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Analysis Of Power Requirements and Solar Power Plant (PV System) Components For an Electric Vehicle Charging Station at Universitas Pembangunan Panca Budi Medan

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ABSTRACT
This study focuses on determining the capacity of the solar power plant (PLTS) components used as an energy source at a public electric vehicle charging station (SPKLU) to charge the batteries of electric cars at Universitas Pembangunan Panca Budi Medan. Calculations are carried out to obtain the area of the solar module, the power required, the number of solar panels, the SCC capacity, the backup battery, and the charging time of the electric vehicle. The research method used is a research method with an approach calculation by comparing several similar references related to planning in building a PLTS. The battery data collection method is carried out by observation, literature study and collection of weather condition data through the BMKG of Medan City. The results of the study show that with a solar intensity of Gav 4.42 kWh/m2/day, a module array area of 42,071 m2 is required. With a sunlight intensity of 1000 W/m2, the power generated by the area is 6,731 Wp. By using a 120 WP solar module, the number of panels used is 60 units consisting of 15 strings of 4 units in each string. The system can produce 8,333 Wp, 71 V 103 A of power. The SCC produces 128.73 A. The charging time required is 8.63 hours or 8 hours 37 minutes.

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INTRODUCTION

Electric cars are one of the environmentally friendly vehicles that use electric motors as their driving force. As a substitute for fossil fuel cars, electric cars have been researched at various universities in the world and have begun to be produced commercially. By knowing this technology, students will be ready to work in the electric car industry, or its supporters, such as workshops, spare part production, and others.

In electric cars, the electrical energy that will be used to supply the electric motor is stored in the battery. This battery must be recharged after its power level reaches a certain minimum value. If fossil fuel vehicles require a fuel filling station to refuel, then electric cars require a battery charging station, which in Indonesia is known as a public electric vehicle charging station (SPKLU). Several SPKLUs that already exist in Indonesia get their electricity source from PLN. However, because the PLN network is not always available throughout Indonesia, it is necessary to develop SPKLUs that use other energy sources, especially environmentally friendly ones. Currently, environmentally friendly energy sources have become a consideration in creating new power plants. One type of environmentally friendly power plant that is easy to operate is a solar power plant (PLTS). This power plant is easier to build in any area in Indonesia compared to other environmentally friendly power plants such as wind power plants (PLTB), micro hydro power plants (PLTMH), because all areas in Indonesia always get sunlight all year round.

In general, the main components of a PLTS are solar panels, solar charge controllers (SCC), batteries, and other components such as inverters, if the DC voltage source obtained from the PLTS is to be converted into AC voltage. In order for a PLTS-based system to work properly, it is necessary to calculate the load, number, capacity and specifications of the equipment to be used. This study aims to analyze the calculation of the PLTS system components that will be used as SPKLU components for electric cars at the Samarinda State Polytechnic.

Literature Review

The following are the theories and calculation bases obtained from the study results, which will be used in calculating system requirements.

Solar Module

Solar modules are semiconductor devices that function to convert solar radiation into electrical energy. Solar modules are solar cells that are connected to each other in series and parallel into a unit, namely a solar module. The more solar cells or modules that are connected to each other as in the picture below, the greater the system's ability to convert solar energy into electrical energy.

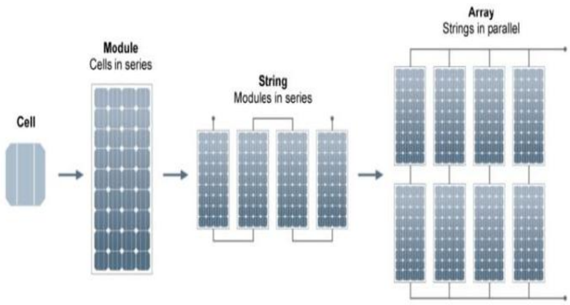

Figure 1. Solar Module

Factors that can influence the electrical energy produced by solar modules include:

1. Solar radiation or the intensity of electromagnetic radiation from sunlight falling on the module surface (W/m2).
2. Module orientation and tilt
3. Shading
4. Temperature rise in the module exceeds 25^0C

The magnitude of the power reduction when experiencing an increase in temperature (°c) exceeding the standard temperature of the solar module can be calculated in Equation 1.

P when the temperature increases (°c)= 0.5% x Pmpp x temperature increase (°c). When the temperature increases (°c) = power is reduced when the temperature is above normal Pmpp = maximum power output of solar module, Based on Equation 1, the amount of output power from the module that decreases when the temperature (°c) increases is shown by Equation 2.

Pmpp when the temperature increases (°c)= Pmpp - P

When the temperature increases (°c). After knowing the amount of reduced solar module power, the Temperature Correction Factor (TCF) value can be calculated

$$\text{TCF} = \frac{Pmpp \text{ increased temperature } (c)}{Pmpp}$$

In determining the number of solar modules, data is required including :

1. Load data
   The calculated load is the total load, with the aim of knowing the amount of usage in the time period desired by the user. Equation 4 used to calculate the load is:
   Energy Consumption (Wh) = Power × Duration of Use
2. PV Area
   The area used for solar modules can be calculated using Equation 5.
   $$\text{PV Area} = \frac{\text{EL}}{GAV \ x \ TCF \ x \ \ PV \ x \ out}$$
   Information :
   EL = Energy generated (Kwh/Day)
   PV Area= Surface area of solar module (m2)
   GAV = Daily solar insolation(Kwh/M^2/Day)
   TCF = Temperature correction factor (%)
   pv = Solar module efficiency (%)
   out = Output efficiency(%)
3. Solar Charge Controller
   Solar charge controller(SCC) or also known as battery charge regulator (BCR) is one of the electronic power components in PLTS which functions to regulate battery charging by solar modules to be more optimal. This device operates by regulating the voltage and charging current based on the power available from the solar module. Equation 6 shows the calculation in determining the capacity of the SCC used.
4. Battery
   A battery is a device that has two or more electrochemical cells that can convert chemical energy into electrical energy. In PLTS, the battery functions to store energy produced by solar modules during the day, then supplies it to the load at night or during cloudy weather, or more easily known as a backup battery. The calculation in determining the number of batteries is:

$$C = \frac{N \ x \ Ed}{Vs \ x \ DoD \ x \ \eta}$$

Information :

C = Battery Capacity (Ah)

N = Number of Autonomy Days (Days)

Ed = Daily Energy Consumption (Kwh)

Vs = Battery Voltage (Volts)

Dod = Maximum Depth of Battery Discharge (%)

η = Battery X Inverter Efficiency

Data

In calculating the needs of a PLTS system for SPKLU energy sources, the data required includes:

1. The data of sunlight intensity, temperature, and weather that are attempted to be obtained from long time intensity. With this data, the potential energy produced by sunlight in the relevant area per day will be obtained. Possible decrease in efficiency due to increased air temperature.
2. Daily load usage requirement data, which is needed to determine daily load requirements in kWh units.
3. The specification data of the required components including solar modules, SCC, and batteries. This data is needed to calculate the number of components required.

METHODS

The method used in this study uses the general research sequence as shown. The study began with a literature study which was then continued with data collection. The learning outcomes from the literature were used to calculate the needs of the PLTS system. After the process was completed, a report was made. For the process of calculating system needs, the details of the work are shown in the Figure below.

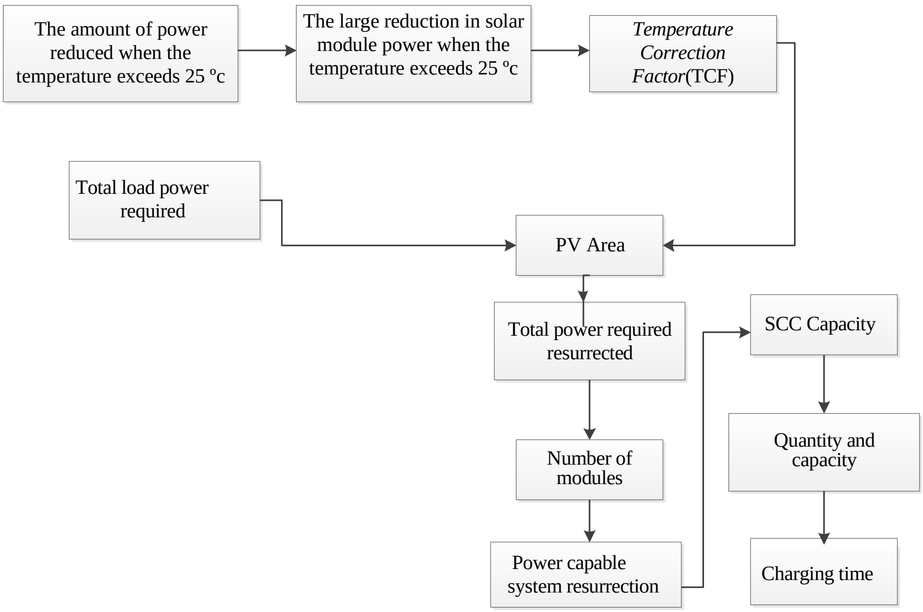

Figure 2. Calculation Process Block Diagram

RESULT

As a basis for considering the calculation of the needs of the PLTS system, solar modules were selected with specifications as shown in the table below.

Table 1. Solar Module Specifications

Information	Specification
Maximum power (Pmax)	120W
Maximum power current (Imp)	6.86 A
Maximum power voltage (Vmp)	17.8 V
Open circuit voltage (Voc)	21.8 V

Another consideration is the battery specifications used in electric cars that have been built by students of the Electrical Engineering Department at the Electrical LAB of Panca Budi University of Development, Medan, as well as the backup battery. Data on voltage, current, power and battery charging time are shown in the table below.

Table 2. Power Requirements Table

Information	Load data		Power	Loading time	Energy(W
	Voltage (V)	Current (A)	P= V x I (W)	(hour)	hour)
Car battery DOD(80%)	48	30	1440	5	7200
Backup battery DOD(80%)	48	50	2400	6	14400
Total power required					27700

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Furthermore, other data needed is the duration of sunlight in a certain period of time (insolation) accompanied by the temperature in the region and the potential for electrical power in a region. The data comes from the Meteorology, Climatology, and Geophysics Agency (BMKG) Class III of North Sumatra and for solar intensity data using research data sources that have been conducted by. All are summarized in the table below.

Table 3. Solar Insolation and Temperature Data for Medan Region 2024

Month	Temperature(cº)	Exposure time (hours)	Solar intensity (Kwh/m2)
January	27.04	2.52	4.66
February	27.33	3.2	4.88
March	27.64	2.67	4.99
April	27.35	3.32	4.98
May	27.69	4.1	4.89
June	27.28	3.96	4.76
July	27.03	2.90	4.76
August	27.26	2.9	4.87
September	27.92	4.09	4.92
October	27.87	3.83	5.04
November	27.61	3.25	4.8
December	27.77	3.32	4.42
Minimum	27.03	2.52	4.42
Maximum	27.92	4.1	5.04
Average	27.48	3.33	4.83

The planning of the PLTS system generally uses the minimum solar insolation value, with the aim that when the solar insolation condition is at its lowest value, the PLTS system that is built can still meet the required power capacity. Temperature data for the North Sumatra region, especially Medan City throughout 2024 shows a maximum temperature of 27.92 (°C) with a large temperature comparison of 2.92 (°C) from the standard temperature (25 °C) required by the solar module.

Based on these parameters, several parameters can be calculated, such as the amount of power reduction due to temperature increase, TCF, and efficiency, with the following results:

a. Knowing the amount of power reduced when the temperature around the solar module increases by 2.92 (°C) from its standard temperature. The calculation is as follows:
   P temperature increase (2.92 °C) = 0.5 %x P mpp x temperature increase (°C)
   = 0.5% x 120 W x 2.92 °C = 1.75 W
b. For the reduced output power of the solar module when the maximum temperature is 27.92 (°C), the calculation is as follows:
   P mpp temperature increase (2.92°C)= P mpp – P temperature increase (2.92 °C)
   = 120 W – 1.75 W = 118.25 W

c. After obtaining the results of the calculation of the output power of the solar module when the maximum temperature is at 27.92 (°C), the TCF (Temperature Correction Factor) value can be determined, which is obtained by the following calculation:

$$TCF= \frac{\text{P mpp temperature rise}}{\text{P mpp}} = \frac{118.25\ W}{120\ W} = 0.98$$

d. Output efficiency (η out) is determined based on the efficiency of the components that complement the PLTS-based charging station such as batteries and SCC, so the value of η out is assumed to be 0.95.

Based on the calculation results above, the calculation of the component requirements of the PLTS system can be done. The calculation is based on the assumption that the backup battery charge is empty, so charging must be done on the 48 (V) / 30 (Ah) car battery and the 48 (V) / 50 (Ah) backup battery with the condition that the solar intensity is at a minimum value of 1000 (W / m2). So the calculation is as follows:

PV Area Calculation

By knowing the value of EL, Gav, TCF, ηPV, and η out, then the PV area value is obtained as follows:

EL = 27,700 kWh/day
Gav = 4.42 kWh/m2/day
TCF = 0.98
ηPV = 0.16
η out = 0.95

$$\text{PV area} = \frac{E_L}{Gav\ X\ TCF\ X\ \eta PV\ X\ \eta out}$$

$$= \frac{27{,}700\ Kwh/hari}{\frac{4.42 Kwh}{\frac{M2}{ariri}} x\ 0.98\ x\ 0.16\ x\ 0.95} = 42{,}071\ \text{m}$$

Calculation of Power Generated by Solar Power Plants

With an array area of 42,071 (m2) and the assumed solar intensity during sunny conditions is 1000 (W/m2) and the efficiency of the solar module used is 0.16%, then the amount of power (wattpeak) generated is:

Pwattpeak = PV area x PSI xηPV
= 42,071 x 1000 x 0.16 = 6,731 Wp

Based on the calculations above, the estimated total daily power required is 27,700 (kWh/day) with the power required to be generated being 6,731 Wp.

Calculation of the Number of Solar Modules

The solar module used has a P specificationmpp of 120 Wp per module. Here is the calculation in determining the number of solar modules:

$$\text{Jumlah Modul Surya} = \frac{\text{P Watt Peak}}{\text{Pmpp}} = \frac{6.731}{120}\ 56.09\ \text{Unit}$$

This means that the solar modules used are 56.09 units. However, the number is not round, so the calculation result is rounded to 60 units with a series circuit to 48 (V) in one string containing 4 module units and paralleled as many as fifteen strings, as shown in Figure 3. The advantage is that the more solar modules installed, the system will be able to work optimally in conditions of less solar intensity.

Vmpp array = 17.8 x 4 = 71.2 V

Impp array = 6.86 x 15 = 103 A

so that

Pmpp array is 71.2 v x 103 = 7.333 Wp

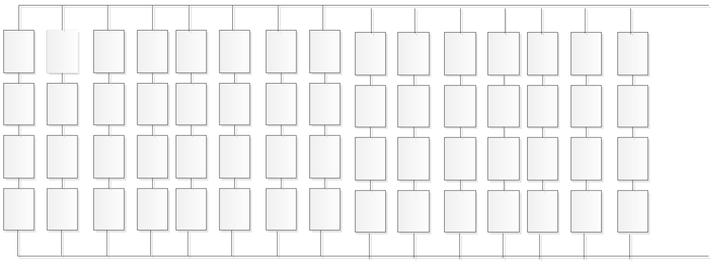

Figure 3. Solar Module Array Circuit

Calculating Charger Controller Capacity

The capacity of the charger controller used at the charging station can be calculated in the following way:

$$\text{SCC Capacity} = \frac{daya\ yang\ dibang\ kitkan\ x faktor\ keamanan}{tegangan\ \ sistem(pv)}$$

$$= \frac{7.333\ x\ 1.25}{71.2\ V} = 128.73\ \text{A}$$

Based on the calculation results, the capacity of the charger controller installed at the PLTS-based electric vehicle charging station is 128.73 (A) or more, adjusted to the availability of existing components and considering the possibility of adding or changing the solar module circuit.

Calculating Battery Capacity

The following is a calculation for determining battery capacity.

$$C = \frac{N\ x\ Ed}{Vs\ x\ DOD\ x\square} = \frac{1\ x\ 27{,}700}{48\ x\ DO(0.8)\ x\ 0.95} = 759.32\ \text{Ah}$$

From the calculation of battery capacity obtained 759.32 (Ah). Consideration of battery selection is adjusted to the planning that will use the desired battery capacity. When using a battery with a backup battery capacity of 12 (V), 50 (Ah) then the number of batteries needed:

$$\text{Number of batteries connected in series} = \frac{sistem\ tegangan\ baterai \quad 48}{tegangan\ baterai\ per\ unit \quad 12} = 4$$

Number of batteries connected in parallel rounded up to 15=

$$\frac{kapasitas\ total\ baterai\ cadangan}{kapasitas\ baterai\ per\ unit} \quad \frac{759{,}32}{50} = 15{,}18$$

So the number of batteries needed is 4 x 15 =60 units

Calculating Battery Charging Time

Due to the different battery capacities (Ah), the capacity (Ah) of the backup battery and the charged load battery are first added together to obtain the total capacity (Ah) value of the battery as a whole. The calculation is as follows: load battery + backup battery = (30+100) + 759.32 Ah = 889.32 (Ah) So the charging time can be estimated by the following calculation:

CONCLUSION

Based on the previous discussion, the following conclusions were obtained: With the solar insolation value Gav at a minimum value of 4.42 kWh/m2/day, the PV area obtained is 42,071 m2. With a solar intensity received by the module of 1000 W/m2, the power that can be generated by the PV area is 6,731 Wp. The number of solar modules with a power of 120 Wp per panel required to produce the power is 60 units arranged in series and parallel. The series (string) consists of 4 panels to obtain a voltage of 48 V, and in parallel there are 15 strings. The maximum power that can be produced by a 60 unit solar module array system is. 7,333 Wp, with a system voltage and current of 71.2 V, 103 A. The SCC used is 128.73 A. Charging time 8.63 hours or 8 hours 37 minutes. The magnitude of the Gav value influences the determination of the PV area, thus impacting the power that the system can generate and the number of solar modules that will be used.

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