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Design of 600 Wp Stand-alone Solar Tree System for Public Charging Station

Desain Sistem Pohon Surya 600 Wp untuk Stasiun Pengisian Daya Umum

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Abstract

Indonesia has significant potential for solar energy utilization with a capacity of 313 MW. The solar tree system is an innovative alternative energy solution that combines functionality and aesthetics by utilizing limited space at Universitas Jenderal Achmad Yani as an electric charging station. The research methods include meteorological data, load calculations by operational time variations, component capacity analysis such as photovoltaic (PV) panels, batteries, inverters, and 3D modelling of the stand-alone Solar tree system. This paper discusses the analysis results for the most optimal operational time of 3 hours with a PV panel power requirement of 599.6 Wp, using 6 PV panels each rated at 100 Wp. The system is designed to supply daytime loads, including charging an electric bicycle 576 W and a laptop 65 W for three hours. At night, the battery supplies power for laptop charging and lighting with a total power of 317.5 Wh for twelve and a half hours. To ensure a two-day autonomy, a battery capacity of 12 V 80 Ah and a 1000 W inverter are considered in the design. The 3D solar tree system model is designed with a pole height of 4000 mm and a circular arrangement of 6 PV panels with a diameter of 4068 mm, equipped with table and chair facilities at several proposed locations, ensuring the Solar tree system design meets the desired capacity based on the selected scenario.

Keywords: photovoltaic, 3D modelling, solar energy, electric bicycle.

***SDGs*:**

7 AFFORDABLE AND CLEAN ENERGY

Abstrak

Indonesia memiliki potensi energi matahari yang signifikan hingga kapasitas 313 MW. Solar tree system merupakan solusi energi alternatif yang inovatif baik secara fungsi dan baik secara estetika dengan memanfaatkan lahan terbatas di Universitas Jenderal Achmad Yani. Metode penelitian meliputi pengumpulan data meteorologi, perhitungan kebutuhan beban dengan variasi waktu operasil, analisis kapasitas komponen sistem seperti panel fotovoltaik (PV), baterai, inverter, dan pemodelan 3D dari Solar tree system yang berdiri sendiri. Makalah ini membahas hasil analisis waktu operasional selama 3 jam dengan kebutuhan daya panel PV sebesar 599,6 Wp, menggunakan 6 buah panel PV 100 Wp. Sistem ini dirancang untuk memasok beban siang hari, untuk sepeda listrik 576 W dan laptop 65 W selama tiga jam. Malam hari, baterai memasok daya untuk pengisian daya laptop dan penerangan dengan daya 317,5 Wh selama 12,5 jam. Untuk memastikan otonomi dua hari, kapasitas baterai 12 V 80 Ah dan inverter 1000 W dipertimbangkan dalam desain. Pohon surya 3D dirancang dengan tinggi tiang 4000 mm dan susunan melingkar dari 6 panel PV dengan diameter 4068 mm, dilengkapi dengan fasilitas meja dan kursi di beberapa lokasi yang diusulkan, memastikan desain sistem pohon surya memenuhi kapasitas yang diinginkan berdasarkan skenario yang dipilih

Kata Kunci: energi surya, fotovoltaik, pemodelan 3D, sepeda listrik.

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1. INTRODUCTION

The demand for electrical energy in the contemporary period has emerged as a fundamental necessity for the global society, particularly for the populace of Indonesia. Data from Perusahaan Listrik Negara (PLN) indicates that electricity consumption in Indonesia in 2023 reached 285.23 TWh, reflecting a 5.32% rise from 270.82 TWh in 2022 (PLN, 2023, 2024). The Ministry of Energy and Mineral Resources (MEMR) and the House of Representatives of the Republic of Indonesia report that Indonesia's electricity generation is predominantly sourced from fossil fuels, comprising 40.46% coal, 30.18% petroleum, and 16.28% natural gas, while energy from new renewable sources accounts for merely 13.09% of the total (IESR, 2024). In the context of new renewable energy, according to the International Renewable energy statistics (IRENA) report, Indonesia is estimated to have solar energy potential with a capacity of 313 MW until 2023 (Syafii *et al.*, 2021; IRENA, 2024). Solar Power Plant is a form of utilization of non-carbon emission energy or environmentally friendly energy that is increasingly popular around the world (Shehadeh *et al.*, 2018). Solar power plant is a utilization of solar energy or better known as solar energy to generate electricity through photovoltaic (PV) technology (Holechek *et al.*, 2022). However, the effectiveness of solar power plants depends on several factors including solar irradiation, temperature and wind speed. Indonesia is classified as a country with a tropical climate that only has a dry season and a rainy season, so Indonesia has a peak sun hour with an average of 4-5 hours a day (Silalahi *et al.*, 2021; Simatupang *et al.*, 2021). The utilization of this energy is a solution that is easily accessible and easily found in all regions in the territory of Indonesia and photovoltaic has a role in reducing carbon emissions as one of the environmentally friendly energy plants in accordance with the motivation of the Indonesian government towards net-zero emission (Mohammadi *et al.*, 2024) and in accordance with the commitment of the Indonesian government in the Paris agreement in 2016 (Widodo, 2016). When constructing a Solar Power Plant, it is essential to choose whether the design will be On-Grid or Off-Grid (Stand-Alone). This architecture warrants consideration due to the attributes of On-Grid systems, which are directly linked to the primary power grid, such as PLN. Off-Grid or Stand-Alone systems operate autonomously, disconnected from the PLN grid. The solar tree system is an application of photovoltaic technology that innovatively converts solar energy into electrical energy. This system integrates functionality with aesthetic appeal, as its design mimics a tree structure adorned with solar panels on its branches or twigs. This solar tree system efficiently utilities constrained area while maximizing sunshine absorption (Gaikwad and Lokhande, 2015; Kar *et al.*, 2020; Almadhhachi, Seres and Farkas, 2022).

Based on previous research and design (Iskandar *et al.*, 2024) with a 12-hour operating time, the type of load taken is only based on gadget loads (laptops and / or smartphones), while the improvements added in further research in this paper are the addition of charging stations for electric bicycles, which is based on general transportation needs for all academicians. Furthermore, this charging station considers battery capacity for lighting and can operate for 24 hours with a divided load, with hourly operating variants discussed further in the study's calculation results. According to the load calculation findings, the capacities of the necessary components, including solar panels, batteries, inverters, and other elements, are determined. This computation utilizes technical information from the component datasheets.

This solar tree system meant to harness Indonesia's substantial solar energy potential, including a total PV capacity of 600 Wp, intended for use as a charging station for laptops (or similar gadget and electric bicycles) in the college environment. This system aims to deliver sustainable energy solutions and assist the government's initiatives to diminish reliance on fossil fuels. The Solar tree system, employing advanced solar panel technology, aims to supply adequate electrical resources for daily requirements in campus settings or public spaces, while also educating the general populace, particularly the students of Universitas Jenderal

Achmad Yani, on the significance of renewable energy utilization.

This paper is divided into chapters, with the first explaining the purpose and background traceability of the research, the second describing the analysis method used, the third discussing the design results and test results in the form of simulations, and the final chapter explaining the output and conclusions drawn.

2. METHODOLOGY

Figure 1 shows the flowchart of this research, employs a multi-stage methodology, commencing with site selection, followed by the acquisition of secondary data concerning Global Horizontal Irradiance (GHI), temperature, and wind from the National Aeronautics and Space Administration (Zhang *et al.*, 2009; Bertrand *et al.*, 2018; Gbémou *et al.*, 2021) for the designated location at Universitas Jenderal Achmad Yani.

This flowchart illustrates the process steps used to design a renewable energy system, specifically for photovoltaic (PV) panel applications. This process includes data identification, load calculation, component capacity calculation, and evaluation of design results. The first step is the identification of energy data and data sources. This process begins with the identification of energy potential, GHI measured in (kWh/m²/day), and data sources including data from trusted institutions such as NASA for global information on solar radiation at the selected location.

The second phase is Load calculation. Once the potential energy data is obtained, the following step is to do a load calculation in kWh to determine how much energy is required by the system or the load to be supplied by the PV panels. This load calculation considers the desired energy consumption over a given time period, as well as other variables like system efficiency and usage length. Knowing the load to be met, the next step is to calculate the capacity of the components. This process involves selecting the datasheet and specifications of the PV panels that match the previously calculated energy requirements. Calculating the load requirements and calculate the capacity of the required components such as PV panels, inverters, and batteries (Bayya *et al.*, 2018; IEEE, 2019).

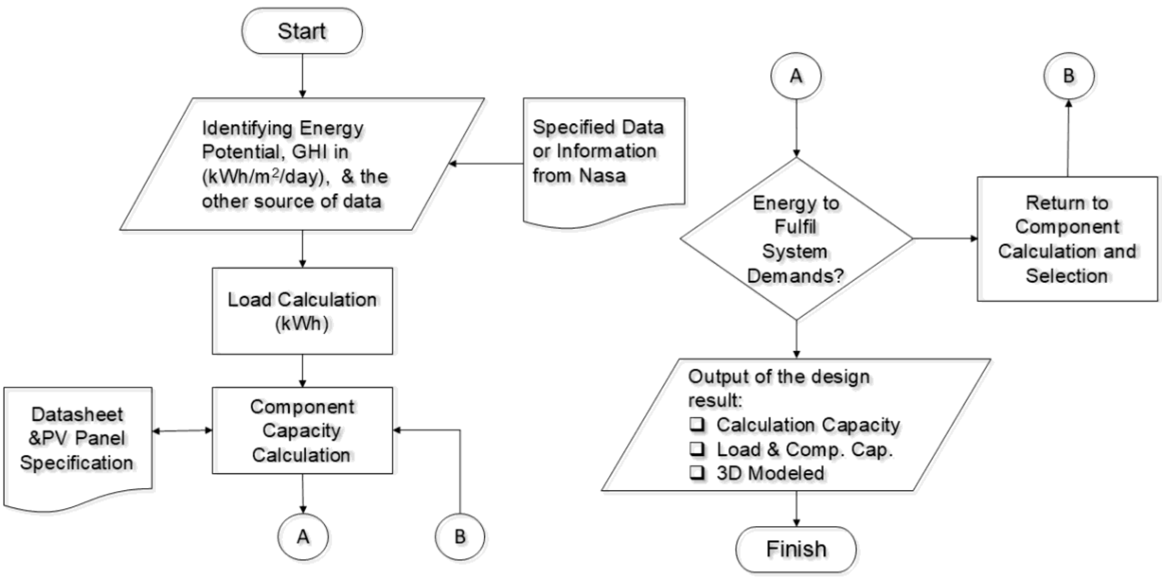

Figure 1. Modelling and design of stand-alone solar tree system flowchart.

Then calculate the energy requirements used with the results of the Solar tree system design capacity, to 3D modeling of the solar tree system frame design. Besides energy potential data, further specialized information may be necessary, such as details on the electrical load that the system must accommodate. Upon collection of the data, the electrical load required by the system is determined. This load is quantified in kilowatt-hours (kWh).

The fourth step is the evaluation stage, which ensures that the system's energy capacity meets its energy demand. If the result is insufficient, the process will go back to the component calculation to change the capacity or component specifications. If the system can meet the energy requirement, the design can be further developed. The final phase is the design results and output. If all calculations and component choices are correct, the design findings can be further analysed to produce outputs such as calculation capacity, load, and component capacity, as well as a 3D model of the designed system. This 3D model depicts how a renewable energy system would be installed in a real-world scenario.

2.1. The Potential Location and Meteorological Data

The study was carried out at Universitas Jenderal Achmad Yani in Cimahi, West Java, using geographic coordinates of -6.88° South latitude and 107.52° East longitude. Coordinates were selected and inputted into the NASA website: https://power.larc.nasa.gov.

Table 1. Meteorological data result.

Month	GHI (kWh/m2/d)	Wind Vel. (m/s)	Temp. (°C)
January	4.74	1.72	21.42
February	4.34	1.84	21.20
March	4.90	1.51	21.67
April	5.07	1.13	22.01
Mei	4.47	1.13	22.02
June	4.11	1.14	21.24
July	4.55	1.37	21.17
August	5.19	1.36	21.36
Sept.	5.10	1.37	21.66
Oct.	4.69	1.34	21.64
Nov.	4.60	1.44	21.42
Dec.	4.52	1.76	21.39
Av. Year	4.69	1.43	21.52

Table 1 shows that in the past five years from PV Syst. software based on site location in Universitas Jenderal Achmad Yani simulation. The highest daily average value of global irradiation was 5.19 kWh/m²/day in August, while the lowest value was 4.11 kWh/m²/day in June. The lowest average wind speed, which occurred in April and May, was 1.13 m/s, while the highest wind speed occurred in February, at 1.84 m/s, the data was obtained from the NASA website.

The global solar irradiation received by the surface of the solar panel is affected by the tilt angle setting on the PV panel. PV characteristics are based on the main components system and the meteorological data; average of Global Horizontal Irradiance (GHI), wind velocity and temperature in one year. The solar trees to be erected at the spot will serve as charging stations for electric bicycles and other electronic device, including cell phones, laptops or the other gadget. The construction of the Solar tree system is anticipated to aid in reducing carbon emissions and enhancing knowledge of renewable energy utilization on the Universitas Jenderal Achmad Yani. Iterative evaluation during the process shows the accuracy for an optimized system.

2.2. The PV Panel Capacity

The determination of solar panel capacity is influenced by three main factors, namely, total load demand per day, Global Horizontal Irradiance (GHI), and adjustment factor. The factor is used when the PV panel module is not operating under Standard Test Condition (STC) (Hassan *et al.*, 2022). Since the adjustment factor is a multiplier number used to account for these factors, it has no unit. For this selected location that avoids shading and gets more sunlight, the adjustment factor calculated is 1.1 to adjust for more energy received. Thus, the adjustment factor is a unitless multiplier that affects the calculation of the power or energy required by the solar system. For the calculation of PV capacity, GHI data is taken from the lowest monthly average value. The following is the equation for calculating the capacity of solar panels, shown in Equation (1) (SNZ, 2010):

$$Cap_{PV} = \frac{E_{Daily}\ (Wh)}{GHI\ (kWh/m^2/day)} \times Adj._{factor} \quad (1)$$

Where:

Cap. PV = PV Capacity in (kWp)
E. Daily = Av. Energy per day in (Wh)
GHI = Global Hor. Irr. In (kWh/m²/day)
Adj. Factor = Adjustment Factor (1.1)

$$ff = \frac{V_{mp} \times I_{mp}}{V_{0c} \times I_{SC}} \quad (2)$$

Where:
ff = fill factor
Vmp = Peak Max. Voltage (V)
Imp = Peak Max. Current (A)
Voc = Open Circuit Voltage (V)
Isc = Short Circuit Current (A)

$$\eta(\%) = \frac{FF \times V_{0c} \times I_{SC}}{Area_{PV} \times Incedent_{Sol_{Irr}}} \quad (3)$$

Where:
η= Efficiency in (%)
Area PV = Effective Area (m^2)
Inc. Solar Irr. = Solar Irradiance (W/m^2)

Based on these parameters, it is known that the calculation of PV area is one of the important factors; to find this value, it is necessary to measure the length and area of the PV panel on each PV panel used. While the Incident Solar Irradiance parameter defines the density of sunlight in units of W/m^2, the amount of solar irradiance recorded after passing through the Earth's atmosphere is 1000 W/m^2 (Iskandar and Fakhri, 2018). The data is obtained from the datasheet or name-plate of the PV panel used.

Table 2. Datasheet Panel PV Existing (Iskandar and Fakhri, 2018).

Technical Data	Information
Manufacture & type	SUMICO TN-100M
Maximum power (Pmax)	100 Wp
Optimum operation voltage (Vmp)	18 V
Optimum operation current (Imp)	5,56 A
Open circuit voltage (V_{OC})	22,36 V
Short circuit current (I_{SC})	6,02 A
Length of PV Panel	1.23 m
Width of PV Panel	0.56 m
Standard Test Condition (STC)	1000 W/m^2, 25°C

Table 2 shows the datasheet of the PV panel components used; this datasheet is taken based on the currently available PV panels, where the main characteristics required are the maximum current (Imax) and maximum voltage (Vmax) that can be generated by the PV panels used. From this data, the maximum power (Pmax) is obtained which is determined by the short circuit current (Isc) and open circuit voltage (Voc), with the highest fill factor (ff) used to measure efficiency. The calculation of ff and efficiency η (%) is done using Equation (2) – Equation (3).

2.3. The Battery System Capacity

The Solar tree system to be developed is a stand-alone type that utilizes solar energy as the primary source for generating electricity. This system requires battery capacity as an energy reserve to meet the electrical load demand when sunlight intensity decreases, a condition known as power autonomy. The calculation of battery capacity can be performed based on the AS/NZS 4509.2 standard of 2010 as follows Equation (4).

$$Stor_{Batt.}\,(Wh) = E_{daily}(\mathrm{Wh}) \times Aut_{day} \quad (4)$$

Where:
Storage Batt. = Battery Energy (Wh)
E. Daily = Energy in Daily (Watt)
Auto. Day = Autonomy Day (day)

Determining the battery capacity in the Solar tree system is influenced by the total daily load requirements, the duration of autonomy days, and the Depth of Discharge (DoD), which is the percentage of the battery capacity that has been used, but it can also be referred to as the remaining battery capacity (Syafii, Mayura and Gazaly, 2019). The battery capacity calculation can be done using equations (5) through (6):

$$Cap._{Batt.}\,(Ah) = \frac{E_{daily}(\mathrm{Wh}) \times Aut_{day}}{V._{Batt.}\,(Vdc) \times DoD(\%)} \quad (5)$$

Where:
Cap. Battery = Battery Capacity (Ah)
V. Battery = Voltage Battery (Vdc)
DoD = Dept of Discharge (%)

$$N_{Batt.} = \frac{Stor_{Batt.}\,(Wh)}{DoD(\%) \times I_{Batt}.(Ah) \times V_{Batt}.(Vdc)} \quad (6)$$

Where:
N. Batt. = Number of Battery (N)
I. Batt. = Battery Current (Ah)

2.4. The Inverter System Capacity

Determining the inverter capacity in a solar tree installation depends on the total load power that will be used. The greater the total load that will be applied to the solar tree system, the greater the inverter capacity required, the goal is to ensure optimal performance and system efficiency. The inverter capacity must be sufficient to handle peak loads and provide tolerance for power surges. Determination of inverter capacity can be calculated using Equation (7) (Wang, Wei and Yin, 2019):

$$Cap_{Inv.}(W) = Energy_{daily}(W) \times 130\% \quad (7)$$

Where:
Cap. Inv. = Inverter Capacity (W)
Tol. For Power Surge = 130%

2.5. The Modelling Design of Solar Tree System

The structural design model of the solar tree system is developed in three dimensions (3D) utilising tools like SolidWorks. The design incorporates drawings from many perspectives, including top and side views, to guarantee correct installation and maximum use of each component. This 3D model enables the designer to evaluate structural integrity, design aesthetics, and modify the dimensions of the solar tree system to harmonize with the surrounding environment, which will be deployed on the campus of Universitas Jenderal Achmad Yani. The design features components such as the structure, solar panel positioning, and a charging station for electrical devices, including laptops and electric bicycles, all constructed to a tailored scale. Each component is designed to be integrated. This model is anticipated to facilitate and streamline the assembly and installation process at the building site, consequently enhancing job efficiency and mitigating the danger of construction mistakes.

3. RESULTS AND DISCUSSION

3.1. The Optimization of PV Capacity Calculation

The first stage in building the solar tree system is estimating the load fluctuation that the PV panel must supply. The loads utilized in the design of the solar tree system as a charging station are classified into two groups. Initially, the load provided by the photovoltaic system during daylight included charging the electric bicycle's battery and the laptop.

Table 3 illustrates the scenarios based on the total load delivered by the solar PV system. Two sorts of loads are considered: E-bikes and Gadgets, with data demonstrating how much energy each load consumes over various time periods. The energy consumption per unit of each load, measured in watts (W). The E-bike requires 576 W, whereas the Gadget requires 65 W. Note (*) denotes the total amount of energy used in watt-hours (Wh) after 1 to 5 hours of operation. The total row displays the amount of energy consumed by both loads combined at each time interval (1 to 5 hours). For example, for one hour, the total energy used by the e-bike and device was 641 Wh, while at five hours, it was 3205 Wh. Overall, this table illustrates the total energy demand for the two types of loads supplied by PV, as well as how energy consumption varies over time.

Table 4 shows the referenced electric bicycle features a battery with specifications of 48 V/12 Ah, totaling 576 W, capable of a travel distance of 45 km, with an estimated operating charge duration from 1 – 5 hours. Concurrently, the reference laptop possesses battery specifications of 20 V and 3.25 Ah, which equates to 65 W. The second load is supplied by the battery during nighttime, which includes charging one laptop battery (65 W) with varying operational durations. Additionally, two lighting loads are used for illumination around the solar tree system area, each with a power rating of 10 W, totaling 20 W. The operational duration for the lights varies from 9 hours to 15.5 hours.

Table 5 shows the various component variations that can be used in the application of the solar tree system. The calculation of the variation in component capacity includes the needs for the PV panel and battery. These variations depend on the load demand and the required operational duration. For the calculation of the PV panel capacity, it is based on the daily energy requirement as well as the operational time of the load to be supplied, considering the solar radiation potential at the location of Universitas Jenderal Achmad Yani.

Table 3. Scenario based on total load supplied by PV.

No.	Type of Load	Qty. (Pcs)	Energy (W)	Total Operational Energy (Wh)				
				1 H*	2 H*	3 H*	4 H*	5 H*
1	E-bike	1	576	576	1152	1728	2304	2880
2	Gadget	1	65	65	130	195	260	325
TOTAL				641	1282	1923	2564	3205

Table 4. Total load supplied by the battery.

No.	Type Of Load	Qty. (Pcs)	Energy (W)	Total Operational Energy of Gadget (Wh)				
				0.5 H*	1 H*	1.5 H*	2 H*	2.5 H*
1	Gadget	1	65	32.5	65	97.5	130	162.5
No.	**Type Of Load**	**Qty. (Pcs)**	**Energy (W)**	**Total Operational Energy of Lamp (Wh)**				
				9 H*	**10 H***	**11 H***	**12 H***	**13 H***
2	Lamp	2	10	180	200	220	240	260
TOTAL				212.5	265	317.5	370	422.5

Additionally, there is a calculation of the variation in the number of autonomy days based on the battery capacity to be used as backup electrical energy when the PV panel is not producing electricity.

Table 5. Variation of time against the total power required for the solar tree system load.

PV Load		Battery Load	
Op. Time (Hours)	Load Power (Wp)	Op. Time (Hours)	Load Power (Wp)
1	171.5	10	56,8
2	343.1	11	70.9
3	514.6	12.5	84.9
4	686.2	14	99
5	857.7	15.5	113.1

Figure 2 compares the predicted PV panel capacity to the existing PV panel capacity in the market (PV Market Existing) in terms of the panel's operating time, which is measured in hours (1-5). These results show how PV panel output capacity develops over time under two separate conditions: theoretical calculations and existing market data. The vertical axis, measured in Peak Watts (WP), indicates how much power is generated by the panel during a certain operational period. The horizontal axis represents the operating time in hours. According to Figure 2, the PV panel capacity analysis shows that a PV panel with a capacity of 600 Wp is the most optimal choice when operating for three hours and twelve and a half hours, resulting in a total power demand of 599.6 Wp. Theoretical calculation curve for the model used. The generated capacity is 238.4 WP in the first hour of operation and increases linearly as operating duration increases. By the fifth hour, the generated capacity had reached 1000 WP, indicating the PV panels' good and constant performance based on the model calculations.

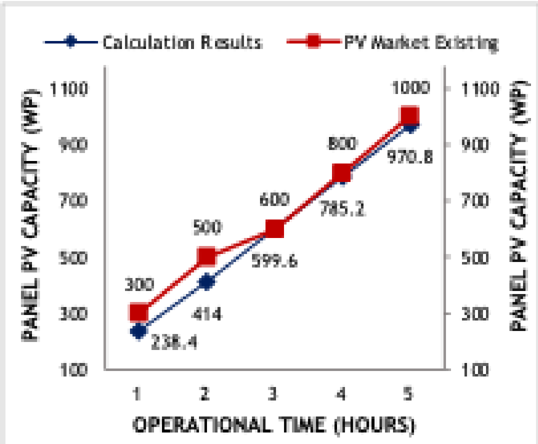

Figure 2. Comparison result; PV capacity to operation hours.

Figure 3 depicts the results of a comparative analysis of battery capacity depending on autonomy needs and number of battery units. This comparison graph depicts the link between battery capacity (measured in ampere-hours or Ah) and the two primary variables observed:

number of battery units (Batt. Pcs) and system autonomy (Auto. Days). The graph shows two types of data for five different battery capacities: 12V, 40Ah, 12V, 60Ah, 12V, 80Ah, 12V, 100Ah, and 12V, 120Ah, represented by two types of bar graphs: one red bar for the number of battery units (Batt. Pcs) and one blue bar for autonomy requirements (Auto. Day).

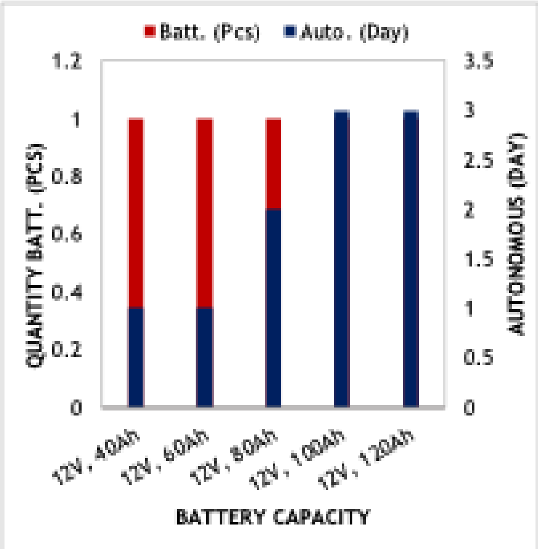

Figure 3. Comparison Results; Number of Batteries to Autonomous Days.

The graph of battery capacity and number of battery units demonstrates that greater capacities (such as 12V, 100Ah and 12V, 120Ah) require slightly less battery units than smaller capacities (12V, 40Ah and 12V, 60Ah). This is because larger-capacity batteries can offer more energy, needing fewer battery packs to meet the same energy demand. Smaller capacities, such as 12V, 40Ah, require more battery packs to attain the same results.

The blue bars reflect autonomy, which grows significantly as battery capacity increases. The higher the battery capacity, the longer the system can go without recharging, which is represented in the increasing number of autonomy days. For example, at 12V, 40Ah capacity, the system can only run for around 0.5 days, however with 12V, 120Ah capacity, the system's autonomy grows to approximately 2.5 days. At lower battery capacities, we see that even though the number of battery units is higher, the autonomy of the system remains low. This shows that even if we increase the number of batteries, the relatively lower energy storage capacity limits the system's ability to last long without recharging. In contrast, at higher battery capacities, even though the number of battery units used is less, the energy stored is greater, providing longer autonomy for the system.

3.2. The Optimization of Component Calculation

Based on the discussion that has been carried out, a calculation optimization result is obtained on each component used in this study, component calculation optimization is calculated using Eq. (1) – (7), and the results obtained that the capacity of the PV panel needed to meet the load requirements per day is 599.6 Wp, thus the PV panel used is 600 Wp, with details of six PV panels with each PV panel with a capacity of 100 Wp, based on the results of the calculation in equation (2), a value for the fill factor (FF) of 0.75 is obtained.

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So, the battery requirement is 66.1 Ah, assuming the autonomous day chosen based on the comparison of the analysis results that best meet the needs, which is two days, the results are calculated using Eq. (4) – (6). Thus, based on the battery capacity available in the market, one battery capacity of 80 Ah can be used, which will be used to supply and meet the daily load requirement of 317.5 Wh. Because the PV and battery supply uses a direct current power source, it requires an inverter component as a direct current converter to alternating current to supply the load voltage. Thus, the inverter capacity that needs to be used is 1000 W, to meet the load size of 726 W with a safety factor of 30%.

Table 6. Component capacity calculation results.

No	Component	Capacity
1	Panel PV Energy	100Wp
2	Panel PV Quantity	6 Pcs
3	Battery Storage	635Wh
4	Battery Capacity	80Ah
5	Battery Quantity	1 Pcs
6	Inverter Capacity	1000 W

Table 6 shows the results of the capacity calculations for the main components in the renewable energy system, consisting of photovoltaic (PV) panels, energy storage batteries, and inverters. The results of this calculation are important to determine the total capacity of the system and its ability to meet the previously calculated energy demand. Each photovoltaic panel has an energy capacity of 100 Wp (watt peak), which is the maximum capacity that the panel can generate under ideal solar radiation circumstances. Overall, the PV panels generate 600 Wp (6 × 100 Wp). This large number of panels will allow the system to generate more energy, which is critical to ensuring that the system can offer adequate power throughout any given operational period.

The battery's overall storage capacity is 635 Wh (Watt hours). This represents the entire amount of energy that can be stored in the battery system and used when needed, such as at night or when solar radiation is less than optimal. Each battery has an 80 Ah (Ampere-hour) capacity, which refers to its ability to store energy for hours. This capacity reflects how much energy the battery can store and how long it will give power under normal operating conditions. With one battery unit with a storage capacity of 635 Wh, the system can store enough energy to meet power demands for a set length of time. Despite using only one battery unit, its capacity is sufficient to store the energy provided by the PV panels.

This system's inverter has a capacity of 1000 W, allowing it to convert DC (direct current) electricity generated by the PV panels into AC power that may be used by household electrical appliances or other systems that require it. The bigger capacity of the inverter means that the system can handle higher power loads and convert energy more efficiently.

3.3. The 3D Design Solar Tree System 600 Wp Result

Based on the optimization results of the component calculations that have been obtained, the solar tree system design is made to display the 3DS image model, and there is also a display of the size specifications of the solar Tree System design which can be seen in Figure 4 and Figure 5.

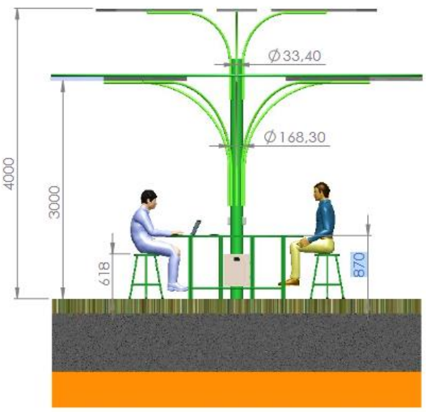

Figure 4. Solar tree system 3D design; solar tree system size.

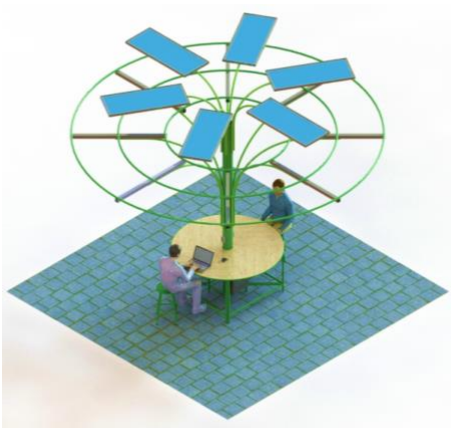

Figure 5. Solar tree system 3D design; side view.

This design is designed using SolidWorks software, the design displays six PV panels, which are arranged to resemble a tree structure that branches out from the main pole. The panels are arranged to maximize the capture of sunlight, to provide electrical energy from solar power sources. Under the canopy of the solar panels, there are tables and seats that make it a multifunctional space for students of Universitas Jenderal Achmad Yani. In this model, the PV panels are designed to resemble a tree composed of six PV panels, each with a capacity of 100 Wp with a total PV panel capacity of 600 Wp, which are arranged like tree leaves around the main pole.

Figure 4 shows the structural size display of the solar tree system to be built, which includes the height of the main pole, as the support of the PV panel has a height specification of 4000 mm, the PV panel is arranged in a circle so the diameter specification is 4068 mm. of canopy material with a height specification of 3000mm, the cover is built in a circle with a diameter of 5033mm, expected to provide a comfortable atmosphere under the PV panel.

Solar tree system is also equipped with a round table with a table height specification of 870 mm, chairs as seats have a height specification of 618mm, while for the part of Figure 5 shows the side view of the solar tree system design, which is positioned in a circular manner to maximize optimal absorption of sunlight throughout the day. This Solar tree system functions as a source of electrical energy that is used to charge electric vehicle batteries and laptop electronic devices, this solar tree offers a comfortable place, while introducing the use of renewable energy. This design features innovations from the utilization of solar energy. The use of SolidWorks software in the modeling ensures that each component of the solar tree system is optimally applied as a battery charging station, while still considering aesthetic aspects.

To replicate the photosynthetic process that trees use to produce energy, the system uses photovoltaic panels that are positioned atop the branches or "limbs" of fake trees. Utilizing this technology, particularly given its 600 Wp capacity, offers an alternate way to supply renewable energy for a variety of uses, particularly in constrained spaces like campus locations that simultaneously demand aesthetically pleasing and effective design.

Discussions that can be taken from the results of this study are, the first difference between the calculation results and the availability of units on the market is that there is a significant difference between the theoretical capacity and the actual capacity that can be achieved by the panels on the market today, so that the selection of types and capacities is adjusted to user needs, but this calculation is a limitation in determining units based on load.

The second is based on a steady trend of increasing capacity as the solar tree system's operational time increases. However, the discrepancy in rate of rise between the calculation and market data suggests that this calculation model paints a more positive image of PV panels' future capacity.

The designed renewable energy system has highly efficient photovoltaic panels, with a total power that may be supplied by six units of PV panels, according to capacity calculations of the system's components. System efficiency and energy availability are continuously improved by the large capacity of the storage battery (635 Wh), which also guarantees that the energy produced by the panels can be stored for use when needed. Even though just one battery is utilized, it has more than enough capacity to keep the system running for a longer period. To guarantee that the generated electricity can be appropriately converted for everyday use, adequate inverters are chosen. Overall, the system is designed to meet the considerable energy demand with good energy storage and conversion efficiency, providing a solid foundation for the application of the proposed renewable energy system and being reliable in the long run.

4. CONCLUSION

Based on the design, calculation, and analysis, the conclusion that can be drawn from the results of the selected scenario optimization shows that the designed system uses two main types of loads, namely the load during the day for charging the electric bicycle battery of 576 W and a laptop of 65 W, and the load at night which will be supplied by the battery for charging the laptop battery and lighting. Optimization analysis of the component calculation results, shows that the most optimal variation of operating time is 3 hours with a total PV panel power requirement of 599.6 Wp, which is already supported by a battery storage system to ensure the availability of electricity supply in the solar tree system.

For the optimization results of the component calculation, it produces specifications for the use of six PV panels, each PV panel has a capacity of 100 Wp with an efficiency of 14.7%. Based on the type of load supplied by the most optimal battery is a battery with a capacity of 12 V 80 Ah. This battery was chosen with the assumption of two autonomous days. For modeling the 600Wp solar tree system, it is visualized through a drawing with a main pole height structure of 4000 mm and for the diameter of the solar panel array of 4068 mm, with a round table as high as 870 mm, and a chair height of 618 mm, thus creating a design that not only focuses on its functionality as a charging station, but also has aesthetics as a multifunctional space for the activities of the academic community of Universitas Jenderal Achmad Yani.

The use of a 600Wp solar tree system provides a novel approach for generating renewable energy in a restricted space while also providing aesthetic value and environmental benefits. The system is appropriate for small-scale applications such as street lighting, parks, and small villages, but it cannot handle large-scale energy requirements. Nonetheless, as technology advances and production prices fall, solar tree systems may become a major component of renewable energy solutions in the future, particularly in urban areas that require ecologically friendly designs and efficient use of space.

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