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SoltarinE: Revolutionary Eco-Friendly Charging Station to Reduce Carbon Gas in PLN Power Consumption

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Abstract

The main objective of this study is to develop a charging station that uses solar energy as an environmentally friendly alternative, in order to reduce carbon dioxide emissions resulting from the combustion of fossil fuels. The method used is qualitative with data collection through system observation and analysis of solar panel performance with dual-axis technology that can follow the movement of the sun. The results of the study show that the use of solar panels equipped with dual-axis actuators can increase the efficiency of sunlight absorption, so that the power produced is more optimal. From the analysis, it was found that this station not only provides an efficient charging solution, but also contributes to reducing the carbon footprint, with the potential for significant reductions in CO2 emissions. The conclusion of this study shows that the development of solar energy-based charging station technology is a strategic step in supporting the transition to more sustainable energy sources in Indonesia.

Keywords: charging station, solar energy, dual-axis solar tracker, carbon emissions, green technology.

INTRODUCTION

With the increasing demand for electricity in Indonesia, PLN faces a major challenge in providing sufficient energy while reducing greenhouse gas emissions. One way to achieve this goal is to integrate renewable energy sources, such as solar energy, into the national electricity grid. The proposed solution through the development of solar panel-based charging stations can help PLN in several aspects. First, the use of solar panels equipped with dual-axis solar tracker technology allows for more optimal absorption of sunlight, thereby increasing the efficiency of electricity production. This has the potential to reduce dependence on fossil fuel power plants which have been the main contributors to CO2 emissions in Indonesia. Second, by providing an environmentally friendly charging alternative, this project can reduce the burden on the PLN grid, especially during peak electricity consumption hours, thereby helping to stabilize the national electricity system.

According to data from the Ministry of Energy in 2022, Indonesia is still highly dependent on fossil fuels such as coal, oil, and natural gas, which account for 87.7% of total energy sources. As a result, in 2021, Indonesia produced 619.28 million tons of CO2 gas , or around 2.26 tons per person. This figure accounts for 1.67% of total CO2 emissions worldwide (Zaky and Sari, 2024).

This situation becomes worse during the dry season due to rising temperatures and increased carbon monoxide gas, which is certainly harmful to human health (Zahra, 2024). As in BMKG data (May 23, 2024), air quality is measured from the PM 2.5 content every hour and is marked with a color code. Currently, many areas are labeled "Unhealthy" which is marked with the color yellow. BMKG also measures Carbon Monoxide (CO) levels every three hours in PPB (Parts Per Billion) units. This CO gas usually appears from imperfect combustion, such as forest fires that often cause haze. The area most at risk of being affected is Java Island, especially West Java.

Poor air quality is also caused by increasing temperatures due to solar radiation reaching the earth's surface, which contributes to global warming. For example, in the IPB Vocational School area, it was recorded that it left a carbon footprint of 369,8143 TonCO2e (Siskandar, 2024). This increase in the earth's temperature is very dangerous because it can cause various problems such as land drought, forest fires, and worsen air quality due to the carbon footprint left behind. To overcome this problem, one solution is to reduce the use of electricity from PLN and switch to solar energy which is a more environmentally friendly renewable energy (Laksono, 2022).

Energy sources are increasingly needed to meet human needs along with the progress and sophistication of the era, where alternative energy sources are increasingly developing to meet the required resources. The use of solar energy is one alternative to reduce CO2 emissions . Indonesia has enormous potential to develop solar power plants as a substitute for coal and diesel, which are safe, non-polluting, and unlimited energy sources. In addition, we know that Indonesia has an equatorial region that is rich in solar energy radiation. Therefore, we can take advantage of certain conditions to generate electrical energy using solar cells.

Solar panels are devices consisting of a collection of solar cells that function to convert sunlight into electricity. How it works is quite simple: solar cells made of p and n type semiconductor materials will produce a flow of electrons when exposed to sunlight. This flow of electrons then becomes a direct current. Inside the solar panel there is a photovoltaic component that is responsible for converting light into electrical energy, which is then stored in a battery as an energy reserve when the sun is not shining. To increase the efficiency of solar panels, LDR sensor technology has been developed that allows solar panels to move in the direction of the sun. This innovation helps optimize the absorption of sunlight so that it produces more electricity. The development of this solar panel technology is an important solution to meet the increasing need for electricity, while reducing the negative impact on the environment by utilizing renewable energy.

The use of linear actuators also affects the optimization of Solar Panel movement, because linear actuators themselves can move very precisely and controllably compared to hydraulic or pneumatic types, thus facilitating flexibility when operating. However, its fast movement cannot match the ability to stop moving quickly too. This can be overcome with a linear actuator movement control system at the *end point position.* (Setiawan et al., 2023).

As in the research of Prasetyo et al. (Journal, 2019) entitled " *Optimization of Dual Axis Solar Tracker Output Power Using the Umbrella System Method* " explains that the installation of static solar panels is still less than optimal, because it does not take into account the optimal point of sunlight. This results in the absorption of solar energy not being maximized, so that the electrical energy generated from the solar panels is also not optimal. So to maximize the absorption of sunlight, solar panels must have a system that always follows the direction of sunlight movement by outperforming the *solar tracker system* .

Other researchers, Samodrawati D and Santoso LI (Journal, 2022) emphasized in a research entitled "Design and Construction of a *Smartphone Battery Charging Station* Based on Solar Panels" explaining that the design of charging stations in public places was carried out because there were no public facilities that provided a place for charging batteries. This study utilizes renewable energy sources of sunlight with solar panel technology which is used to charge *smartphone batteries* . The weakness is that it still uses a 30 Wp solar panel, so the charging needs have not been met properly (*the smartphone* is charged when the solar panel is only exposed to sunlight).

In this study, the installation of sensors on the solar panel is maximized by using a dual-axis actuator that uses 4 actuators on the X and Y coordinates, this innovation is to facilitate the movement of the solar panel with more optimal capture of sunlight. The power captured by the solar panel will be stored in the battery as a power bank, which will be used as a charging station when the sun is not visible. A battery is a tool for storing electrical energy in chemical form, which will then be processed into electric current. The type of battery used is "18650 lithium battery" which is a type of Li-ion battery that can be recharged several times. The use of batteries is a solution for storing power generated by solar panels, batteries are needed as stability that is relied on as an inverter power supply (Nasution 2021).

Following up on the shortcomings of the two researchers above, this study aims to develop previous research to become an environmentally friendly charger solution that has a high efficiency value for charging stations (the solar panels used have actuators as dual-axis drivers so that the solar panels are always exposed to optimum sunlight intensity, thus the battery is also optimally charged). Another advantage of this study is that the power obtained is used as one of the solutions to reduce gas emissions due to the use of PLN electricity activities at SV IPB.

METHOD

Location and Time of Creation

This research was conducted at the Electromechanical Workshop at the IPB Vocational School, Jl. Kumbang No. 14, RT.02/RW.06, Babakan, Bogor Tengah District, Bogor City, West Java 16128, Indonesia. The research took 5 months, starting from August 2024 to December 2024.

Methods and Data Collection

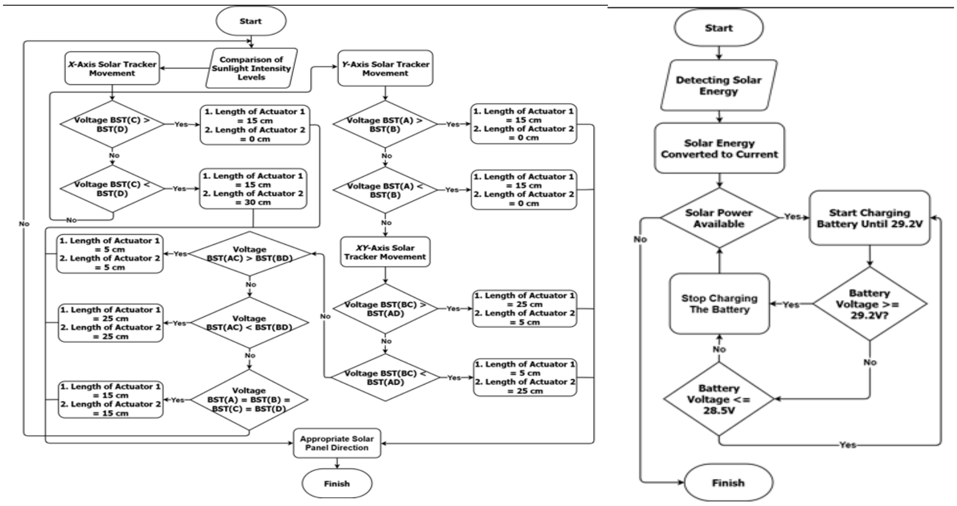
The research method used is a qualitative method by systematically collecting data on previous documentation and observations. So that it can obtain comprehensive and in-depth data on the effectiveness of utilizing solar energy through solar panels as an effort to reduce carbon dioxide emissions. By focusing on the dual-axis Solar Panel movement system and power storage . Another purpose of this study is to utilize renewable energy as an energy source and reduce carbon gas emissions.

Field observation is intended to be done by conducting observation steps on the solar panel system with dual-axis technology. Observations include several things such as panel movement, how much energy is produced, charging efficiency, and several technicalities related to energy storage. Direct observations are to support factual data on the performance of solar panels and the reliability of solar panels in environmental conditions.

Data Analysis Methods

Researchers conducted data analysis methods to evaluate the effectiveness of solar energy utilization through solar panels , dual-axis movement systems, and power storage . The first quantitative approach that may be taken in this analysis is the use of simulation software such as PVSyst to compare the performance of solar panels under various conditions, including the effect of the tilt angle and orientation of the solar panels on the energy output produced. This study can also utilize the performance setting of CO_2 emissions $_{avoided}$ thanks to the use of solar fuel, which can be compared before and after the application of solar panels (Uzair *et al* ., 2024; Elsadek *et al* ., 2024).

In the next stage, the flowchart design of the SoltarinE motion system and the charging station battery charging system is carried out to make it easier for researchers to explain the program breakdown and flow.



(a) (b)

Figure 1 Flowchart: (a) SoltarinE motion system; (b) Battery charging system

Next, SoltarinE is designed using the ESP32 microcontroller as program data, then four LDRs, and four actuators as solar panel drivers through a solar tracker or LDR sensor when following the direction of sunlight. The four actuators will move from different directions, such as when sunlight is in the left oblique direction of axis B, the actuators on axes A and B will go down, then axes C and D will go up.

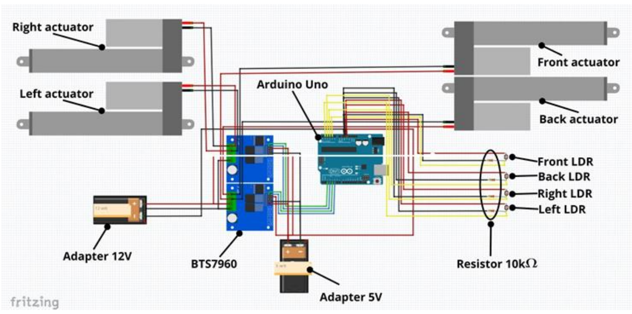
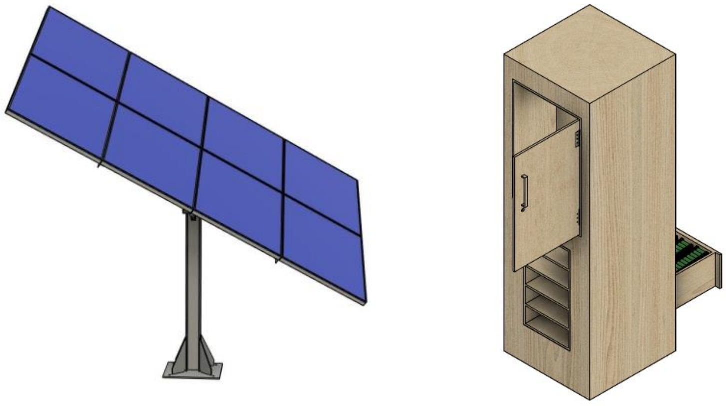


Figure 2 Circuit schematic

In the next stage, the researcher designed the solar charging system design which is an important step to describe the system as a whole. Figure 3(a) shows the isometric mechanical design of the solar tracker. This design shows the solar panels arranged in 2 parallels and 4 series which are placed in balance with the actuator position in the middle. The height of the H-beam iron pole is 160 cm. The actuator position is installed under the solar panel, allowing vertical movement to various angles. The Charging station design shown in Figure 3(b) is designed to have 6 electrical terminals placed at the front of the solar charging system. The power storage battery is placed in the rear drawer of the solar charging system.



(a) (b)

Figure 3 SoltarinE mechanical design: (a) solar charging system; (b) charging station

Materials Used

The materials selected in the construction of this system are carefully considered to ensure strength and efficiency. The main materials include iron plate (40 cm x 40 cm) as a solid base; H-Beam iron (height 160 cm, 10 cm x 10 cm) as the main support; Hollow iron 8x8 with a length of 100 cm to support the movement of the panel in the north-south axis; seamless iron (outer diameter 61 mm, inner diameter 51 mm) with a length of 8 cm for the rotation structure; angle iron (length 150 cm, width 4 cm x 4 cm) as a panel bracket; Axle iron (diameter 25 mm, length 124 cm) as the main axis with the support of pillow block and 6205 bearing to reduce friction and ensure smooth movement.

In the next stage, researchers conducted electrical capacity testing by calculating the power generated by solar panels based on parameters such as maximum power (Pm), maximum voltage (Vmp), maximum current (Imp), and open circuit voltage (Voc) and short circuit current (Isc). The configuration of 4 panels connected in series produces a total voltage (Voc) of 104.04V, while the current (Isc) of two sets of parallel panels reaches 9.28A. With this configuration, the total power generated can reach 800 Wh per second.

After that, the researchers conducted a test on the actuator system where the testing process was focused on the movement of the solar panel following the direction of the sun with the help of LDR sensors placed on each side of the panel. LDR sensor data is sent to the ESP32 microcontroller, which then processes the information and drives the L298N driver motor to regulate the movement of the actuator. This test ensures that the panel moves optimally towards the light source, increasing the efficiency of energy absorption.

The charging system utilizes a Solar Charge Controller (SCC) that functions to convert high-voltage DC current into a voltage suitable for battery charging, while protecting against overcharging. The energy generated is stored in a lithium-ion battery arranged in a 7 series and 102 parallel configuration with a total capacity of around 153-173.4 Ah. The Battery Management System (BMS) ensures monitoring and management of battery conditions, such as voltage, current, and temperature, to optimize service life.

RESULTS AND DISCUSSION

Solar Tracker Movement System

The solar tracker is made with the aim that the panel can absorb the most optimum energy so that it can increase the efficiency of energy absorption from sunlight by adjusting the position of the solar panel according to the direction of the incoming light. The solar tracker can change the orientation of the panel dynamically, ensuring that the solar panel always faces the most optimal sunlight. . In this study, the movement of the solar tracker is assisted by 4 LDR (light dependent resistor) sensors and 2 actuators. This is very important because the intensity of sunlight varies throughout the day, and the position of the sun also changes depending on the time and geographic location. The solar tracker prototype is shown in Figure 4.


Figure 4. Solar tracker prototype

ac>bd side sensor reading value . The performance of the LDR sensor integration with the solar tracker has been successfully carried out as indicated by the movement of the actuator. The results of the solar tracker movement direction test are shown in Table 1.

Table 1 Results of solar tracker motion direction testing

Condition	**Solar Tracker Direction**	**Actuator 1 (cm)**	**Actuator 2 (cm)**	**Actuator 3 (cm)**	**Actuator 4 (cm)**	**Information**
a>b	Towards y(+)	0	40	20	20	Succeed
a<b	Towards y(-)	4 0	0	20	20	Succeed
c>d	Towards x(+)	20	20	0	40	Succeed
c<d	Towards x(-)	20	20	40	0	Succeed
bc>ad	Towards x(+) y(-)	30	10	10	30	Succeed
bc<ad	Towards x(-) y(+)	10	30	30	10	Succeed
ac>bd	Towards x(+) y(+)	5	25	10	30	Succeed
ac<bd	Towards x(-) y(-)	25	5	30	10	Succeed
a=b=c=d	Balanced	15	15	20	20	Succeed

Table 1 shows the results of the light sensor integration test with a solar tracker system that controls four actuators based on differences in light intensity at several points (a, b, c, and d). The comparison of light intensity conditions between these points determines the direction of movement of the solar tracker and the distance of movement of each actuator. The increase in energy absorption generated by the solar tracker can bring a number of significant benefits.

First, by following the movement of the sun, the solar tracker can increase the energy output generated by the solar panel by 20-50% compared to a static system that cannot move. This increase in efficiency means that more electrical energy can be generated in the same time, reducing the need to use more polluting conventional energy sources.

Second, this increase in energy yield has the potential to generate significant cost savings. By generating more electricity from renewable sources, users can reduce their dependence on conventional electricity providers such as PLN. This not only reduces monthly electricity bills but also contributes to reducing greenhouse gas emissions, in line with global efforts to combat climate change (Laksono, 2022). In addition, the use of solar tracker technology can extend the life of the solar panels themselves by optimizing their operational conditions, thereby reducing future maintenance and replacement costs.

Thus, the solar tracker system not only increases the efficiency of energy absorption but also provides substantial economic and environmental benefits. The implementation of this technology in renewable energy projects in Indonesia is very relevant considering the country's great potential in utilizing solar energy (Zaky and Sari, 2024).

Relationship between Current, Voltage, Power and Time

Based on the time-current relationship graph shows the pattern of current changes over time in a system. Initially, from 8:00 to 12:00, the current is at a constant level of about 1.5 amperes, reflecting a stable condition without significant changes. Then, from 12:00 to 14:00, the current experiences a sharp increase, rising from 1.5 amperes to about 2.5 amperes, which may be caused by changes in load or other factors that increase the current flow in the system. However, after reaching a peak at 14:00, the current drops drastically to nearly zero at 16:00. This sharp decrease could indicate a load break, sudden power reduction, or possible problems in the system that cause the current to decrease significantly. Overall, this graph shows that the current in the system experiences a stable condition at the beginning, then increases significantly, and finally decreases drastically, which illustrates the characteristics of the current that is affected by operational factors or changes in load at certain times. The relationship between current and time is shown in Figure 5.

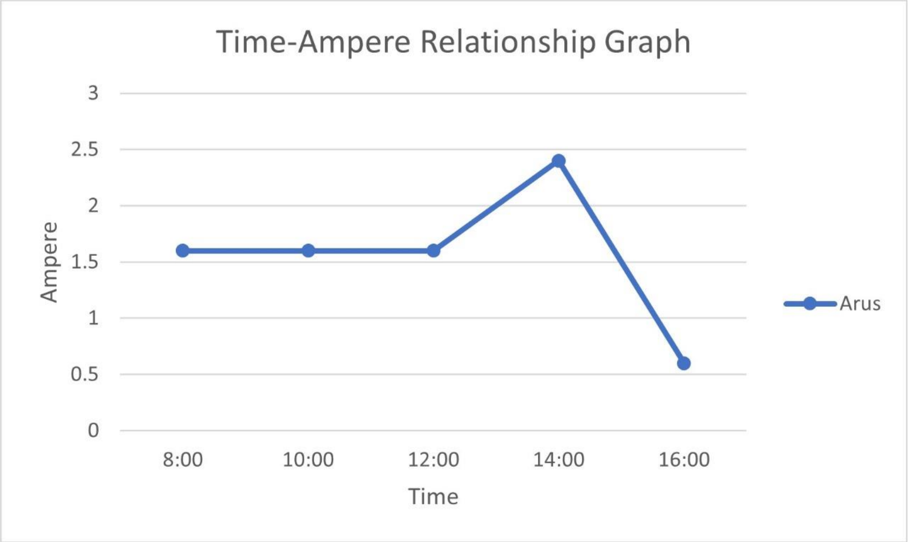


Figure 5. Relationship between Current and Time

The relationship between time and voltage changes periodically over time, forming a sinusoidal wave that oscillates between positive and negative values. This voltage has a certain frequency and period that determine how quickly it changes over time. The graph above shows the relationship between time and voltage in a system. At 8:00 AM, the voltage starts at about 12.4 volts, then increases gradually to about 12.8 volts at 10:00 AM. After that, the voltage continues to increase until it reaches a peak of about 13.5 volts at 2:00 PM. However, after 2:00 PM, the voltage drops drastically to about 12.2 volts at 4:00 PM. Overall, this graph shows a pattern of voltage that is initially stable, increases gradually to a maximum value, and then drops sharply. The relationship between voltage and time is shown in Figure 6.

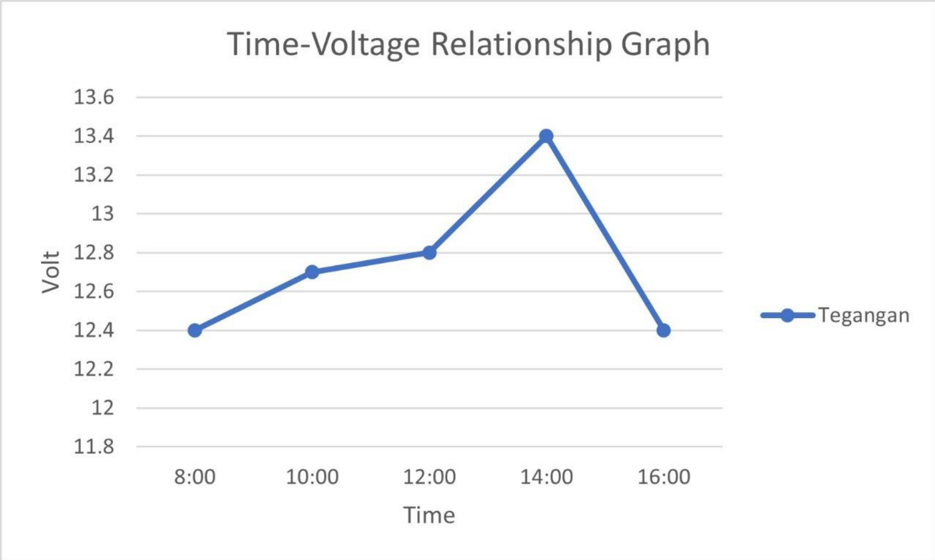


Figure 6. Relationship between voltage and time

The relationship between power and time can be seen in the change in power consumption or output in an electrical or electronic system over time. The graph above illustrates the relationship between time and power in a system. At the beginning of the observation, which is from 8:00 AM to around 2:00 PM, the power is in a stable range of around 25 watts, indicating that the system maintains a relatively constant power consumption or output during this period. However, after 2:00 PM, the power drops sharply to near zero at 4:00 PM. This drastic drop could indicate a significant change in the system, such as a load reduction, blackout, or other change in operating conditions that causes the power to drop drastically. The relationship between power and time is shown in Figure 7.

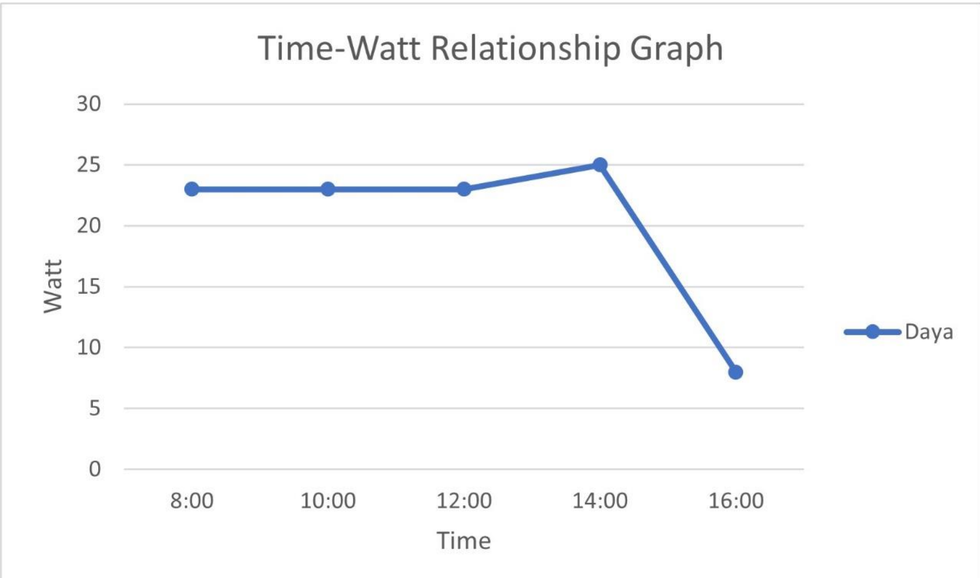


Figure 7. Relationship between power and time

Charging Station

The maximum voltage received by the battery is 28.5 volts. The battery will charge the voltage up to the maximum voltage limit. When the battery voltage reaches 28.5 volts, the battery will not charge the voltage/disconnect. The battery in DC current is converted to AC using a Taffware DC to AC inverter. The conversion results from DC to AC are shown in Table 2, namely the results of voltage measurements (AC) at the charging station terminal.

Table 2. Results of AC voltage measurements at the charging station terminal

Measurement Conditions	Information
	Terminal rated 225.2 volts AC
	The cellphone was successfully charged at the electrical terminal

Table 2 shows that SoltarinE has been successfully created and implemented as an alternative charger for low-power electrical components.

CONCLUSION

SoltarinE has been successfully created, tested and implemented as an alternative means of charging low-power electronic components. The main objective of this study is to develop a charging station that uses solar energy as an environmentally friendly alternative, in order to reduce carbon dioxide emissions produced from the combustion of fossil fuels. The method used is qualitative with data collection through system observation and analysis of solar panel performance with dual-axis technology that can follow the movement of the sun. The results of the study show that the use of solar panels equipped with dual-axis actuators can increase the efficiency of sunlight absorption, so that the power produced is more optimal. From the analysis, it was found that this station not only provides an efficient charging solution, but also contributes to reducing the carbon footprint, with the potential for significant reductions in CO_2 emissions

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