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Electrical Energy Monitoring System and Automatic Transfer Switch (ATS) Controller with the Internet of Things for Solar Power Plants

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ABSTRACT

Internet of Things is a technology that connects communication devices with electronic devices that are used everyday using the internet as a medium to communicate between devices and users. The use of IoT technology can be implemented in solar power generation systems. The IoT technology implemented in this study is to monitor and control the use of batteries in solar power plants. Current technology, battery usage can only be monitored closely to get information about battery capacity and battery usage. When the battery is empty or cannot be used to meet electricity needs, it is not equipped with a diversion of existing electricity sources such as PLN electricity. So, we need a renewable technology to get information about batteries and transfer of electricity sources that can be accessed remotely and can be accessed via the internet. The design of this smart monitoring system has stages, namely planning,design , coding , and test . The results of this study are able to see data in the form of battery capacity, electric current and electric power used in Android applications. The data is obtained from sensors that are on smart monitoring connected to the internet network and stored on a database server. Then the data residing on the database server will be retrieved by the application to be displayed to users in the form of graphics and usage lists. Furthermore, the Automatic Transfer Switch system works if the battery capacity sensor has read less than 11.4V then the relay will automatically transfer electricity to PLN. The Android smartphone application is used as a monitoring tool to view data in realtime.

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1. INTRODUCTION

At this time is an era of technological development that can improve the quality of human life [1]. With internet technologies such as wifi and wireless Internet access, growth continues to facilitate communication [2]. Survey conducted by the Association of Indonesian Internet Network Providers (APJII) in 2018, 171.17 million people in Indonesia have been connected to the internet, an increase of 10.12% from the previous year. 93.9% of smartphone users claim that they access the internet every day [3]. 87.6% of smartphone sales in circulation in 2016 were Android smartphones [4]. The field of research that enables users to manage and optimize electronic and electrical equipment using the internet is often called the Internet of Thing (IoT) [5].

Internet of Things is a technology that connects all devices and the Internet using sensor devices and to identify and manage information [6]. IoT is defined as the interconnection of embedded computing devices (embedded computing) that are uniquely identified in the presence of internet infrastructure [7]. rapid development in the concept of IoT to advance the scheme, namely Internet-of-Everything (IoE) [8]. The concept of IoE is to link all objects with the Internet where all references are for ease of use [9]. IoT can be described as a connecting device commonly used in everyday life such as smartphones, televisions, sensors and actuators to the internet where all devices are connected to each other to enable new types of communication between humans (users) and objects [10]. The progress of IoT which includes anywhere, anytime, and anyone to connect with these objects with the hope that is to expand the network and get ahead of the IoT. The use of IoT technology can be implemented in solar power generation systems.

Electrical energy needs become the main needs in the industrial sectors, housing, education, hospitals, and other places, but sometimes the electricity that is distributed by PLN does not always exist continuously, sometimes there are blackouts and when electricity is needed in important places that should be fulfilled its electricity needs on an ongoing basis would certainly be m ROBLEM great. The control system or control the current began to shift in the automation of control systems or commonly called Autom a tic Transfer Switch (ATS), so that human intervention in controlling very small. When compared with manual workmanship, an equipment system that is controlled by automation will provide benefits in terms of efficiency, safety, and accuracy [11] .

Based on research [12] that applies IoT technology using the ESP8266 Wifi module, so that it can send data to a computer device, but the distance that can be reached is only limited to the ability of the wifi module used (the computer must be connected to the wifi contained in the monitoring tool). Backup system / backup is absolutely necessary in electronic devices that require uninterrupted electrical energy. Reserves are used to replace PLN's main source. Research [13] says that inadequate electricity supply has led to the proliferation of standby generators, especially in developing countries. However, the methods and equipment used to change power supply remain challenging from inefficiency to cost. Most industries still use manual power supply replacement methods, which are covered by various setbacks including: time wasting, heavy operations, vulnerability to fire and high frequency of maintenance. In the study, Aumuzuyi presents a microcontroller-based Automatic Transfer Switch system, which eliminates the challenges of a manual changeover system. Simulation results prove the duration analysis yields very good results.

Based on the description of the problems above, the research focuses on designing an IoT-based monitoring system that can send data to a database server, so that it can be monitored in real time by an Android smartphone anywhere and anytime without being constrained by distance. The Automatic Transfer Switch (ATS) system will also be implemented using the NodeMCU ESP32 Microcontroller which hopes to be more effective because this Microcontroller has been designed as an IoT-based Microcontroller with a Wifi module that is already attached to the NodeMCU. The ATS system will be optimized by applying restrictions on the use of batteries in PLTS at a minimum voltage of 11.4V, so that the tool can make the switch from PLTS to PLN or vice versa.

2. METHOD

This research uses Agile Methods application development method with Extreme Programming (XP) model . According to Pressman, the agile model combines philosophy and steps of development. The philosophy in question covers the demand and development in stages in the scale of its development. The Extreme Programming (XP) approach is a software development model that starts from the planning, design, coding, and test stages [14].

2.1 Planning

In this stage the initial needs of the user are needed or in The XP Process are called user stories. This stage explains the task content, system output requirements and the main features of the application being developed.

2.1.1 Problem identification

This stage identifies problems that may arise during application development. Such as adjusting the voltage level to the condition> 11.4V relay turns on and the voltage condition <11.4V relay does not connect the voltage. As well as features sending data from the tool to the web-server. Smartphones display data flow according to web- server. Problem identification is done so that the application is successfully built properly.

2.1.2 Create user stories

a. User stories on android

Story 1 : users can access the application with a login facility.
Story 2 : users can access the button on the main menu of the application.
Story 3 : users can see the data flow in the real-time menu.
Story 4 : users can zoom in on the graph in realtime data flow.
Story 5 : Users can adjust the data flowing on the graph.
Story 6 : users can see the data flow in decimal form.
Story 7: users can download data from the web-server

b. User stories on the tool

Story 1 : users can see the voltage and current variables according to multitester.
Story 2 : the user can see the relay active at a voltage> 11.4V and the relay turns off at a voltage <11.4V.
Story 3 : Users can see the voltage and current data recorded on the device monitoring to web-server.
Story 4 : users can see the process of recording realtime data.
Story 5 : users can see the recorded data in accordance with the function on monitoring tool.

2.2 Design

The Design Stage describes the system design that will be created according to user requests. Focusing on hardware and software architecture design plans and user interface design.

2.2.1 System design

This section explains the design of the IoT monitoring tool. System design on an IoT - based monitoring tool . There are three sections that include devices Android, web- server as well as a monitoring tool can be seen in Figure 1 .

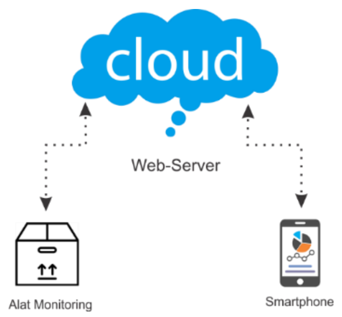

Figure 1. System Design

Android devices function as data visualization into a graph called real- time monitoring. Web-server functions to store and process the data sent. Monitoring tools have a voltage and current sensors that record and send it to the web- server. Recording occurs every 5 seconds and sends it to the web-server continuously.

2.2.2 Design tool

This section explains the design of IoT-based monitoring tools. The monitoring tool uses the NodeMCU ESP32 microcontroller as the main component. NodeMCU ESP32 is connected to voltage, current and relay sensors . The NodeMCU ESP32 wifi module connects the NodeMCU ESP32 with the web-server, when the voltage and current sensors are recording data. Data that is successfully recorded will be sent to the web- server with a span of 12 times in one minute. The web-server converts the data that has been sent into a variable and stores it as a datasheet. The data storage results are visualized on an Android device into a real-time graph. The design of the monitoring tool can be seen in Figure 2.

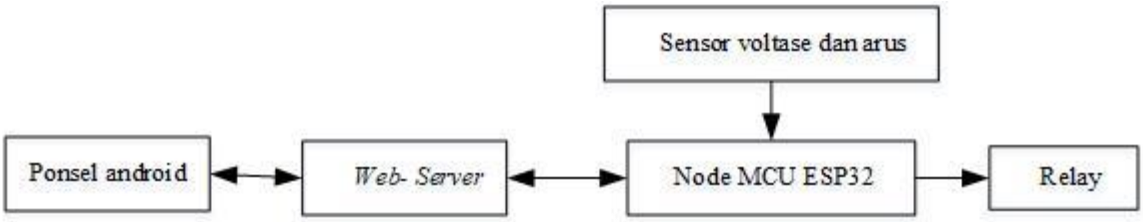

Figure 2. Design of monitoring tools

Circuit design monitoring tools can be seen in Figure 3 .

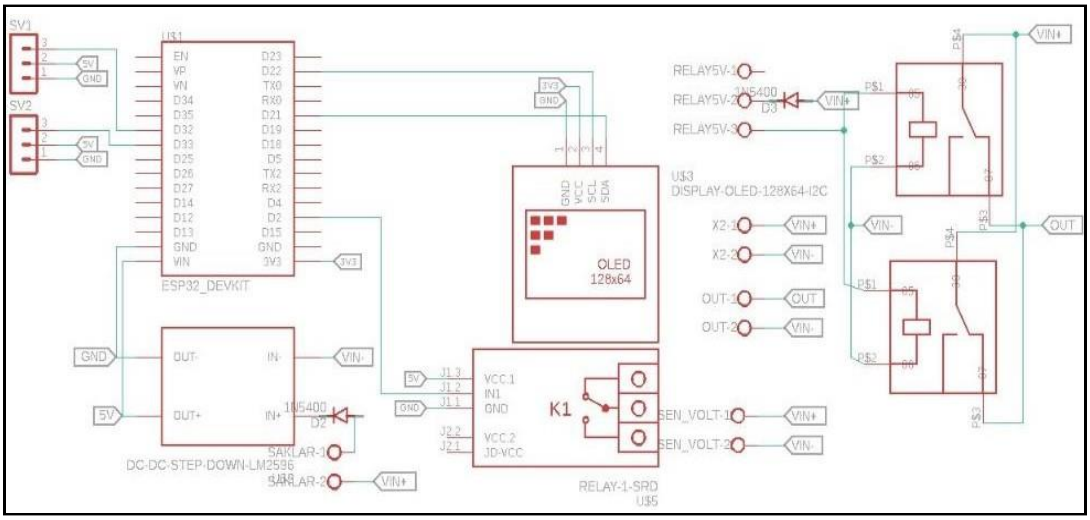

Figure 3. Circuit design

2.2.3 Interface design

The interface design of the IoT monitoring tool consists of 6 pages. The application interface page is as follows:

a. Main Page
b. Menu page
c. Realtime Graph Pages
d. Database page

2.2.4 Database design

IoT-based monitoring tools have a database that is stored on the web-server. The database contains 5 lines which include id, voltage, current, estimated time and date. The id line identifies the data input sequence in the database variable. Voltage and current are inputs provided by the NodeMCU ESP32 microcontroller to the monitoring tool. Date functions to display the time data is recorded as well as a pause for each incoming data per minute

2.2.5 A diagram of how the tool works.

The working principle of this tool is the NodeMCU ESP32 module programmed to read the voltage and electric current sensor . Data received from the sensor is processed by Arduino and sent to the web server. So that it can be monitored and can be controlled directly by an Android-based smartphone or laptop through the website. Block diagram of how the tools used in this study can be seen in Figure 4 .

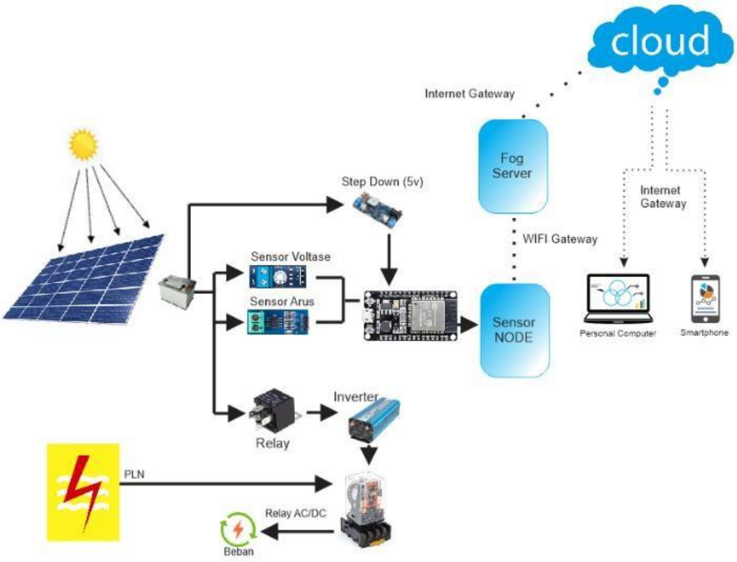

Figure 4. Diagram of how the tool works

2.3 Coding

Retrieval of data from the database using the PHP programming language. Data is changed in the form of JSON first so that it can be displayed on the battery monitoring application. Making an application android smartphone using thinkable. NodeMCU coding uses Arduino IDE which is given a code to connect to a wifi network using the programming language C. Relay Automatic Transfer Switch is controlled if the sensor reads the voltage on the battery less than 11.4V.

2.4 Testing

At this stage the test is done after the tool can be used. The test used is the black box testing method. Black box testing focuses on the functional specifications of the software.

Black box testing tends to find the following things [15]:

a. Incorrect or non-existent function.
b. Interface errors.
c. Errors in data structures and database access.
d. Performance errors.
e. Error initialization and termination.

In black box testing, special knowledge of application code or internal structure and programming knowledge are generally not needed. This test allows developers to obtain a series of input conditions that meet the functional requirements of a program [16] . The advantage of black box testing is that testing can be done from the user's point of view and helps to expose ambiguity or inconsistency in due diligence [17].

3. RESULT AND DISCUSSION

3.1 Result

The results of this study are the monitoring of PV-VP monitoring tool with an android application connected to the Internet of Things (IoT). Error testing and stability of data flow testing are done using Exponential Smoothing. The monitoring tool functions as a research object where voltage and current variables can be monitored through the Android application .

3.1.1 Application design

Visible page real time which contains the value ofthe data voltage, current, and estimated battery usage time da graphs can be seen in Figure 5 .

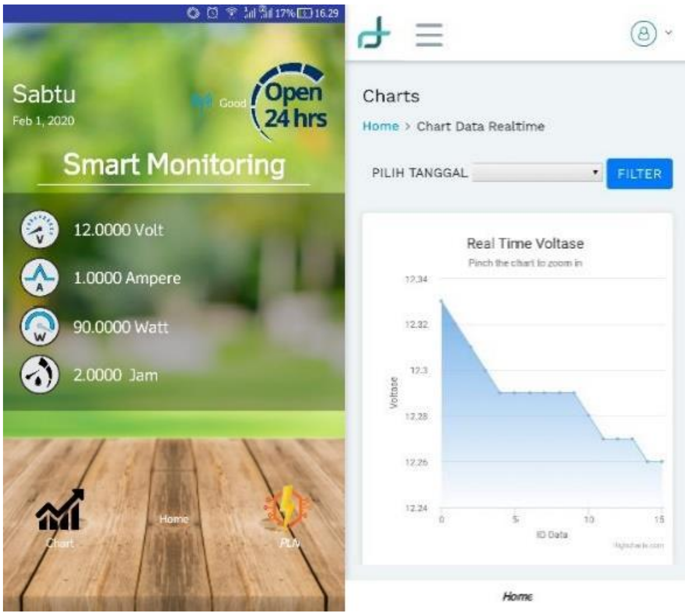

Figure 5. Realtime pages and graph

3.1.2 Testing

Testing is done to test the tool that has been made in accordance with the function and without constraints. The testing to be carried out can be seen in Table 1

Table 1. Testing Tools

No	Requirements tested	Test Item	Conclusion
1	Relay	Able to switch to DC12V input when the battery is more than 11.4V	Valid
2	Sensor	Read battery capacity, current and power used	Valid
3	LCD display	Displays readings of wifi connections, battery status, relay status, data upload status to the web server	Valid
4	ESP32	Sending sensor data to the database	Valid
5	Send Data	The database can store data that has been sent by ESP32	Valid
6	Battery	The battery can power the inverter by supplying a monitoring device with a DC12V voltage	Valid
7	Inverter output	The inverter can turn on the AC220V load by supplying a monitoring device	Valid
9	AC220V output	Can turn on the load	Valid

Tool testing is done using a 1200W inverter and a 40Ah 12V battery and a load of 6 9W AC lamps. testing is done by turning on the lights continuously until the battery can not supply electricity and replaced with PLN.

Sending data in the form of battery capacity, electric current and electric power used for 5 seconds. in the graph above can be seen the voltage based on the data received last to receive information that the battery capacity is 11.4 V. There is a possibility a few moments later before sending data back the battery capacity is 11.4V and the relay automatically cuts off the electricity coming from the battery.

Furthermore testing is carried out on the application to ensure that the application has been made in accordance with the previous plan. In testing this application uses black box testing. The following results of testing with black box testing can be seen in Table 2.

Table 2. Testing of application

No	Testing	Expected results	Test result	Conclusion
1	Open application	Preliminary results	Shows the start page	Valid
2	Showing data record	Displays all data records that have been stored in the database	Data can be displayed in accordance with the database	Valid
3	Showing graph	Displays usage graph	Displays usage graph	Valid
4	Change the date	Change the date and display the usage graph for that date	Date changed and successfully displayed the usage graph according to the desired date	Valid
5	Showing realtime data	Display voltage data in realtime	Display voltage data in realtime	Valid

3.1.3 Evaluating

The evaluation phase is the stage for evaluating the whole starting from the experimental stage, designing tools, making applications, coding and testing. Errors found in the testing phase both in design and coding are evaluated in order to function properly. Evaluation of tools and applications is done when the device is connected to a battery and given an electric load. The following list of evaluations is in Table 3 .

Table 3. Research evaluation

No	Error	Evaluation
1	Usage data cannot be displayed in the application	Check internet connection
2	On the LCD the device only brings up Search for Wifi	Check wifi network
3	The inverter makes a noise	Turn off and turn on the Inverter again

3.2 DISCUSSION

Designing monitoring tools on solar power plants with the internet of things. There are two main components, namely smart monitoring and the Automatic Transfer Switch system. In smart monitoring using NodeMCU as the control brain and coding using Arduino IDE. Data received by the sensor on the monitoring tool will be sent to the database via the internet. Then the data will be retrieved for display on the monitoring application. The application will display data in the form of realtime data and graphics on a predetermined date. The Automatic Transfer Switch (ATS) system works if the battery capacity sensor has read less than 11.4V .

4. CONCLUSION

Based on the discussion of this research, the design of a monitoring tool on solar power plants with the concept of the internet of things is making Android applications using thunkable and using NodeMCU as the control center, and Automatic Transfer Switch (ATS) as a battery controller to move the power source. The results of this study are:

a. Users can view data in realtime in the form of battery capacity, electric current and electric power used through an application on an Android smartphone. The data is obtained from sensors located on monitoring devices that are connected to the internet network so that the data is sent and stored on a database server. Based on black-box testing and testing tools produce a percentage of 100%. Android application displays the results of recorded data on the webserver to the smartphone screen. With an average data change rate of 0.005% for each data recording.

b. The Automatic Transfer Switch (ATS) system works if the battery capacity sensor has read less than 11.4V then the automatic relay ATS will move the electricity needs to the PLN so that the user does not need to move the electric current manually to the PLN and does not worry the battery will overload due to usage The battery is controlled by the ATS system.

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