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Design and Implementation of Smart Bench Integrated Solar Cell for Public Space Electricity Saving

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Abstract

The purpose of this research is to design a multifunctional garden bench integrated with solar panels. The bench product is created by utilizing sunlight as a source of electrical energy for the object features of the bench product. The implementation method for producing innovative bench products uses a research and development approach, including concept, design, collection of materials, assembly, and testing. The bench was tested to supply electricity to the LED lights and USB ports. Furthermore, analyzing statistical data the average value of; current, voltage, and power generated by the intelligent bench object. The study results present the primary resources needed for the design and implementation of intelligent bench products. Experiments show that a load of LED lights and USB station chargers depends on the percentage of battery batteries supplied from solar cells. The innovative bench is designed from hollow steel to support product construction efficiency and electronic effectiveness. In this way, we achieved our goal of designing and implementing a portable garden bench that could function in all open areas.

Keywords: Electrical Energy, Solar Cells, Smart Bench

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Introduction

These last few years, energy problems that hit the world have implications for savings in all fields (Hadiyanto et al., 2020; Kango, Suhaedi, et al., 2021), including public facilities that require electrical power for operations (Frischer et al., 2020). The utilization of solar radiation as a source of electrical energy in green open spaces has not been optimally carried out (Arif et al., 2019). Conventional electricity sources are inappropriate because the monthly electricity costs required are already expensive (Manikandan et al., 2018). The provision of a power source for facilities in the park requires a costly budget calculation in the long term (Tao et al., 2016), and there are many facilities using electricity from State Electricity Enterprise, so there is no alternative source to replace. In the past decade, power plants solar cells that utilize solar energy heat sources continue to be developed (Chen, 2020; Kango & Pongtularan, 2021) because the cost of installing and managing photovoltaic systems has been dramatically reduced (Aromal et al., 2018). The implementation of solar cells (photovoltaic) as a source of electricity in public facility furniture equipment such as benches that require electrical energy (Liberski et al., 2019) needs to be designed with economical and efficient models in mind (Kango & Pongtularan, 2021). So that it becomes a situation that causes an energy crisis if there is no integration innovation with solar cells. So far, solar energy has only focused on lighting open space areas (Durganjali et al., 2020), not as an integrated power source in an open space facility object, in this case, a bench as a seat (Kango, Hadiyanto, et al., 2021). Thus, it is essential to utilize the potential of solar energy as a source of electricity for open space facilities. The main aspects of implementing solar cells on bench objects include a good,

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standard, most efficient and convergent economic model (Liberski et al., 2019). The main drawback of the solar cell model is its efficiency. At low, radiation power generated from solar panels is deficient, and this will also continue to change from the surrounding climatic conditions. Therefore, it is necessary to design a bench object powered by solar cells to save electricity consumption, operational costs and increase work effectiveness, and can play a role in convergent electrical energy savings in Indonesia.

Interesting discussions about the development of lighting systems that can save electricity have been carried out by many researchers worldwide. Research (Hyder et al., 2018) has carried out an analysis of photovoltaic-based garden lighting. Research (Mohammad Bagher, 2015) has revealed that solar cells can convert solar energy into light energy using lighting energy sources. Research (Kango & Pongtularan, 2021) has optimized green open space parks with new and renewable energy. Further research by (Aromal et al., 2018) has designed wheelchair-using solar cells. In this study, it was revealed that solar cells could generate electric power for wheelchair operation. Research (Kango, Hadiyanto, et al., 2021) has designed an electric bench using solar cells. In this study, it has been shown that solar cells can generate electricity for the operation of functions embedded in bench furniture. This research is a research development (Aromal et al., 2018; Kango, Hadiyanto, et al., 2021), designing a photovoltaic powered park bench with the integration of an automated LED light feature and adding a USB port as a mobile phone charging station. Considering all these problems in this work, solar charger control is used as a tracking method in solar cell systems because it can control environmental, climatic conditions are simple and easy to implement.

The study aims to design bench furniture powered by solar cells as a source of electrical energy for electronic features, namely LED lights and USB ports embedded with bench objects. This research product provides a solution for providing lighting sources with LED lights and mobile phone charging stations. In addition, the specific objectivity of this research is to focus on the fabrication of solar-powered park benches using solar charger control with the help of a maximum power point tracking system at an optimal cost designed for implementation in an outdoor environment. Departing from empirical theory, this study believes in providing a solution for providing electrical energy sources for more comprehensive garden facilities because of the standard, most efficient and convergent product design. This research has made a real contribution to energy conservation and electrical energy use in open space areas

Methods

This study discusses the design of a bench that is integrated with solar panels as a source of electrical energy to operate against the features of the bench object. Technically, we are targeting a rectangular bench with a roof that can accommodate solar panels, lights, sensors, electronics and communication systems in one unit, called a smart bench. Our goal is to make electronics invisible from the outside so that they are placed in a panel box while being accessible for exchange and repair, and we install USB ports in an aesthetically pleasing way. Benches must be durable, easy to install, disassemble, and withstand long periods of exposure to sunlight, high/low humidity, and heavy rain. Since there are no commercial goods with such unique characteristics, the need to make products becomes apparent. Furniture manufactures are produced locally, so the designs and materials used are traditional. Therefore, there is no need for extensive furniture performance testing or production quality checks under standard conditions. Since the strength testing of innovative bench products is not outsourced, we introduce two alternative testing methods. Our method for solving this problem can be used as a mode of operation for other researchers.

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The method we propose is the development of a bench product that produces solar cell output power. In the first step, we design a three-dimensional bench model created using AutoCAD software available online and can be used because of its public license. In the second step, we prepared several additives and subtractive manufacturing prototypes. Assembly is carried out at home using the device. Mild steel bar frames are placed as the mainframe in the physical manufacture of benches. Ironwood (Eusideroxylon zwageri) with a thickness of 10 mm was processed using a seven-piece drilling machine with a length of 150 cm which was assembled with bolts. Stamp and laser cutting are outsourced to local companies. In the third step, we tested the strength of the bench with standard methods, which included the use of equipment that applied force to the bench, which was set in a certain way. We estimate the durability of our prototype to be comparable to the existing conventional benches at the implementation site, namely the Bekapai park, Balikpapan City, Indonesia. The bench is made of ironwood (Eusideroxylon zwageri) covered with acrylic lacquer. The bench is loaded with two people with a total weight of 120 kg and stands outdoors for 1 hour. Then, the loaded bench is placed on the deck of the pickup. The car was travelling at a certain speed.

The effects of travel (vibration, jumping) on the structural features of the bench are recorded and compared. Weather resistance (exposure to sun, wind, and humidity to varying degrees) was estimated by placing the bench outdoors for one week. The applied methodology involves only a brief and relative estimation of the endurance parameters. In the fourth step, we installed three 20WP 12v 1A polycrystalline solar panels with a fixed position on the bench object (absorption angle) of the solar cell to the earth. We also used a 12V 18Ah VRLA Battery and a 12/24v 10A MMK Solar Charge Controller, bench mounted using an extension rod and pole (Figure 2). The fifth step is to install a 12V 90mA LED Strip load as a lighting lamp placed on the solar panel roof. Then, a 1A USB port is installed and placed in the bench's middle as a mobile phone charging station.

Results and Discussion

Choosing the optimal furniture design is not a trivial task, but several factors need to be considered, including the aesthetic preferences of the target customer group, functionality, material and processing costs, and durability (Liberski et al., 2019). First, we investigated the online design library (https://www.opendesk.cc). Then, we decided to look for alternatives for the following reasons—the specific and highly regulated urban, social and architectural environment of the City of Balikpapan, Indonesia. The aesthetic and functional values in the public spaces of city parks are associated with the efforts of architects, urban planners, designers, and even artists. Since our goal is to bring furniture that can function (or be present) in a public space, we included a model with a decidedly artistic touch. Our added value to the design is to make a chair that can accommodate electronic devices and a USB port. The first obstacle we encountered was setting the seat parameters due to a large number of indentations. Therefore, we decided to use AutoCAD. In the first feasibility test, the chair was 2D printed (Figure 1). The model is divided into two: side view and front view

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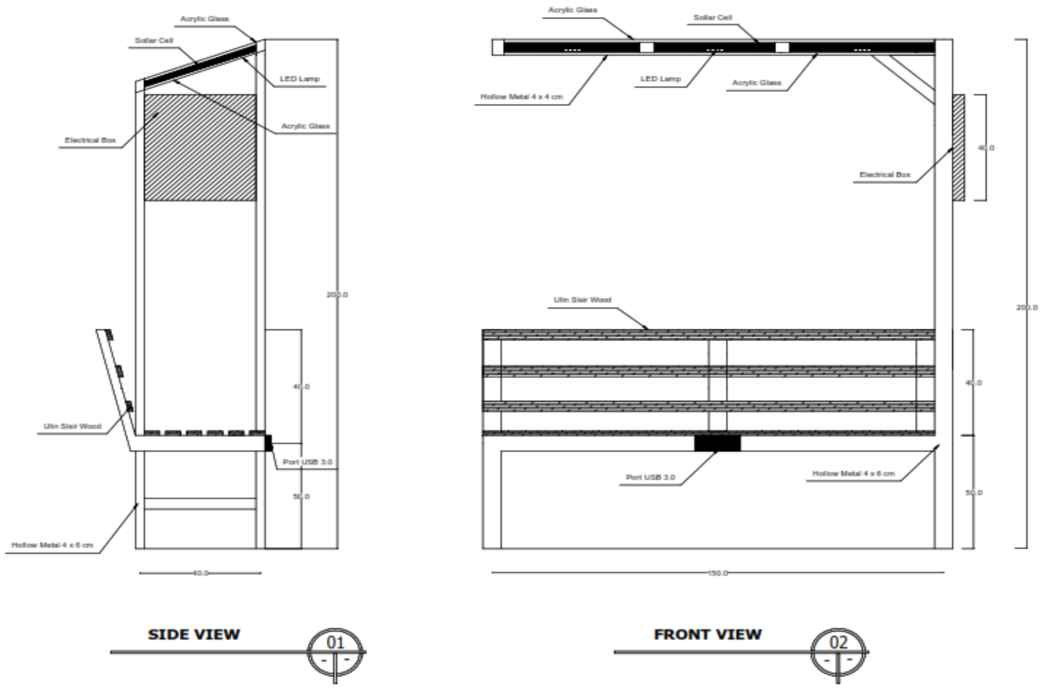

Figure 1. 2D smart bench design

The bench's design mainly depends on the load capacity it can withstand and the size of the solar cell used. The weight of 150-200 Kg is the average capacity that the bench is designed for and its weight. This limits the seating medium made of ironwood (Eusideroxylon zwageri). Instead of using the conventional one, the bench design is slightly modified. The main components of the bench include solar cells, batteries, metal frames, LED lights and USB ports.

The spine of the bench is the mainframe. The frame supports the person's entire weight and other components such as the battery-charged panel box and solar panels. An iron rod of hollow type material with a diameter of 6 cm was used to design the mainframe. This bench has a height of 200 cm and a width of 50 cm with a seating area of 150 x 50 cm2. The primary model of the solar-assisted bench is shown in Figure 1.

Figure 2. Mainframe model

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A solar panel is an interconnected array of solar cells, also known as photovoltaic cells. The solar cell will change according to the material used for its manufacture (Kango, Hadiyanto, et al., 2021). The factors responsible for solar cells depend on the intensity of the environmental light falling on the panels and the electrical characteristics. Thus the efficiency of the system can be optimized when the load characteristics change so that a very efficient power transfer occurs (Kango & Pongtularan, 2021). The calibration of the solar panels carried out is shown in Figure 3

Figure 3. Calibration of solar panel conducted

The bench uses solar panels to charge the battery and is used for small applications such as LED lights and USB ports. Each solar panel consists of solar modules connected in series or parallel. The designed solar panel is connected to the battery assembly, which passes through the solar charger control with the help of a microcontroller (Figure 4). To track the panel's maximum power point, we balanced design simplicity and overall efficiency compromise. The irradiance value of each solar cell on the panel varies according to the position of the solar panel on the electric bench. The controller monitors the power continuously, and the voltage is adjusted as needed. This process continues until the system is turned on

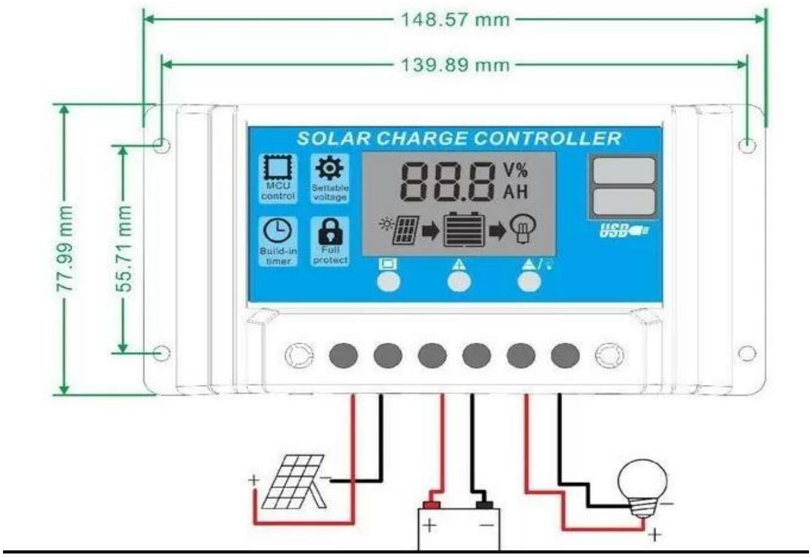

Figure 4. solar charger control

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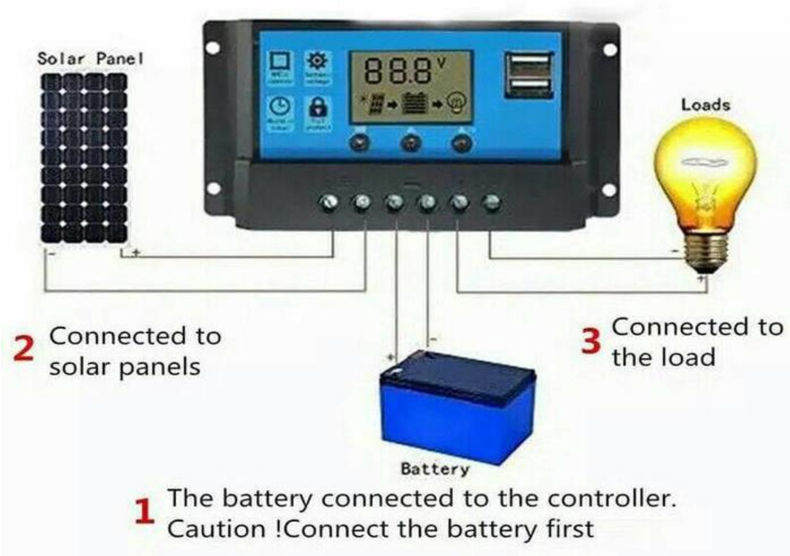

Figure 5. Block diagram of the solar-integrated system

The block diagram in (Figure 4) shows a solar charge controller that regulates the direct current charged to the battery and drawn from the battery to the load. The solar charge controller mounted on the bench object regulates overcharging (overcharging - because the battery is full) and excess voltage from the three solar cell units used on the roof of the bench. Excess voltage and charging will reduce battery life so that the solar charge controller regulates the voltage and current from the solar panel to the battery. A mechanical adjustment of the solar panel has been implemented, which includes mounting the solar panel on a bench and connecting the solar charge controller to regulate the incoming voltage to the battery. The correct panel box is made to house the solar charge controller and battery, and additional components. Precise arrangements have been made to place the battery in the panel box to remain in a fixed position

In this smart bench product design, we use solar panels that produce an output voltage of about 20 volts DC, so if there is no regulation, the battery will be damaged from overcharging. At the same time, the use of a 12 Volt battery (Figure 6) requires a charging voltage of around 13 - 14.8 Volt to be fully charged according to the type of battery we have used. The battery used for this project is a 12 V 18 Ah lead-acid battery. It requires a charging current of 1.8 V and takes 4 hours to charge fully. Shortening battery life due to battery overcharging can be avoided by using lead-acid batteries. The battery is placed in a panel box that is placed next to the bench.

Figure 6. Lead acid Battery

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After implementing the smart bench product in the Taman Bekapai, Balikpapan City, Indonesia, several tests were carried out to determine the capacity of the battery installed on the bench. First, we checked whether the 12V LED lamp was sufficient to illuminate the bench area (Figure 7). It was observed that sun exposure substantially increases the charge in the battery. The time of the lamp (OFF) when the solar panel is exposed to sunlight, while the time of the lamp (ON) when the solar panel is not exposed to sunlight. When the battery still stores a minimum of 11 watts of power, the USB port can still charge mobile devices. We limit the battery power to a minimum so as not to damage it.

Figure 7. Bench with solar panels to turn on LED lights

Figure 8. Implementation of benches with solar panels in the garden area

The park bench component testing is divided into two parts, namely solar panel testing and load circuit testing. We tested the performance of solar cells on a park bench for 1 hour by placing objects in the public space of Bekapai Park, Balikpapan City (Figure 8). The first condition is at noon at 12:30 - 13:30, while the second condition is at 17:45 - 18:45. We did the test by connecting a solar charge controller with three 60 WP solar cells and one 12 Volt 18Ah battery in series. We record the power generated by the solar cell every 10 minutes. The Watt value is obtained using the equation P = V * I for each draw. The experimental results in Table 1 show that all solar cell circuits functioned well during the trial process by obtaining current and voltage parameters. The test results show that the difference in Watts per unit time is taken as the efficiency value. The calculation results show the highest value (12:30-13:30)

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for daytime conditions so that the solar cell can produce electrical power. These results are in line with research (Arif et al., 2019) that solar cells function optimally during the day. This shows that the performance of the solar cell circuit system works well to produce current and voltage during daytime conditions, but its performance is not optimal at night.

Table 1. Performance of solar cell circuit

Time Trial	Average Voltage value	Average Current Value	Watt
12:00–13:00	13.57 V	1.88 A	26.76
17:45–18:45	0.12 V	0.01 A	0.0001

Finally, we conducted a 2-hour test on all sets of park bench objects during the day and night to determine the effectiveness of charging solar panels and the functional status of the bench. The test results are listed in Table 2.

Table 1. Performance of the smart bench during the day (12:00-13:00 and 19:00-20:00) pm

Time Trial (pm)	Voltage	Current	Battery percentage	Condition LED	Condition Charger
12:00	13.3	0.9	98	OFF	ON
12:10	13.3	0.9	98	OFF	ON
12:20	13.4	0.91	98	OFF	ON
12:30	13.4	0.92	98	OFF	ON
12:40	13.4	0.93	98	OFF	ON
12:50	13.4	0.93	99	OFF	ON
13:00	13.4	0.93	99	OFF	ON
19:00	0.1	0.01	73	ON	ON
19:10	0.1	0.01	73	ON	ON
19:20	0.1	0.01	73	ON	ON
19:30	0.1	0.01	72	ON	ON
19:40	0.1	0.01	72	ON	ON
19:50	0.1	0.01	71	ON	ON
20:00	0.1	0.013	71	ON	ON

Table 2 shows that the efficiency of charging the solar panel voltage and current at night is very low compared to the daytime. Our experiments show that LED lights can only work in dark lighting conditions. Conversely, if the battery is higher than 11 watts, the charging condition still applies. This can be applied to situations where the lighting changes drastically during the day and night. However, this change of state will not cause much error when this bench is applied. Current and voltage values indicate that the solar cell is stable at low or high threshold values. Thus, the proposed garden bench can handle different lighting conditions to function within a reasonable range as a dual function bench.

The implication of this research result is to start a hub where small businesses, science, expertise, and research can meet. Furthermore, we would like to provide preliminary information covering all the manufacturing elements from furniture to a stylish stool. In addition, there are electricity savings for public open spaces by integrating solar panels using renewable energy sources. The problem of the design and implementation of supplying electricity for the facilities in the park has been resolved. So that it becomes a situation that can increase the efficiency of electrical energy and the comfort of the target user. The bench has a dual function, namely as a source of electricity for lighting and a mobile phone charging station

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Conclusion

The study results present the primary resources needed to design and implement an intelligent bench, an integrated solar cell park bench as a source of electrical energy for USB station charges and led lights. Experiments show that a load of LED lights and USB station chargers depends on the percentage of batteries supplied from the solar cell. The intelligent bench is designed from hollow steel to support product construction efficiency and electronics effectiveness (cables, sensors). In addition, we combined a charging station with a bench to get a double-duty object. In this way, we achieved our goal of designing and implementing a portable garden bench that could function in all open areas. Further work could be done to improve the improved bench resistance test method to identify areas for improvement, using solar panels with larger peak wattages.

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