator of sunlight, the result is that the efficiency is affected by the open surface.

[9].Baraa Mahmoud Dawoud, made a comparative analysis on the performance of fixed-mounted solar PV systems with solar PV with SAT systems using the PVSyst 6.83 application. The results obtained indicate that the system with the optimization case provides a good increase in efficiency with a low reduction in thermal efficiency compared to constant flow.

[10].The power generated by solar energy is proportional to the intensity of sunlight received by photovoltaic.

[11]**.**The power generated by solar panels can be calculated by equation:

$$P_{\mathrm{PV}} = I_{\mathrm{T}}\, \eta\, A_{\mathrm{PV}} \quad (1)$$

$$\eta = \eta_{\mathrm{mod}}\, \eta_{\mathrm{PC}}\, P_{\mathrm{r}} \quad (2)$$

$$\eta_{\mathrm{m}} = \eta_{\mathrm{r}}\, (1-(T_{\mathrm{C}} - T_{\mathrm{r}}) \quad (3)$$

where **:**

η_{r} = efficiency module references,
η_{PC} = efficiency power conditioning,
η_{mod} = efficiency of module
I_{T} = total solar radiation of the panel

P_r = factor of packing,
β = temperature coefficient of efficiency array
T_r = the reference temperature for cell efficiency
T_c = monthly mean cell temperature
APV = solar array area

[12].APV module will work optimally if the ambient temperature is at 25^{0}C. An increase in temperature higher than the normal temperature will reduce the performance of the PV module in generating voltage. Each 1oC increase will reduce about 0.5% of the total power generated.

[13].Lithium batteries can work in two operating modes, namely: automotive mode (MO) and energy storage mode (MP).

[14].Whereas the resulting energy efficiency of PV panels is affected by the accumulation of dust and debris, even on a single panel in the array.

[15], [16].The solar energy produced is then stored into a storage medium (battery) to be used so that the electricity needs of the load will be maintained at all times. Management of the regulation of the use of electric power is important for energy sustainability and efficiency.

[17].In general, the battery charging system from solar cells uses the P&O (perturb and observation) technique. The MPPT (Maximum Power Point Temperature) technique was chosen based on the consideration that this technique has a simple algorithm and is able to track the maximum power potential of solar cells.

[18].On the other hand, micro-hydro energy is also an option to be developed, especially in remote areas that have water resources but are far from the reach of PLN (State Electricity Company). This power plant can be combined with a stand-alone solar energy generator as a solution to overcome the current electrical energy crisis. Combining micro-hydro energy sources with solar photovoltaic energy can increase electricity service time economically so that the electricity load for remote areas can be fulfilled optimally.

[11]**.**The micro hydro power plant (in Indonesia it is called PLTMH) consists of a generator, water (hydro) and turbine. The discharge capacity and water level are the parameters needed for the performance of the MHP [19]. The water turns the turbine so that it gets mechanical energy and is used to turn a generator that produces electricity. The amount of power obtained at the MHP can be calculated by the following equation:

$$P= \rho \; x \; Q \; x \; H \; x \; \eta \; x \; g \quad (4)$$

Description:
P = turbine power (Watts)
η = turbine efficiency
ρ = density of water (kg/m)
Q = the water flow (m3/ s)
H = effective head (m)
g = force of gravity (m/ s)

This study aims to build a battery charging system for a miniature hybrid power plant between a solar power plant using a solar panel capacity of 20 W type GH20M-36 and a micro hydro power plant using an 18 kW 1750 rpm DC generator type D63 DC MOTOR VP3312D.

II. SOLAR PANEL AND MICROHYDRO POWER PLANT PROTYPE

EQUIPMENT USED FOR RESEARCH HYBRID POWER PLANT PROTYPE (SOLAR PANEL AND MICROHYDRO)

The method used in this research is to build a miniature hybrid power plant and test it in the electrical engineering laboratory of Gunadarma University in Indonesia. Overall, the miniature hybrid power plant consists of several units, including the following:

1. Micro-hydro power generation unit, which converts water energy into electrical energy. In

this section there is a water turbine, pully van belt and a DC generator. This study uses a Pelton turbine as a water turbine in MHP. The Pelton turbine is in charge of converting the entire flow of water into velocity energy before entering the turbine runner. Pully Van Belt as speed transmission from turbine rotation to generator. The DC generator functions to convert the potential energy of water through the turbine and gear box into electrical energy.

2. Solar Power Plant (in Indonesia it is called PLTS), this section contains a solar panel (photovoltaic) which functions to convert solar energy into electric charge. Solar panels with a capacity of 20 Wp (Watt Peak) type GH20M-36. Shown in table 1 is the technical data of the solar panels used in this study.
3. Solar Charger Controller
   The charge controller is an electronic device that functions to regulate the charging of direct current (DC) from the solar panel to the battery which is called the charge process and the regulation of the distribution of electric current from the battery to the electrical load is called the discharge process.
4. Sensor and Selector Switch
   The sensor is in the form of measuring voltage from the results of voltage measurements produced by PLTS and PLTMH power plants for further comparison using a comparator circuit. The results of this comparison move the selector switch which has been set to connect the switch contact point to the battery. The selector switch is a relay switch that is used to connect the battery and which generator has a higher voltage.
5. Battery, Inverter and Electrical Load Equipment
   Battery as a medium for storing electrical energy. In this study, a 12V gel type VRLA battery was used. The inverter is used to convert the DC to AC voltage from the battery. The inverter has a capacity of 1000 W with an input voltage of 12 V and an output voltage of 220 V with a frequency of 50 Hz. Electrical load equipment in the form of lights, personal computers and other inductive loads.

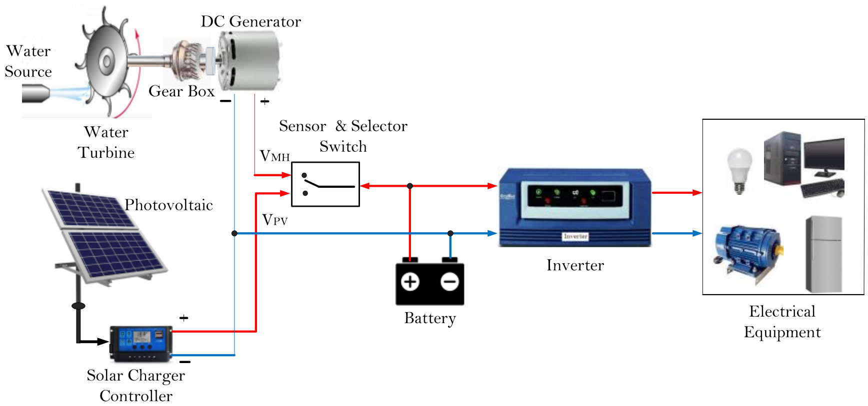

Fig. 1. Architecture of Hybrid Power Plant (PLTH)

III. EXPERIMENTATION

Fig. 2 In general describes the working principle of the design of a hybrid power plant. The workings of the entire series of miniature hybrid power plants is that when both generators work, the comparator circuit will compare the voltages of each generator using the LM741 IC. MHP is connected to the non-inverting (+) leg of ICLM741 (Comparator) and PLTS is connected to the inverting (-) leg of IC LM741, then IC LM741 will compare the voltages as follows:

When the PLTMH voltage is greater than the PLTS voltage, the output of the LM741 IC will be ±10Volt (VSS) which causes the BD139 transistor to activate and the relay to work. The relay that works makes the NO (Normally Open) contact connected to the COM relay contact. The MHP which is connected to the NO relay will supply electric current from the VMH to the battery. On the other hand, if the PLTS voltage is higher than the PLTMH voltage, the switch will be connected to VPH (Normally Closed) so that the solar panels will flow electric charge to the battery. Thus the process of charging the battery will always alternate depending on which power plant voltage is greater.

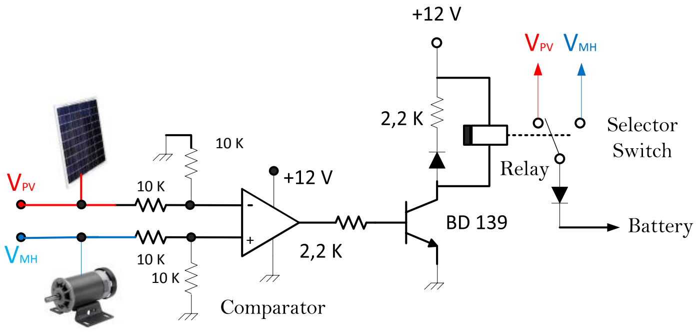

Fig. 2. Line diagram of replacement of soloar cell with hydropower generator

IV. OBESERVATIONS FROM THE TESTS SOLAR CELL WITH HYDROPOWER GENERATOR

Table 2. shows the influence of the generator rotational speed on the voltage generated by the generator, the higher the generator rotational speed, the greater the voltage and current generated by the generator. With the lowest voltage of 13.2V and the lowest current of 0.12A at generator rotational speed of 320RPM and the highest voltage of 13.64V and the highest current of 1.47A at generator rotational speed of 900RPM.

Measurement of the Power Produced by MHP When Charging the Battery

Measurement of generator power is measured using a DC wattmeter to measure the voltage, current, and power generated each time.

Table 2. Measurement of Generator Voltage and Current with Battery Load on Generator Rotation Speed

BATTERY LOAD PLTMH		
VOLTAGE (V)	CURRENT (A)	SPEED (RPM)
13.2	0.12	320
13.2	0.25	380
13.24	0.41	450
13.27	0.52	500
13.36	0.65	550
13.39	0.80	615
13.39	0.90	715
13.64	1.47	900

Table 3(a) to 3(g), describes the measurement of voltage, current, and power generated by the MHP for 7 days. The MHP works after the PLTS voltage is lower than the MHP voltage, so data collection starts from 17.00 WIB - 06.00 WIB with a 30 minutes break each time to rest the water pump. It appears that the highest average voltage output is on 7 September 2021 with an average of 13.97V and the lowest average voltage is on 2 September 2021 with an average of 12.8V. The average current output is almost the same every day with an average of 0.1A – 0.11A. The largest average power is on 6 September 2021 with an average of 1.47W and the lowest average power is on 2 September and September 5th with an average power of 1.37W. The largest average watt hour output is on September 8, 2021 with an average of 1.32Wh and the lowest average power is on September 3 with an average of 1.2Wh. From the data obtained, it can be calculated that the average power generated by MHP every 1 hour is 1.27Wh and the average power that can be generated by MHP is 11.47Wh.

Measurement of generator power is measured using a DC wattmeter to measure the voltage, current, and power generated each time.

Table 3(a). Measurement of PLTMH Output When Charging Batteries on 09/02/2021

Date: 09/02/2021 (with 30 minutes motor rest per session)				
Time Duration	Voltage (V)	Curren (A)	Power (W)	Watt Hour (Wh)
17:00 – 18:00	12.73	0.10	1.273	1.3
18:30 – 19:30	12.74	0.10	1.274	1.1
20:00 – 21:00	12.75	0.10	1.275	1.2
21:30 – 22:30	12.78	0.12	1.5336	1.2
23:00 – 24:00	12.79	0.11	1.4069	1.1
24:30 – 01:30	12.81	0.11	1.4091	1.4
02:00 – 03:00	12.78	0.10	1.278	1.2
03:30 – 04:30	13.03	0.10	1.303	1.3
05:00 – 06:00	12.82	0.12	1.5384	1.2
Total	-	-	-	11.0
Average	12.80	0.11	1.37	1.22

Table 3(b). Measurement of PLTMH Output When Charging Batteries on 09/03/2021

Date: 09/03/2021 (with 30 minutes motor rest per session)				
Time Duration	Voltage (V)	Curren (A)	Power (W)	Watt Hour (Wh)
17:00 – 18:00	13.17	0.1	1.317	1.1
18:30 – 19:30	13.21	0.11	1.4531	1.2
20:00 – 21:00	13.21	0.12	1.5852	1.3
21:30 – 22:30	13.22	0.11	1.4542	1.2
23:00 – 24:00	13.24	0.12	1.5888	1.2
24:30 – 01:30	13.25	0.11	1.4575	1.2
02:00 – 03:00	13.27	0.10	1.327	1.3
03:30 – 04:30	13.29	0.10	1.329	1.1
05:00 – 06:00	13.29	0.11	1.4619	1.2
Total	-	-	-	10.8
Average	13.24	0.11	1.44	1.20

Table 3(c). Measurement of PLTMH Output When Charging Batteries on 09/04/2021

Date: 09/04/2021 (with 30 minutes motor rest per session)				
Time Duration	Voltage (V)	Curren (A)	Power (W)	Watt Hour (Wh)
17:00 – 18:00	12.55	0.10	1.255	0.9
18:30 – 19:30	12.58	0.11	1.3838	1.2
20:00 – 21:00	12.59	0.11	1.3849	1.3
21:30 – 22:30	12.63	0.11	1.3893	1.2
23:00 – 24:00	12.67	0.11	1.3937	1.3
24:30 – 01:30	13.17	0.10	1.317	1.2
02:00 – 03:00	13.15	0.10	1.315	1.2
03:30 – 04:30	13.21	0.12	1.5852	2.4
05:00 – 06:00	13.20	0.11	1.452	1.1
Total	-	-	-	11.8
Average	12.86	0.11	1.39	1.31

Table 3(d). MHP Output Measurement When Charging Batteries on 09/05/2021

Date: 09/05/2021 (with 30 minutes motor rest per session)				
Time Duration	Voltage (V)	Curren (A)	Power (W)	Watt Hour (Wh)
17:00 – 18:00	13.06	0.11	1.4366	1.3
18:30 – 19:30	13.09	0.10	1.309	1.3
20:00 – 21:00	13.11	0.11	1.4421	1.3
21:30 – 22:30	13.14	0.11	1.4454	1.1
23:00 – 24:00	13.15	0.10	1.315	1.3

24:30 – 01:30	13.16	0.10	1.316	1.3
02:00 – 03:00	13.17	0.11	1.4487	1.3
03:30 – 04:30	13.21	0.10	1.321	1.3
05:00 – 06:00	13.21	0.10	1.321	1.3
Total	-	-	-	11.5
Average	13.14	0.10	1.37	1.28

Table 3(e). Measurement of PLTMH Output When Charging Batteries on 09/06/2021

Date: 09/06/2021 (with 30 minutes motor rest per session)				
Time Duration	Voltage (V)	Curren (A)	Power (W)	Watt Hour (Wh)
17:00 – 18:00	13.42	0.11	1.4762	1.3
18:30 – 19:30	13.45	0.11	1.4795	1.5
20:00 – 21:00	13.5	0.11	1.485	1.3
21:30 – 22:30	13.57	0.11	1.4927	1.3
23:00 – 24:00	13.60	0.11	1.496	1.3
24:30 – 01:30	13.74	0.10	1.374	1.1
02:00 – 03:00	13.72	0.11	1.5092	1.4
03:30 – 04:30	13.78	0.10	1.378	1.2
05:00 – 06:00	13.77	0.11	1.5147	1.4
Total	-	-	-	11.8
Average	13.62	0.11	1.47	1.31

Table 3(f). Measurement of PLTMH Output When Charging Batteries on 09/07/2021

Date: 09/07/2021 (with 30 minutes motor rest per session)				
Time Duration	Voltage (V)	Curren (A)	Power (W)	Watt Hour (Wh)
17:00 – 18:00	13.76	0.11	1.5136	1.2
18:30 – 19:30	13.77	0.10	1.377	1.3
20:00 – 21:00	13.77	0.11	1.5147	1.1
21:30 – 22:30	13.86	0.10	1.386	1.5
23:00 – 24:00	13.96	0.10	1.396	1.1
24:30 – 01:30	13.99	0.10	1.399	1.4
02:00 – 03:00	14.17	0.11	1.5587	1.2
03:30 – 04:30	14.18	0.10	1.418	1.4
05:00 – 06:00	14.25	0.10	1.425	1.3
Total	-	-	-	1.5
Average	13.97	0.10	1.44	1.28

Table 3(g). Measurement of PLTMH Output When Charging Batteries on 09/08/2021

Date: 09/08/2021 (with 30 minutes motor rest per session)				
Time Duration	Voltage (V)	Curren (A)	Power (W)	Watt Hour (Wh)
17:00 – 18:00	14.46	0.10	1.446	1.2
18:30 – 19:30	14.46	0.10	1.446	1.4
20:00 – 21:00	13.03	0.10	1.303	1.4
21:30 – 22:30	13.09	0.11	1.4399	1.4
23:00 – 24:00	13.11	0.11	1.4421	1.2
24:30 – 01:30	13.12	0.11	1.4432	1.4
02:00 – 03:00	13.12	0.10	1.312	1.3
03:30 – 04:30	13.16	0.10	1.316	1.3
05:00 – 06:00	13.20	0.10	1.32	1.3
Total	-	-	-	11.9
Average	13.42	0.10	1.39	1.32

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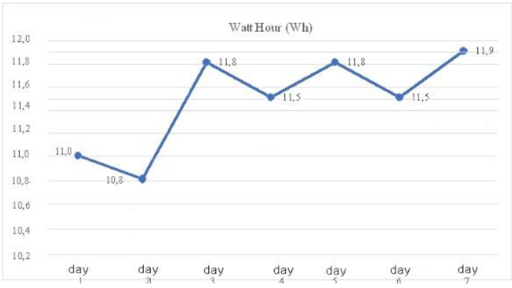
Fig. 3. shows the average output of MHP when charging the battery in the form of average voltage, average current, and average power generated by MHP. Can be seen in Fig. 3. the average voltage produced by MHP is relatively fluctuating while the average current and power produced by MHP is relatively stable.



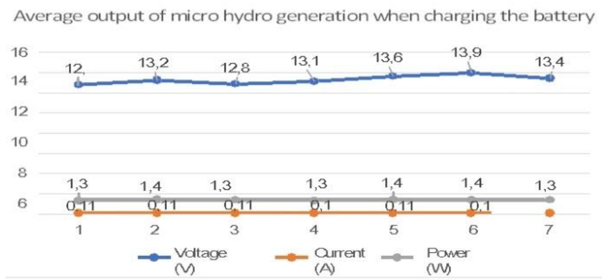


Fig. 3. Voltage, current and average output power of micro hydro generation during battery charging

Fig. 4. Total Watt Hour (Wh) Produced by Micro Hydro Generation Every Day

Fig. 4. shows the total watt hour (Wh) or the power produced per hour every day by MHP is relatively fluctuating with the highest total watt hour (Wh) of 11.9Wh and the lowest total watt hour (Wh) of 10.8Wh.

Load Test

The load testing is carried out to determine the load power (electrical equipment) that will be supplied by the hybrid power plant (PLTH). Measurement of the load (electrical equipment) is carried out using an AC wattmeter. PLTH load testing data can be seen in Table 4.

Table 4. Specifications of Load Power (Electrical Equipment) Used

LOAD (LECTRICAL EQUIPMENT)	POWER SPESIFICATION (W)	POWER MEASURED (W)
Fan	80	34.05
Iron	350	263.9
Cell phone charger	20	8.66
LED Lamp	20	16.3

In Table 4. are measurements taken using an AC wattmeter with a load power of 20W hp charger, 80W fan, 350W iron and 20W LED lamp so that the total load power specification is 470W.

Table 5. is a test carried out to determine the power used by the electrical load and the battery supply time to the electrical load. Can be seen in Table, the power used when the connected electrical load is 120W is 110 watt hour (Wh) and the battery is able to supply the load for 1 hour 7 minutes. When the connected load is 470W, the power used is 332.83Wh and the battery is able to supply the load for 41 minutes.

Table 5. Testing of Power Used and Battery Supply Time to Electrical Load

LOAD (LECTRICAL EQUIPMENT)	POWER SPESIFICATION (W)	POWER MEASURED (W)	WATT HOUR (WH)	TIME OPERATION
Fan + Cell phone Charger + LED 20W	120	54.9	110	1 hour 7 minutes
Fan + Cell phone Charger + LED 20W + Iron	470	267.4	332.83	41 minutes

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Comparator Circuit Test
The test on the comparator circuit aims to determine the input voltage from MHP and PLTS, the voltage at pin 2 (PLTS input voltage), the voltage at pin 3 (PLTMH input voltage), the voltage at pin 6 (output) IC LM741, the condition of the LED when MHP > PLTS and when PLTS > PLTMH, relay conditions when PLTMH > PLTS and when PLTS > PLTMH.

Table 6. Measurements and Conditions in the Comparator Circuit

GENERATOR	INPUT VOLTAGE (V)	VOLTAGE ON IC LM741			CONDITION		BATTERY CHARGER GENERATOR
		PIN 2 (V)	PIN 3 (V)	PIN 6 (V)	LED	RELAY	
PLTMH	13.94	-	6.97	8.45	ON	NO	PLTMH
PLTS	12.05	5.61	-				
PLTMH	12	-	6	0.0033	OFF	NC	PLTS
PLTS	14	7	-				

In Table 6 are measurements and conditions on the comparator circuit. Can be seen in Table 6 the voltage at pin 2 (PLTS input voltage) IC LM741 is not the same as the input voltage given by PLTS, that's because in the comparator circuit there is a voltage divider circuit. The voltage at pin 3 (PLTMH input voltage) IC LM741 is not the same as the input voltage given by the PLTS, this is because in the comparator circuit there is a voltage divider circuit.

When the PLTS (Solar Power Plant) voltage is greater than the MHP (Micro Hydro Power Plant) voltage, the IC LM741 output (pin 6) will be 0.0033Volt, the LED is off, the relay is also off and remains connected NC (Normally closed), so that the PLTS (Solar Power Plant) connected to the NC relay contacts will charge the battery or battery.
When the PLTS (Solar Power Plant) voltage is less than the MHP (Micro Hydro Power Plant) voltage, the IC LM741 output (pin 6) will be 8.45Volt, the LED is on, the relay is also on and the contacts are connected to NO (Normally open), so that the MHP (Micro Hydro Power Plant) connected to the NO relay contact will charge the battery or battery.

Solar Panel Testing
Testing of solar panels is carried out to determine the amount of current, voltage, and power generated at a certain time. The solar panel used is 20Wp (Watt peak) to charge the battery or VOZ brand 12V 18Ah battery, the maximum voltage is 13.8Volt for no-load conditions, and the voltage is 14.4-15Volt when loaded, charging the battery or battery is regulated by SCC (Solar). charge controller). To make it easier to collect test data, a DC watt meter is used which can display voltage, current, and power under load.

Table 7(a). Testing of solar panels on day 1

Date: 08/30/2021 (Day 1)						
Time	Voltage (V)	Current (A)	Power (W)	Energy (Wh)	Battery Voltage (V)	Description
08:00	12.32	0.34	4.19	1.5	12.40 – 13.00	Bright
09:00	13.00	0.64	8,32	4.3		Bright
10:00	13.37	0.84	11.23	8.6		Bright
11:00	13.28	0.47	6.24	11.5		Cloudy
12:00	13.03	0.00	0.00	15.7		Cloudy
13:00	13.31	0.43	5.72	19.5		Cloudy
14:00	13.22	0.20	2.64	25.8		Cloudy
15:00	13.32	0.28	3.73	28.2		Bright
16:00	13.27	0.18	2.39	32.5		Bright
17:00	13.04	0.00	0.00	32.5		Bright
Average	13.12	0.34	4.45	-	-	-

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Table 7(b). Testing of solar panels on day 2

Date: 08/31/2021 (2nd Day)						
Time	Voltage (V)	Current (A)	Power (W)	Energy (Wh)	Battery Voltage (V)	Description
08:00	13.78	0.44	6.06	1.1	12.80 – 13.80	Bright
09:00	13.84	0.58	8.03	7.7		Bright
10:00	13.45	0.20	2.69	12.8		Cloudy
11:00	13.10	0.00	0.00	16.9		Cloudy
12:00	13.33	0.12	1.60	20.3		Cloudy
13:00	13.90	0.50	6.95	24.5		Bright
14:00	17.75	0,57	10.12	29.2		Bright
15:00	13.52	0.10	1.35	32.2		Cloudy
16:00	13.45	0.00	0.00	35.8		Bright
17:00	13.33	0.00	0.00	35.8		Bright
Average	13.95	0.25	3.68	-	-	-

Table 7(c). Testing of solar panels on day 3

Date: 09/01/2021 (3rd Day)						
Time	Voltage (V)	Current (A)	Power (W)	Energy (Wh)	Battery Voltage (V)	Description
08:00	18.72	0.20	3.74	1.3	13.70 – 14.40	Bright
09:00	21.17	0.20	4.23	4.5		Bright
10:00	16.47	0.00	0.00	7.9		Bright
11:00	14.34	0.20	2.87	11.7		Cloudy
12:00	13.78	0.11	1.52	14.7		Cloudy
13:00	21.20	0.31	6.57	17.6		Bright
14:00	19.49	0.33	6.43	20.8		Bright
15:00	16.70	0.19	3.17	23.7		Bright
16:00	14.42	0.16	2.31	25.3		Bright
17:00	13.35	0.00	0.00	25.9		Bright
Average	16.96	0.17	3.08	-	-	-

Table 7(d). Testing of solar panels on the 4th day

Date: 09/02/2021 (4th Day)						
Time	Voltage (V)	Current (A)	Power (W)	Energy (Wh)	Battery Voltage (V)	Description
08:00	13.68	0.45	6.16	0.7	10.70 – 12.60	Cloudy
09:00	12.32	0.47	5.79	4.6		Bright
10:00	12.55	0.83	10.42	8.0		Bright
11:00	12.64	0.91	11.50	18.2		Bright
12:00	12.73	0.85	10.82	27.3		Bright
13:00	12.61	0.2	2.52	29.0		Cloudy
14:00	12.80	0.57	7.30	36.3		Bright
15:00	12.69	0.13	1.65	39.6		Bright
16:00	12.72	0.00	0.00	42.4		Bright
17:00	12.64	0.00	0.00	42.8		Bright
Average	12.74	0.44	5.62	-	-	-

Table 7(e). Testing of solar panels on day 5

Date: 09/03/2021 (5th Day)						
Time	Voltage (V)	Current (A)	Power (W)	Energy (Wh)	Battery Voltage (V)	Description
08:00	12.88	0.24	3.09	1.4		Bright
09:00	12.98	0.40	5.19	6.1		Bright
10:00	13.45	0.71	9.55	15.7		Bright
11:00	13.10	0.84	11.00	26.1		Bright
12:00	13.29	0.99	13.16	32.0		Bright

13:00	13.31	0.75	9.98	41.5	12.70 - 13.00	Bright
14:00	13.24	0.35	4.63	49.2		Bright
15:00	13.21	0.22	2.91	51.4		Cloudy
16:00	13.07	0.00	0.00	52.0		Bright
17:00	13.03	0.00	0.00	52.0		Bright
Average	13.16	0.45	5.95	-	-	-

Table 7(f). Testing of solar panels on day 6

Date: 09/04/2021 (6th Day)						
Time	Voltage (V)	Current (A)	Power (W)	Energy (Wh)	Battery Voltage (V)	Description
08:00	13.68	0.5	6.84	1.9	13.20 - 14.40	Bright
09:00	14.15	0.7	9.91	9.3		Bright
10:00	14.24	0.83	11.82	19.4		Bright
11:00	14.02	0.3	4.21	28.6		Bright
12:00	20.94	0.39	8.17	33.0		Bright
13:00	12.55	0.44	5.52	36.0		Bright
14:00	12.38	0.31	3.84	40.6		Bright
15:00	12.52	0.26	3.26	43.9		Cloudy
16:00	12.53	0.14	1.75	46.7		Bright
17:00	12.49	0.00	0.00	47.0		Bright
Average	13.95	0.39	5.53	-	-	-

Table 7(g). Testing of solar panels on the 7th day

Date: 09/05/2021 (Day 7)						
Time	Voltage (V)	Current (A)	Power (W)	Energy (Wh)	Battery Voltage (V)	Description
08:00	12.74	0.21	2.68	2.1	12.50 – 12.80	Bright
09:00	12.83	0.44	5.65	4.0		Bright
10:00	13.00	0.78	10.14	12.8		Bright
11:00	13.09	0.81	10.60	21.0		Bright
12:00	13.10	0.51	6.68	34.6		Bright
13:00	13.60	0.3	3.92	38.8		Cloudy
14:00	13.11	0.37	4.85	40.9		Bright
15:00	13.70	0.42	5.75	47.1		Bright
16:00	13.12	0.24	3.15	50.1		Bright
17:00	12.91	0.00	0.00	50.1		Bright
Average	13.07	0.41	5.34	-	-	-

Table 7. is a table for testing solar panels for 7 (seven) days. The average temperature when it's sunny is ±32ºC, when it's cloudy ±27ºC, and it's raining ±25ºC to equalize perceptions of sunny, cloudy, and rainy. The temperature data is obtained from weather.com. The highest average stress in table 4.2. obtained on September 1, 2021 or on the 3rd day of testing of 16.96Volt and the lowest average voltage was obtained on September 2, 2021 or on the 4th day of 12.74Volt. The highest average current is in table 7(e) obtained on September 3, 2021 or on the 5th day of testing of 0.45Amperes and the lowest average current was obtained on September 1, 2021 or on the 3rd day of 0.17Amperes. The highest average power is in table 7(e) obtained on September 3, 2021 or on the 5th day of testing of 5.95Watt and the lowest average power was obtained on September 1, 2021 or on the 3rd day of 3.08Watt. The highest watt hour is in table 7(e) obtained on September 3, 2021 or on the 5th day of testing of 52Wh and the lowest watt hour was obtained on September 1, 2021 or on the 3rd day of 25.9Wh. The average voltage, current, and power on the test results can also be seen in Fig. 5.

On the 3rd day, the solar panel voltage is higher, current, power, and watt hour are lower than other days because the battery or battery is full, with a voltage of 13.8Volt. The high voltage occurs because the SCC (Solar charge controller) disconnects the battery or battery because it is full so that there is no overcharge.

On day 4, the battery voltage is at the minimum safe limit, which is around 10.7Volt. The

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charging process was carried out from 08:00 to 17:00, the battery voltage was found to be at 12.6Volt and only fully charged (13.8Volt) on the 6th day which means it takes about 22 hours, because at 12:00 a.m. to 6 solar panel voltage is 20.94Volt (charging is cut off by SCC).

Fig. 5. shows the average output of solar panels for 7 (seven) days.

Fig. 6. is a graph of the total watt hour (Wh) of solar panels for 7 (seven) days for charging batteries or batteries.

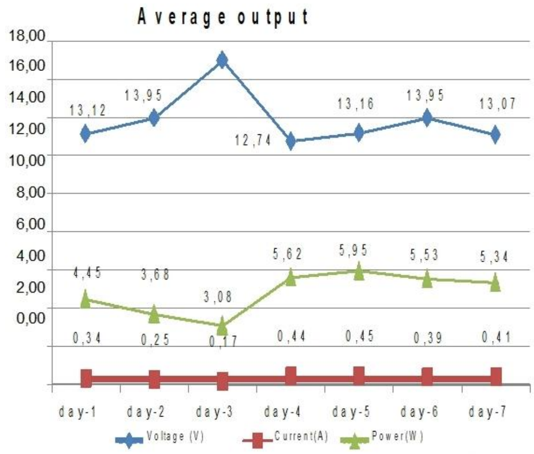

Fig. 5. Average output of solar panels

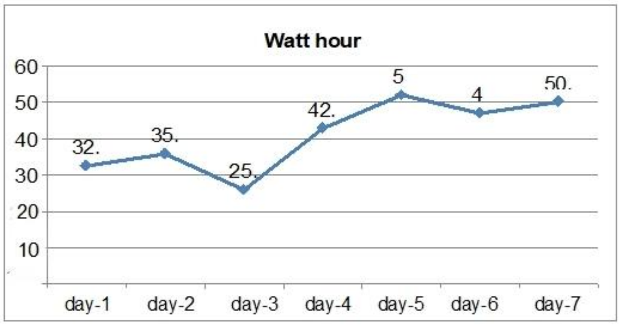

Fig. 6. Total watt hour (Wh) of solar panels

V. CONCLUSION

The prototype of a hybrid system power plant using solar panels and a micro hydro power plant using a DC generator has been completed. The following conclusions can be drawn: The DC generator used in this study has a maximum voltage specification of 180V, revolutions per minute of 3400RPM, maximum current of 3A, and maximum power of 200W. The largest voltage produced by the micro-hydro power plant (PLTMH) without a load with a generator rotation speed of 1180RPM is 64.9V and the smallest voltage produced by a no-load PLTMH with a generator rotational speed of 300RPM is 16.5V. The largest voltage produced by a micro hydro power plant (PLTMH) with a battery load with a generator rotational speed of 900RPM is 13.64V and the smallest voltage produced by a PLTMH with a battery load with a generator rotational speed of 320RPM is 13.2V. The decrease in the rotational speed of the generator and the voltage is affected by the load. Theoretically, when a load is connected to the generator terminals, current will begin to flow in the stator winding. The presence of resistance and reactance in the stator winding will result in a voltage drop. The average power produced by the MHP in one hour is 1.27Wh and the average produced in each day is 11.47Wh.

In solar power plants, after testing, the following results are obtained:

The largest daily average voltage produced by the 20Wp solar panel (Watt peak) in the test is 16.6Volt on the 3rd day because the battery or battery is fully charged. The largest daily average current generated by the 20Wp solar panel (Watt peak) in the test is 0.45A on the 5th day. The largest daily average power produced by the 20Wp solar panel (Watt peak) in the test was 5.95watt on the 5th day. The highest charging power obtained during the test was 52Wh (Watt hour) on the 5th day of testing. When the battery voltage is ±13.8Volt, the SCC (solar charge controller) will cut off charging to avoid overcharge or overvoltage in the battery or battery. The 20Wp (Watt peak) solar panel used can charge 18Ah VOZ batteries or batteries from a minimum safe voltage of 10.7Volt to a full 13.8Volt for ±22 hours. The inverter AC voltage output will be worth 207Volt AC when the battery voltage or VOZ brand battery is 10.8Volt DC, the 207Volt AC voltage is below the minimum safe limit of AC voltage recommended by PLN (State Electricity Company) is 209Volt AC.

SOME OF THE ADVANTAGES FROM THE ABOVE RESULTS

a) Eliminate the presence of power supply breaks throughout the day.

b)It can make clean energy, efficient and responsive.

REFERENCES

[1] Agency for the Assessment and Application of Technology, *OUTLOOK ENERGI INDONESIA 2021 Perspektif Teknologi Energi Indonesia: Tenaga Surya untuk Penyediaan Energi Charging Station*. 2021.

[2] F. D. WIJAYA, I. W. ADIYASA, and E. WINATA, "Analisis Faktor Kapasitas Pembangkit Listrik Hibrida PLTB dengan PLTD di Pulau Terpencil: Studi Kasus Elat Pulau Serau Maluku," *ELKOMIKA J. Tek. Energi Elektr. Tek. Telekomun. Tek. Elektron.*, vol. 9, no. 4, p. 746, 2021, doi: 10.26760/elkomika.v9i4.746.

[3] F. HIDAYAT, D. RUSIRAWAN, and I. R. FAJAR TANJUNG, "Evaluasi Kinerja PLTS 1000 Wp di Itenas Bandung," *ELKOMIKA J. Tek. Energi Elektr. Tek. Telekomun. Tek. Elektron.*, vol. 7, no. 1, p. 195, 2019, doi: 10.26760/elkomika.v7i1.195.

[4] B. Adebanji, O. Atoki, T. Fasina, O. Adetan, and A. Abe, "Comparative study of off-grid and grid-connected hybrid power system: issues, future prospects and policy framework," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 22, no. 2, p. 752, 2021, doi: 10.11591/ijeecs.v22.i2.pp752-759.

[5] R. Hossain *et al.*, "New Design of Solar Photovoltaic and Thermal Hybrid System for Performance Improvement of Solar Photovoltaic," *Int. J. Photoenergy*, vol. 2020, no. 1, 2020, doi: 10.1155/2020/8825489.

[6] S. SYAHRIAL, W. WALUYO, and A. F. FAKHRULLAH, "Studi Kapasitas Daya Pembangkit Listrik Tenaga Hibrida Angin dan Surya Berkapasitas 6 kW berdasarkan Skenario Cuaca," *ELKOMIKA J. Tek. Energi Elektr. Tek. Telekomun. Tek. Elektron.*, vol. 6, no. 1, p. 61, 2018, doi: 10.26760/elkomika.v6i1.61.

[7] E. Radwitya and A. Akhdiyatul, "Kajian Ekonomis PLT-Angin dan PLTS untuk Penerangan Jalan Umum (PJU)," *Elkha*, vol. 10, no. 1, p. 33, 2019, doi: 10.26418/elkha.v10i1.25329.

[8] P. A. Cotfas and D. T. Cotfas, "Solar Hybrid System Component Study in Low Concentrated Sunlight," *Int. J. Photoenergy*, vol. 2021, 2021, doi: 10.1155/2021/6677473.

[9] B. M. Dawoud and S. C. Lim, "Performance comparison of fixed and single axis tracker photovoltaic system in large scale solar power plants in Malaysia," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 21, no. 1, pp. 10–17, 2021, doi: 10.11591/ijeecs.v21.i1.pp10-17.

[10] I. Syarif and A. N. putri, "Desain Simulasi Stabilitas Frekuensi Beban Hybrid PLTS Dengan PLTD," *PROtek J. Ilm. Tek. Elektro*, vol. 7, no. 1, pp. 45–50, 2020, doi: 10.33387/protk.v7i1.1715.

[11] E. A. Syawal and R. Nazir, "Optimization of the Hybrid System for Micro Hydro, Photovoltaic and Biomass Power Generation in Senamat Ulu Village Using Homer Simulation," *J. Nas. Tek. Elektro*, vol. 10, no. 2, 2021, doi: 10.25077/jnte.v10n2.889.2021.

[12] Y. Chandra, "Analisis Ekonomi Energi Perencanaan Pembangunan PLTS (Studi Kasus Gedung Kuliah Politeknik Negeri Ketapang)," *Elkha*, vol. 8, no. 1, pp. 25–31, 2016, doi: 10.26418/elkha.v8i1.17617.

[13] J. Junaidi, K. H. Khwee, and A. Hiendro, "Migrasi Baterai Lithium dari Mode Otomotif ke Mode Penyimpan Energi untuk Sistem Pembangkit Listrik Tenaga Surya," *Elkha*, vol. 8, no. 2, pp. 40–43, 2016, doi: 10.26418/elkha.v8i2.19073.

[14] F. H. M. Noh *et al.*, "Development of solar panel cleaning robot using arduino," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 19, no. 3, pp. 1245–1250, 2020, doi: 10.11591/ijeecs.v19.i3.pp1245-1250.

[15] S. Muhardika, "Design of arduino-based loading management system to improve continuity of solar power supply," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 20, no. 3, pp. 1677–1684, 2020, doi: 10.11591/ijeecs.v20.i3.pp1677-1684.

[16] M. R. Basir Khan, J. Pasupuleti, J. Al-Fattah, and M. Tahmasebi, "Energy management system for PV-battery microgrid based on model predictive control," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 15, no. 1, pp. 20–26, 2019, doi: 10.11591/ijeecs.v15.i1.pp20-26.

[17] R. Rianda and H. Cahyono, "Implementasi Teknik P&O Pada Optimisasi Daya Pengisian Baterai Dari Sel Surya," *Elkha*, vol. 9, no. 2, p. 14, 2019, doi: 10.26418/elkha.v9i2.24355.

[18] N. Kurniasih and R. Nazir, "Analisis Mode Sistem Pembangkit Listrik Tenaga Hibrid Microhydro - Photovoltaic Array Menggunakan Homer (Studi Kasus : Kampung Bayang Janiah, Kabupaten Pesisir Selatan)," *J. Nas. Tek. Elektro*, vol. 4, no. 1, p. 30, 2015, doi: 10.25077/jnte.v4n1.114.2015.

[19] K. Kunek, "Pemodelan Electronic Load Controller Pada Beban Pembangkit Listrik Tenaga Mikro Hidro Merasap," *J. ELKHA*, vol. 7, no. 2, pp. 32–36, 2015.