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Small PLTS Off Grid 240 WP On Residential House Rooftop

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ABSTRACT

Small PLTS on residential rooftops are now being widely applied. It can contribute to using alternative energy to support government programs to save electricity costs. It can also be used as backup electricity when PLN power outage. The purpose of this research is to be able to calculate the use of electric power in residential homes, design and make small PLTS off grid 240 WP from the use of electric power, calculate BEP when the payback time of the total investment in the procurement of small PLTS 240 WP with DC and AC systems. 240 WP power on the rooftop of a residential house is carried out for a load of 8 lights AC with 6 watts and one fan. This research showed that the total daily electric power usage was 0.55 kWh/day or 16.5 kWh/month. The design of 240 WP PLTS on the rooftop of a residential house according to the total household electricity needs of 550 watts/day requires core equipment such as two solar panels (120 WP), one battery (12 V 100 Ah), Inverter (12 V to 220 V) = 1000 Watt or 1 kWh as much as one piece, SCC = 20 A as much as one piece. The results of making 240 WP PLTS on the rooftop of a residential house accorded to the total electrical power needs of the household. Break Even Point on this application of 240WP solar power PLTS on residential rooftops with 1300 V power will return capital in 19.5 years. Where the total investment cost of procuring 240 WP PLTS is Rp. 5,558,000, and the cost of electricity per month from the above load is Rp. 23,850 / month or Rp. 286,200 / year.

Keywords: Electric power, Off grid, Residential rooftop, Small PLTS design, Solar panel

1. INTRODUCTION

The demand for electrical energy is increasing day by day [1] [2]. Electrical energy itself has become a major source of energy to meet human daily needs [3]. In Indonesia, electricity consumption increased annually by 1084 GWH in 2019 [4]. The link with this research is that the use of electricity in the residence is increasing, so an innovation is needed to save electricity by utilizing renewable energy on a small scale.

Electrical energy can be divided into 2 based on its source, namely from non-renewable energy power plants and renewable energy power plants [5]. An example of a non-renewable source of electrical energy is using fossil energy [6], and an example of a renewable source of electrical energy is using solar energy, wind energy, biomass energy, tidal energy, and geothermal energy [7]. Increasing levels of carbon dioxide in the atmosphere are caused by fossil fuels, one of which is for electricity generation. Therefore, a move to renewable energy is needed [8].

A Solar Power Plant (in Indonesia its known as PLTS) is a system that converts energy from sunlight into electrical energy [9]. PLTS can be divided into 2 types based on the system, namely grid-connected and off-grid [10]. Grid-connected PLTS is a system that is connected to the electricity grid distribution network or PLN (State Electricity Company of Indonesia) [11], so that the energy is accessed from grid via net meter which makes more reliability in the consumer ends [12]. Meanwhile, off-grid PLTS is a system that is independent and provides freedom from power quality issues and electricity billing and it has a battery to distribute electrical energy to the load [12]. PLTS can be utilized on a small scale, such as in households [13].

Based on previous research, the use of off-grid PLTS for household scale can save electricity payment costs [14]. For this reason, researchers want to calculate how much total electric power is used in a simple or small-scale residential house, namely 240 WP, then design and calculate how much equipment is needed for the PLTS system according to the use of electric power used in a simple residential scale and can make and assemble PLTS offgrid by themselves. In addition, researchers want to calculate BEP or when capital can return from the total investment in 240 WP off-grid PLTS procurement to the total electricity used and save electricity costs from PLN. From the background above, so in this research, we want to make small PLTS off the grid on the rooftop of 240WP solar energy residential houses.

The application of solar panels or photovoltaic (PV) itself is usually placed on the roof or wall of the building because it gets sunlight [15]. This technology can reduce our dependence on fossil fuels, reduce greenhouse gas emissions [16], and offers economic benefits [17]. However, the design and installation of rooftop PV systems may be complex and challenging, especially in terms of maintaining the structural integrity of the building and the safety of the occupants [18].

PLTS or solar power plant has potential for future electricity energy supply because its leading to improvement in efficiency cost [19]. Using solar panels as alternative power has a huge opportunity, especially in power generation. The earth receives 1000 W/m² of energy from the sun during sunny conditions [20]. With solar energy, Indonesia can produce more than 200000 terawatt-hours of electricity per year, and estimated electricity consumption of Indonesia on 2050 is 9000 terawatt-hours [21] hence, solar cells are very suitable to be implemented in Indonesia.

Solar panels are divided into 3 types. Namely, the first is Monocrystalline, a solar panel that uses single-crystal silicon material. This type of solar panel can convert solar radiation into electrical energy with an efficiency of 15-20% [22]. The second is Polycrystalline; this type of solar panel can convert solar radiation into electrical energy with an efficiency of 13-16%. This type of solar panel is made of multiple silicon fragments that are melted, which causes the electrons in each cell to have limited space for movement because there are many crystals in one cell [23]. The third is Thin Film Solar Cell. This type of solar panel can convert solar radiation into electrical energy with an efficiency value range of 7.6%[24].

The gap in this research is the increasing cost of electricity in residential areas over time. Therefore, this research focuses on using solar panels in residences to save electricity and utilize renewable energy by designing component requirements for solar panel installations, solar panel installations in homes, and cost analysis of solar panel installation applications in residences.

2. RESEARCH SIGNIFICANCE

This research focuses on the application of small PLTS in residential buildings. The application of PLTS as a renewable energy source will positively and economically impact the environment [25]. Why we chose solar cells because it played an important role for the developments of renewable energy [26], and now switching to renewable energy is a good idea because it will lead to sustainable development to avoid negative climate change accompanied by global warming [27]. Based on previous research, solar PV is suitable for application in residential buildings, especially in housing or clusters [28]. Seeing from various studies on PLTS and based on the need for the importance of PLTS at this time. The purpose of this research, first is to be able to calculate the total use of electric power per month (kWh) in residential homes, second is can design PLTS on residential rooftops according to the total needs of household electrical power, third is can make 240 WP PLTS on the rooftop of a residential house according to the total electrical power needs of the household, fourth is can calculate the BEP (Break Even Point) value of 240WP on the rooftop of the residential house with 1300 V power. In the future, using solar energy on a small scale, such as in residential buildings, can become more massive.

3. RESEARCH METHODS

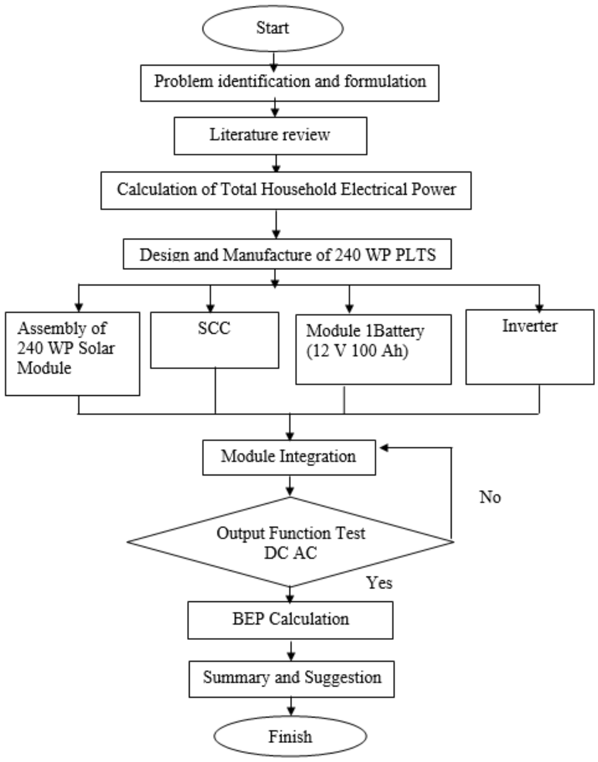

Fig 1. Flowchart of the research

In this study, data collection was carried out in several ways such as:

3.1. Problem identification and formulation

It identifies how much the total monthly electric power usage (kWh) in residential houses, determining the design and manufacture and BEP of solar power plants on residential rooftops according to the total household electric power needs.

3.2. Literature Study

The literature study in this research is data collection using part or all of the existing data from previous research and references related to the research.

3.3. Calculation of Total Household Electricity Power

Data that will be taken in this study.

Table 1. Total Household Electricity Power

Rooms	Electrical power (Watt)	Working hours (Hours/day)	Total electrical power (Watt)
Living room	6	1	
Bedroom 1	6	5	
Bedroom 2	6	5	
Center room 1	6	8	
Center room 2	6	8	
Kitchen	6	4	
Bathroom	6	4	
Terrace	6	10	
Fan	40	7	
Total power	88		
Total power (kWh)			

3.4. Design and manufacture of 240 WP solar power plant

PLTS is designed and manufactured according to the electrical power used and adjusts to the 240 WP PLTS system. As for one of the plans that will be implemented, namely:

a. Solar panels are installed on roofs that receive total sunlight (not covered by the walls of the house)
b. Batteries and electronic equipment are installed on the 2nd floor, the distance between the 2nd floor and the roof is about 4.5m
c. Load for battery testing is used AC lamp and Fan
d. Design and manufacture of PLTS that is optimal and safe for the PLTS equipment itself and safe for the occupants of the house, especially children.

3.5. Tools and materials

In making this off-grid solar power plant, the following materials are needed:

a. Solar panel

The solar panel used is a 12-volt model, 120 WP. Small PLTS off the grid requires two solar panel modules to produce 12V 240 WP because it increases the charging current to speed up the battery charging process.

b. Solar Charge Controller (SCC) 20 A

To manage the battery charging and current discharge functions from the battery to the load. One piece is required.

c. Battery

The number of battery modules used for the powerhouse is a 12 Volt 100Ah battery module of 1 battery.

d. Twin cable 2x2.5 mm^2 solar panel 10 m + MC4 connector + Ferrules

This cable is used to connect from PV to SCC, where this cable is equipped with an MC4 connector to speed up the installation of PV or solar panels.

e. Cable NYM 2x 2.5 mm2

This cable requires only 1 meter to connect from the SCC to the battery. Another 1 meter is used from the SCC to the DC terminal.

f. Cable NYM blue, red and yellow colors

g. Terminal block TB 2512

This terminal serves to connect lights or DC electrical appliances. A total of 1 piece is required.

h. Electricals terminal and plugs

This terminal is needed to connect lights or AC electrical appliances. It takes 1 set to be connected from the inverter to the lamp and AC electrical equipment.

i. Power Inverter Pure SineWave DC 12V to AC 220V 1000 W

Serves to convert DC into AC for electrical equipment and AC lights. It takes one piece and is connected to the battery from the inverter input. The.The inverter output can be directly connected to the power terminal to be used to power AC lights and electrical equipment.

j. Cable MC4 connector 2 branch solar panel connector 2Y 2in1

This cable connects two solar panels in parallel so that it is directly connected from 2 solar panels to Twin 2x2.5 mm2 solar panel 10 m cable + MC4 connector + Ferrules. It takes 1 set and only consists of 2 pieces of wires.

k. DC lights , AC lights and fan

One 5-watts DC lamp and eight 6-watts AC lamps, and one 40-watts fan.

l. MCB DC double and Single 63 A and MCB housing

It is required as a safety on DC electrical equipment when an electrical short circuit occurs. It takes 1 MCB DC 63 A and 2 MCB single DC 63 A. The house is needed to plug the MCB into the place to be plugged in to look neat and safe.

m. MCB AC single 4 A and MCB housing

It is required as a safety on AC electrical equipment when an electrical short circuit occurs so as not to damage AC electrical appliances. It takes one single 4 A MCB.

n. kWh meter AC

One unit is required. With 6 Display appears with a complete display, can measure Volt, Ampere, Watt, Power Factor, Frequency, and KWH meter at once.

o. Low Voltage Disconnect XH-M609 battery protection LVD Modul M609 DC - M609 (Discharge)

One unit is required. This tool keeps the battery from Over Discharger / empty, which will damage the battery.

3.6 DC and AC Output function test

If the module integration has been successful, the DC and AC output tests are carried out whether the PLTS system circuit has been successfully made according to the capacity and electrical power load used per day.

3.7 Break Even Point (BEP) Calculation

Calculate the total cost incurred to buy 240 WP PLTS equipment, calculate the total kWh of electricity per month and the total cost of electricity per month in a 1300 VA residential house, and calculate the BEP of 240 WP PLTS.

4. RESULTS AND DISCUSSION

The energy requirements needed can be adjusted to the needs of each day at home. The following is the daily energy demand in the residential house with 1300 VA power.

Table 2. Electricity demand (kWh) per day in a residential house

Rooms	Electrical power (Watt)	Working hours (Hours/day)	Total electrical power (Watt)
Living room	6	1	6
Bedroom 1	6	5	30
Bedroom 2	6	5	30
Center room 1	6	8	48
Center room 2	6	8	48
Kitchen	6	4	24
Bathroom	6	4	24
Terrace	6	10	60
Fan	40	7	280
Total power	88		550
Total power (kWh)			0,550

So, the total electrical power (kWh) is 0.550 kWh / day. When designing PLTS power in residential houses, we must calculate and collect data on the electric power in residential houses. The total data collection of 1300 VA residential electric power, in table 1 amounting to 0.550 kWh. The electrical energy generated from solar panels or PLTS is not 100% usable because 40% of electrical energy is lost due to the transmission period from solar panels (PV) to electronic equipment loads. So it is necessary to add 40% of the total electrical power used where the calculation is as follows:

$$\boldsymbol{Totalpower} = \frac{\boldsymbol{Electricitypowerofhouse}}{\boldsymbol{100\%-40\%}} \quad (1)$$

$$\boldsymbol{Totalpower} = \frac{\boldsymbol{550watts}}{\boldsymbol{60\%}}$$

$$\boldsymbol{Totalpower} = \boldsymbol{917watts}$$

So the total power required is 917 Watts.

4.1 Design

The following is the design of a small 240 WP Offgrid Solar Power Plant on a residential rooftop.

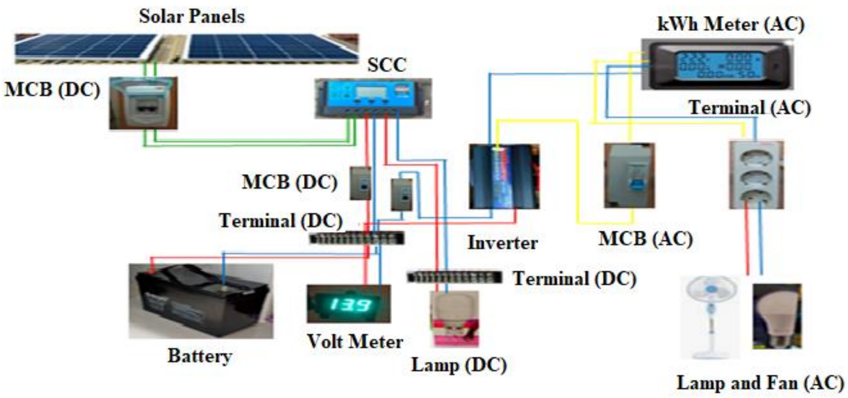

Fig 2. Design of a small 240 WP Offgrid Solar Power Plant on a residential rooftop

4.2 Determination of solar panel requirements

Generally, in Indonesia, the optimal photovoltaic process only lasts about 4 to 5 hours [29]. Solar Module (Photovoltaic) functions to convert solar energy into DC electric current and then forward it to the Battery Control Unit (BCU) to be stored in the battery [30]. So, that the need for solar panels:.

$$Solarpanel = \frac{Totalpower}{Optimumtime} \quad (2)$$

$$Solarpanel = \frac{917Watts}{5hours}$$

$$Solarpanel = 188WattPeak$$

Watt Peak is the amount or optimization of the highest nominal watts that can be generated from a solar panel. Because solar panels are generally sold in the market only at 50 WP and 100 WP, we use 100 WP to calculate the need for solar panels.

$$\frac{184\wp}{100\wp} = 0,92 = 2pieces$$

Due to the unavailability of 100 WP solar panels at the time of the study, researchers used 120 WP solar panels. The calculation of solar panel requirements is as follows:

$$\frac{184\wp}{120\wp} = 1,53 = 2pieces$$

The need is still 2 pieces even though 120 WP solar panels are used, so in this study, 120 WP solar panels or PV are used as many as 2 pieces. If using 100 WP PV, it still requires 2 pieces as well.

4.3 Determining battery requirements

The electrical energy in the battery is 100% usable. However, there is a potential for 5% energy loss in the inverter, so it is necessary to add 5% energy reserves.

$$Reserve = \frac{Totalelectricitydemandofthehouse}{100\%-5\%} \quad (3)$$

$$Reserve = \frac{550Watts}{95\%}$$

$$Reserve = 579Watts$$

So the reference electrical power to calculate the battery requirement is 579 Watts.

The battery specifications are 12 V 100 Ah, so the calculation of the number of batteries needed:

$$Number of batteries = \frac{Total home electricity demand}{Battery capacity} \quad (4)$$

$$Number of batteries = \frac{579 Watts}{12V x 100Ah}$$

$$Number of batteries = \frac{579 Watts}{1200 Watts}$$

$$Number of batteries = 0{,}483$$

Battery capacity will fade after the battery is used for a certain period so by recognizing the percentage of battery capacity fading, it is possible to estimate the battery life and remember when the battery must be exchanged [31]. Battery usage should not run out because it can cause battery damage, so that it can only be used 50%. So the calculation results are multiplied by 2 to get the maximum result. The maximum battery requirement:

$$Max battery requirement = number of batteries x 2 \quad (5)$$

$$Max battery requirement = 0{,}483 x 2$$

$$Max battery requirement = 0{,}966$$

$$Max battery requirement = 1$$

So the battery needs as much as 1 piece with specifications 12 V 100 Ah.

4.4 Determining inverter requirements

An inverter is a device that can convert DC (direct) current into AC (alternating). Inverters are one of the main components of solar cells [32]. From the previous data, if the device is turned on together, 88 Watts are obtained, so an inverter with an output greater than 88 watts is selected so that an inverter with an output of 1000 watts or the equivalent of 1 kW can be chosen where this inverter is widely sold in the market and quickly to get it.

4.5 Determining Solar Charger Controller (SCC) requirements

In determining the SCC, first look at the specifications of the code written on the solar panel. The specifications of the solar panels:

$Pm(Rated Maximum Power) = 120\wp$
$Vmp(Voltage at Pmax) = 17{,}8V$
$Voc(Open-Circuit Voltage) = 21{,}8V$
$Imp(Current at Pmax) = 5{,}62A$
$Isc(Short-Circuit Current) = 6{,}05A$
$Dimension = 910x680x30mm$

Note Isc and multiply it by the required number of solar panels. So the calculation:

$$SCC Power = Isc x Number of solar cell \quad (6)$$

$$SCC Power = 6{,}05A x 2pcs = 12{,}1A$$

$$SCC Power = 12{,}1A$$

So at least the SCC has a power of 12.1 A so use a 20 A SCC.

4.6 Total equipment requirements for PLTS on residential rooftops

Installation of the solar power plant on the rooftop of a residential house with a load of 550 Watts requires the following equipment:

a. Solar panel = 2 pieces (120 WP), using 100 WP as much as 2 pieces is also possible. Because when the order runs out, we use 120 Wp solar panels and the calculations can still be used.
b. Battery = 1 piece (12 V 100 Ah)
c. Inverter = 1000 Watt or 1 kWh as much as 1 piece (DC 12 V to AC 220V)
d. Solar Charger Controller (SCC) = 20 A as much as 1 piece.

4.7 BEP calculation of 240 WP PLTS on residential rooftops

The total average daily energy requirement in a 1,300 VA residential house for lighting and other small loads is 0.550 kWh. According to the PLN basic tariff, the primary electricity tariff (TDL) cost of 1 kWh is Rp. 1,444.70, so the monthly electricity needs:

$$Monthly kWh = kWh per day x 30 \quad (7)$$

$$Monthly kWh = 0{,}550 x 30$$

$$Monthly kWh = 16{,}5 kWh$$

$$Monthly kWh cost = kWh per day x 1300 VA PLN price$$

$$Monthly kWh cost = 16{,}5 kWh x Rp 1.444{,}70$$

$$Monthly kWh cost = Rp 23{,}837{,}55 = Rp 23.850$$

So the cost of electricity generated from 8 lights and 1 fan where the monthly electric power load is 16.5 kWh is IDR 23,850.

$$Cost of yearly kWh = Monthly kWh cost x 12 months \quad (8)$$

$$Cost of yearly kWh = Rp 23.850 x 12$$

$$Cost of yearly kWh = Rp 286.200$$

So the cost of electricity generated from 8 lights and 1 fan in 1 year is IDR 286,200.

So the total cost of procuring 240 WP PLTS is Rp. 5,558,000 where the cost of kWh electricity load per year is Rp 286,200.

Then the cost of procuring PLTS 240 WP will return capital or BEP (Break Even Point) at:

$$BEP time = \frac{Investment procurement cost of PLTS}{Electricity cost per year} \quad (9)$$

$$BEP time = \frac{Rp. 5.558.000}{Rp 286.200}$$

$$BEP time = 19{,}5 years$$

So, the procurement costs to make 240 WP PLTS will return capital or BEP in 19.5 years. The payback period looks long because electrical equipment is only from 8 lights and 1 fan, and the monthly electric power load is 16.5 kWh at Rp. 23,850.

4.8 Fabrication Result

The following are the results of the manufacture of a small 240 WP Offgrid Solar Power Plant on a residential rooftop.

Fig 3. The results of making 240 WP offgrid PLTS rooftop residential houses have successfully turned on with DC output (DC lights) and AC output (AC lights and fans)

Fig 4. The results of 240 WP solar panel application on the rooftop of a residential house

240 WP PLTS on the rooftop of a residential house according to the total electrical power needs of the household.

$$\boldsymbol{Electricalpowergeneratedbysolarpanelsperhour} = \boldsymbol{0,192kWh} \text{ x 4 (ESH/Equivalent Sun Hours)}$$
$$\boldsymbol{Electricitypowerperday} = \boldsymbol{0,192kWh} \text{ x 4}$$
$$\boldsymbol{Electricitypowerperday} = \boldsymbol{0,768kWh}$$
$$\boldsymbol{Electricitypowerpermonth} = \boldsymbol{0,768kWhx30}$$
$$\boldsymbol{Electricitypowerpermonth} = \boldsymbol{23,04kWh}$$

Electrical load energy produced ≥ Load energy per day so 0.768 kWh ≥ 0.550 kWh, then the energy is sufficient for the purpose of turning on the lights and small loads in the residence.

5. CONCLUSIONS

Based on the research results, the following conclusions were drawn:

1. Total daily electric power consumption of 0.550 kWh/day or 16.5 kWh/month in residential houses.
2. The design of 240 WP PLTS on the rooftop of a residential house according to the total household electricity demand of 550 watts/day requires the following core equipment: solar cell two pieces (120 WP), battery one piece (12 V 100 Ah), inverter (12 V to 220 V) 1000 Watt or 1 kW as much as one piece, solar charger controller (SCC) 20 A as much as one piece.
3. Results 240 WP PLTS on the rooftop of a residential house according to the total electrical power needs of the household. The electric load energy produced from solar cells is higher than the load energy for the household, so it's sufficient to turn on the lights and small loads in the residence.
4. BEP (Break Even Point), in applying 240WP PLTS on the rooftop of the residential house with 1300 V power, will return capital in 19.5 years. The payback period looks long because electrical equipment is only from 8 lights and one fan, and the monthly electric power load is 16.5 kWh at Rp. 23,850. The total investment cost of procuring 240 WP PLTS is Rp. 5,558,000, and the cost of electricity per year is Rp. 286,200 or Rp. 23,850 / month with a total electric power usage of 16.5 kWh / month.

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Resources, technical and material supports: Etik Puspitasari, Eko Yudiyanto, Nila Alia
Supervision: Etik Puspitasari

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