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SIMULATION OF ROOFTOP SOLAR POWER PLANT (PLTS) AT ICHSAN UNIVERSITY BUILDING, GORONTALO

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ABSTRACT

Renewable energy generation has become the choice of many countries, including Indonesia. New and Renewable Energy (EBT) generators in Indonesia are Solar Power Plants (PLTS). Not only targeting people who are not reached by alternative distribution networks, but the PLTS system is a necessity for public facilities and is communal in nature in Indonesia. Gorontalo City is part of Gorontalo Province a province which has an area that occupies part of the northern region of Sulawesi Island with various regional characteristics, ranging from coastal areas to mountainous areas, where several areas in this province have an attraction for investors to invest in the industrial and commercial sectors commercial. In addition, the unequal distribution of energy infrastructure is an energy problem faced by Gorontalo City. The research and modelling method in this study uses the Photovoltaic System Software (Pvsyst) application by conducting a survey of the research location for planning the installation of a Rooftop Solar Power Plant (PLTS) to determine the condition of the building, the geographical location of the research location. From the simulation results using the PVsyst Ichsan Gorontalo University Building using a standalone system with a PV array of 1261 units with a total Pnom of 328 kWp, for battery technology, namely lithium-ion, 925 LCO units produce a voltage of 241V with a current capacity of 9990Ah. Produces energy per year of 513619 kWh/yr with a ratio of 70.36% where the active load is 13 hours/day.

Keywords: PVsyst, renewable, PV panel, energy, gorontalo.

1. INTRODUCTION

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

Power transmission lines and power plants use Monte-Carlo simulation, and cost recovery to predict resilience factors including lost power generation capacity and recovery costs for the power transmission network and power generation system breakdowns. Synthetic grid data was used to model the Energy Reliability Council of Texas (ERCOT) power grid. A case study was developed based on Hurricane Harvey. This work was expanded to evaluate changes in resilience as the percentage of renewable sources increased from 2017 levels to levels consistent with the Texas NREL Futures Study 2050 scenario for 50%and 80%renewables. (Watson, 2019)

Solar photovoltaic (PV) systems are used worldwide for the production of clean electricity. Photovoltaicsimulationtoolservestopredicttheamountofenergygenerated by the structure of the PV solar array. This paper presents a photovoltaic system installed on the roof of the Naidu GD Block at Vellore Institute of Technology (Vellore, India). New PV power plant designs were developed here to improve the energy efficiency of existing PV systems. The effectiveness of the proposed design was evaluated over a full year using the PVsyst v6.70 software, which worked to accurate factory specifications. For this purpose, the Metronome 7.1 weather data set of ambient temperature and radiation from the PVsyst database. (Behura, 2021)

Installing a grid-connected rooftop solar system for households is an important issue; therefore, there are many factors to consider before the installation is decided. The main factors that must be considered are the total cost of installation, the amount of electricity generated, and government policy support for the development of solar energy. This article presents the design, simulation, and economic analysis of a grid-connected rooftop solar power project. (Nguyen, T.B. and Van, P.H., 2021)

The process of obtaining photo voltaic power involves designing, selecting, and specifying specifications depending on various factors, such as geographic location, weather conditions, solar radiation, and load consumption. This paper presented a detailed design of a stand-alone rooftop solar PV system to provide an uninterrupted power supply for dormitory buildings. It outlines a detailed procedure for determining each component of a stand-alone rooftop solar PV system and analyzing its performance using simulation software. A detailed cost analysis including installation and maintenance of the rooftop solar PV system over its lifetime was also carried out. PV generation costs and environmental benefits are also highlighted. (Shukla, 2016)

Indonesia for power generation. The work is also to calculate the reduction in greenhouse gas (GHG) emissions that can be obtained with a PV system installed on the roof of the building. The roof surface area is determined using the Polygon feature of Google Earth TM. The energy output of the system was simulated with the Solar GISpv Planner software program. The type of PV system connected to the grid has been selected in the simulation. The analysis of the reduction of greenhouse gas (GHG) emissions was carried out using the RET Screen. Simulation program. (Tarigan, E.2018)

As we know, the need for electrical energy is increasing along with population growth and technological developments. This increase was also triggered by the energy demand growth rate of 6.86% per year. Most of the energy needs come from non-renewable energy which has limitations and is not environmentally friendly. Despite being affected by Covid, this period is a momentum to start the direction of clean energy policies. The utilization of solar power can be started by utilizing a rooftop solar power system on the roof of a hotel or on the roof of other industrial buildings. As one of the research and development institutions in the housing and settlement infrastructure sector, it tries to provide alternative technology solutions through an innovative technology called PV-roof.

Energy is a necessity that is needed by society. The increasing number of people in Indonesia makes the increase in 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 and renewable energy that exists throughout Indonesia such as geothermal, hydro energy, wind energy, bioenergy (bioethanol)., biodiesel, biomass), ocean current energy, nuclear energy, and solar energy. This review article is our view of the potential of new and renewable energy in Indonesia. It is hoped that the use of new and renewable energy can start with people who use small-scale energy so that they 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 4800Wh/m2/day. This potential can be utilized, one of which is as a direct power plant, through the use of Solar Power Plants (PLTS). Rooftop Solar Power Plant (PLTS rooftop) is the 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) as well as distributing electrical energy through the consumer electricity connection system of PT. PLN (Persero). The rooftop PLTS system in system configuration includes an on-grid system because it is connected to the PLN electricity network. This means that the power produced by PLTS is not only for its own use but can be channeled to the systems connected to it. During the day, when the PLTS electricity production exceeds the load requirement, this excess is automatically channelled to the grid and this excess is automatically recorded by the Export-Import kWh meter. However, when the PLTS electricity production does not meet the load needs, then the PLTS electrical energy is prioritized to be used and the remaining electricity shortage is supplied from the grid. Rooftop PLTS is a form of electricity generation that is environmentally friendly and is also suitable for development in urban areas because this plant installation can be installed and placed on the roof, walls, or other parts of the building. Rooftop-type PLTS installation is a form of renewable energy utilization (in this case solar/solar energy), which can be installed on the roof of a building, whether residential, office, educational, or shopping centers. To further encourage the use of solar energy, it is necessary to develop rooftop solar power plants that generally have a small-scale capacity (<1MWp). Rooftop PV mini-grid has their advantages when compared to large-scale PVmini-grid, including it is easier and cheaper to integrate with existing electricity systems, can take advantage of existing land (reducing land investment costs), and can also reduce the burden on the existing system network. The government regulates all rooftop PLTS activities in every building or building. This is in accordance with the recommendations based on the Presidential Regulation (Perpres) in Attachment 1 to the Presidential Regulation of the Republic of Indonesia Number 22 of 2017 concerning the General National Energy Plan. (ESDM, 2020) Feasibility studies are a very important stage to determine whether or not an area is feasible for the development of a power plant, including the Solar Power Plant (PLTS), in terms of technical, economic, and environmental aspects. In some cases, based on development priorities, 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. The difference is in the weight of the investigation and in terms of the assessment. (Wahyudi & Sutikno, 2011), Gorontalo Province is a province which has an area that occupies part of the northern region of Sulawesi Island with various regional characteristics, ranging from coastal areas to mountainous areas, where several areas in this province have an attraction for investors to invest 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 impact on energy needs both now and in the future. The fulfillment of energy in the Gorontalo Province area is currently not fully evenly distributed, especially in several districts. This condition is influenced by the existence of poor people (reaching 18.32%). In addition, the unequal distribution of energy infrastructure is an energy problem faced by this province. The RUED of Gorontalo Province is expected to be a reference for an integrated regional energy management system in overcoming energy problems and challenges in the context of achieving energy security and independence in Gorontalo Province.

The electricity supply in Gorontalo Province, where the peak load reached 81.9MW in 2015, is supplied by power plants located in Gorontalo Province and the North Sulawesi-Gorontalo Interconnection System. The condition of power generation in this province is still dominated by fuel-fueled power plants, PLTD, reaching 63.08 percent of the total generating capacity in Gorontalo Province.

The composition of power generation as mentioned above creates problems in terms of the basic costs of providing electricity which directly affects the selling price of electricity. 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 from the price is charged to subsidies provided by the Government. (RUED Prov. Gorontalo, 2018).

Table-1. Types of power generation in Gorontalo province in 2015.

No	Type of generator	Fuel	Installed capacity (MW)	Electric power Capable (MW)
1	Diesel power plant	Fuel oil	23,2	15,2
2	Gas power plant	Gas fuel	100,0	100,0
3	Hydroelectric power plant	Water	21	4
4	Electrics team power plant	Coal	21	20
5	Solar power plant	Sun	2,0	1,8

The main factor in planning a PV mini-grid apart from the technical aspect is considering factors such as the planned PLTS operating pattern and whether or not PLTS is connected to the electricity network at the location plan. The above factors affect the selection of the type and capacity of the main components, namely: solar modules, and inverters. PLTS capacity is expressed by kilowatt peak (kWp) and inverter capacity is expressed by (kW). The desired level of reliability affects the configuration, capacity, and number of inverters. The first step in the PVmini-grid development planning process is to assess whether it is feasible to continue. Carrying out this assessment requires a study of a number of aspects, including technical, environmental, financial, social, economic, and risk aspects. But the general factors that most people consider are technical feasibility and cost. (Sianipar, 2017)

2. RESEACH METHOD

2.1 Research Type

The search and modeling method in this study uses the Photovoltaic System Software (Pvsyst) application by conducting a survey of research sites for planning the installation of a Rooftop Solar Power Plant (PLTS) to determine the condition of the building, the geographical location of the research location, and collect the necessary data to obtain secondary data which will later become a reference and input data for modeling PLTS Rooftop using PVsyst software. The aim is to obtain a suitable PLTS topology and obtain validation which will determine the magnitude of the loss value from the modeling that affects the performance ratio and efficiency values for Modeling Rooftop PLTS at Ichsan University, Gorontalo.

This research was conducted with experimental research methods. The purpose of this study is to obtain an explanation of the problems examined in the explanation in the form of a causal relationship between the dependent variable and the independent variable that affects the problem, namely by using a questionnaire as an instrument to answer a set of questions or a written statement to the respondent. (Qomariyatus Sholihah, 2019)

2.2 Research Location

This research is located in Gorontalo City at the Ichsan University Building in Gorontalo where the current availability of electrical energy is unable to keep up with demand growth both in the short and long term in Gorontalo City. Increasing the capacity of electrical energy is very strategic in supporting the direction of the development of leading industrial clusters in the Sulawesi region, so the existence of a rooftop Solar Power Plant (PLTS) is very helpful in overcoming the electricity crisis in Gorontalo City where the hydrological condition of Gorontalo City is due to hydrological phenomena such as rainfall, temperature, evaporation, duration of solar radiation, wind speed, river discharge, river water level, flow velocity, and river sediment concentration will always change according to time and have little l and.

Figure-1. UNISAN Gorontalo building layout.

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The modelling of an environmentally friendly Rooftop Solar Power Plant (Plts) in Gorontalo City is carried out by identifying the roof layout of the Ichsan Gorontalo University building, then making the ideal design by compiling specifications for equipment on the market, after that the required cost calculations and calculations are carried out. The output power of electricity generated for analysis of profits and the number of investment costs for installing PLTS Rooftops for buildings is also very dependent on the type and choice of product types used. A good product is a product that can provide reliable guarantees and after-sales. The investment in installing PLTS Roof top for buildings is quite high and with long return (ROI) that is achieved if the electricity is sold directly to PLN.

3. RESULT AND DICUSSIONS

Ichsan University Gorontalo is located in Gorontalo City, precisely on Jl. Drs. Achmad Nadjamuddin No.17, Dulalowo Tim., Kec. Central City, Gorontalo City, Geographically the area of Gorontalo City is located between 00º 28' 17” - 00º 35' 56” North Latitude (LU) and 122º59'44”-123º05'59” East Longitude (BT) with an area of 64, 79 km² Gorontalo City consists of 5 sub-districts, namely West City, Dungingi, South City, East City, and North City Districts covering an area of 64.79 km2 with a total population of 147,354 people. The sub-district with the largest area is Kota Utara District (16.71 km2) while the sub-district with the smallest area is Dungingi District (4.10 km2). Land use in Gorontalo City is divided into paddy fields, gardens/fields, yards, and others. Thelandusedwas1, 013Ha, 695Ha, 452Ha, and 39.74 respectively in 2003. Survey of the location of PLTS Rooftop installation to determine the area of the roof that can be installed PLTS, and whether there is potential for shading around the area to be installed PLTS.

Table-2. Monthly meteo values.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	
Horizontal global	5.45	5.37	5.66	5.95	5.50	5.06	5.21	6.07	6.23	5.49	5.59	4.95	5.54	kWh/m²/day
Horizontal diffuse	2.27	2.69	2.53	2.24	2.35	2.04	2.35	2.50	2.20	2.82	2.37	2.40	2.40	kWh/m²/day
Extraterrestrial	10.02	10.38	10.51	10.23	9.71	9.36	9.46	9.92	10.33	10.37	10.09	9.85	10.02	kWh/m²/day
Clearness Index	0.544	0.517	0.538	0.581	0.566	0.541	0.550	0.612	0.603	0.530	0.554	0.502	0.553	ratio
Ambient Temper.	26.9	26.9	27.3	27.0	27.4	26.5	26.8	27.0	27.0	27.5	27.1	27.2	27.0	°C
Wind Velocity	1.3	1.5	1.4	1.1	1.1	1.2	0.6	1.1	0.7	1.3	1.1	1.1	1.1	m/s

Shadow analysis is a very important step in the planning stage of the PLTS Rooftop, this analysis aims to ensure that sunlight falling on the solar panel is not blocked by objects in the vicinity. Because this shadow effect can affect the efficiency of the solar module in producing electricity (solar module performance). In Gorontalo City, there are generally two types of upper forms, namely flat roofs and sloping roofs (prisms). In the case of the UNISAN Gorontalo Building, the roof is in the form of a Prism Roof, so in planning it is necessary to pay attention to the direction of the roof orientation and the slope of the roof, a roof facing north or south is an ideal condition for the installation of PLTS Rooftop.

Figure-2. UNISAN Gorontalo building directions.

Based on the position of the UNISAN building because 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 panels can be blocked by the shadow of the roof itself so as to reduce the amount of energy that will be generated by PLTS Rooftop. So that in planning it is better to make additions to the roof structure because it is necessary to add solar panel support poles so that the position of the solar panels is higher and avoids the shadow of the roof itself.

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Table-3. Monthly meteo values array losses.

Array losses

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 20.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 0.043 mΩ
Loss Fraction 1.5 % at STC

Serie Diode Loss
Voltage drop 0.7 V
Loss Fraction 2.3 % at STC

Module Quality Loss
Loss Fraction -0.8 %

Module mismatch losses
Loss Fraction 2.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

IAM loss factor
Incidence effect (IAM): Fresnel smooth glass, n = 1.526

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.998	0.981	0.948	0.862	0.776	0.636	0.403	0.000

In addition to the shadow of the roof itself, the shadow of the vegetation around the building can fall on the solar panels if a shadow analysis is not carried out first, as shown in the image below. The solution for the presence of tree shadows falling on the roof, of which is tree cutting or leaf pruning. If viewed from the satellite image of the UNISAN building, it is clear of vegetation shadows. Shadows on the array that occur during the day will affect the output power. It is hoped that a detailed analysis of each occurrence of shadows in the array can be carried out to avoid the occurrence of shadows in the array. The shadow effect can reduce solar radiation and result in a decrease in the energy generated by the system. However, when shadowing occurs only in part of the array, there will be a reduction in maximum stress. Thus, a reduction in the maximum energy will occur in the array.

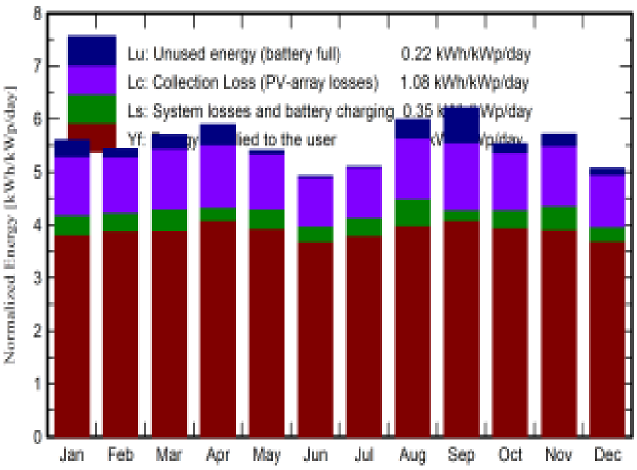

Figure-3. Normalized productions (preinstalled kWp).

The roof area for PLTS installation needs to be calculated carefully, because if the roof is exposed to shadows, or there are utility equipment on the roof (such as outdoor AC units, pumps, etc.), then the potential roof area will be smaller than the total available roof area. From the results of the desk study, it was concluded that the site survey at the University of Ichsan Gorontalo was focused on finding potential are as for the construction of PLTS Rooftop. This is because the roof of the UNISAN Gorontalo building is curved with varying slopes.

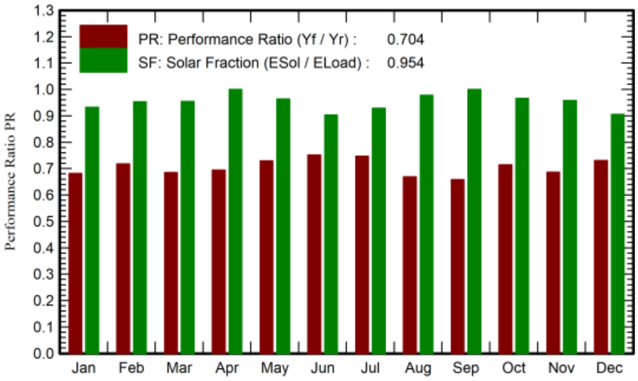

Figure-4. Performance ratio.

The inverter selection in this study is based on the capacity of the PV System simulation results, with a capacity of 320 kWp; the selected inverter must have a decentralized system. The inverter used also has the flexibility to allow for an increase in the number of inverters when there is an increase in power demand. The inverter used also has the ability to operate in parallel when power requirements increase in the area and has the ability to be upgraded from single-phase to three-phase. Inverters also have the ability to be integrated (hybrid) with power plants with energy sources from PLN.

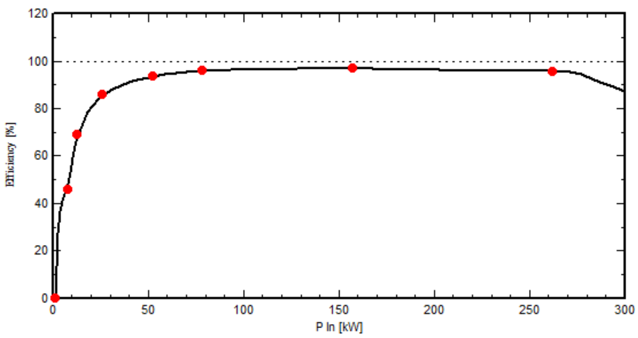

Figure-5. Input power efficiency.

This is done considering that PLTS can be interconnected with the local PLN network or with networks that are managed independently by the local government/local community. PLTS locations are entirely located in office buildings so that the inverter is expected

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to operate reliably in conditions with different types of load with minimal supervision and supervision, as well as against conditions in the field that tend to be corrosive.

The specific energy yield of the solar module is determined taking into account the standard irradiation of 1000W/m2. However, it does not always happen that the irradiation remains the same, and also for several days, the irradiation does not even touch 1000 W/m2. In addition, radiation varies daily, hourly, and even after a few minutes (depending on the cloud). Figure-5.1 below shows the variation of power output with varying irradiation.

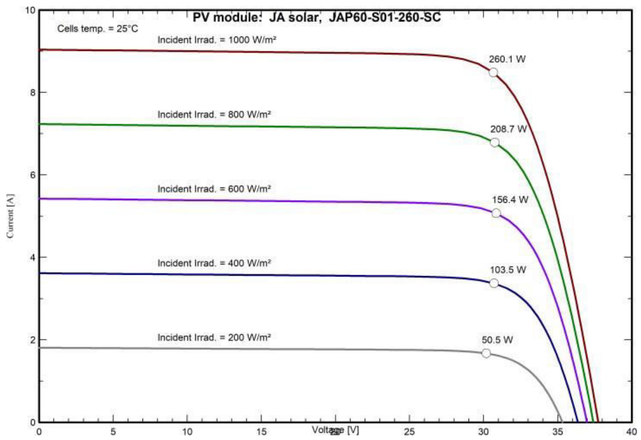

Figure-6. Effect of irradiation on power output of solar module.

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 (because less energy is generated from the same number of module capacities). In addition, such variations in irradiation are continuous throughout the day. This leads to further variation (and mostly reduction) in specific results.

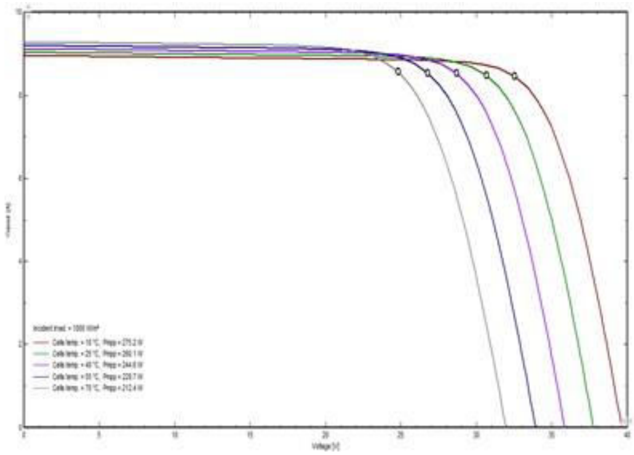

Figure-7. Temperature solar module.

One of the factors that influence the energy produced by PV and perhaps the most uncontrollable factor that affects the yield of a solar module is its operating temperature. Due to various climatic conditions, the temperature variation is quite large. The overall effect of temperature can be visualized in Figure-7, where the variation causes a slight increase in current while reducing the voltage drastically with increasing temperature. Therefore, an increase in temperature will cause a decrease in the overall power output of the module. With such frequent variations, solar modules will not produce the expected specific energy yields.

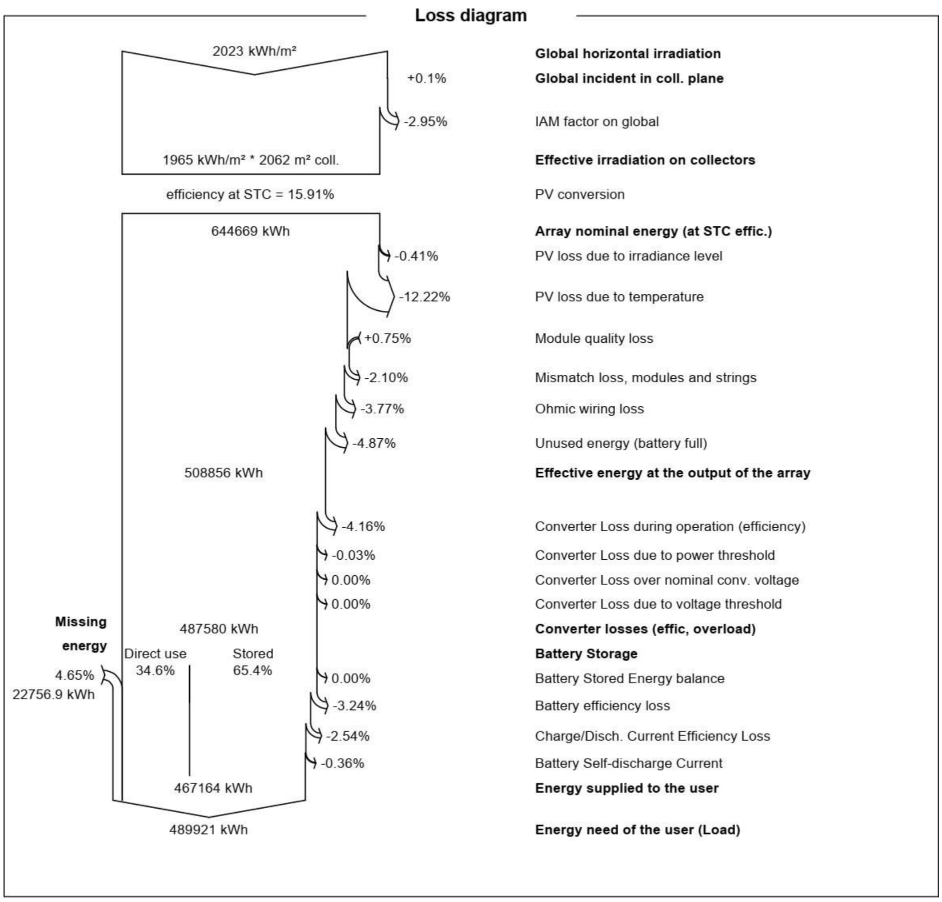

Figure-8. Loss diagram.

From the simulation results using PVsyst Ichsan University Building, Gorontalo, it produces global horizontal irradiation of 2023 kWh/m2 with efficiency at STC of15.91%, in the simulation a PV panel system using a standalone system with PV array1261 units with a total Pnom of 328 kWp, The battery is lithium-ion, 925 units of LCO produce a voltage of 241 V with a current capacity of 9990 Ah. Produces energy per year of 513619 kWh/year with a ratio of 70.36% where the active load is 13 hours/day.

4. CONCLUSIONS

a) There are 2 approaches used in modelling the rooftop PV mini-grid at the University of Ichsan Gorontalo, namely: (1) maximizing the absorption of solar energy by the solar module/photovoltaic module, by optimizing the surface orientation by adjusting the tilt angle of the solar module to the horizontal axis and adjust the direction of the front of the solar module (azimuth angle); and (2) the slope of the solar module is adjusted to the slope of the roof of the existing building. In this dissertation research, the approach used is the condition of the solar module being installed following the slope of the roof (especially for prismatic roofs). This approach was taken in order to minimize modification of the roof structure during the construction phase.

b) 1261 units of PV array with a total Pnom of 328 kWp, for battery technology, namely lithium-ion, 925 units of LCO produce a voltage of 241 V with a current capacity of 9990 Ah. Produces energy per year of 513619 kWh/yr with a ratio of 70.36%.

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