Design On-Grid Solar Power System for 450 VA Conventional Housing using HOMER Software

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Abstract. The on-grid solar power system is a solution that can fulfil the ever-increasing demands for electricity. The important role of a solar grid system is to save and reduce the cost of electricity, particularly those with high energy usage in the daytime. This research aims to design a configuration for placing a solar grid system in the housings for the city of Bandung, Indonesia. The research method used is to collect solar radiation data, tool specifications, and other data needed, and then proceed to optimise on these bases. On-grid solar power system design requires the software HOMER. HOMER is used to find the correct system configuration, payback period, and the best NPC technically. Based on the result of optimization, the system configuration can fill the needs of electricity by about 42% for daily consumption with a total NPC cost of around thirty eighty million one hundred thousand with four years payback period.

1. Introduction

Indonesia is a country that consists of 17,504 islands and have a total population of 267 million which continue to grow every year. The increasing total population of the country means that the need for electricity will also increase. According to the Central Bureau of Statistics (BPS), the amount of electricity consumers has increased to 62,068,283 people. Compared to 2016, this number has risen as much as 3,785,790 consumers, or 5.9%. When looking at the total number of consumers, residential sectors compared to other sectors consists of the most users comprising of 62,543,434 or 91.88% of consumers [1].

Most of the energy infrastructures in countries around the world, whether developed or in the process of development, use fossil fuels as their foundation [2]. Based on other researches, the use of fossil fuel results in problems which have been analyzed and overcome in many researches [3]. Problems such as environmental impacts, scarcity, supply risks, and instability of market and price place fossil fuels in the midst of a carbon-less economic shift [4].

Other than health and environmental issues, fossil fuels cannot be distributed equally causing unrest in the long-term security of electrical energy. This is a result of fossil fuel being the main player in the energy production infrastructure at this moment [5]. Furthermore, fossil fuel is a non-renewable resource which creates the problem in the availability for the next generation of humanity.

The most efficient renewable energy for Indonesia seems to be solar radiation. This is because Indonesia is a tropical country and is positioned in the equator line. Solar radiation can be changed into electrical energy using photovoltaics. Photovoltaics are sets of related components that have been arranged, balanced and loaded [6] which can change solar energy into electrical energy using the photovoltaic effect [7].
Designs of renewable power plants in its development can be classified as either single systems or hybrid systems [8-10]. Hybrid systems in here consist of the merging of two power suppliers which are the power network of PLN (State Power Plant) and solar energy. Installation of suitable solar panels for the household’s needs are required to mesh the energy source from PLN with the installed solar panels. The ratio of power resulted from the hybrid system is 50:50. This installation is hopefully cheap whilst also reducing the amount of power from PLN source.

Energy from the sun can be used by solar panels. Solar panels can convert solar radiation directly into electrical energy so that it can be used to fulfil the needs of residents [8-10]. Design of solar power plants for residential-scale needs accurate calculation so that it can be economic, effective, and efficient. Therein lies the need for tools which can help us simulate and optimize. The tool that can be used in this instance is a software named HOMER (Hybrid Optimization Model for Electric Renewable) [9-10].

In this research, HOMER is used to evaluate the renewable on-grid system design on a scale of 450 VA per household in Bandung. Installations consist of three Trina solar 340 Wp and one inverter 1 kW capacity, with the assumption that the household needs a total power of 2,045 kWh/day.

2. System Design

2.1. Calculation of Electrical Load on a Household Scale

In Table 1. The electrical load is earned from a survey based on the power ratings.

| Types of Electrical Load | Section 1.01 | Total Hours (W) | Total Load (W/day) |
|--------------------------|--------------|----------------|-------------------|
| Rice cooker               | Section 1.02 1 | 24 (cook) | 250 | 1400 |
|                          |               | 50 (heat) |                |       |
| Light                    | Section 1.03 3 | 12 | 12 | 432 |
| Light                    | Section 1.04 1 | 13 | 24 | 312 |
| TV                       | Section 1.05 1 | 16 | 106 | 1696 |
| Fan                      | Section 1.06 1 | 14 | 46 | 644 |
| Fan                      | Section 1.07 1 | 10 | 40 | 400 |
| Dispenser                | Section 1.08 1 | 1 | 70 | 70 |
| Charger                  | Section 1.09 2 | 2 | 135 | 540 |
| Charger                  | Section 1.10 3 | 2 | 10 | 60 |
| Charger                  | Section 1.11 1 | 1 | 8 | 8 |
| Charger                  | Section 1.12 1 | 1 | 4 | 4 |
| Iron                     | Section 1.13 1 | 0.25 | 350 | 87 |
| Total                    | Section 1.14 | 5653 | | |

2.2. Design of Solar Panels Circuitry Installation using Helioscope

Design of solar panel circuitry installation can be done by simulation using Helioscope. Helioscope is an online application that can simulate circuits with inputs such as the area of surface, solar panel brands, inverter, and etc. Data that are earned from Helioscope can become an input for HOMER as a custom input. Figure 1 is the simulation result from Helioscope, circuits in the simulation is located in Latitude of -7.5 and longitude of 107.5.
2.3. On-Grid System Design in HOMER

Generally, the data input in HOMER consists of electrical load per day (kWh/day), installation location, technical specifications of installed components, and cost of installed components. In this research, the specifications of solar panels in Helioscope are inputted with the custom mode. Figure 2 is an on-grid system design which is created using HOMER.

In Figure 2, solar panels function as the DC input which is directly connected to the battery. The battery’s voltage is then changed into AC by the use of an inverter which then flows into an electrical
If the energy from the battery is not enough to fulfill the needed load, then the electrical load will be powered by PLN.

3. Results and Discussion

Results from the evaluated system designed by HOMER gives several configuration options in table 2. Every configuration that are plausible are accompanied by the NPC value from the lowest to the highest. Optimal results will depend on certain factors such as solar radiation and the fraction of renewable energy. The main purpose of optimization using HOMER is to calculate the cost of power per kWh (COE), NPC, and greenhouse gas emissions (GHG).

The daily average solar radiation for the city of Bandung is 4.89 kWh / m² / day which is comparable with the global solar radiation of 4.9 kWh / m² / day and a minimum fraction of renewable energy is 50. Table 2, column 1 to 3 shows the existence of the gridline, PV cells, and PV cell capacity for each case. Column 4 to 9 shows the size of the converter in kW, size of gridline in kW, initial capital, cost of operation, notional principal contract (NPC) and cost of equity (COE) each on a scale of Indonesia Dollar Rupiah (IDR) per kWh. Column 10 shows the minimum fraction of renewable energy ranging at 42.4.

Table 2. On-Grid Solar Power System Configuration by HOMER

| Component                  | PV (unit) | PLN | Inverter (KW) | Dispatch | NPC (IDR) | COE (IDR) | Operating Cost (IDR/year) | Initial Capital (IDR) | Ren fraction (%) |
|----------------------------|-----------|-----|---------------|----------|-----------|-----------|--------------------------|----------------------|-----------------|
| PV + PLN/Grid + Inverter  | 3         | ~   | 1             | LF       | 38.1M     | 673.4     | 1.62M                    | 6.10M                | 42.4            |
| PV + PLN/Grid + Inverter  | 3         | ~   | 1             | CC       | 38.1M     | 673.4     | 1.62M                    | 6.10M                | 42.4            |
| PLN/Grid                   | 0         | ~   | 0             | LF       | 59.8M     | 1.467     | 3.03M                    | 0M                   | 0               |
| PLN/Grid                   | 0         | ~   | 0             | CC       | 59.8M     | 1.467     | 3.03M                    | 0M                   | 0               |

On-Grid system for household scales sees 450 VA as the most optimal setting with a configuration for the PV of 2040 Wp and one kW inverter. This system configuration can fulfill electrical load needs as high as 42% for daily consumption of 5.56 kWh/day. Costs of components can reach up to six million one hundred thousand. The cost is relatively expensive, but with the use of on-grid systems, those costs can be closed with the profit of selling renewable energy (PV) into the PLN or grid network. Because the rates of selling electrical energy from consumers who use renewable energy are much higher compared to the sales of electricity from the grid. The total cost that needs to be paid during the project’s period (30 years) to configure all this is thirty eighty million one hundred thousand. Other than that, with the use of solar power system can lower the operational cost and lower the NPC cost compared to the use of the grid, because the use of solar power system can be sold to the grid. The higher the amount of electrical energy sold to PLN, then the higher the profit earned. This transaction process can be impactful to the amount of operational cost and NPC.

Table 3. Comparison of Cost per Year Between PLN and On-Grid Solar Power System.

| System                  | COE | Total kWh/yr. | Total cost in IDR/yr. | Save in IDR/yr. |
|-------------------------|-----|---------------|-----------------------|-----------------|
| PLN/ Grid Installed Solar Panels | 1467 | 2062          | 3.024.954             | 1.636.404       |
| PLN/ Grid Installed Solar Panels | 673.4 | 2062          | 1.388.550             |                 |
Table 3 shows the amount of money that can be saved per year when using the on-grid system that is designed like that in figure 2. The money saved every year amounts to one million six hundred thirty-six thousand.

Payback period means that the amount of year to restore the amount of investment and analysis cost benefits from the system [11-12]. This parameter is influenced by the rates per Kwh/ hour, cost of fuel and electricity that increases from day today. In Table 4 it can be concluded that for the on-grid system that has been designed it will take four years to restore the investment's cost.

| Metric                          | Value       |
|--------------------------------|-------------|
| Present worth (Rp)              | 21,670,840  |
| Annual worth (Rp/year)          | 1,097,240   |
| Return on Investment (%)        | 19.7        |
| Internal rate of return (%)     | 23          |
| Simple payback (year)           | 4.33        |
| Discounted payback (year)       | 4.71        |

4. Conclusion
The result of the on-grid system design for conventional housing of 450 VA using HOMER software recommends a configuration for the three PV of 2040Wp and one inverter 1 kW. The system configuration can fulfil the needs of the electrical load as high as 42 % from a daily load consumption with the total cost NPC as high as thirty eighty million one hundred thousand. On-Grid System that has been designed can reach a total savings of around one million six hundred thirty-six thousand compared to the use of conventional electricity (PLN). Moreover, based on HOMER analysis investment costs will be paid back after four years.

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