Design and Application of PV Rooftop for Grid Feed in Residential House South Lampung

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Abstract. This study aims to design a rooftop solar power plant system and analyzing the power output using PVsyst Software. The location for the photovoltaic (PV) installation was carried out in the Way Hui local government housing in South Lampung, Indonesia. The method used in this research is direct measurement at the installation site and system design using software. In this study, energy audits were also carried out from the practitioner's residence. The results of the design are obtained from the software to consider the next process. The simulation results produces system energy in a year as much as 1,712 kWh, specific production 1,114 kWh / kWp / year, PF 0.724, normalized production 3.05 kWh / kWp / day, array losses 0.84 kWh / kWp / day, and system losses of 0.33 kWh / kWp / day.

Key words - rooftop PV; PVsyst; PV application; PV simulation

1. Introduction

Solar energy is a source of energy that has advantages over other renewable energies. The advantage is that new and renewable energy technology based on solar energy is a technology with very abundant fuel availability. This is what needs to be considered for researchers, students, and also power holders in order to increase the use of solar energy. One of the technologies to utilize solar energy is photovoltaic (PV) which can convert the photon energy carried by solar radiation into electrical energy.

According to data quoted from the IRENA website [1], the utilization of solar energy using PV continues to increase globally from 2017 to 2019 amounting to 383,596 MW, 480,984 MW, and 578,553 MW respectively. In this case, in 2019, Asia is part of the world involved in the utilization of solar energy using PV with China reaching a capacity of 205,072 MW, followed by Japan with 61,840 MW. This proves that the progress of PV technology is very rapid, making competition between countries more sustainable.

In achieving the energy mix target of 23% by 2025 [2], Indonesian government administers programs and regulations that aim to utilize renewable energy sources to maintain energy availability. One of the regulations governing the technology of utilizing new and renewable energy (RE) is the about the use of the PV rooftop system. The regulation listed on Regulation of the Minister of Energy and Mineral Resources No. 49 of 2018 [3]. In this regulation, it is stated that the use of the PV rooftop aims to save on the electricity bills and reduce the use of fossil energy.

The purpose of this paper is to design a PV rooftop system using PVsyst software. Therefore, it is necessary to understand regarding the design of the PV Rooftop system for technicians, students, or researchers in the energy sector to develop photovoltaic technology in Indonesia.
2. Literature Review

2.1. Rooftop Photovoltaic

According to the book *Renewable Energy* [4], Photovoltaic or solar panels are technologies that can directly convert solar energy into electricity without the need for an intermediate step, such as a generator driven by a turbine.

The way PV works is almost the same as the photoelectric effect, which can eject electrons from the surface of an element that is exposed to electromagnetic radiation with a certain wavelength. However, PV contains an intrinsic electric field that maintains the current allowing PV devices to be used for electricity generation by directly changing the incident sunlight. This internal electric field can be created using a doped semiconductor.

According to Permen ESDM RI No. 49 of 2018 [3], is the process of generating electricity using photovoltaic modules that are installed and placed on the roof, walls, or other parts of the building owned by the consumer of PT Perusahaan Listrik Negara (Persero) and channeling electrical energy through the consumer electrical connection system.

There are two types of home PV systems, such as off-grid and on-grid system. In off-grid systems, usually used for remote areas that the PV systems are not connected to grid distribution. While on-grid systems, the PV systems connected to the grid system [5].

2.2. Application of PV Rooftop

Nowadays, the use of PV Rooftop has several applications or schemes such as the Feed In Tariff (FIT) scheme, Vehicles-to-Buildings (V2B), and PV Electricity Sharing (PVES).

2.2.1. Feed in Tariff (FIT)

Feed in Tariff [6-11] sometimes called Grid Feed, is a policy scheme in which major power companies pay a tariff for electricity generated from renewable energy sources including PV Rooftop. One of the advantages of FIT is its financial rewards, which sometimes have a selling price have many times than purchase price. The FIT scheme is made so that people compete to build renewable energy.

![Figure 1. Feed in tariff scheme [6-11]](image)

2.2.2. Vehicle to Building (V2B) or Building to Vehicle (B2V)

Vehicle to Building (V2B) and Building to Vehicle (B2V) sometimes called Vehicle to Building to Vehicle (V2B²)[12-14], is a scheme that involves electric Vehicle (EV) in the energy storage process as well as a source of energy for buildings. The role of EV as energy storage is when the Rooftop PV has excess electricity and the building does not have Battery Energy Storage System (BESS) (Figure 2a).
EV can be used as an alternative energy source besides Rooftop PV when the Power Grid is down or black out (Figure 2b). If the building has BESS, the function of EV is as an alternative energy storage and BESS can also be swapped with an EV battery when it's empty (Figure 2c). EV can also movable or portable BESS. It can be used as an alternative energy source for other buildings (Figure 2d).

![Figure 2. PV electricity in Vehicle-to-Building scheme](image)

(a) EV charging from PV and grid 
(b) building’s power from EV and PV 
(c) building’s power from PV, EV and energy storage 
(d) EV powering the another building [12-14]

2.2.3. PV Electricity Sharing (PVES)

The PVES scheme [15-17] is a scheme when the excess electricity generated by PV Rooftop is distributed to other buildings in nearby areas. The scheme requires a device such as a Smart Meter to calculate the amount of energy export or energy import. This scheme also requires hardware such as an Intelligent Electronic Devices (IED) to manage electricity power line among the buildings. The drawback of this scheme is the creation of a network topology. This scheme can be effective with star topology, ring topology, central topology.
3. Methods and Design

In this research, the design of the PV rooftop using the PVSyst software. PVSyst is a software to design and analyze the PV system. Reporting from the official website of the software [18], PVSyst is designed for use by architects, engineers, and researchers. It's also a very useful for educational tool that includes a detailed contextual Help menu that explains the procedures and models used, and offers an easy-to-use approach with guides for developing projects. PVSyst can import data, as well as personal data from various sources.

The steps used in this design are shown in Figure 4. The first step is to enter the PV Rooftop location. The location is a GPS coordinate point consisting of latitude and longitude. In PVSyst, there is weather data that is integrated with Meteonorm and NASA which is able to display data according to the location of the PV Rooftop that will be implemented. If we have weather Data, enter personal weather data is alternative data. The required weather data such as temperature, humidity, wind speed, global solar radiance and irradiance solar diffuse.

After entering the PV Rooftop location, the next step is to determine the PV tilt angle and determine the PV Array scheme such as fixed or tracking, etc. Then the PV system design will be used such as the type of PV, inverter, and the number of areas required. At this step also determines the amount of capacity used so that it is not oversized or undersized. The next step is to determine the amount of load used on the building. The load used can also be determined when it is used. The next step, designing 3D from the PV Rooftop used. This is to analyze the shading that may occur in PV. 3D design should also involve buildings or surrounding objects such as trees or poles. After the steps above have been determined, PVSyst is able to analyze the results.
The design of the rooftop solar panel is carried out on the roof of the residential house which is located on Jalan Manggis Raya, No. 21, Blok D, Perumahan Pemda Way Hui, Way Hui, Kecamatan Jati Agung, Kabupaten Lampung Selatan, Lampung as shown by the red box in Figure 5.

4. Results and Analysis
From the simulation, the first step to analyze the system is input the location of PV rooftop design. The location of the system at coordinate -5.348591560202532, and 105.31543930939344, it can be find with the map provided by the google map in Figure 6. From the software, it is include the weather data location connected to Metronome and NASA World Weather.
Figure 6. Map of the location for the roof solar PV installation

After input the location and weather data, the next step is input the orientation of the PV rooftop. In this simulation, we use the orientation of tilt angel 19\(^\circ\) and the azimuth angel 148\(^\circ\) according the rooftop position [Figure 5]. After define the orientation and coordinate, the next step is design the PV system. In this step, we define the large area, PV type, inverter size, and number of modules. The number of modules in series and parallel is adjusted so that the required area is as minimum as possible. The number of modules in the series is 16 units and 1 row parallel so that the total modules required are 16 units and the required area is 16 m\(^2\). The design of this PV rooftop uses the HMB 48 PV module with a nominal power of 1.54 kWp; MPP Voltage 21.3 V; and MPP Current 4.6 A and 1 unit Sunny Boy SWR inverter with 1.5 kW power [Figure 6].
The result of the energy audit activity in this study is the electricity consumption of the house during the day, from 9 AM to 3 PM. The devices being audited are items that are often used during the day and are often used every week. The results of the total energy audit are 8.95 kWh as shown in the Table 1.

In this experiment, shading is not discussed because the position of the PV system is on the roof and right in front of the house there are no large trees so there is no shadow covering the PV module from sunlight [Figure 5].

### Table 1. Daytime Energy Consumption

| No | Device            | Amount | Power (Watt) | Hour | Total Power (Wh) |
|----|-------------------|--------|--------------|------|------------------|
| 1  | Lamp              | 2      | 5            | 6    | 60               |
| 2  | Big fan           | 2      | 45           | 4    | 360              |
| 3  | Small fan         | 1      | 25           | 6    | 150              |
| 4  | Laptop charger    | 6      | 170          | 6    | 6,120            |
| 5  | Monitor           | 1      | 100          | 6    | 600              |
| 6  | Rice cooker (warming) | 1 | 40          | 3    | 120              |
| 7  | Water pump        | 1      | 300          | 3    | 900              |
| 8  | HP charger        | 8      | 20           | 4    | 640              |

As the results of some of the figures listed, the nominal power of the entire PV rooftop is 1,536 Wp [Figure 7]. In the graph, it can be seen produced useful energy is about 3.05 kWh for 1 kWp module on average per day. This designed PV rooftop system has an effective working temperature in the range of...
20°C to 60°C. The energy produced per month with high production in March and November. In one year, users get 1,108 kWh of energy from PV and 2,159 kWh from the grid while the grid receives 604 kWh from the PV [Figure 8].

![Normalized production (per kWp installed): Nominal power 1536 Wp](image1)

**Figure 8.** Normalized production (per kWp installed)

![Rooftop PV Loss Diagram](image2)

**Figure 9.** Rooftop PV Loss Diagram
5. Conclusion
In this paper, it has been design of a PV rooftop at the residential house with the location -5.34851560202532, and 105.31543930939344. The design of this PV rooftop design uses the HMB 48 PV module with a nominal power of 1.54 kWp; MPP Voltage 21.3 V; and MPP Current 4.6 A and 1 unit Sunny Boy SWR inverter with 1.5 kW power. The simulation resulted, using the PVsyst software produces system energy in a year as much as 1,712 kWh, specific production 1,114 kWh / kWp / year, PF 0.724, normalized production 3.05 kWh / kWp / day, array losses 0.84 kWh / kWp / day, and system losses of 0.33 kWh / kWp / day.

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