Modeling of On-Rooftop Solar Power Plant of Universitas Ichsan Gorontalo Building

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Abstract : Renewable energy generation has become the choice of many countries, including Indonesia. The type of New and Renewable Energy (EBT) generation in Indonesia is Solar Power Plants. Not only targeting people who are not reached by alternative distribution networks but also Solar Power Plants systems are a necessity for public and communal facilities in Indonesia. Gorontalo City is part of Gorontalo Province with an area that occupies part of the northern region of Sulawesi Island with diverse regional characteristics, ranging from coastal areas to mountainous areas, where some areas in this province have the potential for investments in the industrial and commercial sectors. commercial. In addition, the uneven distribution of energy infrastructure is an energy problem faced by Gorontalo City. The research and modeling method in this study employs the Photovoltaic System Software (PVsyst) application by surveying the research location for planning the installation of the On-Rooftop Solar Power Plant to find out the condition of the building, and the geographical location of the research. Based on the simulation results using PVsyst, the building of Universitas Ichsan Gorontalo uses a stand-alone system with a PV array of 1261 units with a total PNom of 328 kWp. The battery technology, namely lithium-ion, 925 LCO units produce a voltage of 241 V with a current capacity of 9990 Ah. It generates energy per year of 513619 kWh/year with a ratio of 70.36% in which the active load is 13 hours/day.

Keywords : PVsyst; renewable; PV panel; energy; rooftop, Solar Power Plants.

Introduction

Background

Renewable energy generation has become the choice of many countries including Indonesia. The type of New and Renewable Energy (EBT) generation in Indonesia is Solar Power Plants. Not only targeting people who are not reached by alternative distribution networks, but also PLTS systems are a necessity for public and communal facilities in Indonesia. Including the need for public street lighting (PJU) but also PLTS plays a role in energy sources in the Laboratory. PLTS is developed for electronic devices based on the Internet of Things (IoT). This PLTS is a concern and is used for residential systems. Residential systems have the advantage of being able to connect to the 220VAC/50Hz PLN network with certain characteristics both in homes and also used for buildings that can be used as backup energy besides PLN. (Iskandar, 2020).

Energy is a necessity that people need. The increasing population in Indonesia has increased energy use, in this case, the role of non-renewable energy is increasingly threatened, so it is necessary to utilize and maximize the potential of new renewable energy throughout Indonesia such as geothermal, water energy, wind energy, bioenergy (bioethanol, biodiesel, biomass), ocean current energy, nuclear energy, and solar energy. This review article is a review of the potential of new renewable energy in Indonesia. The utilization of new renewable energy is expected to start with people who utilize small-scale energy so that it can protect the environment, support sustainable development, and support national energy security (Al Hakim, 2020).

Indonesia as one of the countries located on the equator has a very high radiation potential and the amount is estimated at 4800 Wh/m2/day. This potential can be utilized, one of which is as a direct power plant, through the use of Solar Power Plants.

On-Rooftop Solar Power Plant is a process of generating electrical energy using photovoltaic modules that are installed and placed on the roof, walls, or other parts of buildings owned by consumers of PT PLN (Persero) and distributing electrical energy through the electrical connection system of PT PLN (Persero) consumers. The On-Rooftop Solar Power Plant system is configured as an on-grid system because it is connected to the PT PLN's electricity network. This means that the power produced by the solar power plant is not only for its use, but can be distributed to the system connected to it. During the day, when the Solar Power System's electricity production exceeds the load requirements, then this excess is automatically channeled to the grid and automatically this excess is recorded by the Export-Import kWh meter. However, when the Solar Power System's electricity production is insufficient to meet the load demand, the Solar Power System's electrical energy is prioritized for use and the remaining electricity shortage is supplied from the grid. The On-Rooftop Solar Power Plant is one of the environmentally friendly forms of power generation and is also suitable for development in urban areas because this power plant installation can be installed and placed on the roof, wall, or other parts of the building. On-Rooftop Solar Power Plant installation is a form of renewable energy utilization (in this case solar energy), which can be installed on the roof of a building, either residential houses, offices, education, or shopping centers. To further encourage the utilization of solar energy, it is necessary to develop rooftop solar power plants that generally have a small-scale capacity (<1 MWp). The On-Rooftop solar power plants have their

advantages when compared to large-scale solar power plants, including being easier and cheaper to integrate with existing electricity systems, can utilize existing land (reducing land investment costs), and can help reduce the burden on existing system networks. The government regulates all rooftop solar PV activities in every building. It is following recommendations under the Presidential Regulation in Appendix 1 of the Presidential Regulation of the Republic of Indonesia Number 22 of 2017 concerning the National Energy General Plan. (MEMR, 2020)

A feasibility study is a very important stage to determine whether or not an area is feasible for the development of a power plant among them is the Solar Power Plant, in terms of technical, economic, and environmental. In some cases, based on the priority of development, before conducting a feasibility study, it is also necessary to conduct a pre-feasibility study on PLTS in Gorontalo City. These two types of studies have the same object of investigation and sequence of implementation. (Wahyudi & Sutikno, 2011), Gorontalo Province is a province covering an area that occupies part of the northern region of Sulawesi Island with various regional characteristics, ranging from coastal areas to mountainous areas, where some areas in this province have the potential for investments in the industrial and commercial sectors. Thus, the existence of various industries has an impact on economic growth followed by population growth. These conditions can have an influence on energy needs both now and in the future. Energy fulfillment in Gorontalo Province is currently not fully equitable, especially in several districts. This condition is influenced by the existence of poor people (reaching 18.32%). In addition, the uneven energy distribution infrastructure factor has become an energy problem faced by this province. RUED Gorontalo Province is expected to be a reference for an integrated regional energy management system in overcoming energy problems and challenges to achieve energy security and independence in Gorontalo Province. Electricity supply in Gorontalo Province, where the peak load reached 81.9 MW in 2015, is supplied by power plants located in Gorontalo Province and North Sulawesi-Gorontalo Interconnection System. The condition of generation in this province is still dominated by fuel-fired plants, Diesel Power Plant, reaching 63.08% of the total generating capacity in Gorontalo Province.

The composition of electric power generation as mentioned has given problems on the side of the cost of supplying electric power which directly affects the selling price of electric power. Where on the other hand, the purchase price of electricity customers has been determined based on the Electricity Tariff of PT PLN (Persero) The difference in the price is charged to the subsidy provided by the Government (RUED Prov. Gorontalo, 2018).

Table 1. Type of Power Plant in Gorontalo Province in 2015

Type of Power Plant	Fuels	Installed Capacity (MW)	Endurance (MW)
Diesel	Fuel Oil	23,2	15,2
Gas	Fuel Gas	100,0	100,0
Micro Hydro	Water	6,2	4
Steam	Coal	21	20
Solar	Daylight	2,0	1,8
Total		**152,5**	**141**

The main factor in planning a Solar Power Plant in addition to technical aspects is to consider factors such as the Solar Power Plant operation pattern plan and whether or not the PLTS is connected to the electricity grid at the planned location. The above factors affect the selection of the type and capacity of the main components, namely: solar modules and inverters.

Solar PV capacity is expressed in kilowatt peak (kWp) and inverter capacity is expressed in (kW). The desired level of reliability affects the configuration, capacity, and some inverters. The first step in the planning process for a Solar Power Plant is to assess whether it is feasible to proceed. Doing so requires a review of several aspects, including technical, environmental, financial, social, economic, and risk aspects. However, the common factors that most people consider are technical and cost feasibility (Sianipar, 2017).

2 Research Methods

2.1 Type of Research

Research and modeling methods in this studyemploy the Photovoltaic System Software (Pvsyst) application by surveying the research location for planning the installation of the On-Rooftop Solar Power Plant to find out the building conditions, geographical location of the research location, and collecting the necessary data to obtain secondary data which later become a reference and input data for modeling the On-Rooftop Solar Power Plant using PVsyst software. By using SketchUp software in designing the building of Universitas Ichsan Gorontalo in three-dimensional (3D) form and calculating the roof area of the building using the Google Earth Pro application to get a suitable topology for Solar Power Plant and get a shading which determines the size of the loss value or losses from modeling which affects the performance ratio and efficiency value for modeling the On-Rooftop Solar Power Plant at Universitas Ichsan Gorontalo.

This research employs an experimental method. The research aims to obtain a description of the problem being studied. The description is in the form of a causal relationship between the dependent variables and the independent variables that affect the problem through a questionnaire as an instrument to answer a set of questions or written statements to respondents (Qomariyatus Sholihah, 2019).

2.2 Type of Research

This research is located in Gorontalo City, precisely at the building of Universitas Ichsan Gorontalo where the availability of electrical energy is currently unable to keep up with the growth in demand in Gorontalo City, both in the short and long term. Increasing the capacity of electrical energy is very strategic in supporting the direction of the development of leading industrial clusters in the Sulawesi region. The existence of the On-Rooftop Solar Power Plants helps overcome the electricity crisis in Gorontalo City where the hydrological conditions of Gorontalo City are due to hydrological phenomena such as the magnitude of rainfall, temperature, evaporation, length of sunshine, wind speed, river discharge, river water level, flow velocity, and river sediment concentration always changing by time and having a small land area..

Figure 1. Building Layout of Universitas Ichsan Gorontalo

The modeling of the On-Rooftop Solar Power Plant environmentally friendly in Gorontalo City is conducted by identifying the building roof layout of Universitas Ichsan Gorontalo, then making an ideal design by compiling equipment specifications on the market, after which the calculation of the costs required and also the calculation of the electrical output power generated to analyze the benefits and the total of investment costs for installing the On-Rooftop Solar Power Plant for buildings. It also depends heavily on the type and choice of product type used. A good product is a product that is able to provide a reliable warranty and after-sales guarantee. The investment in the installation of the On-Rooftop Solar Power Plant for buildings is quite high and with a long rate of return (ROI) which is achieved if the electricity is sold directly to PT PLN (State Electricity Company).

3 Result and Dicussion

Universitas Ichsan Gorontalo is located in Gorontalo City, precisely on Jl. Drs. Achmad Nadjamuddin No.17, Dulalowo Timur, Kota Tengah Subdistrict. Geographically, the Gorontalo City area is located between 00º 28' 17" - 00º 35' 56" North Latitude (LU) and 122º 59' 44" - 123º 05' 59" East Longitude (BT) with an area of 64.79 km². Gorontalo City consists of five subdistricts namely Kota Barat, Dungingi, Kota Selatan, Kota Timur, and Kota Utara. It covers 64.79 km2 with a total population of 147,354 people. The subdistrict with the largest area is Kota Utara (16.71 km2) while the subdistrict with the smallest area is Dungingi (4.10 km2). The land use in Gorontalo City can be divided into paddy fields, gardens, yards, and others. The land used respectively consists of 1.013 Ha, 695 Ha, 452 Ha, and 39.74 Ha for others in 2003. The On-Rooftop Solar Power Plant installation location is surveyed to determine the area of the rooftop area fitted with a solar power plant, and whether or not there is shading potential around the area to be fitted with a solar power plant.

A shadow can affect the efficiency of solar modules in producing electricity (solar module performance). A shadow can affect the efficiency of solar modules in producing electricity (solar module performance). In Gorontalo City, there are generally two types of roof shapes, namely flat roofs and sloping roofs (prisms). In the case of the building of Universitas Ichsan Gorontalo, the roof has a prism roof. Therefore, in planning it, is necessary to focus on the direction of roof orientation and the roof slope. Roofs facing North or South are ideal conditions for the installation of the On-Rooftop Solar Power Plant.

Figure 2. The Buidling direction of Universitas Ichsan Gorontalo

Based on the position of the building of Universitas Ichsan Gorontalo, it faces West. At certain hours, it will be exposed to the shadow of the roof itself whereas in the morning or evening the solar panel can be blocked by the shadow of the roof itself so that it can reduce the amount of energy that will be generated by the On-Rooftop Solar Power Plant. Therefore, in the planning, it is better to make additions to the roof structure because it is necessary to add a solar panel support pole so that the position of the solar panel is higher and avoids the shadow of the roof itself. In addition to the shadow of the roof itself, the shadow of vegetation around the building can fall on the solar panels if no shadow analysis is done first, as shown in the figure below. One solution to the shadows of trees falling on the roof is tree felling or leaf trimming. When viewed from the satellite image, the building of Universitas Ichsan Gorontalo is clear of vegetation shadows. Shadows on the array that occur during the day affect the output power. A detailed analysis of each occurrence of shadows on the array is expected to be carried out to avoid the occurrence of shadows on the array. Shadow effects can reduce solar radiation and result in a decrease in the energy produced by the system. However, when shadows occur only on part of the array, there will be a reduction in the maximum voltage. Thus, a reduction in the maximum energy will occur on the array.

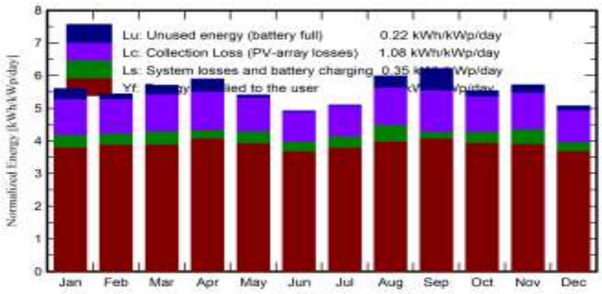


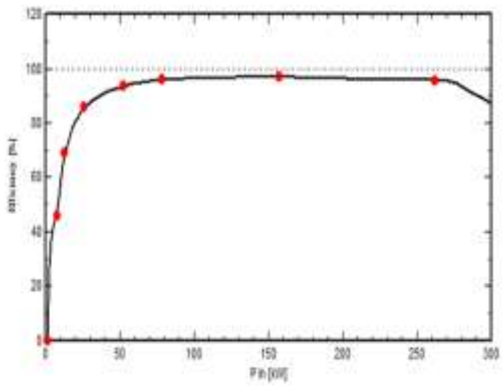
Figure 3. Normalized productions (per installed kWp)

The roof area for the installation of a Solar Power Plant needs to be calculated carefully because if the roof is exposed to shadows, or there is utility equipment on the roof (such as outdoor AC units, pumps, etc.), the potential roof area becomes smaller than the total available roof area.

From the desk study, it is concluded that the site survey at Universitas Ichsan Gorontalo is focused on finding potential areas for rooftop solar power plant construction. It is because the roofs of the buildings of Universitas Ichsan Gorontalo are curve-shaped with varying slopes.

Inverter selection in this study adjusts the capacity of the PV System simulation results, with a capacity of 320 kWp, the selected inverter must have a decentralized system. The inverters used also have the flexibility that allows increasing the number of inverters when there is an increase in power demand. The inverter used also can operate in parallel when the power demand increases in the area and can upgrade from single-phase to three-phase. Inverters also can integrate (hybrid) with power plants with energy sources from PT PLN.

Figure 4. Input power efficiency



It is done because the Solar Power Plant can be interconnected with the local PT. PLN network or with a network managed independently by the local government/community. The location of the solar farm is entirely in an office building, so the inverter is expected to operate reliably in conditions with different types of loads with minimal supervision and supervision, as well as against field conditions that tend to be corrosive.

The specific energy yield of a solar module is determined by considering a standard irradiation of 1000 W/m2. However, it is not always the case that the irradiation remains the same, and also on some days the irradiation does not even touch 1000 W/m2. Moreover, the irradiance varies daily, hourly, and even after a few minutes (depending on the clouds). Figure 5 below shows the variation of power output with varying irradiation.

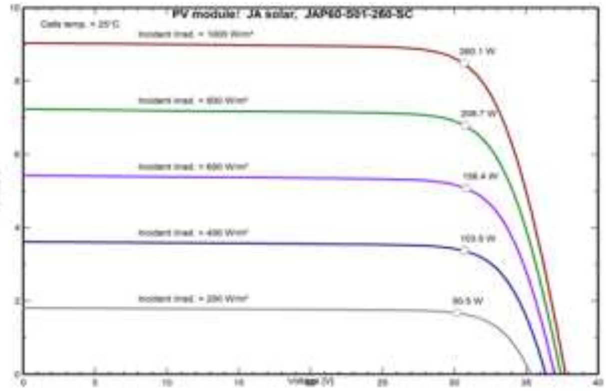


Figure 5. The effect of irradiation on the power output of a solar module

It can be seen that the output power of the solar module decreases with a decrease in solar radiation. Such a decrease will lead to a decrease in the specific energy yield (due to less energy generation from the same amount of module capacity). Moreover, such variations in irradiation take place continuously throughout the day. It leads to further variations (and mostly reductions) in the specific yield

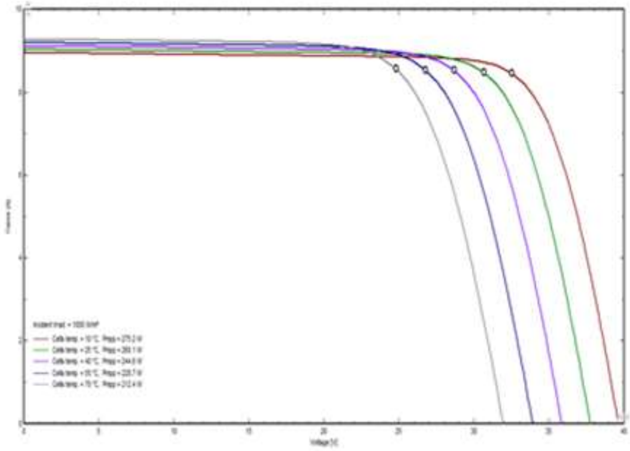


Figure 6. Solar module temperature

One of the factors affecting the energy produced by PV and perhaps the least controllable factor affecting the yield of a solar module is its operating temperature. Due to various climatic conditions, temperature variations are quite large. The overall effect of temperature can be visualized in Figure 5.3, where the variation causes a slight increase in the current while drastically reducing voltage with increasing temperature. Therefore, an increase in temperature will lead to a decrease in the overall power output of the module. With such frequent variations, the solar module will not produce the expected specific energy yield.

4 Conclusion

1. Ichsan University of Gorontalo is located on Jl. Drs. Achmad Nadjamuddin No.17, Dulalowo Tim., Kec. Kota Tengah, City of Gorontalo, which is geographically located between 00º 28' 17" - 00º 35' 56" North Latitude (N) and 122º 59' 44" - 123º 05' 59" East Longitude (E), with an area of 64, 79 km². In planning a Rooftop PLTS, shadow analysis is very important to ensure that the sunlight that falls on the solar panels is not blocked by objects around it. In Gorontalo City, there are two types of roof shapes, namely flat and sloping (prism) roofs. The UNISAN Gorontalo building has a Prisma Rooftop, and a Rooftop facing North or South is an ideal condition for installing a Solar Rooftop. The results of the desk study concluded that the site survey at Ichsan University of Gorontalo was focused on finding potential areas for the construction of PLTS Rooftops because the rooftops of the UNISAN Gorontalo building have curved shapes with varying slopes.

2. The Ichsan University of Gorontalo building has an installed capacity of 124,000 VA for two buildings, with 8

hours of activity per day. Based on the simulation using the PV System application, the offered Rooftop PLTS capacity for the building is 513,619 kWh/year with the energy used of 467,164 kWh/year. However, there is potential for additional capacity to maximize the potential of the available area. Keep in mind that the specific energy of the solar module is affected by irradiation, which does not always stay at 1000 W/m2. The RAB for the installation of PLTS Rooftop for the building reaches IDR 5,359,040,000.

3. The simulation results using the PV System application show that the capacity offered to build a Rooftop PLTS in the Ichsan University building of Gorontalo is 513619 kWh/year (Available Energy) with 467164 kWh (Used Energy) which has a ratio of 70.36% and 90% efficiency. However, in order to maximize the potential of the area where it is possible to install a rooftop PLTS in the building, additional capacity needs to be added.

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