Design and analysis of solar cell systems 100Wp in the Study Program Laboratory Electrical Engineering UHN Medan

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Abstract. Currently, the use of solar cells is being developed as an alternative source of electricity generation. Studies and research are constantly looking for ways to increase the efficiency of using solar cells. This study aims to provide information to students of the Electrical Engineering study program at UHN Medan about the design, manufacture, simulation of the ETAP program, technical and economic analysis. Electrical load capacity in the laboratory room with daily load of 45Wh and peak load of 82 watts. Then the recommended designs are: 100Wp solar panel, BCR 40A, 102Ah battery and 1500VA inverter. The total cost required for the investment period is IDR. 18,954,000. Observations were made by taking light intensity data that occurred for 4 days in the laboratory. The equipment used for this measurement is: a luxmeter for measuring light intensity and a digital multimeter for measuring currents and voltages. The results show that, when the intensity condition is 49.0Klux, the voltage is 12.08VDC and the current is 0.47A. The highest light intensity occurs on the day of August 14, 2020 between 13.00-13.30WIB of 93.0Klux producing a voltage of 12.09VDC and an electric current of 0.90mA.

1. Introduction
The Solar Cell System is a new and renewable energy solution (Renewable Energy / RE), namely by utilizing solar modules or solar modules, or often called solar panels, which function to convert sunlight or sunlight into electrical energy [1]. Solar PV system use solar energy to generate electricity [2]. The application of this Solar Cell system is very broad including the application of back-up power, telecommunications / solar satellite public phones, etc. [3]. Solar thermal energy also plays an important role in maintaining life on this earth [4]. In Indonesia, the potential for renewable energy is huge because Indonesia has a good climate for renewable energy [5]. Some areas have developed renewable energy, for example on the coast, which can use wind as an alternative energy in addition to using energy from the PLN supply, for example: PLTB Sidrap, PLTB Jeneponto, etc. [6]. The solar cell system is a technology that utilizes solar energy to produce electrical energy [7]. The solar module is made of n and p type semiconductor materials, solar energy moves the electron-hole so that a constant DC electric current occurs, flows through a battery charge regulator (BCR) which controls battery charging, the DC voltage from the BCR is flowed to the battery for storage, then from DC voltage battery is supplied to the inverter to be converted into AC voltage to meet the AC load or directly supplied to the DC load [8]. The PLTS system is supported by several components, including: Photovoltaic (solar cells), Battery Charge Regulator (BCR), Batteries and Inverters [9]. The electric power produced by solar cells is the product of the output voltage with the number of electrons flowing or the amount of current [10].
Present Cost (NPC) is the sum of all components used and also operating costs used in the project being undertaken [11].

2. Methods

The construction of a solar cell system begins with a needs analysis or identifying the needs of both tool needs and material needs, then carries out the design process, designing tools, observing the performance of all the materials whether they can work, then the tool making process is carried out [12]. In designing a solar cell system, there are several stages of work, including: determining the intensity of sunlight, studying the load, designing the system and determining the cost of the system [13]. The economic analysis of the Solar Cell system will be carried out by comparing the initial costs, operating costs and maintenance costs with the energy supplied by electricity from PLN [14].

3. System design and analysis

To build a Solar Cell system, it is necessary to make research stages in a laboratory measuring 5 x 10 meters, the data on the lights attached to the PLN connection are poured in a needs analysis so that component specifications can be determined, the Solar Cell system design model and the data obtained during the research are calculations. manually and the discussion of each calculation [15]. The cost of repairing the solar cell system is necessary because some components such as BCR, battery, and inverter have a shorter operating life than the operating life of the solar module so that these components are needed to be replaced based on the average age [16].

3.1. Needs analysis

Logic and microprocessor circuit laboratory where the author takes data or analyzes needs according to the electrical load in the laboratory room (see Figure 2), then it will be a place for solar cell equipment such as: inverters, BCRs and batteries (box control cabinets) and electrical loads from the energy source of the Solar Cell system.

In accordance with the data in the logic and microprocessor circuit laboratory room measuring 5 meters x 10 meters or with an area of 50 square meters (see Figure 1). The data in the laboratory room are as follows (Table 1):

| No. | Description             | Total Load | Amount of power |
|-----|-------------------------|------------|-----------------|
| 1   | LED lamp Philips 5 watt | 1          | 5 watt          |
| 2   | LED lamp Philips 10 watt| 1          | 10 watt         |
| 3   | LED lamp Philips 13 watt| 1          | 13 watt         |
| 4   | SL lamp Philips @18 watt| 3          | 54 watt         |
|     | TOTAL                   | 6          | 82 watt         |

Figure 1. Laboratory room.  
Figure 2. The author makes a needs analysis.
3.2. Solar cell system designs

Furthermore, calculating the load per day in the use of Solar Cell energy in the laboratory is as follows:

3.2.1. Calculation of total load current in Ampere-hour (Ah). Equipment is calculated in terms of alternating current (AC) by dividing the Watt rating of some of the equipment being the load by the system operating voltage of 220 Volt

\[ \text{AC load} = \left( \frac{\text{watts} \times \text{hours used per day}}{\text{system operating voltage}} \right) \]

- Philips LED lamp 5 watts = \((5 \text{ watts} \times 6 \text{ hours})\) Ah = 30 Ah
- Philips LED lamp 10 watts = \((10 \text{ watts} \times 6 \text{ hours})\) Ah = 60 Ah
- Philips LED lamp 13 watts = \((13 \text{ watts} \times 6 \text{ hours})\) Ah = 78 Ah
- Philips SL lamp @ 18 watts = \((18 \text{ watts} \times 12 \text{ hours})\) Ah = 216 Ah

Power source load data in the laboratory can be seen in Table 2.

| No. | Load specifications | Load | Long Operated | Energy /day (Wh) |
|-----|---------------------|------|--------------|-----------------|
| 1   | LED Lamp            | 5 Watt | 6 hours    | 30              |
| 2   | LED Lamp            | 10 Watt | 6 hours   | 60              |
| 3   | LED Lamp            | 13 Watt | 6 hours   | 78              |
| 4   | SL Lamp             | 18 Watt | 12 hours  | 216             |
| 5   | SL Lamp             | 18 Watt | 12 hours  | 216             |
| 6   | SL Lamp             | 18 Watt | 12 hours  | 216             |
|     | **TOTAL**           |       |             | **816 Wh**      |

b) Battery capacity requirement
The battery capacity that will be used is:
- Using 12 V, 102 AH battery. So 102 AH / 19; AH = 5 hours. because the battery is only about 50% for meeting the electricity needs of the load then 2 - (5 x 50%) = 2.5 hours.
- Enough to use the battery / battery 12 V, 102 AH.

c) Determine the Solar Panel Capacity
Determine the solar panel based on the battery used, for optimal sunlight to illuminate the panel for up to 5 hours. The panels used are \(((12 \text{ V} \times 102 \text{ AH} = 1,224 \text{ watts}) / (100 \text{ Wp} \times 5 \text{ hours}) = 2.4\) So it takes 2 solar modules with a capacity of 100 Wp.

![Figure 3. Solar cell system planning.](image1)

![Figure 4. Solar cell system block diagram.](image2)

The fabrication of the solar module frame is made of 2x4 cm square iron with a length of 6 meters plus ¼ inch pipe iron for the solar panel supports to be placed and 20x30 cm aluminum plate for the placement of the Solar Charge Controller and Inverter. The solar module frame is made of aluminum plate assembled in such a way using screws and bolts to form a solar module frame. Furthermore, the manufacture of solar cell equipment will be built in accordance with the previous design.
Figure 5. Tread casting.

Figure 6. Solar panel mounting.

Figure 7. Control cabinet installation.

Figure 8. Solar cell testing.

Figure 9. Measurement of sun intensity.

Figure 10. Measurement of voltage and current.

Table 3. Power source load data in the laboratory.

| Time       | Sun Intensity | Voltage | Current |
|------------|---------------|---------|---------|
| 06:30 - 07:00 | 0.32 Klux     | 12.09 VDC | 0.10 mA |
| 07:00 - 07:30 | 3.62 Klux     | 12.09 VDC | 0.18 mA |
| 07:30 - 08:00 | 9.47 Klux     | 12.10 VDC | 0.22 mA |
| 08:00 - 08:30 | 17.90 Klux    | 12.09 VDC | 0.44 mA |
| 08:30 - 09:00 | 22.17 Klux    | 12.09 VDC | 0.58 mA |
| 09:00 - 09:30 | 25.00 Klux    | 12.09 VDC | 0.66 mA |
| 09:30 - 10:00 | 19.20 Klux    | 12.10 VDC | 0.48 mA |
| 10:00 - 10:30 | 39.78 Klux    | 12.09 VDC | 0.77 mA |
| 10:30 - 11:00 | 59.3 Klux     | 12.10 VDC | 0.75 mA |
| 11:00 - 11:30 | 79.3 Klux     | 12.08 VDC | 0.86 mA |
| 11:30 - 12:00 | 22.07 Klux    | 12.09 VDC | 0.85 mA |
| 12:00 - 12:30 | 59.4 Klux     | 12.09 VDC | 0.84 mA |
| 12:30 - 13:00 | 80.8 Klux     | 12.09 VDC | 0.88 mA |
| 13:00 - 13:30 | 93.0 Klux     | 12.09 VDC | 0.90 mA |
| 13:30 - 14:00 | 53.0 Klux     | 12.09 VDC | 0.85 mA |
| 14:00 - 14:30 | 37.66 Klux    | 12.09 VDC | 0.84 mA |
| 14:30 - 15:00 | 63.3 Klux     | 12.09 VDC | 0.85 mA |

3.3. Solar cell system manufacturing costs

The cost of the solar cell system will be calculated over an estimated investment life of 20 years. The investment age is chosen based on the average age of solar modules on the market, which is around 25
years [16]. The costs calculated in this section use the life cycle cost method which includes all cost components from the beginning to the end of the system's operating life. The inflation used is 3.52% per year (2017). After knowing the component specifications in the PLTS system or solar cell system, the price of each component will be determined. The cost of electrical installation in Medan Helvetia District, the cost per point for 2019 is IDR. 120,000. So the total costs for the initial investment are as follows:

Table 4. Installation cost.

| Components   | Total | Price   |
|--------------|-------|---------|
| Lamp fittings| 5 lot | IDR. 600,000 |
| Electric     | 4 lot | IDR. 480,000 |
| **Total cost** |      | **IDR. 1,080,000** |

Table 5. Total initial investment cost.

| Type                          | Price   |
|-------------------------------|---------|
| Total cost PLTS component     | IDR. 7,588,000 |
| Total cost electrical installation | IDR. 1,080,000 |
| **Total cost**                | **IDR. 8,668,000** |

The total cost of maintenance can be seen in table 4. By knowing the initial investment costs, operational costs, and maintenance costs, the total costs incurred during the investment life can be seen in table 5.

Table 6. Total maintenance costs.

| Components | Cost   |
|------------|--------|
| BCR        | IDR. 1,449,000 |
| Battery    | IDR. 7,646,500 |
| Inverters  | IDR. 1,190,500 |
| **Total cost** | **IDR. 10,286,000** |

Table 7. Installation cost

| Type                          | Cost   |
|-------------------------------|--------|
| Total initial investment cost | IDR. 8,668,000 |
| Total operational costs       | IDR. 0 |
| Total maintenance costs       | IDR. 10,286,000 |
| **Total cost**                | **IDR. 18,954,000** |

Economic analysis of the solar cell system will be carried out by comparing the costs over the life of the investment between the solar cell system and PLN. The basic electricity tariff for the next 20 years is assumed to be the same as the 2010 TDL [17]. The total cost will be calculated over the life of the investment in the solar cell system, which is 20 years. In table 6 it can be seen that the total costs incurred for PLN during the investment life.
Table 8. Load costs for 20 years.

| Types                        | Cost  |
|------------------------------|-------|
| Installation cost            | IDR. 1,320,000 |
| KWh meters installation costs | IDR. 4,500,000 |
| Load costs for 20 years      | IDR. 17,230,000 |
| **Total cost**               | IDR. 23,050,000 |

From the data above, the costs incurred for the solar cell system are IDR. 18,954,000, - cheaper than the costs incurred for state electricity (PLN), namely IDR. 23,050,000, -.

3.4. Results of simulations and analysis using the ETAP software

Simulation of solar cell system design using the ETAP program, the component specifications can be adjusted to the actual situation or real conditions in the field [18].

Figure 11. Single line DC load flow.

Figure 12. Single line DC short circuit.
Figure 13. Single line AC load flow.

Figure 14. Single line AC short circuit.
3.5. **Testing the solar cell system**

The performance test of this equipment aims to determine whether each component is functioning properly, then to analyze the voltage generated by the solar cell and the capacity of the battery used [19].

4. **Conclusion**

With a load of 54Wh per day and a peak load of 82 Watt, the recommended solar cell system is a 100 Wp solar module, 40 A BCR, 102 Ah battery, and 1500 VA inverter. The total cost required during the investment life (20 years) is Rp. 18,954,000. During the test between the first day and the last day, the highest sunlight intensity occurred on Friday, August 14, 2020) at the hour between 13.00 - 13.30, namely: 93.1 Klux. The total electric power generated on the first day was 1.255 watts and the average power was 0.408 watts.

**Acknowledgments**

First, I as the first author to thank my promotor is Dr. Togar Harapan Pangaribuan, MT and my copromotor is Leonard Lisapaly, Ph.D. who has helped and guided me while doing my thesis research in the Department of Magister Teknik Elektronik Universitas Kristen Indonesia, especially in this paper. Hopefully the results of this paper will benefit the academic world, especially renewable energy.

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