PROTOTYPE SOLAR CELL AND HYDROPOWER HYBRID ENERGY STATION AS A POWER SUPPLY FOR PUBLIC STREET LIGHTING BASED INTERNET OF THINGS (IoT) USING ANT COLONY OPTIMIZATION (ACO) ALGORITMA

Ailsa Shafa Nansha Rasendriya[1*] , Hartono[2], Didi Harianto[3]

[1,2,3)] *Aviation Polytechnic of Surabaya, Surabaya, Indonesia*
[*]*Corresponding author. Email:* *ailsashafa@poltekbangsby.ac.id*

ABSTRACT
An increase in population in an area can cause an electrical energy crisis due to the increasing number of electrical energy customers. In addition, the use of fossil energy will also decrease, so alternative energy from renewable energy power supply is needed. The challenge is that combining the potential of renewable energy power supply with generators requires a hybrid power plant. A hybrid system with a generator as energy backup is considered sub-optimal because when the power generator is in deficit, it takes over all the wasted power from the renewable energy generation. The purpose of this prototype is to make it easier for technicians to monitor the hybrid power plant, where monitoring is done via Android using the Internet of Things. With remote monitoring, efficiency will increase compared to direct monitoring. Based on the data obtained, the voltage measurement on the Solar Cell shows that the voltage and current move from the lowest value of 11.51 V, continuing to increase until it reaches the highest value of 17.54 V.

Keywords: *Renewable energy, solar panels, generators, hybrid power plants*

1. INTRODUCTION

The largest continuous supply of energy available to mankind is solar energy, specifically electromagnetic energy emitted by the sun. While solar energy has not been used as a primary power supply for fuel energy at this time. Massive research and development is underway to find an economical system to utilize this solar energy as a primary fuel power supply. Solar energy is remarkable because it is non-polluting, inexhaustible. The drawback of solar energy is that it is very subtle and not constant. Low solar energy flows result in the use of systems and collectors with large surface areas to collect and concentrate the energy. These collector systems are quite expensive and there is the further problem that earth systems cannot be expected to receive a continuous supply of this solar energy. This means that some sort of energy storage system or other conversion is needed to store energy at night as well as during cloudy weather (Widayana, 2012).

A hybrid energy generation system is a system that combines several energy power supplies to supply electrical energy to the load. The application of Ant Colony Optimization (ACO) in hybrid Solar Cell and Hydropower power plants is used as energy management, which helps in optimizing system settings and operations to maximize energy production and efficient use of power supply Ant Colony Optimization (ACO) can be used to optimize the settings of energy storage systems, such as batteries and reservoirs, in hybrid power plants. This algorithm can assist in determining the amount of energy that should be stored or generated from each energy power supply to efficiently meet energy demand.

The main goal of a hybrid system is to maximize energy at a low price, pollution-free, good power quality, and sustainability. With this hybrid-based energy utilization technology can certainly increase energy production and of course electricity from this system and will reduce the risk of energy shortages, to save diesel fuel consumption and reduce the environmental impact it causes. Where this hybrid technology is the concept of combining two or more energy power supplies to achieve an efficiency in various ways and certainly will not cause pollution of harmful environmental impacts on society. (Rosyid, 2010).

2. METHOD

2.1 Research Design

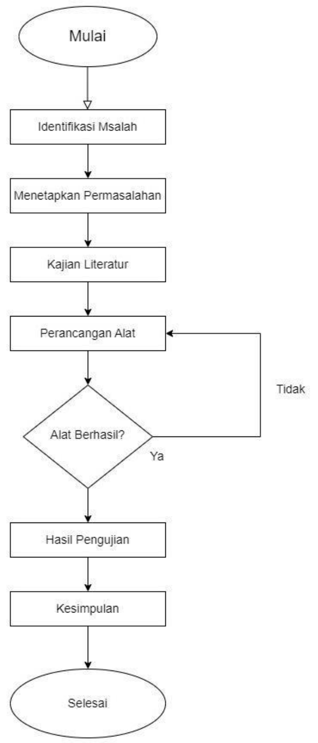

Figure 1 Research Design Diagram

Based on the problems previously described, researchers will design a tool to find solutions to the problems identified. The data analysis techniques used include:

1. Literature study method: Examining, exploring, and reviewing relevant theories for solving the problem being studied.
2. Literature method: Using various reference books, information from lecturers, colleagues, and sources from the internet to obtain a theoretical basis as the basis for this writing and references related to the problem under study.
3. Observation method: Making direct observations in the field to collect data and information that cannot be obtained through literature and laboratory studies, so that their validity can be accounted for.
4. Calculation analysis method: Performing calculation analysis on the construction of the designed components.
5. Experimental method: Conducting trials to obtain data from the simulation results of the designed program, which helps in solving existing problems.
6. Discussion method: Coordinate and get guidance from lecturers and other parties who can support the implementation of this design.

2.2. Tool Design

In the design of the tool design there are Solar Cell and Hydropower (DC Generator) components as the main power supply. INA219 sensor as current and voltage sensor. Wemos D1 Mini as a microcontroller that connects the device with Thingspeak as monitoring. Buck Converter as a step down to reduce the voltage from the power supply of 12 V to the Wemos D1 Mini by 5V. Relay as power supply control. The load used is a DC lamp of 12V.

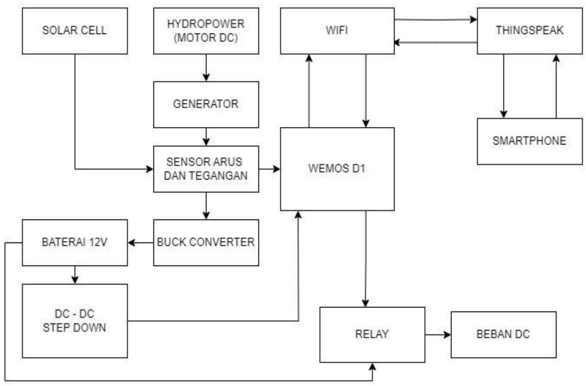

Figure 2. Tooling Design

2.3. Tool Components

2.3.1. Hardware

In making tools, the things that need to be prioritized are the hardware needed in a final project research tool design, including the following:

1. Solar Panel (Solar Cell)

   In the Solar Cell power supply system, there are solar cells that play a role in absorbing heat energy from the sun which is then converted into electrical energy. The Solar Cell used by the author has a capacity of 20WP with an output voltage of 21 V and a current of 0.56 A. This Solar Cell can be arranged in series to increase voltage, or in parallel to obtain a larger current.

2. Relay Module

Relay is an electronic device that can connect or disconnect electric current automatically based on commands from the Wemos D1 module. In this study, the authors used a relay with a voltage of 12V.

3. Wemos D1 Mini Module

The ESP8266-based microcontroller is used to connect the system to the Internet and control various other components. One of the board modules that support this function is Wemos, which is compatible with Arduino and is very suitable for projects that apply the concept of Internet of Things (IoT).

4. INA219 Sensor

The sensor used serves to monitor the current, voltage, and power of the energy source. The current sensor will be connected to the Solar Cell and DC Generator. The working principle of the INA219 sensor module is based on resistance reduction, which allows a decrease in input voltage up to five times the original voltage. The INA219 sensor will be connected to the Solar Cell and DC Generator.

5. DC Generator

A direct current (DC) generator is an electronic device that converts mechanical energy into electrical energy. This mechanical energy is used to rotate a coil of conducting wire in a magnetic field. The energy used can come from steam, water turbines, gasoline engines, or electric motors. In this research, the author utilizes a generator with a voltage of 12V and a current of 1A.

6. HPL lamp

HPL LEDs are LEDs with higher power that function as lamps to replace sunlight. In this study, the author used one lamp with a voltage of 12 V.

2.3.2. Software

In addition to using hardware, the author also needs software or software that functions for programming or monitoring data. Some of them are as follows:

1. Internet of Things (IoT) System

The Internet of Things (IoT) has become an increasingly popular research field along with advances in internet technology and other communication media. Along with the increasing human need for technology, the amount of research in this field is also increasing. In this research, the author utilizes the Thingspeak application as a platform for remote monitoring.

2. Ant Colony Optimization (ACO)

The application of Ant Colony Optimization (ACO) in hybrid Solar Cell and Hydropower power plants is used as energy management, which helps in optimizing system settings and operations to maximize energy production and efficient use of the power supply Ant Colony Optimization (ACO) can be used to optimize the settings of energy storage systems, such as batteries and reservoirs, in hybrid power plants. This algorithm can assist in determining the amount of energy that should be stored or generated from each energy power supply to efficiently meet energy demand.

3. Arduino Integrated Development Environment (IDE) Application

The Arduino Integrated Development Environment (IDE) application allows the integration of various sensors, such as relays to control (Public Street Lighting) (PJU). Programming in the Arduino Integrated Development Environment (IDE) allows reading sensor data and controlling actuators based on certain logic. The Arduino IDE is used to write code that allows the collection of data from various sensors. This data is important for monitoring system performance and for making data-driven decisions in Internet of Things (IoT) systems.

2.4. How the Tool Works

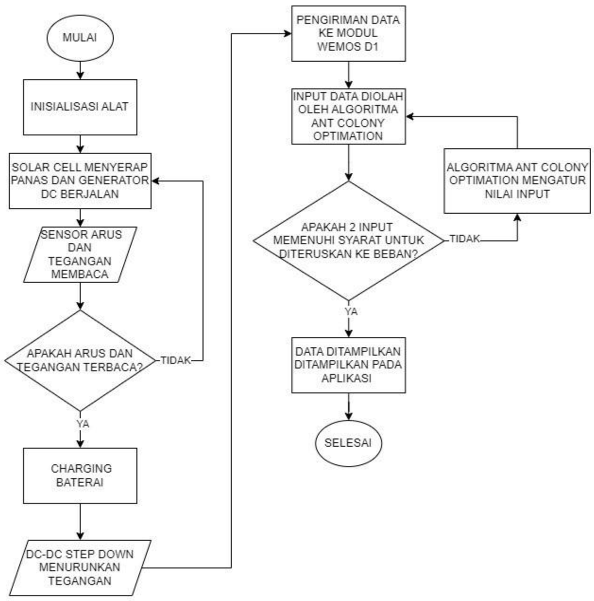

Figure 3 Device Work Flowchart

In the design of the tool using hybrid energy or energy derived from two power supplies, namely Solar

Cell and Hydropower. For Solar Cell power supply there are solar cells that function to absorb heat energy from the sun which will be converted into electrical energy which usually for one Solar Cell block can produce a voltage of 21 V and a current of 0.56 A and a capacity of 20 WP.

For the second power supply, namely the hydroelectric power plant. But in the design of this tool using a mechanical charger as a substitute In the design of the author using DC Motors and DC Generators.

The voltage read by the voltage sensor and current sensor is then flowed to the Wemos D1 Mini module and goes to the buck converter. At the output of the buck converter, the voltage is flowed to the battery which is then flowed to the DC-DC step down to reduce the voltage to 5V. Then the output of the DC-DC step down is flowed to the Wemos D1 module.

When 2 inputs (Solar Cell and Hydropower) enter the Wemos D1 then the two inputs are compared (logarithmic Ant Colony Optimization) if the two inputs meet the work requirements, then they can be forwarded to the load. But if one of them experiences a decrease in power, it will be diverted to a more sufficient input.

In addition, Wemos D1 Mini functions as an output data processor from current sensors and voltage sensors. The Wemos D1 module output is streamed to the relay and Wi-Fi module. The Wi-Fi module as a communication medium which later the results of voltage and current from both power supplies can be monitored through applications on smartphones that are connected to the internet. In addition, the tool can be controlled through an application on a smartphone. While after going through the trade relay will be flowed to the load.

3. RESULTS AND DISCUSSION

In making tools for this Final Project, the author needs a power supply in the form of a 20 Wp Solar Cell and Hydropower (DC Generator) which is used to provide power to electronic devices. Furthermore, there are components that function to control and measure the output of solar panels arranged on a board. These components are, Wemos D1 Mini as a microcontroller in settings through the program, Wemos D1 Mini module as wireless to connect with the application, INA219 sensor to read the current installed before and after the Buck Converter. Buck Converter to reduce voltage, Liquid Crystal Display (LCD) to display current and voltage values. These components are on one Printed Circuit Board (PCB) and a control system that can switch the power supply to the load manually and automatically.

In making a monitoring circuit and control system that can cut off the power supply to the load manually and automatically, the author needs several components or hardware, among others:

1. Wemos D1 Mini Module
2. Current and Voltage Sensor
3. Liquid Crystal Display (16×2 LCD)
4. Relay Module

To facilitate the design and assembly process in the circuit created, the author uses the Fritzing application to create a schematic image of the overall circuit assembled on each component connected to the Wemos D1 Mini microcontroller. In making the Printed Circuit Board (PCB) the author needs an Eagle application where in this application the author can design the flow of the circuit wiring made, so that it can facilitate the placement and assembly of components on the Printed Circuit Board (PCB) board.

2.1. Hardware Testing

2.1.1. Solar Cell Testing

The 20 WP solar panel was tested at 08.00 in the morning until 16.00 in the afternoon with a measurement range of once every hour to take data. Light intensity testing, to determine the value captured by solar panels using a luxmeter that is positioned parallel to the solar panel. Measurements of solar panel output are measured using an Avometer to see the voltage generated from solar panels.

Figure 4 Solar Panel Testing with Luxmeter

Figure 5 Current and Voltage Testing of Solar Cells using Avometer

Time	Voltage Measurement Results Using Avometer (Volt)	Light Intensity (Lux)	Description
08.00	13.75	65.5x1000	Sunny
09.00	13.92	104.5x 1000	Sunny
10.00	13.63	112.8x1000	Sunny
11.00	14.93	113.10x1000	Sunny
12.00	14.91	116.4x1000	Sunny
13.00	17.54	116.3x1000	Sunny
14.00	17.52	100.9x1000	Sunny
15.00	13.75	84.5x1000	Sunny
16.00	11.51	79.5x1000	Sunny

Table 1 Solar Cell test results

In testing solar panels that are measured every one hour, data can be obtained as shown in the table above. By taking measurements every hour, the author can find out the amount of voltage and current obtained from the output of the solar panel. So, it can be concluded that the higher the light intensity, the greater the voltage that will be generated. In the experiment, the highest voltage data was obtained, namely 17.54 V at 13.00 and the lowest was 11.51 V at 16.00 From this experiment, it can be concluded that in one day the 20 WP solar panel can produce a voltage of 17 V with normal sunny conditions.

2.1.2 Generator DC Testing

The second is testing the DC generator, if the working voltage of the generator has been met then the indicator light on the DC Generator will be green and ready to be connected to the load.

Furthermore, the test results of the DC Generator rotation speed measurement are measured using a Tachometer to see the speed (Rpm) generated from the DC Generator.

Table 2. DC Generator Speed Testing

Potentiometer Direction (clockwise)	Speed (Rpm)
1	3295
2	5197
3	5388
4	9984
8	531.8
9	921.0
10	1977
11	2613
12	2858

From the test results, it can be concluded that when the Generator indicator light is green and the DC Generator working voltage has been met, the DC Generator can work well as desired, namely producing a voltage of 12 V and turning on the load.

2.1.3 Buck Converter

Buck Converter testing is done to find out whether the buck converter can work properly or not when reducing the 12V voltage from the power supply then the output is 5V to the Wemos D1 Mini as a microcontroller and LCD as a voltage value viewer. The following is a table of test results.

Table 3. Buck Converter Testing

Attempt to-	Input Voltage (V)	Output Voltage (V)
1	12.37	5.27
2	12.64	5.15
3	12.19	5.54
4	12.95	5.66
5	12.09	5.08
6	12.05	5.73
7	12.94	5.20
8	12.86	5.80
9	12.89	5.92

Based on data from measurements, the input voltage from the battery of 12, V is reduced to 5 V with a Buck Converter, where 5 V is set to supply the Wemos D1 Mini. Based on the table that was measured four times, the output voltage of 5 V was obtained, proving that the Buck Converter works well.

2.1.4 Battery Testing

The battery functions as a storage area for electrical energy, besides that the battery in the design of this tool is also used as a voltage power supply to supply a voltage of 50 inputs to the Wemos D1 Mini and Arduino Nano. So that the battery must be tested to know the condition of the battery in good condition. Testing is done by measuring the voltage using an Avometer and comparing with the specifications of the battery.

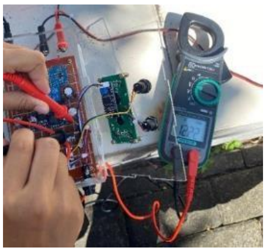

Figure 6 Battery Testing

After taking measurements amount of voltage obtained is 12.22 V where the voltage is in accordance with the specifications of the battery. So, the battery can still function properly.

2.2. Software Testing

2.2.1. Arduino Integrated Development Environment (IDE) Software Testing

Testing the Arduino Integrated Development Environment (IDE) application has the aim of ensuring that this software functions properly and as expected. Testing is done to identify and fix bugs, test functionality, and ensure reliability and good performance. This goal includes ensuring the compilation and transfer of the program runs smoothly, finding, and fixing errors. This test is carried out to find out some of the coding that is input into the microcontroller is correct and functioning properly, where there are no errors when uploading to the microcontroller.

When you want to upload a program to a microcontroller, you must choose the type of microcontroller used. In this design using Arduino Nano, so in the Arduino Integrated Development Environment (IDE) application in the tool's menu, select the board that says Arduino Nano.

After selecting the Board, compiling the program is done by clicking the check mark on the top left menu. After pressing the check mark, the compiling process will take place which when finished will show whether there are errors or not in the program.

When the compiling process is complete, the bottom will say "Done Compiling" and the black part will show whether there is an error or not. In this picture there are no errors, so the program can be uploaded to the microcontroller.

Figure 7 Notification Done Compiling.

2.2.2. Internet of Things (IoT) Testing

Testing on the Internet of Things (IoT) which aims to facilitate the monitoring control system of the Internet Of Things (IoT)-based Hybrid Solar Cell and Hydropower Energy Plant Prototype Using Ant Colony Optimization (ACO) Algorithm in my tool uses a smartphone as the main interface equipped with a control and monitoring display. This tool uses a website server as an interface for control and monitoring, equipped with a user and password before the login display so that some people can access it as technicians.

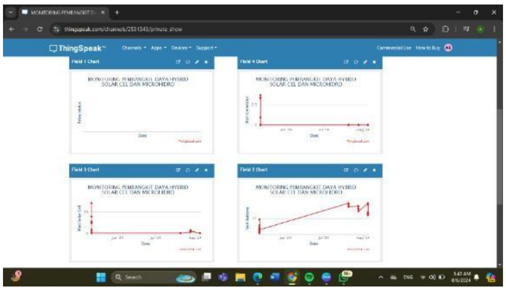

Figure 8 Monitoring View on Thingspeak

4. CONCLUSION

To answer the problem formulation that has been made in chapter two, the author can conclude that:

1. Based on the experiments conducted, the output voltage of the solar panel with a maximum output of 17.54 V and at least 11.51 V. As well as the Buck Converter output voltage generated maximum 12.9 V and minimum 12.0 V. The process of charging the battery with a voltage source from solar panels using a Buck Converter, there is an INA219 sensor and a voltage sensor at the output of the Solar Cell and Buck Converter to monitor the value and display it on the Liquid Crystal Display (LCD) and can be monitored in realtime based on the Internet of Things (IoT) by utilizing the Wemos D1 Mini to send data to the Thingspeak application which is accessed via a smartphone.
2. In the tool control there is a button that is used to change the mode on the power supply. There are three modes, namely Auto mode, Solar Cell mode, and Generator mode. In Auto mode the tool will work automatically to select one of the power supplies to supply a more optimal and efficient load. While in Solar Cell mode the power supply used to supply the load is Solar Cell and in Generator mode the power supply used to supply the load is Generator.
3. The Use of Ant Colony Optimization (ACO) Algorithm in the Prototype of Hybrid Solar Cell and Hydropower Energy Generation as a Power Supply for Internet Of Things (IoT)-Based Public Street Lighting (PJU) Using the Ant Colony Optimization (ACO) Algorithm as a method that will analyze and assist in optimizing energy distribution so that energy use becomes more efficient.

5. SUGGESTION

1. The Hybrid Solar Cell and Hydropower Energy Generation Prototype as an Internet Of Things (IoT)-based Public Street Lighting (PJU) Power Supply Using Ant Colony Optimization (ACO) Algorithm adds a remote control system to regulate the use of the power supply.

2. This prototype design has the potential to be further developed by adding various other power supply sources to create new innovations in the field of renewable energy.

REFERENCES

[1] Alexander, D. (2015). Pengembangan Sisrem Relay Pengenadalian Dan Penghematan Pemakaian Lampu. *Seminar Nasional Informatika*, 75-85.

[2] Athar, M. (2020). Rancang Bangun Kontrol Dan Monitoring Pembangkit Energy Hybrid Solar Cell Dan Hydorpower Berbasis Internet of Things. *Prosiding SNITP (Seminar Nasional Inovasi Teknologi Penerbangan)*, 1-8.

[3] Auliya, A. Y. (2022). Prototype Monitoring Generator Alternatif Hybrid Solar Cell Dan Wind Turbine Berbasis Nodemcu Esp8266. 1-6.

[4] Badri, H. (2022). Rancangan Alat Pengaman Instalasi Listrik Menggunakan Sistem Proteksi Relay Terhadap Beban Lebih Dan Hubung Singkat Berbasis Mikrokontroler. *Agustus*, 224-234.

[5] Christian, J. (2013). Prototipe Sistem Pendeteksi Kebocoran Gas LPG Menggunakan Sensor Gas MQ2, Board Arduino Duemilanove, Buzzer, dan Arduino GSM Shield pada PT. Alfa Retailindo (Carrefour Pasar Minggu). *Jurnal Ticom*, 58-64.

[6] Dilla, B. (2022). Implementasi Solar Charge Controller Untuk Pengisian Baterai Dengan Menggunakan Catu daya Energi Hybrid Pada Sepeda Motor Listrik. *Jurnal Edukasi Elektro*, 128-135.

[7] Gunawan, L. A. (2021). Rancang bangun Pembangkit Listrik Tenaga Surya portable. *Jurnal Teknik Elektro*, 65-71.

[8] Hakim, T. R. (2015). Hybrid Genetic Algorithms(GA) dan Ant Colony Optimization (ACO) dalam Menyelesaikan Dynamic Travelling Salesman Problem (DTSP). 1-4.

[9] Hasrul, R. (2021). Rancang Bangun Prototipe WC Pintar Berbasis Wemos D1R1 Yang Terhubung Pada Android. *Jurnal SainETIn*, 51-59.

[10] Ii, B. A. (2010). Gambar 2 . 1 Kontruksi Generator Catu daya : Niko. 5-20.

[11] Ii, B. A. (2010). Gambar 2.1 Konstruski generator DC Catu daya: Ardian, 2010: 7. 5-21.

[12] Katona, G. (2019). Parallel ant colony algorithm for shortest path problem. *Periodica Polytechnica Civil Engineering*, 243-254.

[13] Manan, S. (2009). Energi Matahari, Catu daya Energi Alternatif yang Effisien, Handal dan Ramah Lingkungan di Indonesia. *Energi Matahari Catu daya Energi Alternatif Yang Effisien, Handal Dan Ramah Lingkungan Di Indonesia*, 31-35.

[14] Ramady, G. D. (2020). Rancang Bangun Model Simulasi Sistem Pendeteksi Dan Pembuangan Asap Rokok Otomatis Berbasis Arduino. 212-218.

[15] Rani, P. (2014). PEMANFAATAN AIR BUANGAN TURBIN PEMBANGKIT LISTRIK TENAGA *MINI*HIDRO DENGAN MODEL DESAIN INTEGRASI POWERHOUSE BERBASIS ANT COLONY OPTIMIZATION. *Range Management and Agroforestry*, 1-15.

[16] Ridhani, W. (2014). Optimisasi Biaya Pembangkitan Pada Sistem 500 Kv Jawa- Bali Menggunakan Metode Ant Colony Optimization (Aco). *Transient*, 1-8.

[17] Salam, F. (2023). Perancangan Monitoring Suhu Berbasis Internet of Things Dengan Node Mcu Esp8266, Dht 11 Dan Thingspeak. *Jurnal Ilmiah Informatika*, 22-26.

[18] Saputra, F. A. (2018). “ WATERSOR ” (Waterlogging Sensor) Monitoring Genangan Air di Kota Malang Berbasis ThingSpeak Framework. *Seminar Nasional Ilmu Komputer dan Teknologi Informasi*, 165-168.

[19] Suryana, D. (2016). Pengaruh Temperatur/Suhu Terhadap Tegangan Yang Dihasilkan Panel Surya Jenis Monokristalin (Studi Kasus: Baristand Industri Surabaya). *Jurnal Teknologi Proses dan Inovasi Industri*, 5-8.

[20] Tharo, Z. (2019). Pembangkit Listrik Hybrid Tenaga Surya Dan Angin Sebagai Catu daya Alternatif Menghadapi Krisis Energi Fosil Di Sumatera. *Prosiding Seminar Nasional Teknik UISU (SEMNASTEK)*, 141-144.

[21] Wahyuni, N. T. (2020). Rancang Bangun Monitoring Dan Kontrol Beban Pada Solar Cell Dengan Sistem Internet of Things.

[22] Wicaksani, E. (2023). Perancangan Aplikasi Sistem Monitoring Arus, Tegangan Dan Daya Berbasis Internet of Things (IoT). *JATI (Jurnal Mahasiswa Teknik Informatika)*, 1907-1912.