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Design of Hybrid Solar Power Plant for household Electricity Loads 1300 VA

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ABSTRACT

Indonesia is a country that is rich in sunshine. Based on NASA's Power Data Access Viewer data in 2021, Indonesia has an average radiation level of 5.6 kWh/m2/day. This situation is a big advantage for Indonesia in utilizing solar energy into electrical energy through photovoltaic, especially in the Semarang City area which has an average radiation level of 5.6 kWh/m2/day. The house where the research is located is in Pudakpayung, Semarang City with a roof area of 24m2. The Hybrid Solar Power Plant that is designed is an electric power supply system whose sources come from the Solar Power Plant and the State Electricity Company alternately which are regulated automatically by automatic control equipment with battery capacity mode. The results of the calculation, the required components consist of 9 solar modules with a capacity of 120 WP, 4 batteries with a capacity of 12v100Ah, 1 unit of 3000Watt inverter and 1 unit of Solar Charger Controller 60A. The results of the tests that have been done, the solar panels produce an average power of 5446 wh per day, the battery will be full at 13.00.

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1. INTRODUCTION

Indonesia is a country based on its geographical location which is crossed by the equator so that it has great potential to utilize solar energy. This is because the amount of solar radiation is influenced by latitude, equatorial position, and atmospheric conditions,[1][2] Indonesia has a high radiation average of 5.6 Wh/m2/day[3].

For the conversion of sunlight into electrical energy, a Solar Power Center was made[4]. In this study, the Solar Power Center was made with a hybrid system where the electricity generated came from two sources, namely the Solar Power Center and the PLN electricity network [5]. Thus this system will help each other when one cannot free the load due to a lack of electrical power or a power outage occurs.[6] In this system. the energy source from the solar panel is accommodated in advance with the battery, and if the use automatically exceeds the battery capacity, it will automatically switch to PLN.

On the other hand, when a blackout occurs, the source will automatically switch to the battery. The advantage of this system is that it can cover the weaknesses of other systems[7]. In addition, it is easier to carry out maintenance because the electricity flow is maintained. In the operation of photovoltaic cells, there are factors that affect the performance and efficiency of these cells, including irradiation, temperature, and the angle of the photovoltaic cell to the sun [8]. In order for the output power to be maximized, photovoltaic cells must get maximum solar radiation so that the output power generated increases[9].

In this study, the author will design and implement a hybrid solar power center with PLN for households. How the Solar Power Center system works during the day around 10.00 – 14.00 with solar heat conditions, solar energy is absorbed by photovoltaic from solar cells which is then controlled by the Solar Charger Controller (SSC) for the battery. When the battery is charged and the voltage level exceeds 12 volts, the Auto Transfer Switch (ATS) will replace the electricity source from PLN to the Solar Charger Controller (SSC). When the battery voltage level exceeds the upper limit of 14 volts, the Solar Charger Controller (SSC) will cut off electricity from the photovoltaic to the battery[10]. When the heat cannot be absorbed by the photovoltaic, then the battery charging process is complete, the battery will continue to be used until the minimum usage limit has been determined, namely when the battery capacity is 20%. If the battery has reached the minimum capacity, ATS will automatically change the source to PLN[11]. This study aims to design and implement a Solar Power Center and PLN with a hybrid system with the aim of saving energy and costs[12].

2. RESEARCH METHOD

2.1. Design Stage

Estimated Expense, [13], [14] The installation location for the Solar Power Center is located on Jl. Muara Utama Housing G-4 Payung Mas Pudak Payung. Semarang. Central Java. Astronomically, Payung Mas Housing is located at -7.091160, 110.415564.

The use of electrical energy in households is very necessary to calculate the need for PV mini-grid components. In this study, the daily house load estimation was carried out by means of manual and periodic observations to determine the estimated daily load used every day. [15]

Table 1.
Estimated Daily Energy Needs

No	Item	Amount		Power (Watt)	Total (W)	Duration (hour)	Energy (wh)
1	Porchlight	1	Unit	12	12	12	144
2	Street light	1	Unit	12	12	12	144
3	Living room light	1	Unit	15	15	5	75
4	Bedroom light	4	Unit	10	40	5	200
5	Kitchen light	1	Unit	15	15	5	75
6	Bathroom light	3	Unit	7	21	2	42
7	Warehouse light	1	Unit	7	7	2	14
8	Dining room light	1	Unit	15	15	5	75
9	Living room light	1	Unit	14	14	5	70
10	Stair light	1	Unit	12	12	12	144
11	Backroom light	1	Unit	10	10	12	120
12	Workspace light	1	Unit	15	15	5	75
13	Iron	1	Unit	350	350	1	350
14	Router	1	Unit	30	30	24	720
15	Washing machine	1	Unit	350	350	1	350
16	Laptop	2	Unit	65	130	2	260
17	LCD TV 24" (bedroom)	1	Unit	60	60	4	240
18	Water pump	1	Unit	125	125	2	250
	Total load (W)				1233	Total (wh)	3348

From Table 1, it is known that the total daily household energy is 3,348 Wh, with a total load of 1233 W. If the daily load is in hourly time, the load graph can be seen as below.

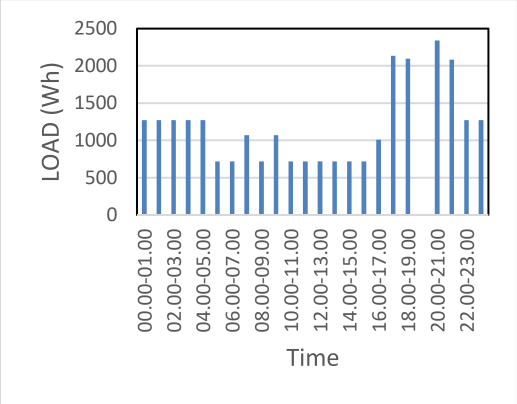

Figure 1. Daily Expense Chart

Based on Figure 1, it can be seen that the peak load occurs at 19.00 – 21.00 WIB with a large electricity consumption of 2356 Wh. The peak hourly load data is important for designing PV mini-grid, because the PV mini-grid system must be able to supply hourly power for its peak load.

2.2. PLTS Hybrid Design

[16]The design of household-scale PLTS Hybrid uses automatic control, namely the Automatic Transfer Switch (ATS) which functions to move the power source from one power source to another automatically. The working principle of the system to be built is a PLTS system where solar panels as the main energy supplier will supply the load and charge the battery (charging) [17], during the day and will continue to supply the load at night until the battery voltage level limit is 24.2. Volt. If the battery capacity is less than 24.2 Volts, the inverter will turn off and the load supply will return to PLN, while the PLTS battery is in a charging condition. If the battery capacity reaches 26.2 Volts, the load supply will switch back to PLTS.[18], [19]

Components of household-scale PV mini-grid.[20], The model of the Solar Power Generation System (PLTS) to be designed consists of solar panels (photovoltaic), inverter, battery and solar charge controller, and others as follows:

a. Solar Panel.

[21] The types of solar panels used in the planning of household-scale Solar Power Plants (PLTS) use solar panels with the brand Maysun Solar model 120 Wp Mono-36 with the specifications in table 2 and the figure in Figure 2 as follows:

Tabel 2.
Solar panel specification Maysun MSI 20 M-36

Parameter	**value**
Rated Maximum Power (Pm)	120 Wp
Open Circuit Voltage (V_{oc})	21,51 V
Short Circuit Current (I_{sc})	7,19 A
The voltage at Pmax (V_{mp})	18,2 V
Circuit at Pmax (I_{mp})	6,67 A
Operating Temperature	-40 - 85^{O}C

Figure 2. Mysun solar panels[22]

By knowing the total daily energy for 24 hours, the number of panels needed can be searched by considering the average hours of sunshine per day is 4.5 and autonomous days = 1,[23]

$$Total\ \text{PV} = \frac{3348\ x\ 1}{120\ x\ 4{,}5}$$

= 7,9 panel round up = 8 panel

b. Inverter

The type of inverter used in this study is a SUNYIMA 24 VDC to 220 VAC inverter with a peak power of 3000 W with a continuous load of 1500 W, ±90% efficiency and the output signal is a pure sine wave. In terms of quality, an inverter with a sine wave is the best because it is the same as the PLN electricity wave, in fact in general the quality is better. So that the inverter with a sine wave can be used for all installation purposes. We can see Sunyima Inverter specifications in table 3 below. [24]

Tabel 3.
Spesifikasi Inverter Sunyima 24V- 3000 W

Parameter	Value
Voltage Output	220 V
Voltage Input	24 VDC
frequency	50 Hz
Output waveform	pure sine wave
Peak Power	3000 W
Continuous Power	1500 W

To take into account the possibility that the system will expand, the inverter capacity is multiplied by the previous value by 1.25 as a factor of safety. [25]

P_{inverter} = 1233 x 1,25 = 1.541 Watt

Installed inverter with peak load 3000 W with continuous load 1500 W according to table 3

c. Battery.[26]

The storage battery capacity can be calculated:

$$C_x = \frac{1\ x\ 3.348}{0{,}8\ x12\ x0{,}85} = 410\ \text{Ah}$$

The number of batteries required:

$$N_{batt} = \frac{410}{100}$$

= 4,1 battery units

Then, based on the calculation of the total number of batteries needed, and the number of batteries connected in series are also connected in parallel to get a 24 Volt system voltage, then 4 batteries are connected, each 2 batteries are connected in series and then in parallel. The connection configuration for the battery is shown in Figure 3. [21]

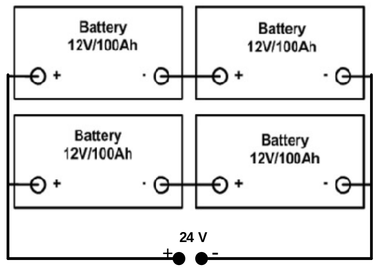

Figure 3. Series-parallel connection of 4 batteries [27]

d. Solar charge controller (SCC)

To determine the capacity of this SCC, we need an SCC that has a capacity that is in accordance with the solar panel working voltage that has been previously selected. In this plan, the SCC brand is used, namely POWMR MPPT 60 A. [28]

Figure 4. SCC MPPT 60 A

3. RESULTS AND DISCUSSIONS

3.1. Schematic of solar panels in series-parallel circuit.

The components of a solar power generation system are:

The number of PV panels needed is 9 solar panels with a power of 120 WP each, so the number of PVs connected in series must pay attention to the SCC specifications, as follows:

(1) The total voltage of the PV open circuit voltage (Voc) connected in series does not exceed the SCC open circuit voltage. (Maximum 150 VDC).

(2) The maximum total PV voltage connected in series is not lower than 50 volts. So, 9 PV panels are arranged in series-parallel as shown in figure 5.

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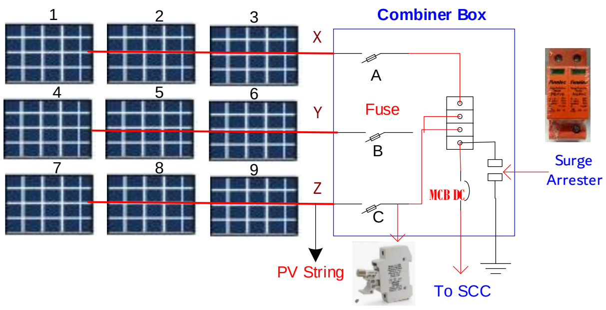


Figure 5. Schematic of solar panels in series-parallel circuit.

Figure 5. shows that:

1. PV string X is PV-1, PV-2, PV-3 connected in series.
2. PV string Y is PV-4, PV-5, PV6 connected in series.
3. PV string Z is PV-7, PV-8, PV-9 connected in series.
4. PV Arrays PV string 1, PV string 2 dan PV string 3 connected in parallel using Combiner Box. combiner as shown in Figure 5.

For the total output voltage PV string 1, PV string 2 and PV string 3, based on table 2 (Voc), the voltages are obtained as follows:

Maximum voltage of each PV String (Voc):

PV String 1 = PV String 2 = PV String 3 = 21.51 +21.51+21.51 = Voc String = 64.53 Vdc

Then, the total output current of PV string 1, PV string 2 and PV string 3, based on table 2 (Isc) is obtained as follows:

PV String 1 + PV String 2 + PV String 3 = 7,19 +7,19+7,19 = I_{sc} String = 21,57 A

So, the total output of the installed PV array is as follows:

Voc String = 64.53 Vdc

Isc String = 21.57 A

Maximum PV output power is obtained:

Pmax PV = Voc x Isc = 64.53x21.57 = 1.391 Watt

Installation of a PV array on the roof of a house, as shown in Figure 6.

3.2. Hybrid system equipment installation

Next, all the equipment is installed and placed in a room in the house, as in the following picture:

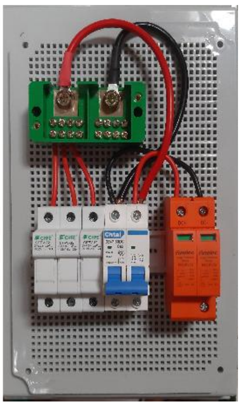
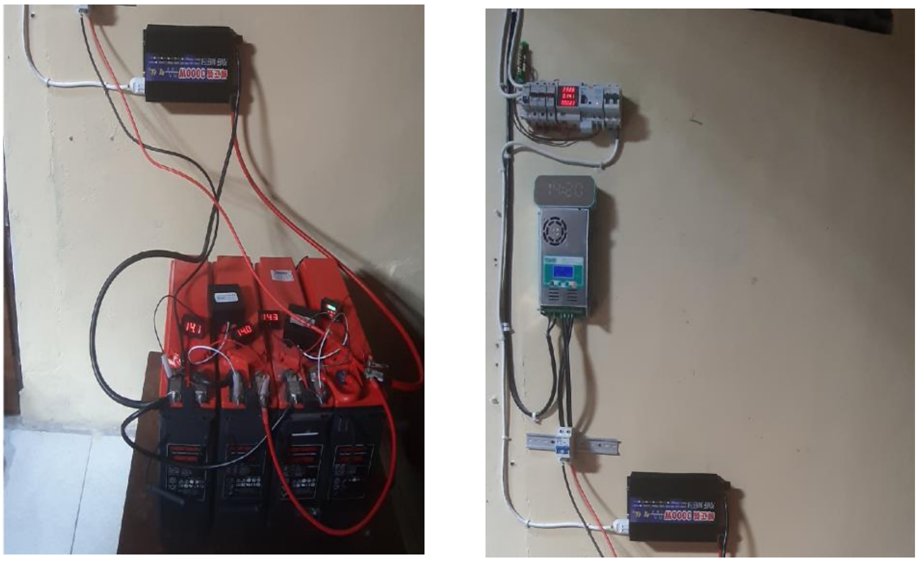


Figure 9. Combiner Box

The figure below shows the entire series of solar power system equipment:



(a) (b)

Figure 10. Complete range of solar power system equipment

3.3. Testing

The solar power generation system was tested to supply a fixed load, namely a 50 inch 100 Watt TV and a 110 Watt refrigerator with a total of 210 Watts, the test was carried out for 6 hours, from 08.00-14.00 for 3 days, from the test results obtained an average result. As shown in table 4. The battery at night is used as a load supply so that the percentage of stored power is around 20% (24.2 Volts). Weather for 3 days of testing conditions sunny and slightly cloudy. The test results are shown in Table 4:

Table 4.
Testing result

No	Time	Solar Panel			Battery	Inverter	load
		Voltage	Current	Power	Voltage		
		Volt	Ampere	Watt	Vdc	Volt	Watt
1	08.00	52,9	12,40	326	24,4	224	210
2	09.00	58,8	23,10	573	24,7	224	210
3	10:00	56,5	32,90	869	25,3	224	210
4	11:00	55,5	35,80	926	26,4	224	210
5	12:00	55,9	34,30	949	27,5	224	210
6	13:00	60,9	31,00	881	28,4	224	210
7	14:00	57,0	17,70	503	28,4	224	210
8	15:00	40,8	08.70	213	28,4	224	210
9	16:00	50,8	07,80	206	26,1	224	210

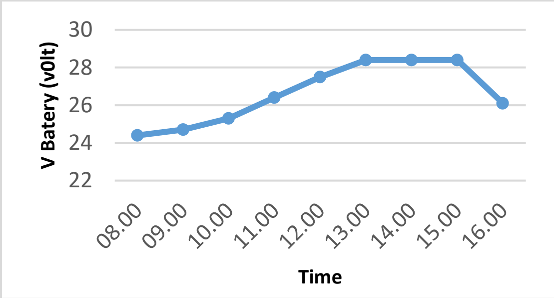


Figure 11. The relationship between test time and battery voltage

It can be seen in Table 4 that battery charging depends on the condition of the brightness of the sun. If PV gets sunlight in high heat, then the voltage obtained will be large and quickly accepted. And on and picture 12 is seen at 13.00 the condition of the battery shows it is full.

4. CONCLUSION

Based on the research entitled Potential and Performance Analysis of Hybrid Solar Power Design and Implementation for Household Loads, it can be concluded that: The design of hybrid solar power plants for household loads with a power of 1233 watts and a load of 3448wh based on power and load loads can be calculated to find the number of components needed. Based on the calculation, it takes 9 120 wp solar panels, 1 SSC 1500w 60A, 4 100Ah batteries, 1 3000w inverter, and based on the tests we did, the solar panels produce an average of 5446 wh per day, the battery will be full at 13.00. When the battery is full, the solar panels supply the daytime load, while the battery supplies the night load.

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