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Design of Smart Solar Panel System as a Source of Electrical Energy

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Abstract: Designing a smart solar panel system as a source of electrical energy is an important step in facing increasing global energy challenges and climate change. The system combines sustainable solar panel technology with smart elements that enable more efficient energy use and management. The advantages of smart solar panel systems include the ability to produce clean electrical energy and reduce long-term operational costs. By utilizing smart technology, users can monitor and optimize their energy use in real time, reduce waste, and minimize environmental impact. However, there are also several challenges that need to be overcome, including high initial costs, dependence on weather conditions and sunlight intensity, and limitations in energy storage.

Keywords: Solar Panels; Sun; Batteries; Inventors; Sensors

INTRODUCTION

The sun is a giant star in the universe that provides unlimited energy in it and is the main source of energy for life on Earth. The source of energy produced by the sun is very abundant and useful. As time goes by, technology continues to develop, currently, the form of utilization of the energy in the sun is to change the energy into energy that can be used, namely into electrical energy. Solar energy can be used as electrical energy that we need in everyday life such as watching TV, ironing, lighting the way, cooking rice, and much more. This technology is called solar cells (photovoltaics) or solar panels(Rudiyanto et al., 2023).

Energy needs in Indonesia continue to increase along with increasing population growth and economic growth. Fulfillment of electricity needs currently still depends on fossil fuel sources whose availability is limited. Therefore, in the future, the use of renewable energy sources is an alternative that needs to be continuously developed. Indonesia as an archipelagic country with a population of ± 240 million people has a relatively low electrification ratio problem, especially for the eastern part of Indonesia, compared to the electricity infrastructure on the island of Java. The solution is to utilize more potential.

It is no longer a secret that Indonesia is known as a tropical country. The changing temperature and climate create its own advantages for those who realize it. One of the advantages is having fairly continuous sunlight which is rarely owned by other countries. Unfortunately, there are still very few who use the sunlight to become something valuable.

Electrical energy sources are one of the basic needs in driving human life activities. To help improve the community's economy, support is needed as one of the household or industrial needs. Renewable energy sources have renewable and sustainable properties. Solar Power Plants (PLTS) use solar energy as a renewable energy source. The main component of PLTS is solar cells (photovoltaic cells). PLTS is generally used in areas with high solar radiation and areas that have not been reached by PLN electricity.

In Indonesia, the type of solar cell that is widely used is the polycrystalline silicon type. The abundant and abundant source of solar energy is certainly something that can be utilized for technology. The utilization of renewable energy, namely sunlight, is very good because Indonesia's geographical location in the equatorial region has sufficient radiation potential. Solar energy can shine for 12 hours per day, for each year, with a fairly high intensity of around 4.8 kWH / m2 / day.

Energy is one of the needs of human life sources. Increasing energy needs is an indicator of increasing prosperity. The utilization of solar energy in Indonesia has very good prospects, considering the geographical area of Indonesia as a tropical country. The utilization of solar energy through photovoltaic conversion is widely

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applied, including the application of individual systems and hybrid systems, namely a system that combines conventional resources with renewable energy sources.

Renewable energy sources have renewable and sustainable properties. Solar Power Plants (PLTS) use solar energy as a renewable energy source. The main component of PLTS is solar cells (photovoltaic cells). PLTS is generally used in areas with high solar radiation and areas that have not been reached by PLN electricity. In Indonesia, the type of solar cell that is widely used is the polycrystalline silicon type. There are several environmental parameters that can affect the performance of solar cells, including changes in temperature, intensity of solar radiation, partial coverage of the solar cell surface (shadow)(Samsurizal et al., 2021).

Solar cells are a set of modules to convert solar energy into electrical energy. Photovoltaic is a technology that functions to change or convert solar radiation into electrical energy directly. PV is usually packaged in a unit called a module. A solar module consists of many solar cells that can be arranged in series or parallel. What is meant by solar is a semi-conductor element that can convert solar energy into electrical energy based on the photovoltaic effect. Solar cells have become popular lately, in addition to the dwindling fossil energy reserves and the issue of global warming. The energy produced is also very cheap because the energy source (sun) can be obtained for free(Safitri et al., 2019).

Solar energy is being touted by many as the ultimate energy source of the future, so let's take a look at the pros and cons of solar energy. Solar energy has more pros than cons, but these cons are still major stumbling blocks to the wider adoption of solar energy. At this point, we will first discuss the pros of solar energy. We already know that solar energy is a renewable energy source. The sun is almost limitless as an energy source, and solar energy cannot run out, unlike fossil fuels which will eventually run out. Once fossil fuels run out, the world will need a good alternative energy source, and solar energy certainly looks like one of the best alternatives(Suhendra, 2022).

Solar energy is an unlimited source of energy and will never run out of availability and this energy can also be used as an alternative energy that will be converted into electrical energy, using solar cells. Solar panels as an alternative source of electrical energy can be used by people who need electrical energy, but are constrained by the unavailability of electrical energy from PLN such as street vendors, people who live in remote areas, or areas that have not been supplied with electricity from PLN. Another source of electrical energy that can be used by the community, a source of electrical energy other than PLN, is a generator or more often referred to as a Genset. The efficiency of use of each alternative source of electrical energy needs to be known so that in its use maximum results are obtained(Purwoto et al., 2018).

Electrical energy is an important need for humans and the use of electrical energy is quite a lot in the household sector. The use of electrical power depends on usage. The more equipment used, the greater the power used, which can cause excessive current loads. In order to be able to carry out better electricity management in household cases, an electronic device is needed that can make human work easier by utilizing technological advances in monitoring the use of electrical energy on these electrical devices(Anantama et al., 2020).

At this time the need for energy sources is one of the main needs. However, in certain areas to get maximum lighting services is still difficult. This is because the source of electrical energy is lacking. Because of this problem, new technology is sought to replace the source of electrical energy. One way is to use solar energy which is very abundant and will not run out if used continuously. By combining two existing energy sources, a way is found to reduce the use of limited PLN electricity sources. The advantage that can be obtained from this tool is that there is no need to replace the energy source that will be used because this tool will automatically regulate the replacement of PLN energy and solar energy usage(Anantama et al., 2020).

In this study, solar panels are used for ship lighting as a substitute for generator engines. However, this system does not yet have a monitoring system to see whether the brightness level of solar energy obtained is optimal or not, and also does not have a control system that is connected to a smartphone via Bluetooth(Haryanto et al., 2024).

Based on this, the author raises research entitled "Design of a Smart Solar Panel System as a Source of Electrical Energy". This system can monitor the level of sun brightness so that users can find out whether the level of sun brightness obtained is optimal or not and also has a control system, such as turning off or on lights and fans via a smartphone device connected to Bluetooth as a tool to control the available equipment.

LITERATURE REVIEW

Solar Panels

Solar panels are a collection of solar cells arranged in such a way that they are effective in absorbing sunlight. The one responsible for absorbing sunlight is the solar cell. Solar cells themselves consist of various photovoltaic components or components that can convert light into electricity (Mungkin et al., 2020)

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Solar panels can be a more efficient and promising independent power generator for the long term. This electric power is different from conventional electric power because it is a renewable energy source that comes from sunlight. Conventional electric power itself still uses fossil fuels that cannot be renewed. With an increasing population, the need for electricity will also continue to increase sharply. Therefore, switching to using renewable energy such as solar power is increasingly necessary to maintain the balance of the earth (Samania et al., 2020)

Electrical Energy

Electrical energy is the movement of electrons from one place to another to produce energy. Electrical energy can be useful for everyday life such as turning on lights, fans, or other household items (Eka Saputra et al., 2024).

Quoting from Circuit Globe, electrical energy is a source of energy produced by the movement of electrons from one place to another. The movement of electron flow occurs due to the potential difference from one place to another. Electrical energy is produced when electrons move through a conductor, one of which is copper wire. If there is an electric voltage at the end of the conductor, electrons begin to move from one end to the other. This condition will create an electric current flow and is useful for doing various jobs. In general, electrical energy comes from various sources, ranging from hydroelectric power plants, solar power, and fossil fuels. Of course, this material does not produce greenhouse gas emissions, so it is clean energy (Erianto & Haryudo, 2023).

Arduino Uno IDE

Arduino IDE is software used to create programming sketches in other words Arduino IDE is a medium for programming on the board to be programmed. Arduino IDE is useful for editing, creating, uploading to the specified board, and coding certain programs. Arduino IDE is made from the JAVA programming language, which is equipped with a C/C++ (wiring) library, which makes input/output operations easier (Sinurat & Bella, 2022).

METHOD

Design is the main basis for creating a system with the aim of providing a complete and clear picture of what will be created. Design or design is a series of procedures to translate the results of analysis and a system to describe in detail how the system components are implemented(Sari et al., 2021).

A smart system is a form of technology that integrates artificial intelligence (AI) and computing to increase the efficiency, productivity, and performance of a system(Satria et al., 2024).

Solar panels are tools for converting solar energy into electrical energy. Solar panels consist of an arrangement of solar cells connected in series. Solar cells function to convert sunlight into electrical energy. Solar cells are generally made of silicon which is a semiconductor material(Gunawan et al., 2019).

Electrical energy is energy generated by an electric charge (static) resulting in the movement of an electric charge (dynamic)(Mujiraharjo & Basuki, 2019).

Arduino Uno is a type of microcontroller board developed by Arduino.cc. Arduino can be connected to a computer with a USB cable and programmed using Arduino Software (IDE) that supports C and C++ programming languages or with other software such as Scratch for Arduino or Common-Coding that uses block/image-based programming languages(Pratidhina et al., 2021).

MIT App Inventor is a platform for creating simple applications without having to learn or use too many programming languages(Darmayanti et al., 2022).

Analysis of the current system is an analysis of the needs of a running system that requires development in it. In general, analysis of the current system is done by looking at the data obtained through the case study taken, creating a process model for the running system, and then analyzing the problems in the system. So far, security and control on smart solar panels are still rarely used for household needs. Most smart solar panels are still used as lighting for street lights and no one uses smart solar panels for household needs. Smart solar panels on street lights still work automatically, during the day the solar panels will absorb solar energy into electrical energy so that during the day the lights turn off and at night the lights will turn on automatically.

From this analysis, the author developed a system to be built, namely the IoT (Internet of Things) system. The system designed is based on a microcontroller as the control center of all systems to be built.

The microcontroller here functions as a placement of programs created for system design and as a regulator of all tool work. The author developed a smart solar panel system design as a source of electrical energy using the MIT App Inventor application on a smartphone and is also connected to Bluetooth. Where this system will work according to the commands that come out through the server or from the MIT App Inventor application on the smartphone.

This smart solar panel can turn on lights, and fans and can also charge smartphones. This smart solar panel has two Light Dependent Resistor (LDR) type light sensors that are useful for detecting sunlight. In addition to sensors, this smart solar panel also has two servos that are useful for moving the solar panel according to the direction of the sun's movement.

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System design is a stage after the analysis process of a system development or construction, defining functional needs, and preparing to design and build an implementation that describes how a system is formed. The main purpose of this system design is to provide a description of the system design that will be built or developed, to understand the flow of information and processes in the system to meet the needs of system users, and to provide a clear picture

From the results of the analysis above, the author continues to make a picture or design that will be built as follows:

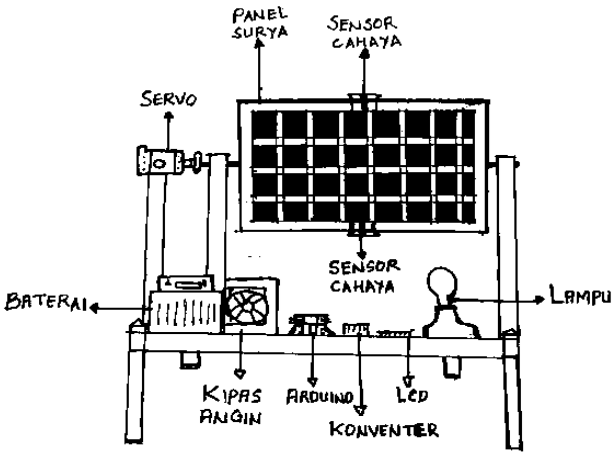

Figure 1. Initial Design of System Design

The working system of the Smart Solar Panel System Design as a Source of Electrical Energy is shown in the block diagram below.

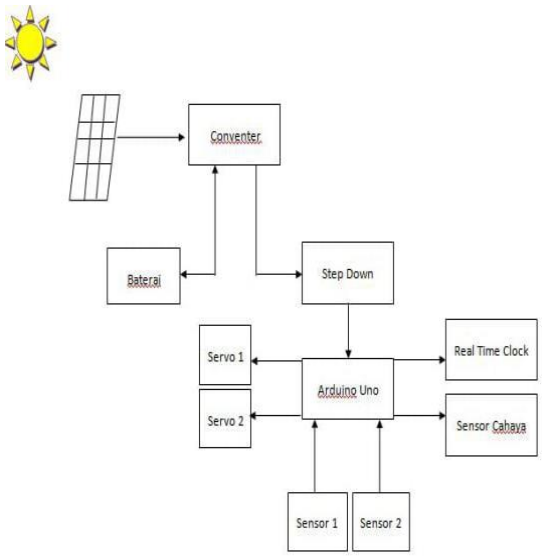

Figure 2. Block Diagram Design

The working system of each component in the image above can be explained as follows:

a. The sun functions to produce electrical energy through the process of converting solar energy into electrical energy.
b. Solar Panel functions to capture solar energy and convert it into electrical energy.
c. The converter functions to convert DC electrical energy from solar panels into AC which can be used for electrical equipment.
d. The battery functions to store the solar energy produced and provide electricity when the sun is not shining.
e. Step Down functions as a tool to reduce the electrical voltage produced by solar panels.
f. Arduino Uno functions to control and regulate the operation of solar panels such as optimizing the direction of the solar panels to get maximum sunlight.

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g. Servo functions to move or adjust the position of the solar panels so that they can be directed automatically following the movement of the sun.
h. The Light Sensor functions to regulate and optimize the operation of solar panels so that they always face the strongest light source such as the sun and can produce electrical energy according to changing environmental conditions.
i. Real Time Clock (RTC) functions to provide accurate time for monitoring and supervision systems.

The tools and materials used in this design include the following:

1. Grenda
2. Electric Drill
3. Saw
4. Brush
5. Scissors
6. Sensor
7. Real Time Clock
8. Lamp Fitting
9. Motorcycle Battery
10. Arduino Uno
11. Solar Panel
12. Step Down
13. Servo
14. Converter
15. LCD
16. Fan
17. Acrylic
18. DC Lamp

In designing this software system, the following software is used:

a. Software Arduino IDE 1.6
The Arduino IDE software display is as shown below:

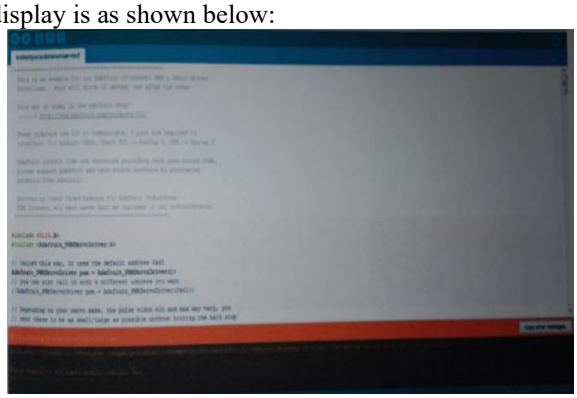

Figure 3. Arduino IDE 1.6 program display

b. Software MIT App Inventor
The MIT App Inventor display looks like this:

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Figure 4. MIT App Inventor software

RESULT

System implementation is a procedure that has been carried out to complete the system design in the approved design document, test the system, install the system, and start the new system that has been created. In programming the smart solar panel system as a source of electrical energy, it is designed using hardware and software that have been tested at the Robotics Lab of the Indonesian Institute of Technology and Business and can function as desired. The following is a display of the final results of the design that has been completed and is ready to be used using simulation, namely as follows:

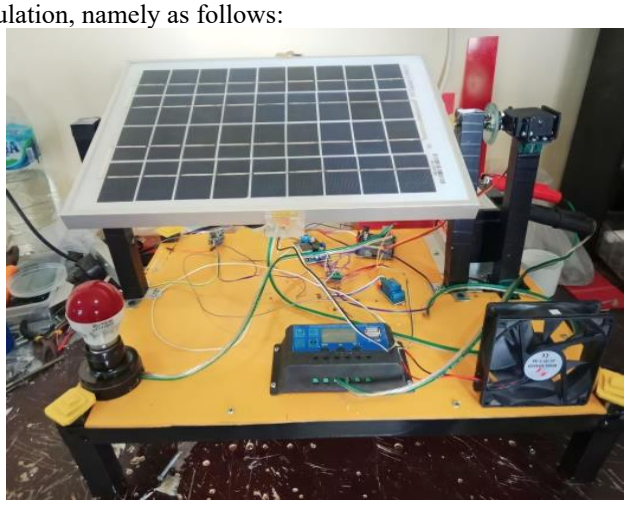

Figure 5. Front View Results

The image is the final design result of the physical design that has been made, the display is a simulation display with a miniature frame shape made using acrylic with a thickness of 2 to 3 mm.

The display above is also the result of a simulation with two light sensors where this light sensor will automatically detect the movement of sunlight, and then provide notification to the owner so that they can control the condition of the sunlight. On the device, there is one servo motor to move the solar panel to the right and left and a motor driver to move the servo that is connected to the solar panel, there is also one fan and a lamp as a light.

The benefit of testing the application is to determine the effect of commands on the performance of the device, whether it functions or works as expected. The following are some of the work processes of the device, namely:

1. Data entry process
   In the process of entering data using commands and using a smartphone to move the solar panel, it will be sent via a Wifi signal that is already connected to the smartphone. Make sure your smartphone's Wifi is turned on first.
2. Data transaction process
   The Arduino Uno microcontroller can run and process data sent by the smartphone application when the program list is attached. The list of programs created is uploaded to Arduino using the Arduino IDE programming tool. The programming function converts data sent by Android to the "HIGH" or "LOW" logic command that activates or deactivates the relay and other outputs. After the smartphone's Bluetooth is

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connected to the MIT App Inventor application on the smartphone, it is ready to issue commands. When the Bluetooth signal receives a command, Arduino processes it and sends it to the lamp, servo, and fan outputs.

3. Data presentation process

The data presentation process includes the results of testing various types of components used in the research process.

The following is a test of several smart solar panel system design tools, namely:

1. Servo testing

The purpose of this servo testing is to find out whether the servo rotates properly or not. The following is a table of servo testing results in designing a smart solar panel system as a source of electrical energy, namely:

Table 1. Servo Test Results

No	Servo	Input Conditions	Servo Condition
1	Servo	HIGH	ON
		LOW	OFF
		LOW	OFF
		HIGH	ON
		LOW	OFF
		LOW	OFF

2. Bluetooth Module Testing

The following is a table of Bluetooth module testing in the design of a smart solar panel system as a source of electrical energy, namely as follows:

Table 2. Bluetooth Module Test Results

No	Condition	Distance	Results	
			Connected	Not connected
1	Without barriers	1-10 meters	✓	
		11 meters	✓	
		12 meters		✓
		13 meters		✓
2	There is a barrier	1-10 meters	✓	
		11 meters	✓	
		12 meters		✓
		13 meters		✓

3. Lamp testing

This test is done to find out whether the lamp is on properly or not. The following are the results of the lamp test when the lamp is connected, namely as follows:

Table 3. Lamp Test Results

No	Input Signal	Light Condition	Voltage	Information
1	Low	ON	5	True
2	High	OFF	5	True

The overall test results are as follows:

1. Moving Solar Panels

The solar panel display moves following the sunlight with a sunny or cloudy weather control system, and the owner can also control it via the MIT App Inventor application on Android. If the Solar Panel does not get sunlight, the solar panel also works using a battery system, the solar panel will move as usual to the right and left. The following is a picture of the results of the design of a smart solar panel system as a source of electrical energy, namely as follows:

Figure 6. Solar Panel Display Results

2. Lamp

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Currently, owners can turn on the lights with a command control system from the MIT App Inventor application on their smartphones. Here is a picture of the lighting system, namely:

Figure 7. Lamp Display

3. Fan Control
   When the owner is outside or inside the house, the owner of the solar panel can turn the fan on and off using the smartphone command control system. Here is a picture of the fan control, namely:

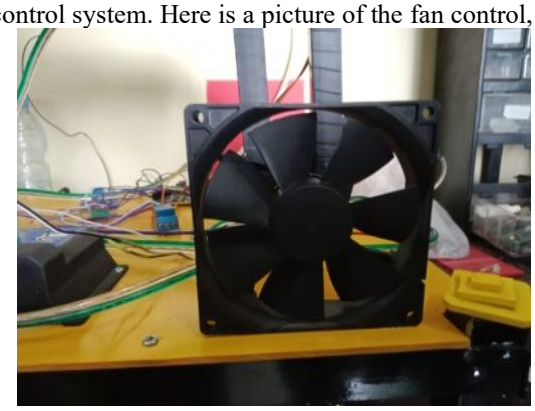

Figure 8. Fan Control

4. Solar Panel Motion Sensor
   The security system of the sensor works when there is movement of sunlight at a certain point so that the sensor provides movement according to the direction the sun moves. The following is a picture of the sensor movement on the solar panel, namely as follows:

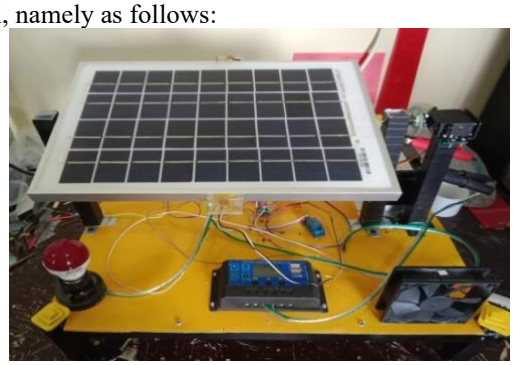

Figure 9. Sensor

DISCUSSIONS

At this stage, a discussion is conducted on the working principles of the control and monitoring system on smart solar panels. This control system uses an Arduino Uno 328 microcontroller, 2 light sensors, 1 servo, 1 converter, 1 step down, 1 LCD, and 1 RTC. The light sensor used is the Light Dependent Resistor (LDR) sensor. This sensor is installed at certain points on the left and right sides of the solar panel which are considered to be the points where motion activity often occurs. The sensor will work if there is sun movement.

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Then the sensor provides input to the Arduino Uno microcontroller to transfer data into the database. Arduino is connected to the MIT App Inventor application on the smartphone and the smartphone is connected to wifi. From this MIT App Inventor application, all system processes such as turning on the lights, turning on the fan, and also charging the battery.

From the results and discussions, there are also advantages and disadvantages of the Design of the Smart Solar Panel System as a Source of Electrical Energy. The advantages and disadvantages of the Design of the Smart Solar Panel System as a Source of Electrical Energy are as follows:

1. System Advantages
   The advantages of this smart solar panel system are as follows:
   a. The system uses 2 light sensors to detect the movement of the sun.
   b. Provides convenience to control and monitor the condition of the solar panels.
   c. With this system, we can save electricity because the system uses sunlight or batteries.
   d. The system is very helpful in terms of time and handling which will be more efficient and effective
2. System Deficiencies
   The disadvantages of this smart solar panel system are as follows:
   a. The control and monitoring system on this smart solar panel cannot be used if there is no sun and battery.
   b. The system is made to utilize sunlight so that if there is no sunlight, other ways can be used to anticipate it by providing a backup battery and turning on the generator so that the system can continue to run.
   c. The system created is still a prototype, namely a simulation example, and has not been developed for actual household equipment.

CONCLUSION

After conducting an analysis and evaluation of the Design of a Smart Solar Panel System as a Source of Electrical Energy, the author can draw several conclusions. The conclusions are as follows: (1) The smart solar panel system is carried out automatically, (2) The solar panel work process is through sunlight and if there is no sunlight it will be replaced with a battery, (3) Solar panels can reduce electrical voltage and also electricity bill costs, (4) The smart solar panel system is not yet effective and efficient.

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