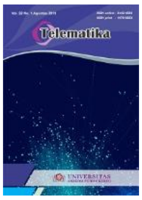

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Smart Solar Tracker and Energy Control Based on Internet of Things (IoT)

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ABSTRACT

Indonesia's electricity consumption per capita in 2022 will reach 1,173 kWh/capita sourced from the Ministry of Energy and Mineral Resources. This consumption rate increased by around 4% compared to 2021, as well as a new record high in the last five decades. This must be accompanied by the availability of energy from power plants, especially renewable energy, namely solar energy because this solar power plant is considered safer for the environment and has a minimal maintenance schedule. In addition, it requires maximum utilization of solar panels and a monitoring system in real time so that the reliability of the power plant is maintained, the Smart Solar Tracker and Energy Control Based on Internet Of Things (IoT) are the answer to this problem. This research uses PV (Photovoltaic) as a power source in the system accompanied by a tracker drive in the form of actuators and servo motors that move in the direction of the sun. This IoT is integrated with a database server so officers can monitor and control if the device is damaged. The IoT module in this research uses the ESP8266 which functions for device control and relay. In addition to reading the voltage and current, both incoming and outgoing, use the ACS 712 voltage sensor and current sensor, not only that, there is also an LDR sensor to read the position of the sun.

INTRODUCTION

Energy is a very important need for living things in everyday life. Energy is divided into 2, namely renewable energy and non-renewable energy. Renewable Energy is energy obtained from unlimited natural resources and will never run out even if it is used continuously.(McNeil, Karali, & Letschert, 2019).(Mohite, & Butale, 2019) This research focuses more on discussing renewable energy that comes from light or what we often know as solar panels or Photo Voltaic (PV) solar panels themselves are generators or producers of electrical energy by converting light energy into electrical energy, in the form of solar panels. Itself is in the form of a sheet containing several small solar panels arranged in series or parallel depending on the amount of voltage or current needed.

Solar energy is an excellent energy to be developed in Indonesia. This is because Indonesia is a country that is on the equator. Solar energy that can be used for the whole of Indonesia with an area of 2 million km2 is 4.8 kWh/m2 in one day or the equivalent of 112,000 GWp (Silalahi et al., 2022)(Tira, Natsir, & Putranto, 2020). However, a new problem arises in this solar power plant, namely the efficiency is quite low so that the energy resulting from the conversion of light energy into electrical energy contains a lot of losses that harm the electrical energy that should be accommodated by the battery, but lost due to loss of controller and connector.

Apart from MPPT, the angle between the sun and the solar panel also affects the efficiency of the solar power. Therefore it is necessary to make a solar tracker which is made to move the solar panel module automatically so that it is perpendicular to the direction of sunlight and is able to absorb sunlight optimally (Dahliya et al., 2021)(Makkulau, 2019). This problem is the background for researchers to make a prototype of a sun tracker using two axes using an Arduino microcontroller. The use of two axes or one axis in sun tracking systems is categorized into 2, namely passive tracking (mechanical) and active tracking (electrical). Passive tracking states that efficiency increases between 2%-23% compared to fixed systems based on previous research. While the active tracker consists of one axis tracker and dual axis tracker which generally use an electric motor as the propulsion. Active trackers can be useful for improving solar energy conversion with fixed systems with an average improvement result of 29.37%. (Samsurizal, Christiono, & Husada, 2020)(Aji et al., 2022)(Eteruddin, and Setiawan, 2020).

The research conducted is an IoT development with an arduino ESP8266 which functions as a wifi module, (Siswanto, S. Et al, 2020)(Lestariningsih et al., 2019) (Eteruddin, Setiawan, and Atmam, 2019)(Ningsih, 2020) and iOS platforms using Blynk and Arduino-compatible Android, Raspberry Pi (Artono, and Susanto, 2018). The power source is useful for converting solar energy into electrical energy in this study uses a PV system so that panels are more effective in absorbing energy, a tracker system is implanted to be able to follow sunlight using an LDR sensor. Batteries are used to store energy and power all tools. This research is expected to help increase the efficiency or conversion of solar energy to make it better. Besides that, it also facilitates monitoring and control via the internet so that officers do not need to come directly to this solar power plant.

RESEARCH METHODS

The research was conducted using the following methods shown in figure 1.

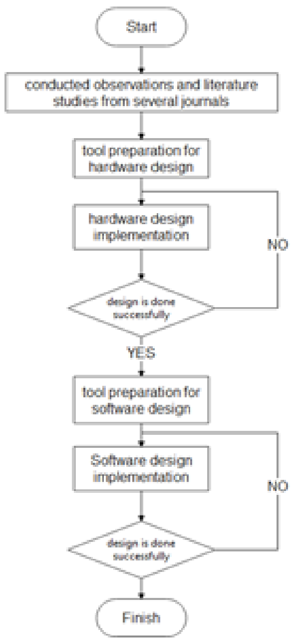

Figure 1. Step-by-step drawing of the research methodology in a flow chart

1. **Data Collection**

Data collection uses observation which functions to obtain data directly. Then after seeing the tool will analyze the shortcomings that can be improved, to perfect the previous research. (Yusuf, M. Et al, 2021). The experimental method is conducted to draw conclusions by making further observations and experiments.

2. **Hardware Design**

a. DC Current and ACS712 Sensor

DC current and sensor ACS712 5A are used to monitor battery charge in terms of voltage and current. The 3 pins that include the DC and ACS712 current sensors are Vcc (+), out (s), and ground (-). the DC sensor is attached to the Arduino by => the Vcc pin is connected to the Arduino 5V, then the out pin and analog port are connected, and the ground pin and ground port are also connected. Figure 1 is a simulation of the DC current circuit and the ACS712 sensor.

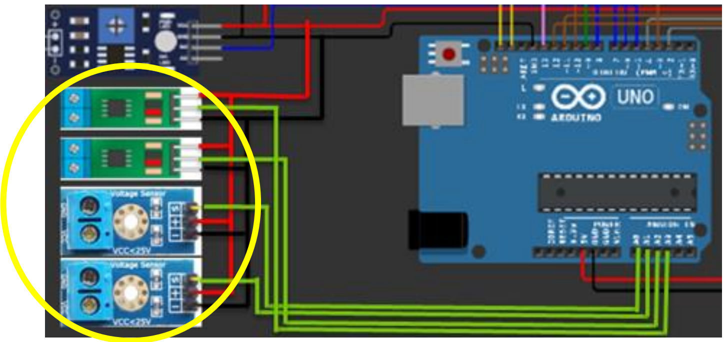

Figure 2. Simulation of the DC current circuit and the ACS712 sensor

b. LDR (Light Dependant Resistor) sensor

LDR (Light Dependant Resistor) sensor functions to detect sunlight whose purpose is to detect the presence of the sun. The four pins on the pressure transmitter are VCC, analog output, digital output, and ground; VCC, analog output, digital output and ground. Install the LDR sensor on the Arduino by connecting the Vcc pin to the Arduino 5V, then connect the digital output pin to the digital port on the Arduino, and connect the ground pin to the ground port on the Arduino. In Figure 2 below is the LDR sensor circuit.

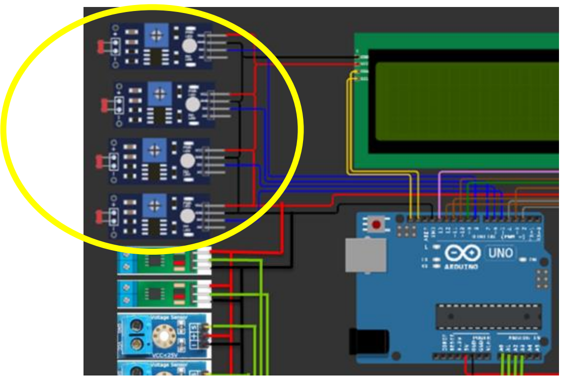

Figure 3. LDR (Light Dependant Resistor) sensor

c. Control Circuit

The modules used in the control circuit are single and double relay modules that function to control the lamp load and control the actuator manually and there is a servo motor to move the panel manually. How to install the light load relay by connecting the COM pin of the relay to the positive part of the battery, the NO pin of the relay is connected to the positive part of the light load, then connecting the negative source of the battery and the lamp. Connect the VCC pin to the 5V port then the GND pin is connected to the Arduino ground port, and connect the IN pin to the digital port on the Arduino. Figure 4 is a control circuit.

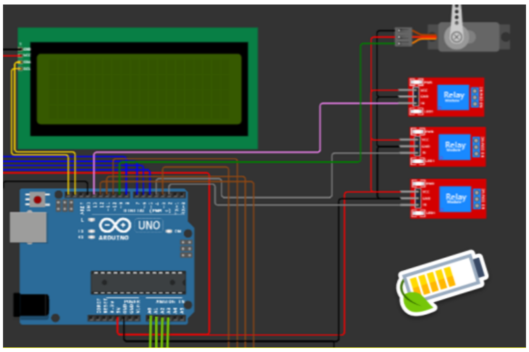

Figure 4. Control Circuit

d. ESP8266 Generic Wifi Module Circuit

The use of a generic ESP826 Wifi module as a means of communication between Arduino Uno and monitoring devices through databases and websites. In general, the ESP8266 installation with Arduino is by connecting pin D2 (TX) on the Arduino to pin RX on the ESP8266 module, then pin D1 (RX) and pin TX on the ESP8266 module are connected, as shown in Figure 5.

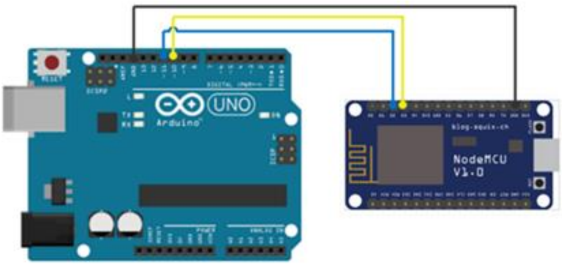

Figure 5. Wifi ESP8266 Generic Module Circuit

3. Software Design

Making tools in research requires the following software design.

a. Arduino IDE

Arduino program and flow chart for control and monitoring system. the software for programming arduio is C language.

b. Visual Studio Code

Website display programming is done using code in html format which is done with the Visual Studio Code application

c. User Interface on Android

Firebase database is used to design the website display, The function of ESP8266 is to send data from Arduino Uno to the Firebase database and data from the Firebase database which will then be displayed on the monitoring website, besides that there is also a manual tracker control menu to make it easier to operate the tracker when it is cloudy. here the website can be opened from all devices that can open a browser including smartphones and PCs.

4. Device Schematic

Figure 6 below is a schematic of the device.

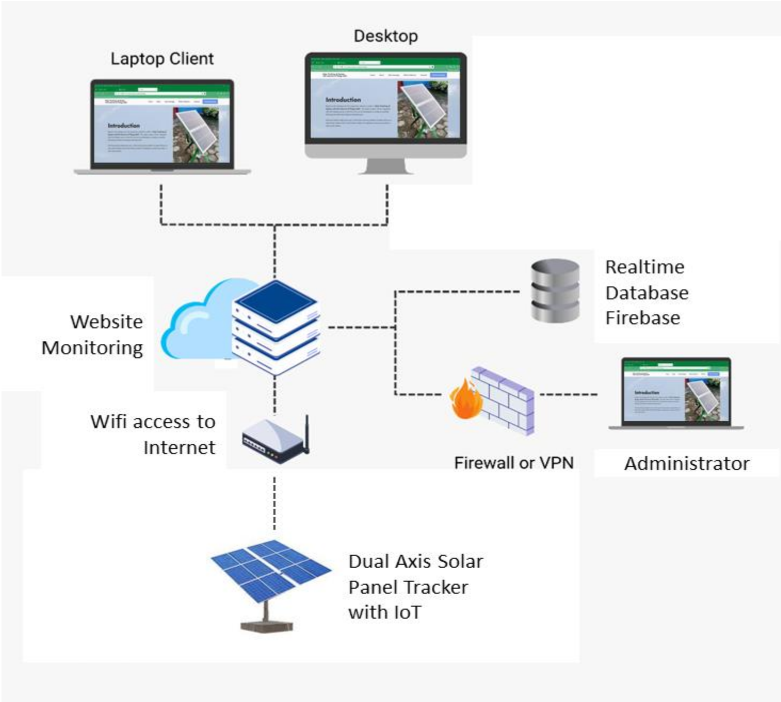

Figure 6. Device schematic

Figure 6 explains that as long as the internet network is connected, remote monitoring and control system will run. Data sensor reading is the beginning of the monitoring system using ACS712 sensors and DC voltage sensors with the aim of detecting the current and voltage values both entering and leaving the battery to the load, not forgetting to read the LDR sensor besides directing the panel towards the sun, the LDR sensor value is also sent to monitoring for distance monitoring. remotely, apart from monitoring there is also control to control the tracker's motion manually, all of these processes are processed on Arduino and the firebase database connected via ESP8266 which is connected to the Internet.

RESULT AND DISCUSSION

Make sure if all parts can work properly and get data, it is necessary to carry out an analysis with the following steps. Then it is necessary to test each tool and work system of the whole process by analyzing the data.

1. System testing

Research tests were conducted to find out the following: (i) Understand the system design (iito find out the problems, deficiencies, system errors. (iii) Know the advantages and disadvantages of the system created.

2. Testing stage

Each part of the tool is tested separately. Then the test results are used as reference material to compare between planning and making a series of tools that are carried out. The testing stages are carried out by means of test steps, test results, analysis, and conclusions. Tool testing on each circuit is presented as follows.

How to check that the program uploaded to Arduino Uno can run or not, then test the Arduino Uno board. The testing steps are as follows: (i) coding the program. (ii) Arduino Uno and the laptop's USB port are connected using a connector cable (mini usb). (iii) On the "Tools" menu =>

Arduino Uno board => detected port. (iv) Program compilation made to ensure the program is correct, => compilation completion notification appears. (v) Upload the program => if "Done Uploading" means the program upload was successful.

ESP8266 Generic Wifi Module: To find out whether the android application and the wifi module are connected and communicate using wifi and to find out the level of internet stability, a wifi module test is carried out. ESP8266 generic testing is carried out in the following steps:

(i) Arduino IDE Software opened. (ii) Menu file => preferences, on the add-in board manager URL, http://arduino.esp8266.com/stable/package_esp8266com_index.json. OK. Menu Tools - Board - Board Manager, search for ESP8266 => click install. (iii) It says the installation was successful => menu tools - board, the ESP8266 Board (3.1.2) option appears. Select the ESP8266 Module generic Compilation board then select the usb port connected to the ESP8266 and upload the program to the ESP8266. (iv) After the upload is complete, open the serial monitor if communication appears between the Arduino and the ESP then the test is successful. Figure 7 is a series of generic ESP8266 wifi module tests.

Figure 7. Wi-Fi module Testing Suite

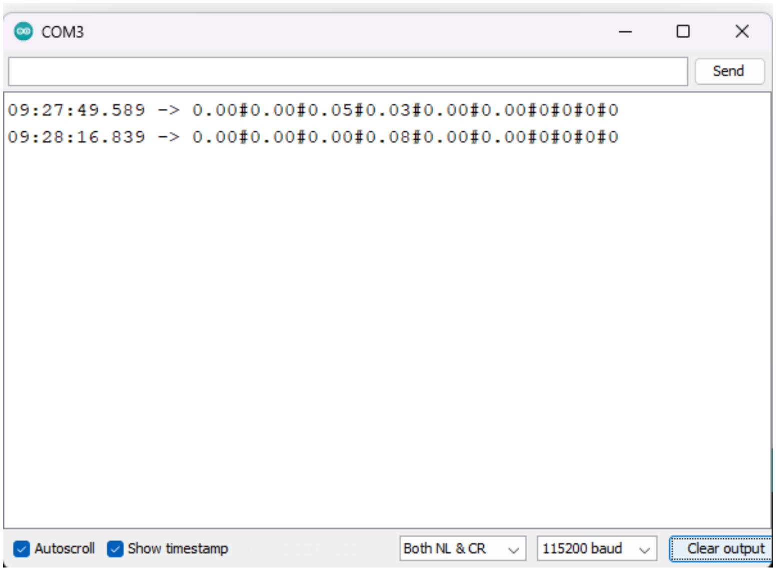

Figure 8. Wi-Fi module serial communication test

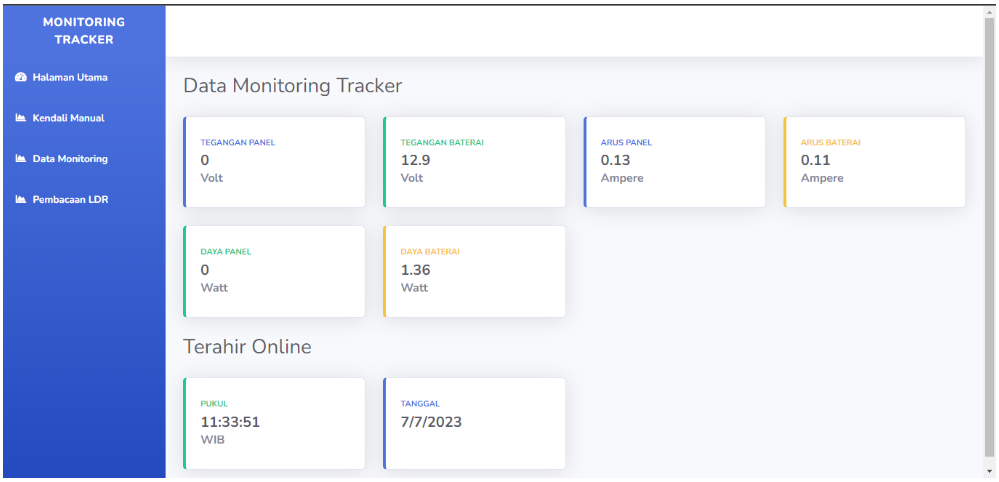

Figure 9. Wi-Fi module serial communication test

The results of testing the wifi module are that the wifi module works well with the stability level of the wifi module depending on the speed of the wifi network on the wifi module. This can be seen in Figure 8 which shows the transfer of data from Arduino to ESP8266 takes place and then from ESP8266 will be read and then will be forwarded to the database displayed on the website as shown in Figure 9, it can be seen that the data from the tool can reach the website this shows the tool can connect to the internet properly.

The DC and ACS712 voltage sensors were tested to determine the accuracy of the voltage and current contained in the battery charging process using a solar cell voltage source. The high level of sensor accuracy affects the system performance of the tool. The dc voltage sensor and ACS712 sensor are tested with the following steps: (i) connect the DC voltage sensor VCC and ACS712 to 5VDC, => GND to GND. (ii) the dc voltage sensor pin and ACS712 are connected to the ADC pin. (iii) Write program in Arduino IDE Software => upload program. (iv) Use digital multitester to measure voltage and current => do comparison test with sensor reading data. Figure 9 is a test display of the DC voltage sensor and ACS712.

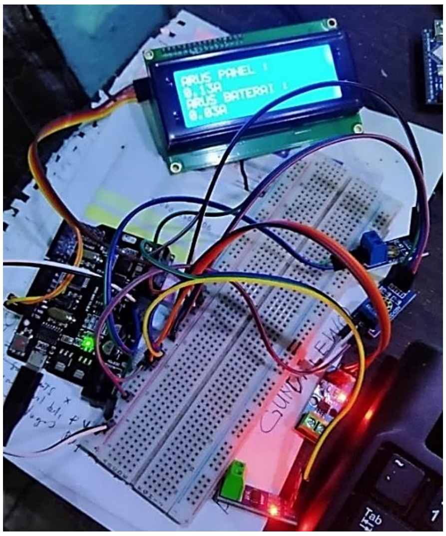

Figure 10. Testing the voltage sensor and ACS712

below is a table 1, of data retrieval results before the tool was made.

Table 1. the result of the DC voltage sensor experiment.

Time	voltage with load (V)	no-load voltage (V)
07:00:00	10	10
08:00:00	10	12
09:00:00	11	13
10:00:00	13.5	17
11:00:00	15	17.5
12:00:00	16	17
13:00:00	15	16
14:00:00	16.5	17.6
15:00:00	16	16
16:00:00	13	14

The conclusion from table 1 states that the DC voltage sensor is working properly, this can be seen from the resulting voltage which is read well, both when loaded and not loaded.

LDR (Light Dependant Resistor) sensor testing: Testing the LDR sensor or light sensor is intended to ensure the sensor works properly and functions according to the actual conditions whether the sun is covered or exposed by clouds. Here the LDR sensor is attached to the sun view chamber which consists of 4 LDR sensors, if one two or three sensors detect a different value then the program will move the tracker according to the commands that have been implanted. Here the output value from the LDR sensor is in the form of a HIGH or LOW value, therefore the input value goes to the Arduino Uno digital pin. You can actually use an analog pin, but because of the limited number of pins, the LDR sensor is inserted into the digital pin. The following is a picture of the LDR sensor that has been installed in the 4-chamber sight. In the picture below it can be seen that the LDR sensor used is an LDR sensor with an additional circuit so that it can produce an output or output in the form of a digital signal that produces High and LOW values, if light is detected, the sensor will produce a LOW value; if light is not detected or dark, it will produce HIGH value.

Figure 11. LDR (Light Dependant Resistor) sensor

Research experiments from the LDR sensor are presented in Figure 11, this is a 20x4 LCD screen display that displays the condition of the LDR sensor.

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Figure 12. LDR Sensor Reading Results

From figure 11, it appears that the LDR sensor can read sunlight well, with a sign that the display appears on the LCD display.

Control system test: carried out aims to determine the automatic control can be done by the tool. With the LDR sensor which is used as a benchmark in the control system. When sunlight appears, the LDR sensor will read the location of the sun's direction and will move the solar panel with the help of actuators and servo motors so that the panel can point to the sun besides the system, the complete working steps are as follows. (i) When the device is turned on, the tracker will be in the standby position (ii) After the sun's position is read by the ldr sensor, Arduino will direct the panel with the help of actuators and servo motors towards the sun. (iii) After the panel is facing the sun, the process returns to the first part so that the sun's position is always updated.

Monitoring System Testing on the website: This test uses a laptop to open a browser and open the tool's website page. Testing of the monitoring system is carried out in the following steps: (i) Assembling the tracker and turning on the tool. (ii) The portable router is turned on and ensures a stable internet network to get real-time data. (iii) Connect the laptop with wifi and make sure the internet network is stable. (iv) Open the monitoring website page. (v) Press the monitoring button to open the monitoring page. (vi) Make observations => analyze sensor data values that appear on the website. Figure 12 is the result of testing the monitoring system on the website.

3. Final Testing

In this test, it is carried out to compare the voltage value between the condition of the tracker in automatic conditions and the stationary tracker facing up, this is done to test whether the tool is functioning according to its purpose or not, therefore testing is necessary, then in this section testing is carried out without load so that the output is not given additional load. Shown as Table 2.

Table 2. Voltage Data Table With Tracker On and Off Without Load

	Tegangan Panel Tracker Aktif	Tegangan Panel Tracker Mati
7:00	14	10
7:30	14	10
8:00	19,21	10
8:30	19,18	10
9:00	19,33	11
9:30	18,84	13
10:00	18,79	14
10:30	18,79	17
11:00	18,67	18
11:30	18,52	18
12:00	18,48	18
12:30	18,33	18
13:00	18,44	18
13:30	18,23	18
14:00	18,43	17
14:30	18,91	13
15:00	18,16	12
15:30	14,44	10
16:00	14,44	9
16:30	14,2	10
17:00	14	10

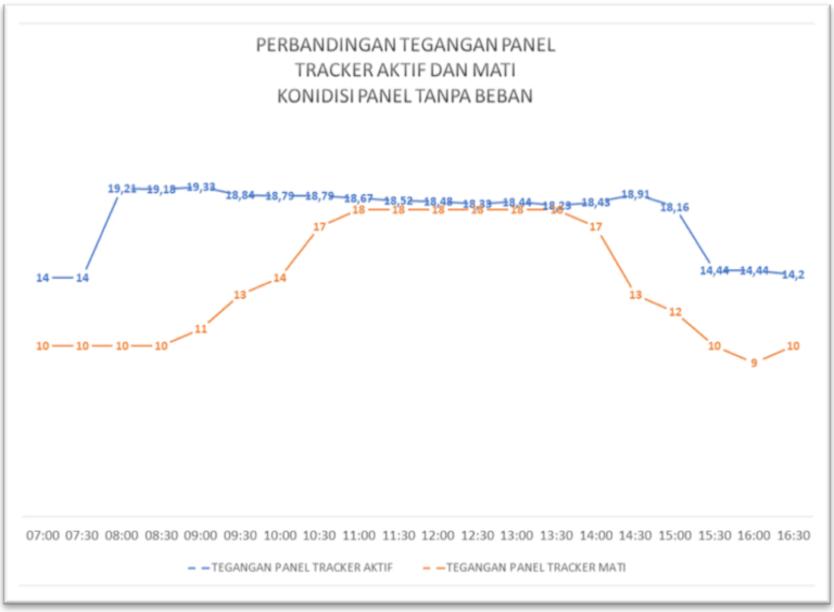

Figure 13. Voltage Data Figure With Tracker On and Off With No Load

It can be seen in the figure above that the blue line is the voltage value with the tracker and the orange line is the voltage value without the tracker, on the voltage value with the condition of the tracker on, it can be seen that the voltage is more sloping and the voltage value is more evenly distributed, in contrast to the condition when the tracker is turned off, it can be seen that the voltage is steeper and the voltage value is lower, this indicates that the tracker can improve the quality of irradiation of solar panels, besides that the voltage value is also higher and more effective.

Figure 14. Monitoring system test circuit

From Figure 14 above we can see that the tool is working, this tool is positioning the panel facing directly to the sun obtained from the sensor reading, after the reading is obtained, the Arduino will move the panel facing the sun with the best direction optimization, if the sun moves then the sensor will read the movement which then the panel will be moved again to face the sun and can get the best optimization.

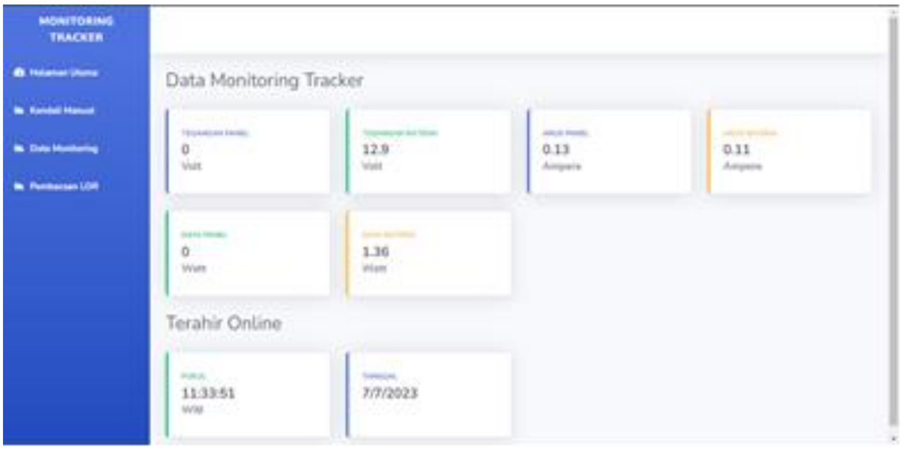

Figure 15. Monitoring system on the website

In the figure 15 we can see the display of the monitoring website starting from the value of panel voltage, panel current, battery voltage, battery current, panel power, battery power last time the tool was online and working and the last date the tool was online and working, all of this data can be accessed through the website that has been created. The reason for choosing the dashboard as a means of displaying the value is that almost all current tools can access the browser so I think with the website there are more options to access and see the state and value in this tool.

From the basis of the sensor data obtained, an analysis is carried out and the conclusion is that the monitoring website can properly monitor devices (all sensors) in real time.

CONCLUSIONS AND RECOMMENDATIONS

The test results state that the system can monitor and detect the position of the sun and direct the panel towards the sun, this is evidenced by all existing sensors being able to read properly, with an accuracy level that is still not optimal. This happens due to inaccuracy in the sensor calibration process.

The tool can be supplied with energy by a solar cell and the system can control lights as a load using the website and the website can control the tracker manually making it easier to operate. The delay in response from the website is caused by an unstable internet network. What needs to be done for further research development is the wifi module that is used integrated with the microcontroller, for example the Raspberry Pi with the aim of eliminating delays in the data transmission process and can be developed further because the use of Arduino Uno sensors is still limited.

REFERENCES

Artono, S., Susanto F. "Wireless Smart Home System Using Internet Of Things". Jurnal Teknologi Informasi dan Terapan (J-TIT). Vol 5 No 1. 2018. doi: 10.25047/jtit.v5i1.74

Aji, E. P., Wibowo, P., & Windarta, J. (2022). Kinerja Pembangkit Listrik Tenaga Surya (PLTS) dengan Sistem On Grid di BPR BKK Mandiraja Cabang Wanayasa Kabupaten Banjarnegara. *Jurnal Energi Baru Dan Terbarukan*, *3*(1), 15–27. doi: 10.14710/jebt.2022.13158

Dahliya, D., Samsurizal, S., & Pasra, N. (2021). Efisiensi Panel Surya Kapasitas 100 Wp Akibat Pengaruh Suhu Dan Kecepatan Angin. *Sutet*, *11*(2), 71–80. doi: 10.33322/sutet.v11i2.1551

H. Eteruddin, D. Setiawan, Atmam, and B. N. (2019). Solar home system with diversified roofing construction. *Universal Journal of Electrical and Electronic Engineering*, *6*(5), 351–358.

H. Eteruddin, D. Setiawan, and A. A. (2020). Web Based Raspberry Monitoring System Solar Energy Power Plant. *IOP Conference Series: Earth and Environmental Science*, *469*(1).

Lestariningsih, T., Artono, B., Hidayatullah, N., & Kusbandono, H. (2019). Microcontroller and Android HMI Based Water Level and Control System. *EAI Endorsed Transactions on Internet of Things*, *5*(17), 162807. doi: 10.4108/eai.28-1-2019.162807

M. Rudrendu, Madhav, P., Sananda, G., Sumani, M., & Rabindranath, G. 2018, "IoT-based Home Appliances Control System Using NodeMCU and *Blynk* Server" International Advanced Research Journal in Science, Engineering and Technology, vol. 5, hh. 16-22. doi: 10.17148/IARJSET.2018.563

M. Yusuf, G. Priyandoko, I. Istiadi, and F. Rofii, "Wireless Digital Multimeter Data Logger Prototype Based on Smartphone", JASEE, vol. 2, no. 02, pp. 61-74, Sep. 2021. doi: https://doi.org/10.31328/jasee.v2i02.16

Makkulau, A. C. and S. (2019). Characteristics of Temperature Changes Measurement on Photovoltaic Surfaces Against Quality of Output Current on Solar Power Plants. *In International Conference on Technologies and Policies in Electric Power & Energy, IEEE*, 1–4. doi: doi: 10.1109/IEEECONF48524.2019.9102630

McNeil, M. A., Karali, N., & Letschert, V. (2019). Forecasting Indonesia's electricity load through 2030 and peak demand reductions from appliance and lighting efficiency. *Energy for Sustainable Development*, *49*, 65–77. doi: 10.1016/j.esd.2019.01.001

Mohite, V. P., & Butale, M. C. (2019). Parametric Study of Grid Connected PV System with Battery for Single Family House. *International Research Journal of Engineering and Technology (IRJET)*, *6(8)*, 66–70.

P. S. Ningsih. (2020). Pengukuran Tegangan, Arus, Daya pada Prototype PLTS Berbasis Mikrokontroller Arduin Uno. *SainETIn*, *5*(1), 8–16.

Samsurizal, S., Christiono, C., & Husada, H. (2020). Studi Kelayakan Pemanfaatan Energi Matahari Sebagai Pembangkit Listrik Tenaga Surya Di Dusun Toalang. *Setrum: Sistem Kendali-Tenaga-Elektronika-Telekomunikasi-Komputer*, *9(1)*, 75–83.

Silalahi, D. F., & Gunawan, D. (2022). Solar Energy Potentials and Opportunity of Floating Solar PV in Indonesia. *Indonesia Post-Pandemic Outlook: Strategy towards Net-Zero Emissions by 2060 from the Renewables and Carbon-Neutral Energy Perspectives*. doi: 10.55981/brin.562.c5

Siswanto,S, S. Sutarti, H. R. Naufal, A. A. Setyo. " Prototype Wireless Sensor Network (Wsn) Forest Fire Early Detection System". Jurnal Perspektif. Vol 4, No 2. 2020. doi: http://dx.doi.org/10.15575/jp.v4i2.85

Tira, H., Natsir, A., & Putranto, T. (2020). Kinerja modul surya melalui variasi solar collector dan kecepatan angin. *Dinamika Teknik Mesin*, 25–32.