Rooftop Photovoltaic System for Microgrid Design in State Polytechnic of Ujung Pandang

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Abstract: Renewable energy sources are promised alternative energy to reduce using thermal power generation which emitted emission gas. Solar energy is a good alternative choice for power generation in tropical country such as Indonesia because of the geographical condition and a good duration time of sunlight every year. The implementation of solar energy for campus electrical installation as a microgrid system to bring out the idea of "green campus" is proposed in this paper. This microgrid system is design based on the potential of solar energy sources and the load characteristics at the electrical engineering department building campus 2 State Polytechnic of Ujung Pandang in South Sulawesi, Indonesia. Maximum consumed energy per day in this building during weekdays is 380 kWh. Therefore, PV panels power capacity is 108 kWp and the number of installed PV for this system is 360 PV panels with battery capacity 10000 Ah. Based on the area of the rooftop, needed space for installing the PV panel is 54% of the total wide area.

1 INTRODUCTION

Nowadays, looking for friendly resources of energy becomes a big issues in all countries. The drawback of conventional fossil fuel energy that emitted hazardous emission gas alert people to care the negative affect to human being and environment. Therefore, the sources of conventional energy are limited and some countries such Indonesia have moved to the renewable energy sources. The big challenge of using the renewable energy is the low efficiency, reliability and its high initial cost. Photovoltaic (PV) energy is one of the important sources of renewable energy. In the recent decade, PV has been a competitive energy source. The efficiency of PV modules has been increased significantly and now it is reaching 40% by the use of new technologies (Tahri et al., 2018). Power quality is also improved (Yusran et al., 2013).This made the PV system become an essential system in worldwide electrical power production.

Electrification ratio of Indonesia on December 2017 is around 95.35%, it is better than the government target of 92.75% and electric ratio for south Sulawesi is 99.12%. However, majority of the power generation are thermal power plants. Therefore, to reduce the dependency to fossil sources, the government has set the target 23% from the total used energy from renewable energy till 2025. Based on Electricity Supply Business Plan (RUPTL) from PLN as utility company from Indonesia, the target of solar power is 1047 MWp and the realisation of solar power generation till 2018 is 94.42 MWp (ESDM, 2018). Therefore, there are still a big challenge to fulfil the target of the solar power generation. Campus as an educational institution and research has a chance to build a solar power generation in a microgrid system and there are still small number of campus in Indonesia provide electrical energy from renewable energy sources. In campus, space is limited, so placement of PV panels is usually only possible on the rooftops. Various parameters have to be considered when installing solar panel depend on the shape of buildings' roofs and regarding the received solar irradiance. Some of the more important considered parameters in solar potential estimation are geographic location, surface topography and shadowing effects from surrounding (Yuan et al., 2016). PV power output has a strong correlation with ambient temperature and irradiation of the

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sunlight so the intermittency of PV power supply can threaten microgrid integrity (Ho et al., 2013).

Studies on microgridsare generally classified into two groups: system design and operation planning. System design involves the selection and sizing of the distributed energy resources, minimum investment cost and environmental issues. The optimal design is very important to maintain the reliability of the system. Selection and sizing is related with load characteristic, operation and maintenance cost and weather conditions (Hirsch et al., 2018). The optimal sizing is between peak load satisfaction and minimalized investment cost. Microgrid operation planning includes the management of a microgrid (Sahoo et al., 2015).

Considering the role of campus as an education and research institution, campus can be a role model to apply renewable energy sources in microgrid system for its electricity demand. So, the purpose of this research is as preliminary study for microgrid installation on the rooftop electrical department buildings. Number of PV panels, sizing of battery and used area for PV panel placement on the buildings' roof are considered in this study.

The rest of this paper is organized as: location and solar potential in section 2 followed by investigating the campus load characteristic in section 3. Section 4 presents the result and discussion then conclusion are drawn in section 5.

2 METHODOLOGY

2.1 Location And Potential

Buildings of Electrical Engineering Department, Campus 2 of state Polytechnic of Ujung Pandang are located in Moncongloe, Maros Regency, South Sulawesi. The buildings location is at 5°08'40.9"S, 119°31'24.3"E. There are 4 main buildings in Electrical Engineering Department; 1). Theatre Building 2). Laboratory Building 3). Administration Building and 4). Classroom Building. Those are figured out in figure 2. The shape models of these buildings are a little bit different. Theatre buildings is half round. It is clearly shown in number 1 of Figure 1. The roof shape is combination of concrete deck roof and hipped roof. The roof shape of building number 2,3 and 4 are shed model. From the left side, theatre and laboratory buildings can be shown in Figure 2. Those buildings are potential for PV panel placement.

Figure 1: Buildings of Electrical Engineering Dept.


Figure 2: Electrical department building from left side.

Photovoltaic energy is the transformation of sunlight into electrical energy through PV array panel which is depend on irradiance and temperature. The production of this energy fluctuates in nonlinear characteristic because of intermittency condition and the depending on the amount of radiation striking the surface of the PV array and temperature of the location. Based on the location, meteorological data can be obtained. Daily radiation and temperature data are provided by NASA Surface Meterology and Solar Energy Database for monthly average values over 22 year period. Those data are global irradiation and ambient temperature for a year. From Figure 3, the highest global irradiation is in September. The average irradiation is around 5.87 kWh/m^2/day. Basically, on July till October is the higher irradiation during the dry season in this area. The lower global irradiance is in December and January because of cloudy and rainy season in this area.

Temperature in this location is high enough. The data are shown in Figure 4. The average temperature is 26.38 °C. Basically, temperature influences the behavior of solar PV because increased temperature will increase the current of PV and the effect is the decreasing of the maximum harvesting power from the panel (Hedi et al., 2017). However, global irradiation and temperature in this location is potential for solar photovoltaic system installation.

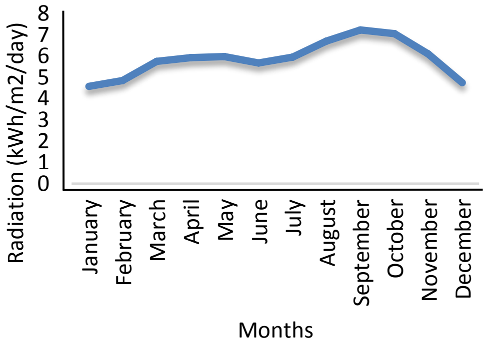

Figure 3: Average daily radiation.

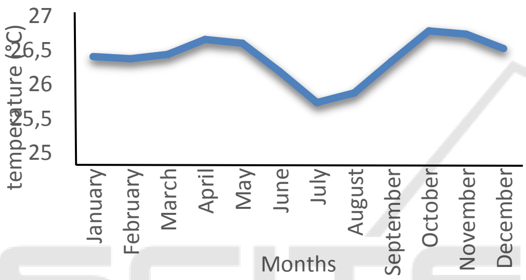

Figure 4: Average daily temperature.

2.2 Campus Load Characteristic

Electrical Engineering Department in campus 2 is new buildings. Majority of teaching activity is still in campus 1 of Tamalanrea but some of laboratories are located in campus 2. Therefore the consumed energy is not yet really significant. The kind of loads in these buildings are lighting lamps, electric machines, water pumps, power electronics devices, computers and laboratory devices. Most of big energy comsumption is from laboratory equipments such as electric machines. Normally, daily operation is from 8 to 16 o'clock during weekdays (Monday to Friday). On the weekend, the electrical load is only lightings in the hall and parking area. Peak hour of energy consumption is around 10 to 12 0'clock every weekdays

Daily load of the buildings is measured and recorded with power quality meter METREL for 5 days from monday to friday during working hours. Range of data is every 30 minutes. Combined power (active, reactive and apparent power) are measured to define the load characteristic of these building. The instalation is in three phase R, S and T to supply load in electrical department buildings. Measurement device installation is took place in the distribution panel of the buildings as shown in Figure 5.

Figure 5: Installation of combined power measurement.

Following figures from Figure 6, Figure 7, Figure 8, Figure 9, and Figure 10 are measured data from 12 to 16 March 2018 or Monday to Friday during working hours.

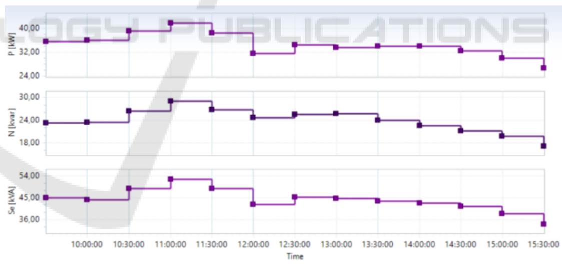

Figure 6: Consumed power on Monday 12 March 2018.

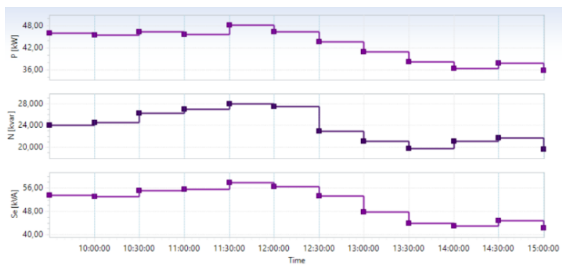

Figure 7: Consumed power on Tuesday 13 March 2018.

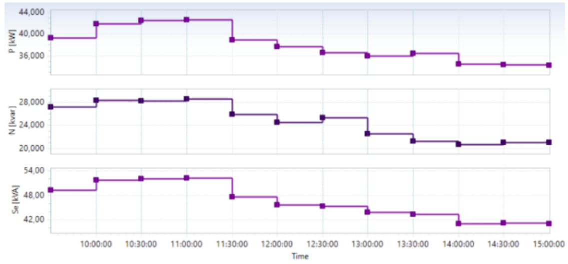

Figure 8: Consumed power on Wednesday 14 March 2018.

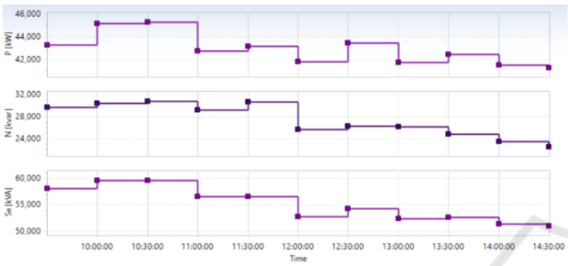

Figure 9: Consumed power on Thursday 15 March 2018.

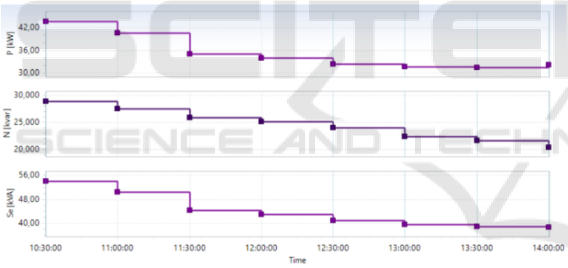

Figure 10: Consumed power on Friday 16 March 2018.

From Figure 6 to 10, it is shown the condition of consumed power in the buildings. Peak hour on Monday is from 10.30 to 12 o'clock in which maximum active power 41.77 kW, maximum reactive power 29.01 kVAR and maximum apparent power 52.69 kVA. Peak hour on Tuesday is from 11.30 to 12.30 o'clock, where maximum active, reactive and apparent power are 47.50 kW, 27.99 kVAR and 57.92 kVA. On Wednesday, the peak hour is from 10 to 11.30 o'clock and the maximum active, reactive and apparent power are 42.66 kW, 28.62 kVAR and 52.26 kVA. Peak hour on Thursday is around 10 to 11 o'clock and the maximum active, reactive and apparent power are 45.31 kW, 30.86 kVAR and 59.65 kVA. For the last day of research data, the peak hour is from 10 to 11.30 o'clock with maximum active power 43.64 kW, maximum reactive power 28.96 kVAR and maximum apparent power 54.09 kVA.

The varied data and peak hour depend on the teaching activities in campus. Most laboratory and workshop activities are in the morning from 8 to 14 o'clock. Most of operated laboratory devices for obtained data is from 10 to 12 o'clock. Therefore, that is the reason why the peak hour is around that time.

Consumed reactive power for electrical applience is high. It is indicated that many inductive load operated in campus. Electric machines, air conditioner, water pumps are example of applied inductive loads. For solar system design, only active power will be considered because reactive power is produced from electrical moving sources such generator.

3 RESULT AND DISCUSSION

PV panels placement planning is on the rooftop of Theater and Laboratory building because of better position to the sun. The roof shape of the theater building is combination of concrete deck roof and hipped roof with estimated area 528 m^2 meanwhile laboratory building roof shape is shed roof in west facing with 10 degree inclination and wide area is 782 m^2. So total estimated area of the two building is 1310 m^2. However the PV panel placement area must be smaller than the wide area of both buildings.

To design this system, choosing the PV panel and inverter is very important. In this research, polycrystalline 300 $W_P$will be chosen because of availability on the market and certified PV panel and the capacity of chosen inverter is 20 kW. Table 1 provides the specification of applied PV panel.

Table 1: PV panel specification.

Parameter	Value
Pmax	300 W
Imp	8.28 A
Vmp	36.2 V
Isc	9.27 A
Voc	43.4 V
NOTC	45±2 °C
Max. System Voltage	1000 V
Max. Series Fuse	16 A
Weight	20.65 kg
Dimension	1956 x 992 x 40mm

To calculate the power capacity of PV system daily load supply, it can be determined using this equation [10]:

$$\mathbf{P_{PV}} = \frac{\mathbf{E_C}}{\mathbf{H_{sun}\,x\,\eta_{sys}}} \tag{1}$$

Where:

$\mathbf{P_{PV}}$: Power capacity of PV [kWp]
$\mathbf{E_C}$:Total energy demand per day [kWh]
$\mathbf{H_{sun}}$: Sun hour per day [h]
$\boldsymbol{\eta_{sys}}$: System efficiency [%]

Maximum active power consumed from all data is 47.5 kW on Tuesday and it is shown on Figure 8. This data becomes the base to determine the load demand. So the total consumed energy for 8 hours (working hours) is 380 kWh. Normally, total sun hour in Indonesia especially in South Sulawesi is 4 hour/day, the condition when the PV panel working in maximum point to harvesting energy from sun. If the system efficiency is 88%, then the power capacity of PV will be:

$$\mathbf{P_{PV}} = \frac{\mathbf{380\ kWh}}{\mathbf{4\ x\ 0.88}} = \mathbf{107,98\ kWp} = \mathbf{108\ kWp}$$

From the table 1, capacity of the PV panel is 300 Wp so number of PV panel need is:

$$\frac{\mathbf{108\ kWp}}{\mathbf{300\ Wp}} = \mathbf{360\ PV\ panel}$$

To determine the number of series connection of PV panel, formula (2) can be applied:

$$\mathbf{J_S} = \frac{\mathbf{V_{INV}}}{\mathbf{V_{mp}}} \tag{2}$$

Where;

$\mathbf{J_S}$: number of series connestion [unit]
$\mathbf{V_{INV}}$: inverter voltage [volt]
$\mathbf{V_{mp}}$: maximum power voltage [volt]

Maximum power voltage (V_{MP}) from the PV specification is 36.2 V and the maximum input voltage of inverter (V_{INV}) is 800 V. So number of series connection is:

$$\mathbf{J_S} = \frac{\mathbf{800}}{\mathbf{36,2}} = \mathbf{22,099} = \mathbf{23\ unit}$$

Therefore, there are 16 panel arrays in parallel which consist of 23 PV panels in series connection.

This system is design to operate in connected grid mode and islanded mode. Islanded mode will handle the system in the weekend or vacation to supply only lighting loads in campus because of lower consumed energy. Then if the system is islanded mode, it means need batteries. Total capacity of battery is usually signed with C, which means measurement of how much energy can be store in the battery. The battery capacity is calculated using formula as follows (Giriantari, 2016):

$$\mathbf{C_{bat}} = \frac{\mathbf{E_C}}{\mathbf{U_{sys}}}\,\mathbf{x\ H_{aut}\,x}\,\frac{\mathbf{1}}{\mathbf{DoD}} \tag{3}$$

Where;

C_{bat} : Battery Capacity [Ah_{c10}]
E_C : Total Energy Demand per day [VAh]
Usys: DC System Voltage [V_{DC}]
H_{aut} : Autonomous day [day]
DoD : Depth of Discharge [%]

DoD means how much energy that the battery delivered to the load. If the battery is 100% fully charged, it indicates the DoD of the battery is 0% and if the battery is 100% empty, DoD is 100%. In order to provide a longer cycle life of battery, DoD cannot be 100%. Therefore, the DoD of this battery storage system is 80%. DC system voltage is usually 24 V or 48 V and this system is design for 48 V. the autonomous day is set for 1 day, so battery capacity will be:

$$\mathbf{C_{bat}} = \frac{\mathbf{380000}}{\mathbf{48}}\,\mathbf{x\ 1\ x}\,\frac{\mathbf{1}}{\mathbf{80\%}} = \mathbf{9896\ A}$$

The battery capacity can be designed to be 10000 Ah, therefore the energy storage capacity is 480 kVAh.

Applied inverter for this design is bidirectional inverter because of the connection of on grid and off grid mode.

For the placement of PV panel on the roof, needed space on the roof is 700 m^2 or around 54% of the total wide of the rooftop buildings. This is available because of the total rooftop area is 1310 m^2. However, the weight of the installed panels should be seriously considered because of the structural elements of building. For this design, the weight of the panels will be 7.434 kg, so it is heavy enough for the existing buildings which are not constructed for PV panels on the roof.

To keep the continuity of electric supply if the PLN utility supply is collapse or the energy from the solar panel and battery are not enough to supply the loads, diesel generator is set to back up the system. Output of the diesel generator for these buildings is 80 kVA. Specification of the diesel generator can be seen in Table 2.

Table 2: Diesel generator specification

Parameter	Value
Model	HT - 80
Output	80 KVA
Voltage	220/380 V
Current	122 Amp
Pf/Phase	0.8 / 3
Speed	1500 Rpm
Frequency	50 Hz
Rating Cont.	80%

4 CONCLUSIONS

Rooftop photovoltaic system for microgrid design is presented in this paper and the results can be concluded as this system for daily energy demand 380 kWh of 3 phase connected system in Electrical Engineering Department, Campus 2, State Polytechnic of Ujung Pandang needs 360 PV panels to supply the loads. The power capacity of the PV panels is 108 kWp with installed battery capacity 10.000 Ah. Roof space needs 54% of the total existing roofs for installed PV panels. To keep the continuity power supply, diesel generator with 80 kVA capacity is set to back up the system.

Campus as a role model to develop microgrid system to response the government policy of applied renewable energy sources as an environmentally impact consideration to reduce the thermal power generation. Microgrid system design in campus is very important as the basic knowledge to develop microgrid system.

To explore the potential of renewable energy in this location, future research will be developed a microgrid system with considering wind turbine as a hybrid power generation. Wind speed in this location is considerable to harvest electrical energy.

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