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Calculation Array Solar Panel Capacity of 50 kWP Pamulang University South Tangerang

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Abstract – **Pamulang University is located in the South Tangerang area consisting of three buildings and 6 faculties and 5 of them are engineering faculties. Currently implementing Solar Panels is being carried out by the Faculty of Electrical Engineering, namely the application of new renewable energy sources. Installation of a solar power plant with a capacity of 50 KWP On-Grid is used as a provider of electricity for building lighting. The purpose of calculating the number of arrays is to determine the area and output power of the arranged solar panels. The problems faced before installation are the number of solar panels that will be arranged in the rooftop area, the amount of solar radiation and the output power. The use of research methods through the stages of calculation, monitoring, and standardization references was carried out for two weeks. The measuring instrument used in the research is the Seaward Solar Survey 200R, while the Global Solar Atlas (GSA) is used as a reference for insolation values in December 2022. The calculation results for the area of the array are 325.62 m², the PLTS electrical energy (EL) calculation is 393, 12 kWh, GSA of 6.14 kWh /m²/day, temperature correction factor (TCF) of 0.96, number of PLTS 102 solar panels with 6 PV strings, highest inverter output of 272.8 kWh and lowest value of 133.2 kWh.**

Keywords: Pamulang university, PLTS on Grid, Array Seaward 200R, PV String.

I. Introduction

Indonesia is still facing challenges in achieving development goals, especially in the energy sector. Indonesia still depends on fossil fuels which are the main problem in the country's energy supply. Power plant capacity reached 64.5 GW in 2018, an increase of 3% compared to 2017. The highest installed capacity for power plants in 2018 came from fossil fuels, namely 50% coal, 29% natural gas, 7% fuel, and 14 % of new renewable energy[1]. The energy produced by the sun is an energy source that can be converted into electrical energy and can be used for today's energy needs[2]. Likewise, the need for electricity at Pamulang University continues to increase due to the increasing lecture infrastructure. Electricity needs have been borne by the State Electricity Company (PLN). Therefore, the use of renewable energy as alternative energy to reduce dependence on PLN, namely the construction of an On-grid Roof Solar Power Plant (PLTS) with a capacity of 50 kWp in Building B Viktor[3][4]. PLTS construction also requires several calculations, especially the area of the photovoltaic array. Because it affects the capacity of inverters and components in other PLTS. Calculations for the area of the photovoltaic array use the equation according to the literature in previous research journals[5]. The results of the calculations can determine the number of solar panels needed and the number of solar strings installed to reach the capacity of the inverter and other components[6]. These calculations are supported by direct measurements using the Seaward Solar Survey 200R measuring instrument available at the Pamulang University Viktor electrical engineering laboratory.

Solar Power Plant (PLTS) is a generator with the method of converting electromagnetic energy by converting sunlight that radiates to the earth into electrical energy that can be utilized[7]. The process of change occurs in solar panels because there are many solar cells in them the electrical energy released by solar panels is DC (Direct Current). This DC (Direct Current) energy can be converted into AC (Alternating Current) energy with an inverter. PLTS is a power supply design for electricity needs from low to high, either independently or hybrid[8]. Solar panels are tools or devices consisting of several solar cells that convert light into electricity[9]. Part of the solar cell is called a cell because the sun is the biggest energy available to be utilized. Solar panels are also often called solar cells. Photovoltaic power can be defined as the luminous flux. Solar cells or PV cells rely on the beneficial photovoltaic effect to absorb solar energy and allow current to flow between two oppositely charged layers[10].

Inverters Is an electronic device that converts direct current/DC into alternating current/AC. An inverter is needed in PLTS because the current generated by the module is DC, while the current used in electrical equipment and electrical networks, in general, is AC.

The inverter used in this study is a type of Grid Tie Inverter (GTI). This type of inverter is also known as a synchronous inverter or grid-interactive inverter. The purpose of this research is to find out the amount of solar panel use by adjusting the area and knowing the amount of output power from the implementation of solar panels. research is expected to achieve maximum output results from the use of 50 KWP solar panels. [11].

II. BASIC OF THEORY

A. Solar Power Plant

A solar power plant is a generator using the method of converting electromagnetic energy by converting sunlight that radiates to the earth into electrical energy that can be utilized. The process of change that occurs in solar panels because there are many solar cells in it. The electrical energy released by solar panels is DC (Direct Current). This DC (Direct Current) energy can be converted into AC (Alternating Current) energy with an inverter. PLTS is a power supply design for electricity needs from low to high, either independently or hybrid[12].

B. PLTS On Grid System

PLTS On Grid System or Grid Connection Photovoltaic System is a system that uses solar radiation to produce electricity. The system will be connected to the PLN network by optimizing the use of solar energy using solar modules or photovoltaic modules that produce maximum electricity[13].

C. Solar Panels

Solar panels are tools or devices consisting of several solar cells that convert light into electricity. Part of the solar cell is called a cell because the sun is the biggest energy available to be utilized. Solar panels are also often called solar cells. Photovoltaic power can be defined as "luminous flux". Solar cells or PV cells rely on the beneficial photovoltaic effect to absorb solar energy and allow current to flow between two oppositely charged layers. All panel groups (strings) in the system are called arrays[14].

D. Inverters

Inverter is an electronic device that converts direct current/DC into alternating current/AC. An inverter is needed in PLTS because the current generated by the module is DC, while the current used in electrical equipment and electrical networks in general is AC. The inverter used in this study is a type of Grid Tie Inverter (GTI). This type of inverter is also known as a synchronous inverter or grid interactive inverter[15].

Figure 1 shows the circuit schematic of the inverter:

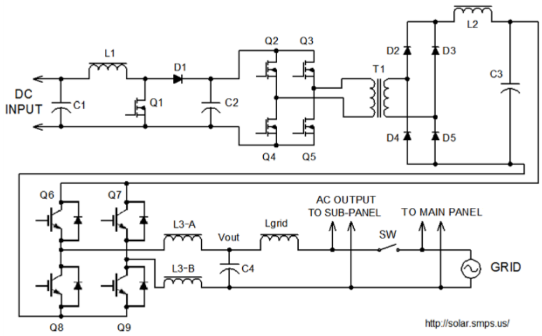

Figure 1. GTI Inverter Circuit

III. METHOD AND DESIGN

A. Research Stages

The steps are carried out by preparing a literature review for validating research data. while the measurements were carried out directly on the roof of the Pamulang University campus. using the Seaward Solar Survey 200R measurement tool, measurements are carried out, measurement data is monitored on the inverter side, calculations with equations that have been reviewed from previous journals and validation of temperature data according to reference from GSA[16].

Figure 2 shows the flowchart of research;

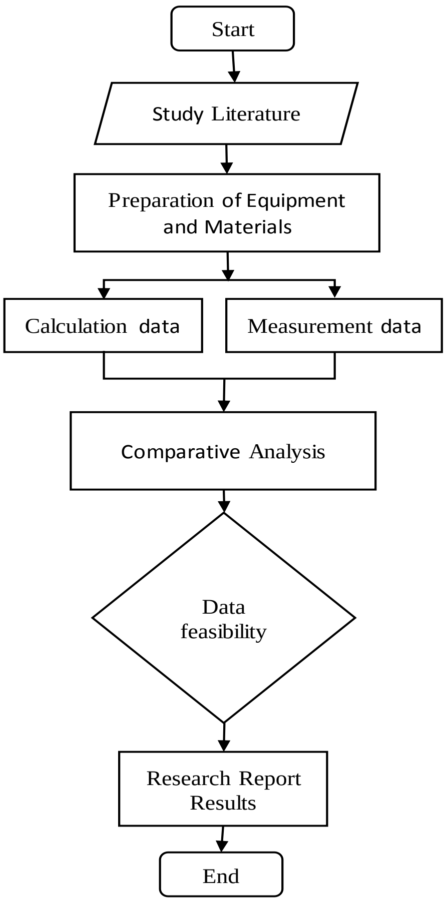

Figure 2. Flowchart Research

B. Calculating the Area of a Photovoltaic Array

The calculation of the area of the photovoltaic array will be calculated using the following equation:

$$PV\ Area = \frac{EL}{G_{av} \times \eta PV \times TCF \times \eta out} \quad (1)$$

Where:
EL =Energy Consumption (kWh/day).
Gav = Daily Solar Insolation Average (kWh/m²/day).
ηPV = Solar Panel Efficiency
TCF = Factor Correction temperature
ηout = Inverter Efficiency

The calculation of the array area or photovoltaic area has been carried out, followed by the calculation of the power (Wp) generated by the PLTS using the following equation or formula.

$$P_{Watt\ peak} = PVArea \times PSI \times \eta PV \quad (2)$$

Where:

Calculation of the number of solar panels needed is calculated by the following formula.

$$Number\ of\ Solar\ Panels = \frac{P_{Watt\ peak}}{P_{MPP}} \quad (3)$$

Where:
$P_{Watt\ peak}$= Power generated
P_{MPP} = Maximum output powersolar panels (W)

Calculation of the number of modules arranged in series or parallel using the following equation.

$$R.Seri\ Minimum = \frac{V_{Min\ Inverter}}{V_{oc\ Modul}} \quad (4)$$

$$R.Seri\ Maxsimum = \frac{V_{Max\ Inverter}}{V_{mp\ Modul}} \quad (5)$$

$$R.Paralel\ Maxsimum = \frac{I_{Max\ Inverter}}{I_{mp\ Modul}} \quad (6)$$

C. Calculation Solar Panel Array

Che calculation equation of the area of the array can use the following equation[17]:

$$PV\ Area = \frac{EL}{G_{av} \times \eta PV \times TCF \times \eta out} \quad (7)$$

Where:

EL= Energy Consumption (kWh/day).

Gav= Daily Solar Insolation Average (kWh/m²/day).

ηPV= Solar Panel Efficiency

TCF: Factor Correction temperature

ηout: Inverter Efficiency

D. Block Diagrams

Retrieval of measurement and monitoring data in research obtained from the main source and through an inverter as a load conversion equipment taking into account the output load of the solar panel power can be seen in Figure 3 below.

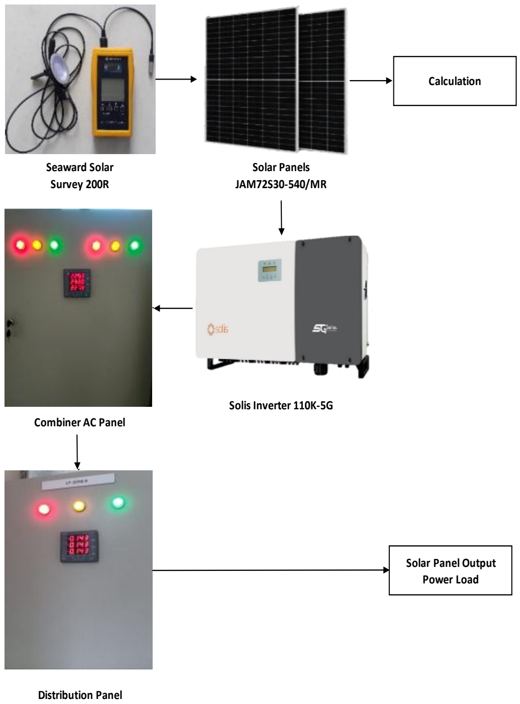

Figure 3. Block Diagrams Research

IV. RESULTS AND DISCUSSION

A. Research Tools and Materials

Seaward Solar Survey 200R for measurements for solar radiation in solar photovoltaics. besides that the tool can be used to determine or search for a PV temperature, ambient temperature, slope angle and cardinal angle. Solar Module JAM72S30-540/MR The module to be used is JAM72S30-540/MR monocrystalline type, Inverter Solis-110K-5G.

B. Calculation results of the Photovoltaic Array Area

Using the equation of the PV area, the following data is obtained:

$$PV\ Area = \frac{EL}{Gav \times \eta PV \times TCF \times \eta out}$$

$$= \frac{393.12\ kWh}{6.14\frac{kWh}{m^2} \times 0.209 \times 0.96 \times 0.98}$$

$$= 325.62\ m^2$$

so that an area of 325.62 m² is obtained.

1. Calculating PLTS Power (Wp).

From the calculation of the area of the photovoltaic array, so that the calculation of the power from the PLTS can be carried out as follows:

$$P_{Watt\ Peak} = PV\ Area \times PSI \times \eta PV$$

$$= 325.62\ m^2 \times 1000\ {W}/{m^2} \times 0.209$$

$$= 68{,}054\ W$$

2. Calculation of the Number of Solar Panels.
   The result of the area and power produced can be seen the amount of use of solar panels:

$$Number\ of\ Solar\ Panels = \frac{P_{Watt\ Peak}}{P_{MPP}}$$
$$= \frac{68{,}054\ Wp}{540\ Wp}$$
$$= 126 \text{ solar panels}$$

The number of solar panels installed is 126 units of solar panels to facilitate configurations that are arranged in series and parallel. The installed PLTS capacity is 126 units x 540 Wp = 68,040 Wp or 68 kWp.

3. The number series and parallel arrangement of solar panels:
   1) Minimum series circuit.

$$R.Seri\ Minimal = \frac{V_{Min\ Inverter}}{V_{oc\ Modul}}$$
$$= \frac{600\ Volt}{49.60\ Volt}$$
$$= 12\ solar\ panels$$

   2) Maximum series circuit.

$$R.Seri\ Maksimal = \frac{V_{Max\ Inverter}}{V_{mp\ Modul}}$$
$$= \frac{1100\ Volt}{41.64\ Volt}$$
$$= 26\ Panel\ Surya$$

   3) Maximum parallel circuit.

$$R.Paralel\ Maksimal = \frac{I_{Max\ Inverter}}{I_{mp\ Modul}}$$
$$= \frac{260\ Ampere}{12.97\ Ampere}$$
$$= 20\ solar\ panels$$

C. Measurement of input power to solar panel output power

Power measurements in PLTS research are installed and connected to the workload on the lighting of the Pamulang University building, especially where to eat. Each room has a kWh meter with a capacity of 1300 Watt for monitoring power usage. The number of kiosks in operation with a total of 63 kiosks. The electricity supplied to the 63 kiosks comes from PLN and the On Grid PLTS installed and operating with two inverters each with a PLTS capacity of 50 kWp. The total load of the Pamulang Viktor University baseman canteen is 81,900 Watts.

Measurements were made on inverters and solar panels for 10 days by monitoring the inverters. The results obtained are the output of the solar panel, namely DC voltage (Voltage), DC Current (Ampere) and Power (kWh) with perstring monitoring. The total string installed is 6 strings with the number of solar panels per string, namely 17 solar panels.

Data collection for 10 days obtained varied values due to factors from the weather and the use of loads on the solar panel output. The following are the results of measurements on solar panel radiation input and output with the highest value on day 7 and the lowest value on day 3.

D. The highest power yield on the seventh day.

On average from the measurement results on the 7th day, data collection on inverters and solar panels is carried out every 1 hour which shows the values of Radiation, DC Voltage, DC Current, and Power. Weather factors affecting radiation on the seventh day can be seen that the highest radiation was at 13.30 WIB with a radiation value of 835 W/m² with the highest voltage at 9.30 WIB with an average value of 633.9 V and the highest current output was at 11.30 WIB with an average value of 11.4 A, while the measurement results with the lowest radiation value were at 15.30 WIB with a value of 460 W/m² but at 16.30 WIB there was no solar radiation value, then the measurement results with the lowest voltage were at 15.30 WIB with an average value of 580 V and the lowest output current is at 13.30 WIB with an average value of 0.4 A. Table 1 describes the measurements and the highest output power on the 7th day.

Table 1. Measurement and monitoring of the highest power on the 7th day

Day	Time (mnt)	Solar Radiation (W/m²)	Voltage DC (V)	Current DC (A)	Power (kWh)
7th	9.3	643	633.9	9	53.7
	10.3	757	632.4	10.1	87.5
	11.3	829	625.6	11.4	127.7
	12.3	821	624	10.9	178.4
	13.3	835	631	6.5	209.2
	14.3	716	595.6	2.5	244.1
	15.3	460	580	5.2	262.5
	16.3	-	624.3	0.4	272.8

Figure 4 shows the following is a graphic image of the increase and decrease in the current and voltage values on the 7th day of the solar panel.

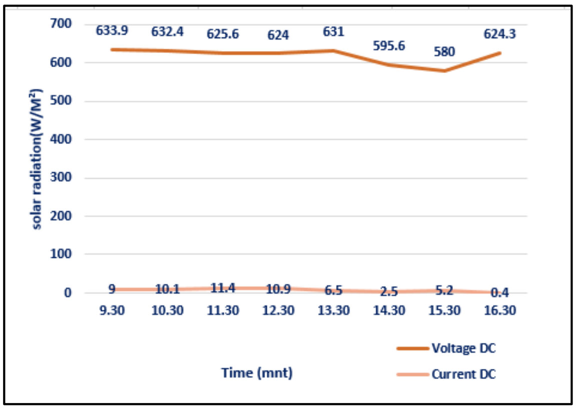

Figure 4. Current and voltage values on the 7th day

E. The lowest power yield on the third day.

On average from the measurement results on the 3rd day, data collection on inverters and solar panels is carried out every 1 hour which shows the values of Radiation, DC Voltage, DC Current and Power. Weather factors affecting radiation on the third day can be seen that the highest radiation was at 10.30 WIB with a radiation value of 415 W/m² with the highest voltage at 10.30 WIB with an average value of 664.7 V and the highest current output was at 13.30 WIB with an average value of 4.8 A, while the measurement results with the lowest radiation value were at 14.30 WIB with a value of 112 W/m² but at 15.30 WIB there was no solar radiation value, then the measurement results with the lowest voltage were at 13.30 WIB with an average value of 636.2 V and the lowest output current is at 16.30 WIB with an average value of 0.5 A. Table 2 shows the lowest power on day 3.

Table 2. Measurement and monitoring of the lowest power on day 3

Day	Time (WIB)	Solar Radiation (W/m²)	Voltage DC (V)	Current DC (A)	Power (kWh)
3th	9.3	372	663.5	5	36.1
	10.3	415	664.7	4.4	57.7
	11.3	309	646.7	3.7	75.4
	12.3	301	648.7	4.4	99.1
	13.3	212	636.2	4.8	117.5
	14.3	112	664.1	1.1	125
	15.3	-	655	2.2	130.2
	16.3	-	648.8	0.5	133.2

Figure 5 shows the following is a graphic image of the increase and decrease in the current and voltage values on the 3th day of the solar panel.

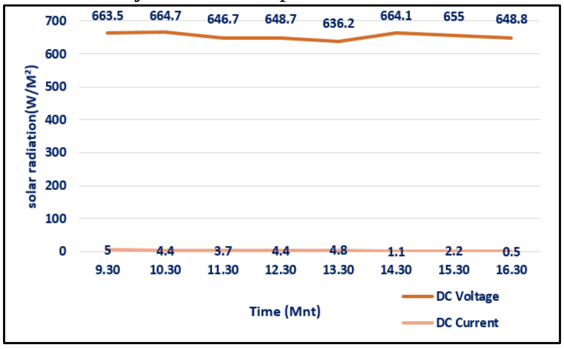

Figure 5. Current and voltage values on the 3th day

F. The results of measuring and monitoring the average power of 10 days.

The average measurement results per day, data collection on inverters and solar panels is carried out for ten days which shows the values of Radiation, DC Voltage, DC Current and Power. Weather factors that affect radiation per day can be seen that the highest radiation is on the 8th day of measurement with a radiation value of 881 W/m² with the highest voltage on the 10th day of measurement with an average value of 656.1 V and the highest output current is on the 7th day of measurement with an average value of 7 A, while the measurement results with the lowest radiation value of the 3rd day measurement with a value of 415 W/m², then the measurement results with the lowest voltage, namely on the 8th day measurement with a value the average is 615.6 V and the lowest current output is on the 3rd day of measurement with an average value of 3.2 A. Table 3 shows the average monitoring power for 10 days.

Table 3. The results of measuring and monitoring the average power for 10 days

Day(th)	Solar Radiation Maks. (W/m²)	Voltage DC Maks (V)	Current DC Maks (A)	Power (kWh)
1	744	646.9	3.4	161
2	836	640.7	5.2	215.7
3	415	653.4	3.2	133.2
4	868	638.7	4.6	208
5	820	635.9	5.6	211.2
6	879	626.6	5.4	156.2
7	835	618.3	7	272.8
8	881	615.6	6.2	201.7
9	829	647.3	3.9	170.6
10	561	656.1	4	162

The power value (kWh) was measured for ten days with different results every day. The highest generated power is on the seventh day of measurement with a power value of 272.8 kWh and the lowest generated power is found on the third day of measurement with a power value of 133.2 kWh. The fluctuations in the power generated are of course affected by several things and factors, especially the weather factor where in December 2022 it often rains so that it affects the power generated by PLTS.

Graphical data from the results of the 10-day average power measurement and monitoring. Figure 6 shows average voltage and current 10 days.

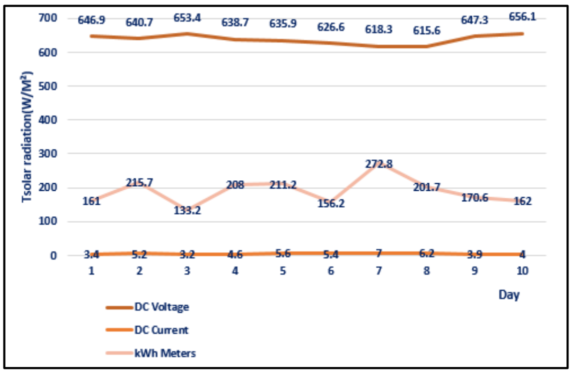

Figure 6. Average data of voltage and current 10 days

V. CONCLUSION

Calculation of the area of the photovoltaic array using calculation data Electrical energy supplied by PLTS (EL) is 393.12 kWh, average daily solar insolation (kWh/m²/day) with a reference value from the Global Solar Atlas (GSA) in December is 6.14 kWh/m² / day, the calculated efficiency value of solar panels and inverters is 0.96 so that the calculation of the array area uses an equation that yields the result of the area of the photovoltaic array which is 325.62 m². The number of PLTS solar panels installed on the rooftop is with an arrangement of 17 solar panels arranged in series and the number of strings is 6 strings. So that the total number of solar panels currently installed is 102 solar panels. The highest generated power is on the seventh day of measurement with a power value of 272.8 kWh and the lowest generated power is on the third day of measurement with a power value of 133.2 kWh. The fluctuations in the power generated are of course affected by several things and factors, especially the weather factor where in December 2022 it often rains so that it affects the power generated by PLTS. With an average value of Power (kWh) every hour for 10 days. The maximum power generated is at 16.30 WIB, which is 272.8 kWh. With the tilt position of the solar panels facing north, so that every hour the solar panels can absorb sunlight. The comparison was made by looking at previous data in November of 535.3 kWh compared to measurement data in December of 416.4 kWh. Comparison of measurement and monitoring data can be seen from the previous data in November, the power generated at the inverter output was 535.3 kWh, while the measurement and monitoring data in December was 416.4 kWh.

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