Promoting Solar Home System as Renewable Energy System Using Limited Available Resources

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Abstract. This paper will discuss the usage of Photo-Voltaic (PV) solar panel as one of the renewable energy sources. And the most important benefit of using a solar panel, is to lower our dependency with fossil fuel, and thereby reducing CO2 emission that has bigger impact to the earth global warming. We measured the efficiency of this Solar Home System (SHS) to about 75\%. In which, we focus primarily to household appliance usage, to support electricity for a daily life. The result of this experiment has shown that the investment in solar panel has a Return Of Investment (ROI) of approximately 5 (five) years.

Keywords: Solar Panel, Greenhouse, Renewable Energy System, ROI, PV.

1. Introduction

The world has experienced energy crisis with the whole world population has reached 7.8 billion people in the year 2020. And from the beginning of industrial revolution, humanity has been relying on fossil fuel as the main energy source to drive the industry. Even though the fossil fuel is also originated from the sun energy, but the process of it, takes billions of years ago, and therefore the fossil fuel is not renewable energy. And there is another important factor, regarding sustainability, which is the human activities in industrial revolution have increased our earth temperature, due to a greenhouse effect, caused by burning of fossil fuel. This increasing earth temperature is not good for our next human generation. Therefore, a renewable energy source, such as water, earth’s heat, and the sun, is considered as a solution to this green-house effect.

The use of solar energy as a renewable energy source, has not been widely used in Indonesia, especially in home residential [1-5]. Even though, there are already government projects that use solar panel or wind turbine, as a renewable energy source. In this paper, a solar panel system will be discussed compare to wind turbine, because of high initial cost of wind turbine.

The greenhouse effect is a major factor that is due to the use of fossil fuel as our primary energy source in industry. As we have known, the cars’ combustion and industrial machine, have produced a CO2 that increased the world temperature. This increased of temperature, will disturb our life ecosystem on earth. Therefore, we need to use this high technology conversion, especially in solar system [6].
Another factor that needs to be addressed, is the fact that the world population has increased tremendously [7]. And so, our needs for energy have increased, and if we do not use renewable energy, the fossil fuel will be depleted very quickly.

The discussion will start from the sun as our primary energy source, and then how a solar panel convert the sun energy directly into electricity. With this understanding, a last discussion is about Solar Home System (SHS) that can be designed and implemented in our own neighborhood.

1.1 The Sun
The sun is our direct primary source for our PV system. The sunray is called photons. When sufficient photons entered a solar panel, the positive charge and the negative one will be formed inside the solar cell. And if the positive and negative terminal from the solar panel is connected to a load, such as a DC lamp, then it will glow accordingly.

Energy that is produced by the sun at noon, is called Standard Test Condition (STC), which is 1000W/m². This STC is done inside a laboratory. As in real situation, the irradiance of the sun depends on the location in which the solar panel is placed. SolarGIS has mapped the irradiance of the sun, so that we can calculate the sun full hour in one day (generally about 5 hours in the Jakarta’s region).

1.2 Solar Panel Type
Solar cells are created using crystalline silicon (c-Si), and there are two types of solar cell [8], i.e.:

A. Mono Crystalline
B. Poly Crystalline

The process of mono-crystalline ingot is a continuation from the poly-crystalline ingot, and therefore the price of mono-crystalline solar cell is higher than poly-crystalline one [12].

For high end application, in which the price of the solar cell is not an issue, but the efficiency of the solar cell is more important, than another material called Indium Gallium Arsenic or InGaAs is used in the making process of a solar cell, with an efficiency of up to 39.2% [13].

1.3 Solar Charger Controller Type
1.3.1 Based on the charging algorithm [9],

A. Pulse Width Modulation (PWM)
B. Maximum Power Point Tracking (MPPT)

PWM solar charge controller is cheaper compare to MPPT one. But if the solar panel is not under shadow from the tree or building, then PWM is an interesting choice of charge controller, from money’s investment point of view.

While MPPT solar charger uses a kind of buck-converter, that convert a maximum voltage point from solar panel, into the battery voltage system. The advantage of MPPT solar charger is that the device can increase the power receptance as much as 30% more compare to PWM solar charger.

1.3.2 Based on DC or AC charging current [10]:

A. Central Charger (DC)
B. Power Optimizer (DC)
C. Central Inverter (AC)
D. Micro Inverter (AC)
E. Hybrid (DC & AC)

Central Charger and Power Optimizer, work as DC-DC converter, where in Central Charger, all the solar panel’s output are connected to this device, meanwhile for Power Optimizer, this device is located for each solar panel module. As well as for Central Inverter and Micro Inverter, both functions as an inverter that change DC input into AC output, for appliances at home. As the name suggest, a central inverter receives DC input and convert it into a 220VAC. While the micro-inverter is placed for each individual solar panel, this is done to prevent shadowed-solar panel to have bad influence in
sagging the other solar panel power output. The disadvantage of micro-inverter is the price of this technology which is higher than Central Charger.

Hybrid solar charge controller combined solar charger and inverter capabilities into one module [11], in which the input DC is directly from solar panel, and this controller has also the ability to convert DC voltage into AC voltage.

2. Literature Study

2.1. Installation of PLTS in Indonesia/world

China is ranking one in the world, based on International Energy Agency (IEA) report, with the number capacity of PLTS installed up to the year of 2020, is 204.7 GW. Compare to China, the installed capacity PLTS in Indonesia is 152.44 MW. This number is small compare to our neighbor country, which is Malaysia, with the installed capacity of 882MW.

2.2. Comparison of Pembangkit Listrik Tenaga Air(PLTA) and PLTB(ayu) with PLTS(olar)

PLTA and PLTB require capitals’ investment, while PLTS can be developed on a single house. Of course, the efficiency of PLTS is lower compare to PLTA and PLTB.

3. Solar Home System (SHS) Configuration

* Hybrid PWM

Based on load usage in a prototype house, then it is decided to use a controller Hybrid PWM with (1KVA-800Watt). The reason for not using MPPT solar charger, is that it has no inverter build in, and moreover it is more expensive than PWM solar charger.

* Flooded Lead Acid Battery

The chosen technology to store electric coulomb is a flooded Lead Acid battery, based on price/usage ratio, in which a good maintenance is needed. And as time advances, the other battery technology such as LiFePO4 will get cheaper.

* MCB Disconnect Safety Panels

For safety reason, each solar panel is connected to Miniature Circuit Breaker (MCB). So that if one of the solar panels are defected, then it will not impact to the other solar panels.

The following figure shows the implementation of this SHS:

* Figure 1 - (a) 1080Watt PV (b) Safety MCB (c) Hybrid Solar Charger/Inverter
3.1. Load Calculation in the Prototyping House

Table below shows the loads that are common at the residential house:

| Appliance Name | Amount | Wattage [W] | Avg. time of Usage [h] | Days of Usage In years | Total watt [Wh/year] | Information |
|----------------|--------|-------------|------------------------|------------------------|----------------------|-------------|
| Lamp           | 10     | 12          | 12                     | 365                    | 525600               | LED lamp    |
| Lamp           | 1      | 20          | 12                     | 365                    | 87600                | LED lamp    |
| Lamp           | 1      | 15          | 12                     | 365                    | 65700                | CFL lamp    |
| Television     | 1      | 46          | 12                     | 365                    | 201480              | Sharp LED TV |
| Computer       | 1      | 120         | 8                      | 365                    | 350400              | Laptop computer |
| Electric Fan   | 2      | 64          | 12                     | 365                    | 560640              | KDK electric fan |
| Sharp Refrigerator | 1 | 67           | 24                     | 365                    | 588000              | taken from https://www.energystar.gov/productfinder/product/certified-residential-refrigerators/details/2351227 |

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The total wattage of this house is 344 Watt. Therefore, the hybrid charge/inverter controller with 1KVA (800 watt) can be used. The installed solar panel is 1080Wp, with the output voltage of 12 volts.

3.2. Calculation of Battery Capacity for House’s Appliances

The installed batteries capacity is 175Ah*12V = 2100 watt-hour. But because this is flooded Lead-acid battery, the Depth Of Discharge (DOD) that can be taken from this type of battery is only 50% from the total batteries capacity. Therefore, the maximum energy taken from the batteries are 1050 watt-hour.

3.3. Data Analysis of The Energy Receive from SHS

Theoretically, the total energy receive in a day with full sun hour of 5 hours, is as follow:

\[
\text{Total Energy Received} = \text{The full sun hour} \times \text{Solar Panel Installed} \times \text{Efficiency} \quad (1)
\]

\[
\text{Total Energy Received} = 5 \times (100W \times 4 + 4 \times 170Wp) \times 75%
\]

\[
\text{Total Energy Received} = 4050 \text{ Watt-hour/day}
\]

The following experimental data (Figure 2 and Figure 3) were taken on September 9, 2020. The total energy receive from the sun are 3322 Watt-hour/day. Of course, the real energy received on that day, cannot be exactly equal to the calculation above. That is due to the local weather’s condition, but the total energy received from the sun was not far from the theoretical calculation.

Figure 2 shows the current received from the solar panels within that day. The curve forms a bell shape, that follows the pattern of the sun, and the peak value happened mostly at noon, when the sun is straight above our head. While figure 3 shows the voltage received from the solar panel of the same time and day as figure 2.

By taking the multiplication of current and voltage, we can calculate the total power received for 1 day, which is already mentioned above, that we got 3322 watt-hour in that particular day.
4. Conclusion
The cost of installation for the PhotoVoltaic (PV) system was around 10 million rupiah, therefore the Return of Investment (ROI) from this system is about 5 years. This is calculated from the average energy production in one day, which is 3300 Watt-hour, in which 1KWh is valued Rp. 1500,-. Therefore, 3.3 * 1500 is equal 4950 rupiah, that can be saved from the electricity bill. And for one year, we can save 365 * 4950, that is around Rp. 1.800.000,-.

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