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Monitoring and assembly of internet of things-based solar power plants

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ABSTRACT

Electricity is a major need in the industrial era 4.0, where almost all human activities use electricity both at home and in companies. The state electricity company can meet not all electricity needs. Therefore, alternative energy sources are needed to be used as power plants to meet the huge demand for electricity by paying attention to safety. Because it is located in the tropics, the potential for solar energy in Indonesia is very large, in the range of 4.8 KWh/m2 equivalent to 112,000 GWp, which can be used as an alternative energy source for electricity generation using solar panels. Meanwhile, the security system for solar power plants can utilize internet of things technology to be monitored anytime and anywhere by accessing a website that has been created using the Codeigniter framework. The tools used as a monitoring system include Arduino Uno R3, nodeMCU ESP8266, voltage sensors, acs712 sensors, and so on. While the software used is Arduino IDE which has been installed on a computer or laptop and uses a web browser. The method used in this study is the prototyping method. A prototype tool with a limited capacity is created, determining which tools are required. The process is then repeated to create a security monitoring system in tools and websites.

ABSTRAK

Listrik merupakan kebutuhan utama di era industri 4.0, dimana hampir semua aktivitas manusia menggunakan listrik baik dirumah maupun di perusahaan. Kebutuhan listrik tersebut belum semuanya dapat dipenuhi oleh perusahaan listrik negara. Oleh karena itu diperlukan sumber energi alternatif untuk dijadikan sebagai pembangkit listrik untuk memenuhi kebutuhan listrik yang sangat banyak dengan memperhatikan keamanannya. Karena terletak di daerah tropis, potensi energi surya yang ada di Indonesia sangatlah besar, yaitu kisaran 4,8 KWh/m^2 setara 112.000 GWp yang dapat dijadikan sebagai sumber energi alternatif pembangkit listrik dengan menggunakan panel surya. Sedangkan dalam sistem keamanan pembangkit listrik tenaga surya dapat memanfaatkan teknologi internet of things sehingga dapat di awasi kapanpun dan dimanapun dengan mengakses website yang telah dibuat menggunakan framework codeigniter. Alat-alat yang digunakan sebagai sistem monitoring diantaranya yaitu Arduino uno R3, nodeMCU ESP8266, sensor tegangan, sensor acs712, dan lain sebagainya. Sedangkan software yang digunakan yaitu Arduino IDE yang sudah di install pada komputer atau laptop dan menggunakan web browser. Metode yang gunakan pada penelitian ini yaitu metode prototyping. Dimulai dari penentuan alat sesuai dengan yang dibutuhkan, yang kemudian dibuat menjadi prototype alat dengan kapasitas kecil dan dilanjutkan membuat sistem monitoring untuk keamanan berupa alat danwebsitenya.

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1. Introduction

In the industrial era 4.0, almost all human work is assisted by machines that use electric power, especially in companies such as welding machines, stamping press machines, computers, lights, etc. Electricity has become a major need in everyday life. Almost all human activities use electrical equipment, ranging from basic to complex. Even when our smartphones are low, we need to find a power source as soon as possible. Currently, electricity seems to have become a basic human need, both in household activities, public services, and companies [1]. The more established companies, the more electricity will be used, while the increase in power generation from the state is less than the increase in the amount of existing electricity use. BPPT in 2015 revealed that state-owned power plants could generate 57.6 GW of electricity and an increase of 6.3% every year [2]. Meanwhile, the national electricity demand was 232 TWh in 2016, increasing 6.6% annually. Based on these data, the increase in electricity use is greater than the growth in the number of generators, around 0.3% per year. Given the large amount of electrical energy used, especially in companies, it is necessary to have other energy sources to meet the needs and reduce costs for energy use.

Indonesia is located in the tropics, so there are only two seasons, namely the rainy season and the dry season. When the dry season arrives, the sunlight produced is very high. The potential for solar power in Indonesia is very large, namely 4.8 KWh/m^2 or equal to 112,000 GWp, but which is utilized around 10 MWp according to the ministry of energy and mineral resources [3]. Based on these data, it can be seen that there is a large amount of natural energy, but very few use it. Solar energy is a renewable energy source that is environmentally friendly because it comes directly from nature and easily without spending money to get it. This energy source is expected to help meet electric power needs in Indonesia. The sun is a thermonuclear furnace with 100 million degrees Celsius. Every second converts 5 tons of matter into energy emitted into space as much as 64.1 million W/m^2. Indonesia is a country that has an optimal temperature and gets radiation from the sun for a long time, which is 12 hours [4]. For a fairly long time, solar energy will be very useful if used optimally.

Digitalization and increasing connectivity between devices, citizens, and governments continue to change many aspects of society and the economy in Indonesia. The internet of things is all activities whose actors interact with each other and are carried out using the internet. Enables physical objects to see, hear, think and do work by making them communicate together [5]. The many benefits of the Internet of Things make everything easier to do various kinds of activities [6]. The fundamental problem in the internet of things is bridging the gap between the physical world and the world of information, one of which is processing data collected from electronic equipment through the user-equipment interface. Sensors collect raw physical data from real-time scenarios and convert it into a machine-understandable format to be easily exchanged between various forms of data formats [7]. The internet of things can be used for various fields and can support various activities carried out by humans. In this research, the internet of things is used as a monitoring system for solar power plants so that the security of this solar power plant is always under control. The internet of things is very useful because the monitoring process can be done anytime and anywhere so that if something is not normal, it can be corrected immediately. After all, it only requires a computer or smartphone connected to the internet to access the monitoring system website.

2. Research Methodology

2.1. Research Framework

The following is a framework for thinking about the flow of research that has been carried out:

a. Preliminary stage. The researcher determines the object be studied based on the problems around him, then identification and problem formulation are carried out from the object that has been determined. After that, the researcher determines the boundaries and methodology used to conduct research and determines the research objectives to be carried out. After the object of research is determined, the researcher continues by conducting a literature study to find out all the components needed and how to use them in research to make it easier to conduct research.
b. Design stage. The tools used for research are determined at this stage. The selection of tools must be following what is needed to research so that research can run smoothly. After that, the UML and User Interface design is carried out to create an overview of the research and what steps must be taken.
c. Manufacturing and testing stages. The tools that have been decided will be constructed and used following the design stage plan. After the tool has been properly assembled, testing is carried out under several conditions. Likewise, the application that has been made will be tested using the black box testing method to obtain results from the tools and applications that have been made.
d. Result stages. At this stage, an analysis of the research results obtained is carried out.

2.2. Research Instrument

Penelitian ini mengunakan instrumental peralatan yang meliputi perangkat keras beserta perangkat lunak. Adapun perangkat yang dibutuhkan adalah sebagai berikut :

a. Perangkat keras (hardware). Perangkat keras berperan penting karena dalam penelitian ini membutuhkan sensor maupun alat fisik untuk menghasilkan tenaga listrik. Berikut merupakan perangkat keras yang digunakan dalam penelitian ini :
    1. A computer or laptop with minimum specifications, namely Intel® CoreTM i3-3220, minimum 4 GB RAM, minimum 500 GB hard drive (recommended using SSD), and a 13” monitor.
    2. Arduino Uno R3 DIP. Arduino Uno R3 is used to read data from the voltage sensor and acs712 sensor which is then sent to the nodeMCU.
    3. NodeMCU ESP 8266. NodeMCU ESP 8266 is in charge of reading data sent by Arduino and then sending it to a website using an internet connection.
    4. Solar Panels 20WP. 20WP Solar Panel is used to convert solar energy into electrical energy.
    5. Alligator Clip Cable. Alligator Clip Cable is used to connect solar panels with batteries and led lights.
    6. Cables. Cable is used to connect solar panels, voltage sensors, acs712 sensors, and led lights.
    7. 12V battery. The 12V battery is used as a storage medium for converting solar power into electrical energy by solar panels.
    8. Power bank. Powerbank is used as an energy source to activate Arduino and nodeMCU
    9. Solar Charger Controller. Solar Charger Controller is used as a voltage stabilizer.
    10. Sensors ACS712-30A. The ACS712-30A sensor is used to detect the current and power used and then send it to the Arduino.
    11. Voltage Sensor. The Voltage Sensor is used to detect the voltage from the solar panel and then send it to the Arduino.
    12. LCD Adapter I2C. The I2C LCD Adapter is used to connect the I2C LCD with Arduino.
    13. I2C LCD. The I2C LCD is used to display the data read by the Arduino according to the commands made.
    14. LED light. The LED light is used as a load.

15. USB cable 2.0. USB cable 2.0 is used to connect Arduino and nodeMCU with powerbank.

b. Software. In addition to requiring hardware (hardware), this study also uses software (software) to give orders and monitor the research results. The following software uses an operating system (OS) at least Windows 7, Arduino IDE1.8.13 is used to make commands or code on Arduino and nodeMCU, and a web browser displays data sent by nodeMCU to the website using an internet connection.

2.3. Internet of Things

Internet of things is a scenario that utilizes the internet and computer networks developed for objects, sensors, and everyday devices based on the ability to create, exchange, and use data to a minimum. IoT makes computers, sensors, and networks monitor and control existing devices the meaning of the internet of things, according to [8]. While a concept when objects - industrial machines, electric generators, vehicles, household appliances, to devices used by the body are connected through a network to exchange data in real-time is Furinto's opinion about IoT [9]. IoT has grown rapidly, starting from incorporating wireless technology, MicroElectromechanical Systems (MEMS), and the Internet. IoT uses several technologies broadly combined into one unit, including sensors as data readers, internet connections with various network topologies, Radio Frequency Identification (RFID), wireless sensor networks, and technology that will continue to grow according to needs [10].

IoT products and the IoT market developed a lot in 2019. By utilizing sensors, IoT can bridge the machines that produce data in mobile phones and other devices to collect information in real-time [11]. The internet of things works by utilizing an interaction between fellow devices connected automatically without human intervention, even at long distances. The liaison is the internet connection, while humans are only regulators and supervisors of the tool. The internet of things has been widely used in various fields related to human life, including the solar power plant carried out in this research. In this research, the internet of things is employed as a security system for solar power plants, with sensors attached directly to solar panels reading and sending data from solar panels to the website in real-time. Users or administrators may quickly detect anything wrong. As a result, it will be repaired as soon as possible.

2.4. Pembangkit listrik tenaga surya (PLTS)

PLTS is a power plant that converts solar power into electricity [12]. This conversion occurs in modules consisting of solar cells. This plant utilizes solar energy to produce DC (direct current) electricity. Electricity generation can be done directly using photovoltaic or indirectly by concentrating solar energy. Photovoltaic converts directly using the photoelectric effect while concentrating solar energy uses a lens or mirror combined with a tracking system to focus the sun's energy into a single point to drive a heat engine.

2.5. Panel surya

The solar panel is a device made of solar cells that can convert light into electricity [13]. These solar cells need to be protected from moisture and possible damage to reduce their service life. Solar cells use the photoelectric effect to convert light energy into electrical energy. Photovoltaic type PLTS utilizes the voltage difference due to photoelectricity to generate electricity. The solar panel has three layers: the P panel layer at the top, the middle layer boundary, and the N panel layer at the bottom. The photoelectric effect is when sunlight causes electrons in the P panel layer to be released, so that this causes protons to flow into the N panel layer. This transfer of proton current is called electric current [14]. Simply put, solar panels work to absorb sunlight and store the energy produced in a battery.

Solar panels are the main device in solar power plants because only solar panels can convert sunlight into electrical energy. Later, electrical energy will be used by humans for daily life. With the large capacity of sunlight in Indonesia, solar panels are considered very effective for utilizing solar energy as alternative energy in helping to meet the needs of electrical energy for various activities. This study will demonstrate solar energy conversion into electrical energy using a 20 Wp solar panel, and the energy is stored in a 12 V battery. The solar panels generate the pressure, and there is also an acs712 sensor used to detect the amount of current generated and the power output. The data obtained from the solar panel sent to the Arduino filled with a program to be translated into human language.

2.6. Arduino

An open-source electronics platform based on flexible and easy-to-use hardware and software intended for artists, designers, and everyone interested in creating an interactive object or environment can be defined as Arduino [16]. Arduino is an open-source single-board microcontroller derived from the wiring platform and designed to facilitate electronics in various fields. The hardware has an Atmel AVR processor, and the software has its programming language [15]. Furthermore, according to Himawan et al., an Arduino definition is a microcontroller board based on the ATmega328. The Arduino includes 14 input and output pins, which may be used as PWM outputs, six analog inputs, a 16 MHz crystal oscillator, a USB connection, a power connector, an ICSP head, and a reset button. Arduino is connected to a computer using a USB cable [17]. Arduino used in this research is Arduino Uno R3 DIP. After coding to give orders to Arduino, Arduino will read the data sent by the voltage sensor and ACs712 sensor obtained from the solar panel, which will later be translated into human language for easy understanding. To activate the Arduino, all you have to do is connect the Arduino to a power source without connecting it continuously to the computer because the command for sensor readings is already stored on the Arduino. The researcher displays the Arduino reading results on the i2c LCD, which can be seen immediately on the little screen. The data is transferred to the nodeMCU to be uploaded to the website, viewed by simply browsing the website using a computer or smartphone connected to the internet.

2.7. NodeMCU

NodeMCU is an open-source Internet of things platform. NodeMCU consists of the system on chip ESP8266 made by the Espressif system and the firmware used using the Lua scripting programming language. NodeMCU refers to the firmware used in the hardware development kit [18]. NodeMCU is a product that has special rights from Arduino to use the Arduino application and uses the same programming language as the Arduino board [19]. In this study, the nodeMCU used is the nodeMCU ESP8266. The researcher did the coding so that nodeMCU could read the data sent by Arduino, which then nodeMCU was also tasked with sending the data to the server with the help of the internet. Here the researcher makes a code when the nodeMCU is connected to the internet. The lights on the nodeMCU light up continuously without blinking. When the lights on the nodeMCU flash, it indicates that the nodeMCU is not connected to the internet or the internet connection is broken. If it is connected to the internet, nodeMCU will periodically send the data obtained by Arduino from the readings of the voltage sensor and acs712 sensor to the website.

3. Result and Discussion

3.1. Research Method

To obtain the expected results in the development of this research using the prototype method. The prototype is a way of creating a structured system that includes numerous phases that must be completed. Software changes are made continuously until the device operates properly. However, the system will be re-evaluated from the initial stage when the final stage is declared incomplete or still has shortcomings [20]. The stages in the prototype method are [21]:

a. Gathering needs. Client and developer define the software format and identify the system's requirements created.
b. Building prototypes/prototyping. Build prototyping by making temporary designs that focus on serving customers.
c. Prototyping evaluation. The client carries this stage, regardless of whether the prototype developed meets the customer's preferences and demands. If it is not suitable, the prototyping will be revised by repeating the previous steps.
d. Code the system. The agreed prototyping is translated into the appropriate programming language at this stage.
e. Test the system. Program testing minimizes errors with black boxes, architecture testing, baseline testing, etc., after the system is converted into ready-to-use software.
f. System evaluation. At this stage, the client evaluates the system that has been made as desired. Otherwise, the developer will repeat steps 4 and 5. But if yes, then step 7 will be done.
g. Using the system. Software that has been tested and accepted by the client is ready to use.

3.2. System Implementation

3.2.1. Prototype of solar power plant and its monitoring

The design of this arrangement is based on the tool that is assembled for testing. The design of the tool assembly is shown in Figure 3. The circuit consists of a solar charger controller, which regulates the incoming electric power from the solar panel to the battery. If the battery is fully charged, the solar charger controller will stop sending electrical energy from the solar panel so that the battery is not damaged quickly. Then there are solar panels used to convert solar energy into electricity. In this study, the solar panel used was 20 WP purchased from an online store.

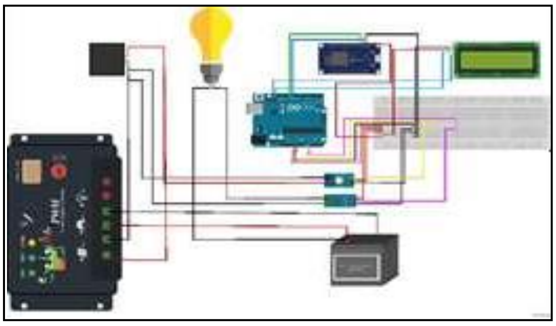

Figure 3. Tool arrangement design.

This research chooses solar panels because of microscale. If applied in real, a solar panel with a larger size is needed to meet the existing electricity needs. There is also a 12 V dry battery. This battery functions as a storage medium generated by solar panels. Then there is also a 15 W led lamp used as a load to measure the power used and help measure the current flowing. Without a load, what the system can read is only the voltage generated by the solar panel because to find the current flowing (I), i.e., power (P) divided by voltage (V). If the P-value is not met, the sensor will not read the current. Next is Arduino Uno R3. Here Arduino is the central government control, where Arduino manages all commands. In other words, the voltage sensor is given an order by Arduino to read the voltage generated by the solar panel. In contrast, Arduino sends an instruction to the acs712 sensor to read the current flowing and the power consumed to power the load, which is then delivered to NodeMCU and relayed to the server.

3.2.2. Solar power plant prototypes and their monitoring

The PLTS prototype design is shown in Figure 3. The network topology used for data communication in this study can be seen in Figure 4. The network topology used in this study is a star topology, where the server used is hosting as the center or in the middle and surrounded clients in the form of Arduino + NodeMCU, smartphones, and PCs. Here Arduino functions to read data from solar panels in the form of voltage, current, and power using the acs712 and voltage sensors. After obtaining the data, Arduino will send data to NodeMCU to be forwarded to the server or hosting. In hosting, data will be stored and viewed on DNS (Domain Name Server) by accessing it via a web browser on a smartphone or PC. On the website, the display of data sent by NodeMCU has been changed in the form of graphs and tables by changing the appearance so that it is easy to read and user friendly with PHP as the programming language and using the CodeIgniter framework.

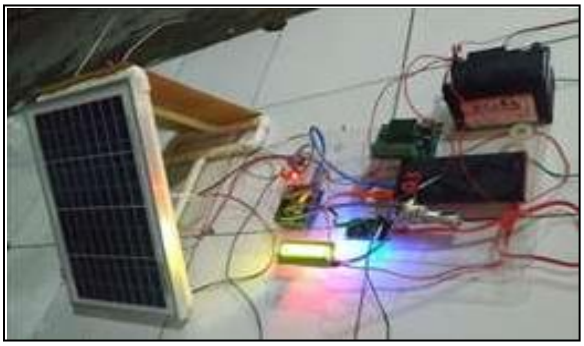

Figure 3. Prototype of solar power plant and its monitoring.

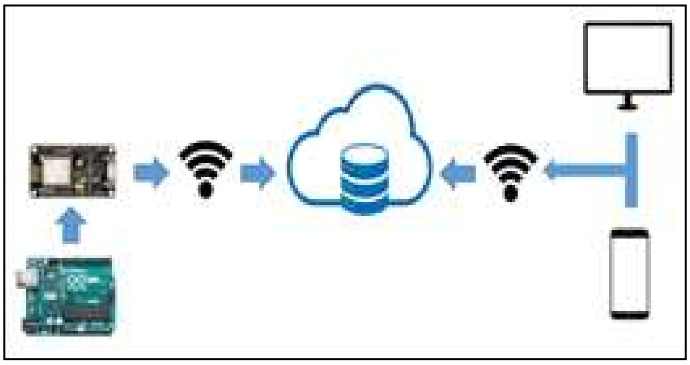

Figure 4. Network topology.

3.3. Test Result

After analyzing, designing, and assembling a solar power plant, the author also tested the tools and monitoring system of the solar power plant. After analyzing, designing, and assembling a solar power plant, the author also tested the tools and monitoring system of the solar power plant. The current, voltage and power tests are shown in Table 3, Table 4, and Table 5, respectively.

Table 1. Current monitoring.

No	Date	Time	Test results (Ampere)
1	15/10/2020	10:45:41	0.00
2	15/10/2020	10:45:43	0.14
3	15/10/2020	10:45:46	0.12
4	15/10/2020	10:45:48	0.12
5	15/10/2020	10:45:50	0.00
6	15/10/2020	10:45:53	0.00
7	15/10/2020	10:45:56	0.00
8	15/10/2020	10:45:58	0.00
9	15/10/2020	10:46:00	0.15
10	15/10/2020	10:46:02	0.14

Table 2. Voltage monitoring.

No	Date	Time	Test results (Volt)
1	15/10/2020	10:45:41	20.00
2	15/10/2020	10:45:43	11.00
3	15/10/2020	10:45:46	11.00
4	15/10/2020	10:45:48	11.00
5	15/10/2020	10:45:50	20.00
6	15/10/2020	10:45:53	20.00
7	15/10/2020	10:45:56	20.00
8	15/10/2020	10:45:58	20.00
9	15/10/2020	10:46:00	11.00
10	15/10/2020	10:46:02	11.00

Table 3. Power monitoring.

No	Date	Time	Test results (Volt)	No	Date	Time	Test results (Volt)
1	15/10/2020	10:45:41	0.00	6	15/10/2020	10:45:53	0.00
2	15/10/2020	10:45:43	1.49	7	15/10/2020	10:45:56	0.00
3	15/10/2020	10:45:46	1.35	8	15/10/2020	10:45:58	0.00
4	15/10/2020	10:45:48	1.27	9	15/10/2020	10:46:00	1.60
5	15/10/2020	10:45:50	0.00	10	15/10/2020	10:46:02	1.57

3.4. Black Box Test Results on Monitoring System

Black box testing is a test carried out on research on the system based on its function. Table 4 shows the test results of the monitoring system.

Table 4. Test results on the monitoring system.

No	Test	Condition	Expected results	Result
1	Form login	Username and password are not filled	Can not login	Success
		Username is filled and password is not filled	Can not login	Success
		Username is not filled and password is filled	Can not login	Success
		Entering username and password incorrectly	Can not login	Success
		Fill in username and password correctly	Login successful	Success
2	View monitoring	No input energy source	Graphics do not move	Success
		There is an input energy source	Graphics move up/down	Success
3	Print data	Date and time not entered	Unable to print data	Success
		Date filled and time not filled	Can print data from 00.01-23.59	Success
		Date and time filled	Can print data according to the specified time	Success
4	Form logout	Already logged in	Logout successful	Success

3.5. Discussion

The research aims to utilize solar energy, which is so high, to meet electricity needs in various human needs by making solar power plants and their monitoring systems to maintain security. This investigation shows that current, voltage, and power are constantly monitored and saved in the system database. Problems found will be fixed as soon as possible. For example, with 20 WP solar panels, researchers can convert solar power into electrical energy to turn on LED lights. The results prove that solar energy can meet human needs if used optimally. The disadvantage of this study is that it only uses a solar panel measuring 20 relatively small WP, so the output obtained is also small. It takes a very long time to fully charge the 12 V battery used as a storage medium.

4. Conclusion

A 20 WP solar panel can produce 20 V without a load in sunny weather. When a 15-watt led light is loaded, the voltage becomes 11 V stable with a current of 0.12-0.15 amperes and a power of 1.27-1.60 watts. Meanwhile, at night, solar panels can only produce 2 – 10 Volts DC if faced directly with a smartphone flashlight in lighting conditions around the panel, which is a bit dark. Under these conditions, the solar panel can turn on a 3V LED lamp without a battery, but the current is small around 34.7 microAmperes. LCD can not read the measurement results because the value is very small. The data is displayed on the i2c LCD and website. TOne way to solve the problem of light sources at night is to use large capacity batteries with more numbers to meet electricity needs at night and larger solar panels for wider capacities. The data is displayed in the form of graphs and tables and stored in a database so that if you want to view previous data or make a report, the data is ready to be processed.

The monitoring system has been tested using the Black box testing method. From the test results, it is found that the website created has met the researchers' expectations because the results are appropriate. The conclusion obtained from this study is that solar power generation is an alternative that can help meet the community's unmet electricity needs due to various factors. Supported by the internet of things devices, this solar power plant is considered to create a safe power plant. In addition, this solar power plant is very environmentally friendly because the main energy source comes directly from nature.

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