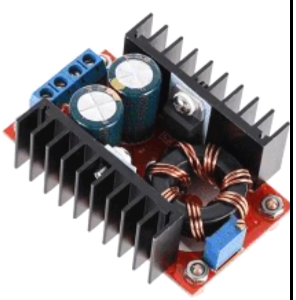
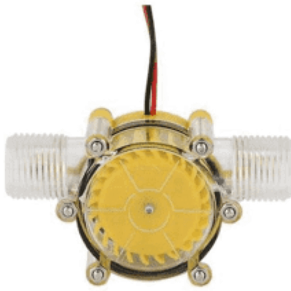
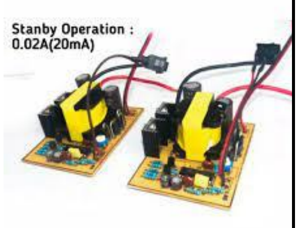
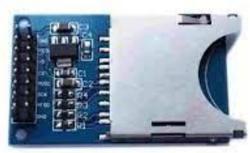
LAMPIRAN

No.	Tanggal	Kegiatan	Hasil	Dokumentasi
1.	30 Januari 2023	Pembelian komponen Low Voltage Disconnect Baterai Battery Charging Control Module XH-M609 Lithium Proteksi LVD Modul Over	melakukan pembelian kompoen melalui toko online shofee pesanan diterima pada tanggal 03 Februari 2023	
2.	30 Januari 2023	Pembelian Modul Pelindung DC6-60V Saklar Pelindung Charger Baterai Lead-acid 12V 24V 48V	melakukan pembelian kompoen melalui toko online shofee, pesanan diterima pada tanggal 04 Februari 2023	
3.	31Januari 2023	Pembelian MCB SCHNEIDER ORANGE 2A 4A 6A 10A	melakukan pembelian kompoen melalui toko online shopee pesanan diterima pada tanggal	
4.	02 Februari 2023	Pembelian box plastik	melakukan pembelian box plastik yang digunakan sebagai prototype pemapungan air untuk pompa	

5.	04 Februari 2023	Pembelian Pompa WATERPUMP 1500 LPH POMPA CELUP AQUARIUM	Melakukan pembelian pompa air yang dipergunakan untuk beban pada pembangkit listrik tenaga surya melalui toko online shopee pesanan diterima 07 Februari 2023	
6.	05 Februari 2023	Pembelian Kabel panel / solar cable visero 2250 TWIN 18m	Melakukan pembelian kabel panel solar melalui toko online shopee pesanan diterima 08 Februari 2023	
7.	05 Februari 2023	Pembuatan tiang dan dudukan panel surya menggunakan baja ringan	melakukan pembuatan tiang dan dudukan panel surya dengan menggunakan baja ringan dengan posisi box dipasang dibawah panel yang diperlukakan sebagai prototype PLTS di desa Pandan Arang. pembuatan prototype dilakukan untuk peralatan uji kendali jarak jauh (IoT) sebelum dilakukan pemasangan di lokasi PLTS roop dan floating di desa Pandan Arang	
8.	06 Februari 2023	Pembelian Boost Converter 10-32V to 12-35V Step Up Charger 150W DC-DC	melakukan pembelian Boost Converter toko online shopee pesanan diterima 08 Februari 2023 yang dipergunakan sebagai converter DC to DC 150 W inputan mini PLTHM 12 V yang diletakan pada output pompa air celup untuk hybrib energi listrik	

			PLTMH dan PLTS	
9.	06 Februari 202	Pembelian mini PLTMH 12v Pembangkit Listrik Tenaga Air Generator Hydroelectric Turbin	melakukan pembelian mini PLTMH 12v Pembangkit Listrik Tenaga Air Generator Hydroelectric melalui toko online shopee pesanan diterima 14-02-2023. dipergunakan unutk hybrib energi listrik PLTMH dan PLTS sebagai tambahan suplay energi listrik untuk pengecsaan baterai yang memanfaatkan output air pompa celup sebagai sumber	
10.	06 Februari 202	Pembelian MPPT Solar Panel Battery Regulator Charge Controll	Melakukan Pembelian Solar Panel Battery Regulator Charge Controll melalui toko online shopee pesanan diterima 10-02-2023	
11	08 Februari 2023	Pembelian Mini inverter 12V to 220v Up to 300watt max	melakukan pembelian Mini inverter 12V to 220v Up to 300 watt max melalui online shopee pesanan diterima 13-02-2023, yang dipergunakan sebagai sumber inverter 220 Vac, 300 Watt untuk sumber hybrib energi listrik PLTMH dan PLTS	
12	11 Februari 2023	Pengujian PLTS dengan menggunakan 3 Panel surya 50 WP	melakukan pengujian PLTs dengan pompa air. video dapat dilihat dengan mengklik link : https://drive.google.com/file/d/1OsInMAz0i6MZ4a-	

			tu9kfgz2Sl9bdYHem/ view?usp=sharing	
13	13 Februari 2023	Pembelian DHT22 DHT-22 AM2302 HUMIDITY & TEMPERATURE SENSOR SUHU DHT22	melakukan pembelian HUMIDITY & TEMPERATURE SENSOR SUHU DHT22 melalui toko online tokopedia. sensor yang digunakan untuk mengukur suhu dan kelembapan. Sensor ini juga dikenal sebagai AM2302. Sensor DHT22 menggunakan teknologi digital untuk mengukur suhu dan kelembapan, sehingga hasil pengukurannya lebih akurat daripada sensor analog.	
14	13 Februari 2023	Pembelian SD-MMC Card Module	melakukan pembelian SD-MMC Card Module melalui toko online tokopedia. SD-MMC Card Module adalah perangkat keras yang digunakan untuk membaca dan menulis data pada kartu SD dan MMC. Fungsi utama dari modul ini adalah untuk menyediakan antarmuka antara kartu memori dan mikrokontroler atau komputer untuk mengakses dan memanipulasi data pada kartu memori.	

15	13 Februari 2023	pembelian GY-302 Light Intensity BH1750 Module Sensor Intensitas Cahaya	melakukan pembelian GY-302 Light Intensity BH1750 Module Sensor Intensitas Cahaya melalui toko online tokopedia. sebuah sensor intensitas cahaya yang dapat mengukur tingkat kecerahan lingkungan dalam satuan lux. Sensor ini bekerja dengan menggunakan teknologi fotoelektrik yang mengubah energi cahaya menjadi sinyal listrik. nilai intensitas cahaya dapat ditampilkan pada sebuah display atau disimpan pada sebuah memori. Selain itu, sensor ini juga dapat dihubungkan dengan sebuah sistem mikrokontroler seperti Arduino untuk melakukan pengolahan data lebih lanjut.	
16	13 Februari 2023	Pembelian PZEM-017 0-300V RS485 Modbus DC Meter Current Voltage Power Energy - 50A	melakukan pembelian PZEM-017 0-300V RS485 Modbus DC Meter Current Voltage Power Energy - 50A melalui toko online tokopedia. PZEM-017 adalah perangkat yang dapat digunakan untuk mengukur konsumsi energi pada sistem listrik DC, dan dapat diintegrasikan ke dalam sistem pemantauan energi yang lebih besar melalui protokol	 

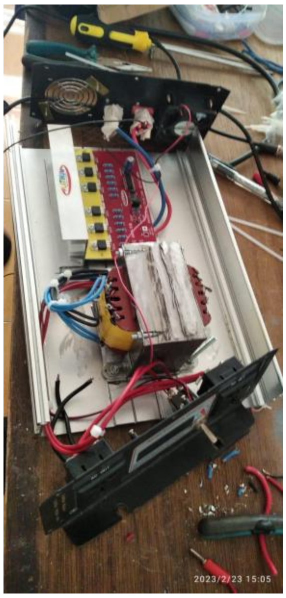
			komunikasi RS485 Modbus. perangkat metering yang digunakan untuk mengukur tegangan, arus, daya, dan energi pada sistem listrik DC. Perangkat ini dapat beroperasi pada rentang tegangan 0-300V dan arus hingga 50A.	
17	13 Februari 2023	Pembelian DS18B20 Water Proof Temperature	melakukan pembelian DS18B20 Water Proof Temperature melalui toko online tokopedia. Water Proof Temperature Sensor adalah sensor suhu digital yang dirancang untuk memberikan pembacaan suhu yang akurat dalam berbagai lingkungan. Sensor ini dilindungi dengan bahan waterproof sehingga dapat digunakan dalam lingkungan yang lembab atau basah, seperti dalam air atau di luar ruangan.	
18	13 Februari 2023	Pembelian MAX485 TTL TO RS485 CONVERTER MODULE	melakukan pembelian MAX485 TTL TO RS485 CONVERTER MODULE melalui toko online tokopedia. Modul elektronik yang berguna untuk mengubah sinyal TTL (Transistor-Transistor Logic) menjadi sinyal RS485 (Recommended Standard 485) yang lebih handal dan dapat digunakan untuk komunikasi serial	

			jarak jauh. Berikut adalah fungsi dan cara kerja MAX485 TTL to RS485 Converter Module: Fungsi: Mengubah sinyal TTL menjadi sinyal RS485, Meningkatkan jangkauan komunikasi serial antar perangkat, Mengurangi noise dan interferensi yang terjadi pada transmisi data, Meningkatkan kehandalan dan integritas data yang dikirimkan	
19	13 Februari 2023	Pembelian LCD 20x4 LCD 2004 2004A BIRU BLUE	melakukan pembelian LCD 20x4 LCD 2004 2004A BIRU BLUE melalui toko online tokopedia. LCD 20x4 (2004) adalah sebuah display atau tampilan visual yang dapat menampilkan teks dan karakter pada empat baris dan 20 kolom. Display ini biasanya digunakan pada berbagai perangkat elektronik, seperti pengukur suhu, alat ukur, dan perangkat elektronik lainnya.	
20	13 Februari 2023	Pembelian Raindrop Module Sensor Hujan Module	melakukan pembelian Raindrop Module Sensor Hujan Module melalui toko online tokopedia.Raindrop module atau modul sensor hujan adalah sebuah perangkat elektronik yang digunakan untuk	

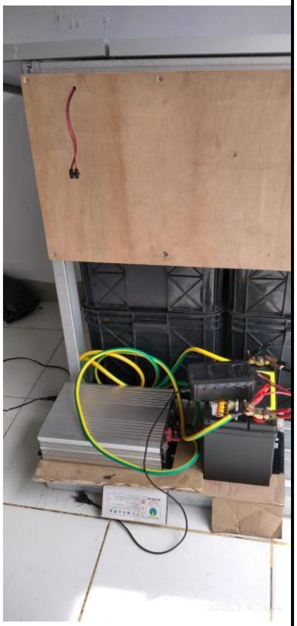
			mendeteksi keberadaan air atau hujan pada permukaan sensor. Modul ini dapat digunakan untuk mengontrol sistem irigasi, penutup jendela otomatis, atau sistem lain yang terkait dengan kelembaban atau keberadaan air. Fungsi dari modul sensor hujan adalah untuk mendeteksi apakah hujan sedang turun atau tidak. Modul ini biasanya terdiri dari dua pin atau lebih yang terhubung ke permukaan sensor, dan sebuah rangkaian elektronik yang mengolah sinyal yang diterima oleh sensor. Ketika permukaan sensor terkena air, sinyal yang diterima oleh modul akan berubah, dan modul akan memberikan output yang sesuai. Cara kerja modul sensor hujan adalah dengan memanfaatkan sifat listrik air yang dapat menghantarkan arus listrik. Ketika permukaan sensor terkena air, sinyal listrik akan mengalir melalui air dan melalui pin sensor, sehingga menghasilkan perubahan pada sinyal yang diterima oleh modul. Modul ini kemudian akan mengolah sinyal	

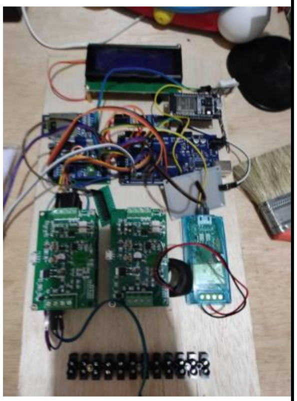
			tersebut dan memberikan output yang sesuai, misalnya dalam bentuk sinyal digital atau analog. Untuk menggunakannya, modul sensor hujan dapat dihubungkan ke mikrokontroler atau sistem elektronik lainnya, dan diatur untuk mengendalikan sistem terkait dengan kelembaban atau keberadaan air. Dalam aplikasi yang lebih kompleks, modul ini dapat digunakan bersama dengan sensor lainnya, seperti sensor suhu dan kelembaban, untuk memonitor kondisi lingkungan yang lebih lengkap.	
21	13 Februari 2023	melakukan pembelian Modul IIC I2C Serial Interface LCD 1602A 2004A	melakukan pembelian Raindrop Module Sensor Hujan Module melalui toko online tokopedia. Modul I2C Serial Interface LCD 1602A 2004A adalah modul eksternal yang digunakan untuk menampilkan karakter pada layar LCD dengan menggunakan protokol komunikasi I2C (Inter-Integrated Circuit). Modul ini memiliki fungsi untuk memudahkan proses tampilan karakter pada layar LCD, terutama dalam aplikasi mikrokontroler atau sistem embedded.	

22	13 Februari 2023	Pembelian arduino mega	melakukan pembelian arduino mega melalui toko online tokopedia. Arduino Mega adalah salah satu jenis papan pengembangan mikrokontroler yang populer digunakan dalam proyek-proyek elektronik. Papan ini menggunakan mikrokontroler ATMega2560 sebagai inti sistemnya, yang memiliki lebih banyak pin input/output (I/O) dan memori yang lebih besar dibandingkan dengan Arduino Uno. Fungsi utama dari Arduino Mega adalah untuk mengontrol dan memproses data dari berbagai sensor dan aktuator pada proyek elektronik. Papan ini dapat diprogram menggunakan bahasa pemrograman Arduino yang cukup mudah dipelajari dan digunakan. Cara kerja Arduino Mega adalah dengan memasukkan kode program melalui software Arduino IDE, yang kemudian di-upload ke papan Arduino Mega melalui koneksi USB. Setelah di-upload, program tersebut akan dijalankan oleh mikrokontroler ATMega2560, dan papan Arduino Mega	

			akan mulai mengontrol sensor dan aktuator yang terhubung ke pin input/output-nya sesuai dengan instruksi dalam program tersebut.	
23.	15 Februari 2023	Pembelian KIT INVERTER DC TO AC 220V 1000W	Melakukan pembelian KIT INVERTER DC TO AC 220V 1000W melalui toko online shopee pesanan diterima 17-02-2023, inverter dipergunakan sebagai sumber utama dari PLTS 100 WP untuk sumber energi listrik pompa celup	
24.	22 Februari 2023	Pembuatan BOX Inverter 1000 Watt	Melakukan pembuat box inverter 1000 Watt yang sumber utama dari PLTS 100 WP untuk sumber energi listrik pompa celup	
25.	23 Februari 2023	instalasi dan perakaitan inverter	melakukan instalasi dan perakitan inverter 1000 watt untuk dibebani pompa air celup	

				
26	25 Februari 2023	instalasi komponen kendali Internet of Thing (Iot) pada sistem PLTS untuk data lingkungan dan sistem photovoltaik	Untuk menginstalasi data lingkungan dan sistem photovoltaic, terlebih dahulu dibutuhkan beberapa sensor yang dapat mengukur intensitas cahaya, suhu, kecepatan angin, arus, dan tegangan. Sensor-sensor tersebut kemudian dapat dihubungkan ke papan mikrokontroler seperti Arduino Mega untuk membaca dan memproses data yang dihasilkan oleh sensor. Dalam program, pengguna dapat menentukan cara pembacaan data dari sensor-sensor tersebut, seperti melalui koneksi serial atau tampilan di layar LCD. Data yang dihasilkan oleh sensor-sensor dapat juga disimpan pada media penyimpanan eksternal seperti kartu SD atau dikirim ke server melalui koneksi internet untuk pemantauan jarak jauh.	percoaba dengan dengan 11 volt https://drive.google.com/file/d/1b3jkgkqf_q6IQyy7gGATSePRi_jw_mbS/view?usp=sharing percoaba dengan dengan 12,9 volt https://drive.google.com/file/d/1kF4Ve6ODR8ndqo7LFi851cshswfKpCmR/view?usp=sharing

27	4 Maret 2023	Instalasi komponen sistem photovoltaic dengan beban pompa air	melakukan instalasi seluruh komponen PLTS seperti modul photovoltaic, MCB, SCC baterai dan inverter	 
28	6 Maret 2023	pengujian dan pengukuran arus, tengan pada photovoltaic, baterai dan beban	melakukan pengujian dan pengukuran sistem PLTS beban pompa air dengan menggunakan tang amper	https://drive.google.com/file/d/1VNoM3qR1HjsSMnm7DOu9j4QOsH3zVlOR/view?usp=sharing
29	16 Maret 2023	Intaslasi Ardunio dengan komponen sistem	melakukan instalasi seluruh komponen kedalam ardunio mega	

				 
30	30 Maret 2023	Intalasi komponen kendali ke dalam box panel	melakukan intalasi komponen kendali kedalam box panel	
29	7 April 2023	pengujian sistem kendali	melakukan pengujian sistem kendali dengan output LCD, data Logger dan IoT	

Lampiran 1 - Publikasi Jurnal IJACSA (Q3)

International Journal of Advanced Computer Science and Applications (Q3)

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1 pesan

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The tentative publication date is 30 April 2025.

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IJACSA Acceptance Notification - Volume 16 No 4 April 2025

1 pesan

Editor IJACSA <editorijacsa@thesai.org> 9 April 2025 pukul 16.22
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Dear Author(s),

Congratulations, your submitted paper titled "Photovoltaic Fault Detection in Remote Areas Using Fuzzy-Based Multiple Linear Regression (FMLR)" has been reviewed and accepted for publication in the International Journal of Advanced Computer Science and Applications (IJACSA) - Volume 16 No 4 April 2025.

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Photovoltaic Fault Detection in Remote Areas Using Fuzzy-Based Multiple Linear Regression (FMLR)

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***Abstract*—This research focused on developing and implementing a fault detection model for photovoltaic (PV) systems in remote areas, utilizing a Fuzzy-Based Multiple Linear Regression (FMLR) approach. The study aimed to address the challenges of monitoring PV systems in locations with limited access to conventional power grids and technical resources. The fault detection system integrated environmental parameters such as solar radiation, temperature, wind speed, and rainfall, alongside PV system parameters like panel voltage, current, battery voltage, and inverter performance. Data collection and preprocessing were conducted over a specified period to identify operational patterns under both normal and faulty conditions, ensuring data accuracy through cleaning, normalization, and categorization. The research was conducted in *Pandan Arang* Village, *Kandis* District, *Ogan Ilir* Regency, South Sumatera, Indonesia, contributing to the improvement of reliability and sustainability of renewable energy sources in isolated communities. The total number of data points for 276 rows with 6 attributes each was 1656 records. The MLR model was developed to predict the output power of the PV system, while fuzzy logic was employed to handle uncertainties in the data, offering a more flexible and adaptive decision-making process. The system applied fuzzy rules to determine the charging status (P3), categorizing it into Optimal Charging, Adjusted Charging, Charging Delay, or Fault Alert. The model was tested with real-time data, and its performance was validated through comparison with manual inspections. The results showed that the FMLR-based fault detection system effectively identified faults and optimized the performance of the PV system, making it suitable for remote areas in South Sumatera.**

***Keywords*—Photovoltaic; multiple linear regression; fuzzy; fault detection; remote areas**

I. Introduction

Solar energy has become one of the most promising renewable energy sources in addressing global challenges related to energy security and environmental sustainability [1]–[3]. Photovoltaic (PV) systems have been widely implemented, particularly in remote areas where access to conventional power grids is limited. However, the effectiveness of PV systems heavily depends on the performance of solar panels, which can be influenced by various factors, including environmental conditions, dirt accumulation, shading, and component failures [4]–[6].

Fault detection in photovoltaic systems remains a major challenge in ensuring system efficiency and reliability. Undetected or delayed fault identification can lead to reduced energy production, extensive component damage, and increased maintenance costs [7], [8]. Therefore, an efficient and accurate method is required to detect faults in PV systems in real-time, especially in remote areas where technical resources and maintenance capabilities are limited [9]–[12].

The latest research trends focus on improving detection accuracy and enhancing PV system monitoring by integrating multiple data sources, including electrical performance indicators, environmental conditions, and system degradation metrics. Several key studies have significantly contributed to the advancement of fault detection g in photovoltaic (PV) arrays. Jordan & Hansen (2023) introduced a clear-sky detection approach using time-averaged plane-of-array irradiance to assess PV system health under clear-sky conditions, allowing for better identification of environmental factors affecting PV degradation using linear regression [13].

Jufri et al. (2019) developed a hybrid detection model combining regression analysis and Support Vector Machines (SVM) to detect abnormal conditions in PV systems. Their method enhanced fault prediction accuracy by incorporating daylight time and interaction variables between independent parameters, validated through multi-stage k-fold cross-validation [14]. Heinrich et al. (2020) explored machine learning techniques, particularly Logistic Regression, to monitor cleaning interventions in PV modules, ensuring optimized maintenance scheduling [15].

Harrou et al. (2021) utilized Gaussian Process Regression (GPR) and Support Vector Regression (SVR) for fault data modelling, showcasing the flexibility and adaptability of kernel-based learning methods for real-time PV system monitoring [16]. Additionally, Kim et al. (2020) introduced multivariate analysis using least-square regression to detect PV system faults, integrating both electrical and environmental parameters to provide a structured statistical framework for system health assessment [17]. These studies demonstrate the evolution of fault detection methodologies, emphasizing the role of statistical, machine learning, and hybrid approaches in improving PV system reliability and efficiency.

While previous studies primarily focused on machine learning and statistical regression techniques, a hybrid solution that integrates the strengths of fuzzy logic and multiple linear regression can be used for uncertainties decision [18]–[20]. This method is particularly advantageous in handling uncertainties in photovoltaic (PV) system operations in environmental conditions vary significantly [21]–[23]. By effectively modeling nonlinear relationships between multiple independent variables—such as temperature, solar irradiance, wind speed, humidity, and power output—and their influence on fault indicators, this approach enhances the accuracy of fault detection

Unlike traditional regression models that depend on fixed threshold values, Fuzzy-Based Multiple Linear Regression (FMLR) utilizes fuzzy membership functions to dynamically categorize data, allowing for greater flexibility in identifying faults within PV systems in South Sumatera's diverse climatic conditions [24]–[26]. Moreover, this method improves fault classification by facilitating gradual transitions between fault states rather than the rigid categorizations typically employed in Support Vector Machines (SVM) and Logistic Regression, ensuring a more adaptive and resilient monitoring system for PV operations in the region [27]–[29].

The remainder of this paper is organized as follows: Section II provided a detailed literature review on the various fault detection methods used in PV system, with a particular focus on the integration of fuzzy logic and MLR. Section III outlines the research methodology, including data collection, preprocessing, and the design of the fault detection model. Section IV presented the experimental setup and the implementation of the photovoltaic system in the remote area. Section V discussed the results and validation of the proposed model, including comparisons with manual inspection data. Finally, Section VI concluded the paper by summarizing the findings and offering recommendations for future work in PV system fault detection.

II. Literature Review

A. Multiple Linear Regression

Regression analysis is a statistical-based method used to analyze the relationship between independent variables (X) and a dependent variable (Y). In the context of fault detection in photovoltaic systems, Multiple Linear Regression (MLR) is often employed to assess the impact of multiple independent variables on system performance. The general equation is expressed as (1).

$$y = b_0 + b_1X_1 + b_2X_2 + \cdots + b_nX_n \quad (1)$$

In the context of fault detection in photovoltaic systems, the dependent variable (Y) represents the system's output or fault indicator, while the independent variables ($X_1, X_2, ..., X_n$) include factors such as panel temperature, solar radiation, wind speed, and other operational parameters. The equation incorporates b_0 as the intercept (constant term) and $b_1, b_2, ..., b_n$ as the regression coefficients, which indicate the related to each independent variable on the dependent variable.

B. Fuzzy Logic

In photovoltaic fault detection, once all propositions have been evaluated, the output consists of a fuzzy set that represented the contribution of each rule to the final decision that is represented and expressed as (2).

$$\mu(x_i) = (\mu_{sf}(x_i), \mu_{kf}(x_i)) \quad (2)$$

Value of $\mu_{sf}(x_i)$ denoted the membership value of the fuzzy solution up to the *i-th* rule, indicating how well a specific condition aligns with the defined fuzzy rules for system performance evaluation. Meanwhile, $\mu_{kf}(x_i)$ denoted the membership value of the fuzzy consequent up to the *i-th* rule, reflecting the degree to which the system's response or output is influenced by a given rule.

The input for the defuzzification process in photovoltaic fault detection is a fuzzy set derived from the composition of fuzzy rules, while the output is a crisp numerical value that provides a definitive assessment of the photovoltaic system's performance. Given a fuzzy set within a specific range, a crisp output can be determined using a defuzzification method. When multiple rules contribute to the decision-making process, defuzzification is performed by calculating the centre of gravity (centroid method) to determine the most representative output value. This approach helps in accurately detecting faults in photovoltaic panels, inverters, and power output variations by translating fuzzy logic-based rule evaluations into precise system diagnostics. The final crisp decision can be obtained using centroid-based defuzzification, allowing for proactive fault identification and optimization of photovoltaic energy generation as presented in (3).

$$C = max\,(a, b) \quad (3)$$

where C represents the most significant fuzzy membership value, aiding in the identification and classification of faults in photovoltaic operations.

III. Research Methdology

The research is initiated with a literature review and problem identification, which examined previous studies on fault detection in photovoltaic (PV) systems using artificial intelligence methods such as Fuzzy Logic and Multiple Linear Regression (MLR). This phase identified key challenges encountered by PV systems in remote areas and fault detection is depicted in Fig. 1.

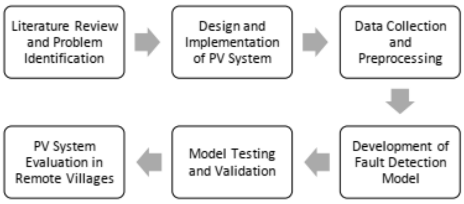

Fig. 1. Research phase

Data collection and preprocessing were carried out over a specified period to identify operational patterns of the photovoltaic (PV) system under both normal and faulty conditions. The process involved cleaning the data by eliminating anomalies and noise to ensure its accuracy. Afterward, the data was normalized to ensure compatibility with the regression model and categorized based on the operational conditions of the PV system. The collected environmental parameters included solar radiation intensity, air temperature, humidity, wind speed, rainfall, and panel temperatures (both top and bottom). The total number of data points for 276 rows with 6 attributes each was 1656 data.

The development of the fault detection model for the photovoltaic (PV) system involved several stages, starting from the system setup to the implementation of the fault detection mechanism. Initially, the necessary hardware components, including photovoltaic panels, solar charge controllers, batteries, inverters, and MCBs, were configured. Environmental parameters such as solar radiation, temperature, wind speed, and rainfall, along with system parameters like current, voltage, power, and temperature at various points in the system, were continuously monitored. The fault detection system was designed to trigger alerts based on FMLR and presented in Fig. 2.

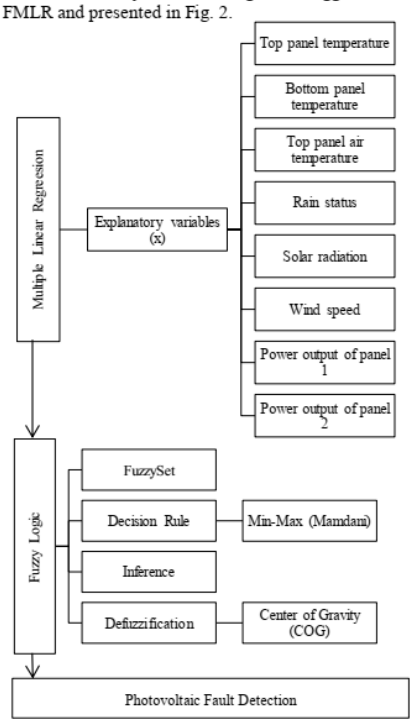

Fig. 2. Photovoltaic fault detection based on FMLR

The research was conducted using an experimental method by implementing PV system integrated with fault detection. The study took place in Pandan Arang Village, Kandis District and Ogan Ilir Regency with its located in South of Sumatera. Data was collected over a specific period to identify operational patterns in both normal and faulty conditions. This data was preprocessed by eliminating anomalies, normalizing values for compatibility with the regression model, and categorizing it based on operational conditions.

The fuzzy-based multiple linear regression (FMLR) model was designed to enhance the fault detection process in photovoltaic (PV) systems by analyzing the relationships between various environmental and system parameters. These parameters include temperature, solar irradiance, wind speed, humidity, and power output, which directly influence the performance of the PV system. The FMLR model incorporates fuzzy logic to handle uncertainties and nonlinearities in these parameters, offering a more flexible and dynamic approach compared to traditional methods.

The model was trained using historical data collected from the PV system, which included instances of both normal operation and various types of faults. By processing this data, the model learned to identify distinct patterns associated with typical system behavior as well as fault conditions. The use of fuzzy logic rules allowed the model to adapt to varying operational conditions and gradually transition between different system states, rather than relying on rigid, predefined thresholds. This adaptability makes the FMLR model particularly useful for systems that operate in dynamic and unpredictable environments, such as those found in remote or off-grid locations.

Once trained, the FMLR model was able to classify system conditions into several categories, each reflecting a different state of operation. These categories included "Optimal Charging", where the system is functioning at peak efficiency, "Adjusted Charging", which occurs when external factors such as weather conditions require adjustments to the charging process, "Charging Delay", which is triggered when system temperatures are too high to ensure safe operation, and "Fault Alert", which indicates that a significant fault has been detected, requiring immediate attention.

The developed model underwent testing and validation using test data to assess its accuracy. The fault detection results were compared with manual PV system inspections to validate the model's accuracy. The fault detection system was deployed and observed in a remote village in South of Sumatera for detect fault conditions in real-time.

IV. RESEARCH RESULT

The identification process carried out through a site survey for the placement of the photovoltaic system resulted in the required photovoltaic (PV) components amounting to 6 x 200 WP. The required solar charge controller (SCC) was 2 x 12V 60A, while the battery capacity needed was 8 x 12V 100Ah. Additionally, a single inverter unit with a capacity of 12V 6000-watt peak (WP) was used to support the system. The photovoltaic (PV) panels were installed on top of a water storage tank, arranged in parallel configuration using six panels.

The installation of the PV system followed a parallel PV configuration, where the panels were placed on the roof (rooftop) above the water storage tank. The PV panels were connected to a miniature circuit breaker (MCB) as a protective device before being linked to the solar charge controller (SCC). The SCC was set according to the battery voltage to optimize charging efficiency. From the SCC, the energy was stored in batteries, which were then connected to the inverter. The inverter was also linked to an MCB before converting DC (Direct Current) into alternating current (AC) to power the water pump. The proposed PV system as illustrated in Fig. 3.

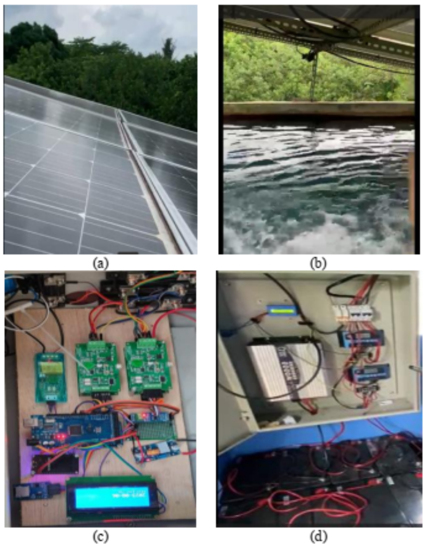

Fig. 3. PV system in remote areas (a) solar panels (b) solar panels integrated to water storage tank (c) IoT for environment paramater control (d) IoT for PV system control

The implementation of this system ensured that the photovoltaic system provided a stable energy supply for operating essential equipment in the remote area. The use of the Internet of Things (IoT) allowed real-time monitoring and control of the system, enabling efficient management of power generation and consumption. This approach contributed to improving access to renewable energy in isolated rural areas of South Sumatra, where conventional electricity sources were limited or unavailable.

The photovoltaic fault detection for the PV system was designed to optimize the battery charging process by considering various environmental factors and the output power from solar panels. This system integrated sensors, an Arduino Mega, data storage, and fuzzy-based multiple linear regression (FMLR) to provide more accurate decisions regarding photovoltaic fault detection based on battery charging conditions.

The DSS utilized sensors to collect real-time data on environmental parameters such as solar radiation, temperature, and battery voltage. These data were then processed using an Arduino Mega microcontroller, which acted as the main control unit for data acquisition and transmission. The multiple linear regression (MLR) approach was used to predict the output power of photovoltaic in panel 1 (P1) and panel 2 (P2) by utilizing six independent variables, including top panel temperature (X_1), bottom panel temperature (X_2), panel surface temperature (X_3), rain status (X_4), solar radiation intensity (X_5) and wind speed (X_6). The calculation P1 and p2 using MLR approach is presented in (4) and (5).

$$P1 = -1.0389 + (0.1656 \times X1) + (-0.0754 \times X2) + (-0.0688 \times X3) + (0.4500 \times X4) + (-0.0025 \times X5) + (13.6189 \times X6) \quad (4)$$

$$P2 = -55.9447 + (0.6757 \times X1) + (5.0193 \times X2) + (-3.5212 \times X3) + (-0.9017 \times X4) + (0.2040 \times X5) + (4.6400 \times X6) \quad (5)$$

The fuzzy rules for predicting P_1 and P_2, along with other input data established several important steps. First, the fuzzy sets for the P_1 power output variable and the charging status (P3) variable were defined. Based on the MLR prediction, a fuzzy classification category was generated for predicting P_1 and P_2, which included three levels: Low, Medium, and High. The classification determined based on fuzzy set values in Table 1.

TABLE I. FUZZY SET VALUES

Variable	Membership	Value Range
Top Panel Temperature (X_1)	Low	≤ 25°C
	Medium	25°C < T ≤ 35°C
	High	> 35°C
Bottom Panel Temperature (X_2)	Low	≤ 25°C
	Medium	25°C < T ≤ 35°C
	High	> 35°C
Air Temperature (X_3)	Low	≤ 25°C
	Medium	25°C < T ≤ 35°C
	High	> 35°C
Rain (X_4)	Rain	1
	No Rain	0
Solar Radiation (X_5)	Low	≤ 10 W/m²
	Medium	10 < W/m² ≤ 100 W/m²
	High	> 100 W/m²
Wind Speed (X_6)	Low	≤ 1 m/s
	Medium	1 < m/s ≤ 3 m/s
	High	> 3 m/s
Power Output Panel 1 (P_1) & Power Output Panel 2 (P_2)	Low	≤ 50 Watt
	Medium	50 < Watt ≤ 100 Watt
	High	> 100 Watt

The comparison graph between actual data and the multiple linear regression (MLR) model predictions illustrated the relationship between observed power output values and the predicted values generated by the model. The first graph presented the actual data for P_1 (x-axis) against the predicted P_1 values (y-axis), where the blue scatter points were closely aligned with the dashed diagonal line (y = x). This pattern indicated that the model had achieved high accuracy, with minimal error in predicting P_1. Meanwhile, the second graph compared actual P_2 data (x-axis) with its predicted values (y-axis), where the green scatter points appeared more dispersed, though they still largely followed the y = x diagonal line. The visualizations provided insight into the prediction accuracy and reliability of the MLR model is depicted in Fig. 4.

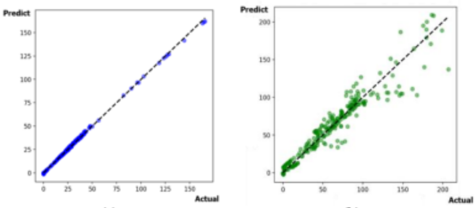

Fig. 4. Comparison of actual data and MLR model predictions for (a) panel P1 (b) panel P2

In a photovoltaic system, the value of the battery charging status (P3) functioned to regulate the battery charging level by considering various environmental factors and the operational conditions of the solar panels. This process used fuzzy logic, which enabled the system to dynamically adjust charging decisions based on input values that were not always precise or binary. Fuzzy logic worked by translating environmental variables such as temperature, solar radiation, wind speed, and rainfall into linguistic categories like low, medium, or high. Then, the system applied fuzzy rules in the form of IF-THEN statements, which determined P3 based on the combination of existing variables and represented through pseudocode, as shown in Fig. 5.

Algorithm 1: Decision Rule for PV Fault Detection

```
BEGIN
| INPUT P1, P2, X4, X1, X2, X3, X5, X6

    IF P1 == "low" AND P2 == "high" AND X4 == "no" AND X1
    == "high" AND X2 == "high" AND X3 == "high" AND X5
    == "high" AND X6 == "medium" THEN
    P3 = "Optimal Charging"
    END IF

    ...

    IF P1 == "medium" AND P2 == "medium" AND X4 == "no"
    AND X1 == "medium" AND X2 == "high" AND X3 ==
    "medium" AND X5 == "high" AND X6 == "medium" THEN
    P3 = "Optimal Charging"
    END IF

    IF P1 == "high" AND P2 == "high" AND X4 == "no" AND
    X1 == "high" AND X2 == "high" AND X3 == "high" AND
    X5 == "medium" AND X6 == "high" THEN
    P3 = "Optimal Charging"
    END IF

| DISPLAY "Charging Status: ", P3
END
```

Fig. 5. Decision rule for photovoltaic fault detection

. To understand P3 operated in the photovoltaic system, a logical representation was required to illustrate the relationship between input and output variables based on the defined fuzzy rules. Pseudocode could be used to illustrate how environmental variables such as panel power (P1, P2), rainfall (X4), panel temperature (X1, X2), air temperature (X3), solar radiation (X5), and wind speed (X6) interacted in determining the charging status (P3). Each observed variable combination was processed using IF-THEN rules. With the application of fuzzy rules, the system was able to optimize charging when environmental conditions were favorable, adjust the charging mode in response to external disturbances such as rain, and delay or reduce charging to prevent overheating if the panel temperature became too high.

Based on the applied rules, the fuzzy inference system output in fault detection for photovoltaic operations was categorized into four main conditions. The "optimal charging" condition occurred when environmental conditions supported maximum charging, such as high solar radiation, panel temperature within a safe range, and sufficient wind speed to maintain panel temperature stability. The "adjusted charging" condition was applied when external factors influenced the charging process, such as rain, where the system adjusted the charging mode to remain efficient and safe. The "charging delay condition was implemented when panel temperature was too high, potentially causing overheating, leading the system to automatically delay charging to prevent component damage. The "fault alert" condition was triggered when the system detected issues that could cause malfunctions or damage, such as high panel temperature but low solar radiation, which could indicate problems with the panel or electrical system.

In the defuzzification process, the input used was the fuzzy set obtained from the composition of fuzzy rules. This process aimed to determine a crisp value that represented the system output based on the distribution of membership degrees from the various rules that had been previously applied. One of the most commonly used defuzzification methods was the Center of Gravity (COG), where the output value was obtained by finding the central average of all values within the given range. This method calculated the balance point of the fuzzy membership distribution, ensuring that the final result reflected the most representative value based on the applied fuzzy rules.

If the fuzzy inference system generated membership values for multiple output categories such as Optimal Charging, Adjusted Charging, and Charging Delay, then the defuzzification process determined a crisp value among these categories based on their membership weights. Thus, defuzzification enabled the system to translate fuzzy results into concrete actions, such as determining the charging level or detecting potential errors in the photovoltaic system. The structured output in the Arduino Command Line Interface (CLI) environment provided a clear representation of how the fuzzy-based decision support system (DSS) functioned in real-time fault detection is presented in Fig. 6.

```
==================================================
              DSS FAULT DETECTION
==================================================

Enter value for Top Panel Temperature (X1): 39.99
39.99
Enter value for Bottom Panel Temperature (X2):
40.00
40.00
Enter value for Air Temperature (X3): 40.00
40.00
Is it Raining? (1 = Yes, 0 = No) (X4): 0
0
Enter value for Solar Radiation (X5): 500.00
500.00
Enter value for Wind Speed (X6): 4.03
4.03

--------------------------------------------------
PREDICTION: FUZZY-BASED MULTIPLE LINEAR REGRESSION
--------------------------------------------------
Predicted MLR Value for P1: 53.4406
Predicted MLR Value for P2: 151.7050
Fuzzy Category for P1: Medium
Fuzzy Category for P2: High

--------------------------------------------------
                CHARGING STATUS
--------------------------------------------------
P3 Status: FAULT ALERT

** WARNING **
Please check the **panel condition, environmental
factors, and system configuration** for possible
issues.
```

Fig. 6. Output of Arduino CLI for fault detection

Fuzzy inference was a rule-based reasoning process used to determine the output based on input variables that had been classified into membership categories. In the fault detection system for IoT-based photovoltaic operations, the fuzzy inference method was applied to link input variables with the charging level and potential system disturbances based on environmental and operational conditions of the solar panels. The method used for fuzzy inference was the MIN-MAX method. Once all propositions had been evaluated, the output contained a fuzzy set that reflected the contribution of each proposition, as shown in Fig. 7.

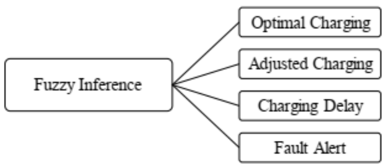

Fig. 7. Fuzzy inference

The output generated from the Arduino Command Line Interface (CLI) code represented the fault detection process in an IoT-based photovoltaic system using a fuzzy inference model and multiple linear regression (MLR). The system prompted the user to input environmental parameters, including top panel temperature (X_1), bottom panel temperature (X_2), air temperature (X_3), rainfall status (X_4), solar radiation (X_5), and wind speed (X_6). Based on these inputs, the system computed predicted power values (P_1 and P_2) using the MLR model and classified them into fuzzy categories such as Low, Medium, or High. The final step involved evaluating the charging status (P3) using predefined fuzzy logic rules. If an anomaly was detected, the system triggered a Fault Alert, indicating a potential operational issue within the photovoltaic system. The warning message advised further inspection of panel conditions, environmental factors, and system configurations to prevent potential failures or inefficiencies.

V. CONCLUSIONS

This research successfully developed and implemented a Fault Detection Model for photovoltaic (PV) systems in remote areas, utilizing the Fuzzy-Based Multiple Linear Regression (FMLR) approach. The model demonstrated its potential to address the challenges of monitoring PV systems in regions with limited access to conventional power grids and technical resources. By integrating environmental parameters such as solar radiation, temperature, wind speed, and rainfall, along with PV system parameters like panel voltage, current, battery voltage, and inverter performance, the system effectively tracked and evaluated the operational conditions of the photovoltaic system. The system was successfully deployed in Pandan Arang Village, Kandis District, Ogan Ilir Regency, South Sumatera, Indonesia, providing a reliable and sustainable solution for enhancing the efficiency of renewable energy sources in isolated communities.

Data collection and preprocessing were carefully executed to ensure the quality and accuracy of the data, with anomalies removed, normalization applied, and data categorized based on operational conditions. The MLR model was used to predict the output power of the PV system, while fuzzy logic enabled the handling of uncertainties in data, offering greater flexibility in decision-making. The system utilized fuzzy rules to determine the charging status (P3), categorizing it into Optimal Charging, Adjusted Charging, Charging Delay, or Fault Alert, ensuring adaptive and responsive fault detection. The developed model was tested using real-time data, and its performance was validated against manual inspections, demonstrating its high accuracy and effectiveness in fault detection.

Future research focused on further validating the proposed fault detection model by conducting long-term field studies in various geographical regions with different climatic conditions. This approach helped assess the model's robustness and adaptability in diverse environments. Additionally, the integration of advanced machine learning techniques, such as deep learning, was explored to improve the model's predictive accuracy and real-time fault detection capabilities. Future studies also investigated the optimization of energy storage and grid integration in remote PV systems to enhance the overall efficiency and sustainability of renewable energy solutions.

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Lampiran 2 - Publikasi Jurnal BEEI (Q3)

Model Decision Support System for Fault Detection in Photovoltaic System in Remote Village Area

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ABSTRACT

This study developed a fault detection and monitoring system for photovoltaic (PV) systems based on the Internet of Things (IoT), implemented in remote areas, specifically in Pandan Arang Village, Kandis District, Ogan Ilir Regency. The PV system was equipped with various sensors, such as the DHT-22, PZEM-017, BH1750, and DS18B20, to monitor essential environmental and PV system parameters, including temperature, humidity, wind speed, light intensity, and electrical load. The data collected by these sensors was transmitted via wireless connections to the Adafruit cloud server for real-time monitoring and stored in a data logger for backup and further analysis. The system used a Multiple Linear Regression (MLR) prediction model to estimate the power output of the PV panels based on environmental and PV system variables. The power output prediction models for panel 1 (P1) and panel 2 (P2) were generated through MLR equations that integrated various parameters such as panel temperature, air temperature, solar radiation, and wind speed. The MLR prediction results were further analyzed using Fuzzy Logic (FL) to address uncertainties caused by changing environmental conditions and to provide battery charging recommendations and detect potential system faults, such as excessively high or low panel temperatures. The findings showed that the integration of IoT, MLR, and FL systems could effectively detect faults in PV system operations in remote areas. The system successfully predicted PV system performance and automatically detected faults based on data collected from various environmental and PV system sensors using an IoT-based data logger, continuously, even in infrastructure-limited conditions.

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1. INTRODUCTION

A photovoltaic (PV) system is an electricity generation system that converts energy from solar radiation into electricity through solar cells or photovoltaic cells. The higher the solar radiation that strikes the photovoltaic cells, the higher the electricity output generated. Generally, PV systems can be classified based on their operating mode, installation location, and system design. The operating modes are divided into two types: on-grid (connected to the electrical grid) and off-grid. The installation positions of PV systems are divided into three types: ground-mounted (installed on the ground surface), rooftop (installed on top of or integrated with the roof), and floating [1]–[3].

The solar power generation system and its components are used as objects in a Decision Support System (DSS) to assess the performance and reliability of the system. Data inputs are gathered through current, voltage, and temperature sensors placed on the PV system components. These sensors are connected through the Internet of Things (IoT), resulting in multivariable outputs. The definition of a Decision Support System (DSS) is a set of models based on procedures for processing data and evaluations to assist in decision-making and achieving goals [4]–[6].

The PV system consists of photovoltaic modules, batteries, a charge controller, and an inverter. The photovoltaic module is a device that converts solar thermal energy into electrical energy. There are seven types of photovoltaic materials commonly used, namely: Monocrystalline Silicon (mono-Si), Multicrystalline Silicon (multi-Si), Ribbon Silicon (ribbon-Si), Cadmium Telluride (CdTe), Copper Indium Gallium Diselenide (CIGS), Amorphous Thin-Film Silicon (a-Si, TF-Si), and Gallium Arsenide (GaAs). The battery is an energy source that can convert the chemical energy stored within it into electrical energy that can be used by electronic devices. Each battery consists of a positive terminal (cathode), a negative terminal (anode), and an electrolyte that functions as a conductor. The charge controller is an electronic device used to regulate the direct current (DC) flowing into the battery and the current drawn from the battery to the load. The solar charge controller manages overcharging (excess charging when the battery is full) and excess voltage from the PV system. The inverter supplies DC to AC current and also works to convert DC voltage into AC current. The inverter uses Pulse Width Modulation (PWM) circuitry in the process of converting DC voltage into AC voltage[7]–[9].

The components of the Decision Support System (DSS) manage input data from sensors, which are stored in the system's database with the help of computer software. The sensors used include voltage sensors, current sensors, and temperature sensors. The voltage sensor uses a voltage transformer to step down the voltage from 220V AC to 5V AC, which is then rectified using a diode bridge to convert the AC voltage to DC voltage. This is filtered using a capacitor and passed through a voltage divider circuit to lower the voltage, ensuring that the output voltage does not exceed 5V DC, which then serves as input to the microcontroller. The current sensor uses the ACS712, a current sensor that handles overcurrent conditions with devices up to 5 times the required current. The conductive terminals are electrically isolated from the signal cable pins (pin 5 to pin 8), allowing the ACS712 to be used without requiring electrical isolation. The temperature sensor utilizes the BH1750 digital light sensor. This sensor can measure light levels without requiring additional calculations. The output data from this sensor is directly in lux (Lx) units [10]–[12].

The sensors used in the PV system are integrated with the Arduino UNO microcontroller, an open-source hardware device. The Arduino board is based on the Atmega328 microcontroller and features 14 digital input/output pins, with 6 pins capable of being used as PWM outputs, and 6 analog input pins. It also includes a 16 MHz ceramic resonator, USB connectivity, a power jack, an ICSP header, and a reset button. The Arduino UNO is connected to a data logger shield, which functions as an Internet of Things (IoT) device for storing information on a Secure Digital (SD) card. This system enables automatic data collection and monitoring, allowing for the archiving or analysis of data for further evaluation [13], [14].

The use of monitoring systems in PV installations can optimize performance by obtaining indicator data regarding the operational status. Additionally, these monitoring systems and tools are essential for data collection, analysis, comparison, identification, and the detection of faults occurring in the PV system. The PV monitoring system works by collecting data about the operational conditions, enabling the detection of faults and failures that may reduce the system's performance and prevent it from operating optimally. [15], [16],

Several studies have been conducted on PV systems, particularly focusing on the use of Decision Support Systems (DSS) for fault detection in photovoltaic systems based on the Internet of Things (IoT). López-Vargas et al. (2019) utilized Arduino Uno to monitor current, voltage, solar radiation, and temperature in photovoltaic systems, with the data being monitored in real-time via ThingSpeak. Additionally, they used a data logger for continuous analysis [17]. Pereira et al. (2019) also used the PIC18Fxx5x microcontroller and Raspberry Pi to monitor similar parameters, transmitting the data wirelessly to a web platform for real-time monitoring [18]. Paredes-Parra et al. (2019) used Arduino Uno and the RFM95W LoRa module to transmit monitoring data, including DC current, voltage, DC power, and solar radiation, to a web platform. They leveraged LoRa technology for real-time data management [19]. Cheragee et al. (2021) applied Arduino Uno and NodeMCU ESP8266 to monitor PV parameters in a rooftop-installed system, using ThingSpeak to detect both uniform and non-uniform system conditions [20].

The novelty of this research lies in the application of a combination of methods for fault detection in photovoltaic (PV) systems in remote rural areas, using various techniques such as Fuzzy Logic, Multiple Linear Regression (MLR), and the Internet of Things (IoT). Previous studies, such as those conducted by López-Vargas et al. (2019), Pereira et al. (2019), and Paredes-Parra et al. (2019), have utilized IoT to monitor various parameters of PV systems in real-time. However, they have not addressed fault detection or fuzzy logic for classifying and analyzing faults in PV panels [17]–[19].

Li et al. (2017) and Wu et al. (2017) have applied fault detection techniques in PV systems using methods such as extreme learning machine (ELM) and radial basis function-extreme learning machine (RBF-

ELM). While ELM and RBF-ELM offer advantages in terms of accuracy and detection speed, especially in analyzing and classifying faults in photovoltaic (PV) systems, they have not yet been applied in remote areas. The need for sufficient infrastructure to support the training and operational processes of these models requires high-performance hardware, such as servers or devices with GPUs, which may be difficult to access in remote regions. Furthermore, ELM and RBF-ELM rely on large training datasets to achieve accurate results, which may not be available in remote areas with limited historical data [22], [23].

Aragon et al. (2022) used the ordered weighted averaging (OWA) method, which requires the accurate determination of weights for input parameters. For PV systems in remote areas, selecting the correct weights can be challenging without sufficient historical data or adequate knowledge about the priorities and relationships between different variables. Errors in weight assignment may lead to suboptimal decisions or inaccurate fault detection [26].

This research will use Multiple Linear Regression (MLR) because it allows for the analysis of relationships between multiple variables, such as current, voltage, and power in a photovoltaic (PV) system, while considering environmental factors such as solar radiation and temperature. By using MLR, the system can identify faults in PV components that may affect system performance. The use of MLR is suitable for areas with limited infrastructure because it requires fewer computational resources compared to more complex machine learning methods, making it more appropriate for locations with limited infrastructure and access to hardware. MLR also requires less historical data to generate a valid model, which is highly relevant given the challenges of data collection in remote areas [27]. In addition, this research will use a data logger to store data continuously, as applied by Cheragee et al. (2021) and Rouibah et al. (2021), allowing for long-term analysis to automatically identify faults in PV panels, batteries, and inverters [20], [21].

Based on the background above, this research aims to develop a monitoring and fault detection system for photovoltaic (PV) systems based on the Internet of Things (IoT) in remote areas, using Multiple Linear Regression (MLR) and Fuzzy Logic (FL). The system will utilize a data logger to continuously record and store data from various parameters affecting the performance of the PV system, such as the upper panel temperature (X_1), lower panel temperature (X_2), air temperature (X_3), rainfall (X_4), solar radiation (X_5), and wind speed (X_6). These parameters will be used to predict and detect potential faults or performance degradation in the system, particularly in the Power Output of Panel 1 (P_1) and Power Output of Panel 2 (P_2).

The Multiple Linear Regression (MLR) method will be used to analyze the linear relationship between these parameters and the power output of the PV panels. The MLR method can identify the contribution of each variable to the panel's power production and develop a predictive model that can be used to project system performance based on environmental conditions and system parameters. MLR is chosen because it is relatively simpler and requires fewer computational resources compared to machine learning methods, and it is effective in handling the relationships between multiple interconnected variables [28], [29].

In photovoltaic (PV) systems in remote areas, the components to be analyzed include PV panels, panel temperature, environmental parameters such as solar radiation, air temperature, wind speed, rainfall, batteries, inverters, and the IoT-based monitoring system along with the data logger. In this context, the application of Fuzzy Logic (FL) is crucial for handling uncertainty and fluctuations in these variables, such as temperature, which can affect the efficiency of the PV panels, fluctuations in solar radiation that are difficult to predict, and the frequently changing environmental conditions in remote areas. FL can also be used to analyze abnormalities in batteries and inverters, as well as handle incomplete or missing data due to network disturbances. With its ability to manage uncertainty and changing conditions, FL enables the PV system to operate optimally even in areas with extreme environmental challenges, such as air pollution, natural disasters, or remote locations with limited infrastructure [30]. With the support of a data logger, data from various sensors installed on the PV system will be recorded and stored continuously. The data logger enables more detailed and long-term monitoring, providing a more accurate picture of the system's performance over time. This collected data will be used to train the MLR and FL models, providing fault detection analysis for the PV system.

2. METHOD

This research consists of several stages to achieve the main objective, which is the development of a fault detection system for photovoltaic (PV) systems based on the Internet of Things (IoT) in remote areas. The first stage is the Literature Review and Problem Identification, which aims to review previous studies related to PV technology and fault detection, as well as identify the issues that need to be addressed. In the Design and Implementation of the PV System stage, the PV system is designed and implemented, considering various components and configurations suitable for the needs in remote areas. The next stage is Data Collection and Preprocessing, where data from the sensors installed on the PV system is collected and processed to ensure the quality of the data for further analysis. Once the data is collected, the Fault Detection Model Development stage is conducted to develop the fault detection model using the Multiple Linear

Regression (MLR) and Fuzzy Logic (FL) approaches to predict and classify the conditions of the PV system, as shown in Fig. 1.

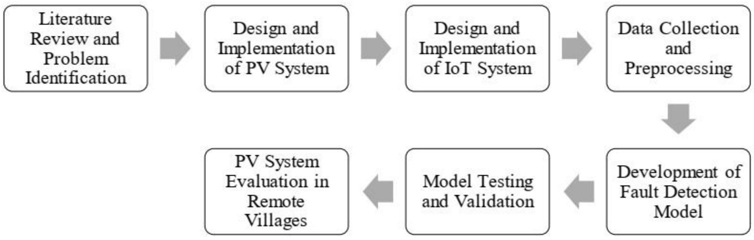


Figure 1. Research phase

The research conducted uses an experimental method by implementing a solar power plant (PLTS) integrated with a monitoring system, diagnosis, prediction, and DSS fault detection. The research is located in Pandan Arang Village, Kandis District, Ogan Ilir Regency.The photovoltaic panel components in the PV system for this study consist of several solar modules installed to capture solar energy and convert it into DC (direct current) electricity. The energy generated by these solar panels is then routed through a protective system, which includes a Miniature Circuit Breaker (MCB), to protect the system from overcurrent. The DC current then enters the Solar Charge Controller (SCC), which regulates the flow of electricity to ensure that the battery is safely charged and prevents overcharging or damage. The energy stored in the battery is used to supply power to the inverter, which then converts the DC energy into AC (alternating current) energy for use by loads, such as water pumps in this system. The components used in the PV system are shown in Figure 2.

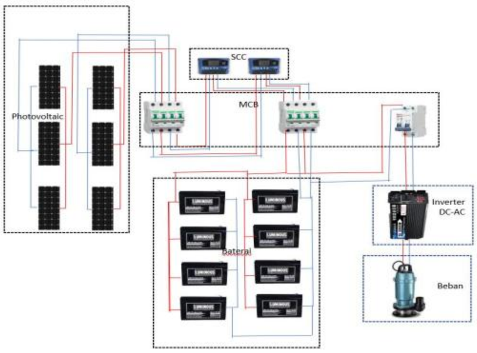
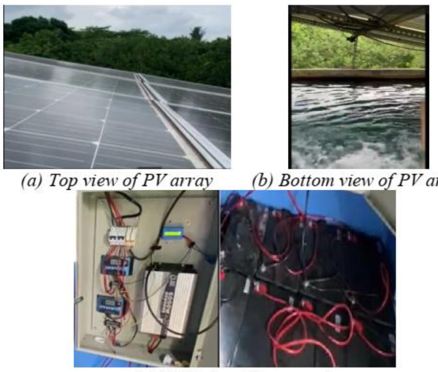


Figure 2. Design of PV System Components

3. RESULTS AND DISCUSSION

The architecture of the photovoltaic (PV) system designed for deployment in remote areas begins with the identification of the main components required for the system. Based on the site survey results, the required PV components include 6 solar panels with a capacity of 200 WP each. To regulate the flow of current and protect the system, two units of Solar Charge Controllers (SCC) with a capacity of 12 V 60 A are needed, as well as 8 units of 12 V 100 Ah batteries to store the energy generated by the solar panels. The system is also equipped with a single 12 V 6000 WP inverter, which is used to convert direct current (DC) to alternating current (AC), necessary to operate equipment such as water pumps.

The solar panels are mounted on the roof of the building and connected in parallel configuration to ensure even power distribution. The system is equipped with a Miniature Circuit Breaker (MCB), which acts as protection against potential disturbances or overloads. From the solar panels, the current flows through the MCB and into the Solar Charge Controller (SCC), which regulates the battery charging by adjusting the voltage according to the capacity of the batteries used. Once the batteries are charged, the energy is transmitted to the inverter to be converted into AC power, which is then used to drive the water pump. The pump is also protected by an MCB to prevent damage from overcurrent. This process of regulating and distributing power ensures the optimal efficiency of the PV system in generating and using renewable energy, as shown in Figure 3.



(a) Top view of PV array *(b) Bottom view of PV array*

(c) PV System Components

Figure 3. Implementation of the PV System

The implementation of the Internet of Things (IoT) in the photovoltaic (PV) system is carried out to monitor the system's performance in real-time using 10 integrated sensors. Five sensors are used to monitor environmental parameters, while the other five sensors monitor the PV system parameters. The environmental parameters monitored include wind speed, light intensity, rainfall, panel temperature, and air temperature. Specifically, for panel temperature, there are two measurements: one for the top side and one for the bottom side of the panel, providing more accurate data on the solar panel's condition.

On the PV system side, the monitored parameters include variables related to PV panels, solar charge controller (SCC), batteries, and load. The PV variables consist of three PV panels, each with two parts connected in parallel configuration. The stored data includes DC current and voltage, represented by entities Pzem1 and Pzem2. The SCC monitors the charge data entering the battery, with entity Pzem3 storing data on the DC current and voltage of the charge. Furthermore, the battery variable monitors the current and voltage during the discharge process, which is connected to the inverter and stored in entity Pzem4. The load variable measures the output of the inverter in the form of AC current and voltage, stored in entity Pzem5.

The data collected from these sensors is stored in a format accessible through a website and can be downloaded in CSV and JSON formats. Thus, the developed IoT system allows for efficient and accurate monitoring of the operational conditions of the PV system, providing users with easy access to and analysis of the stored data. The IoT implementation also includes the use of a data logger and a 20x4 LCD display to show the data directly, providing clear visualization of the system's performance at any given time. The IoT implementation in the PV system is illustrated in Figure 4.

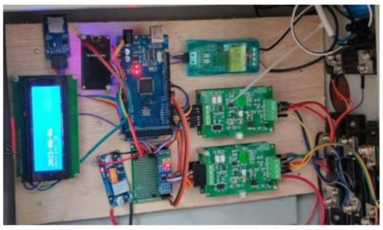


Figure 4. Implementation of IoT in the PV System

The relationship between the DSS model and the PV system is related to the data used from sensor components such as WindSensor, LightSensor, RainSensor, TemperatureSensor, and PowerSensor, which are processed by the Arduino Mega. This data is stored in the SSD data logger and sent to the Cloud for real-time monitoring. The predicted power results are used in the fuzzy logic system, which involves fuzzification, fuzzy rule formation, inference, and defuzzification to determine battery charging decisions, as shown in Figure 5.

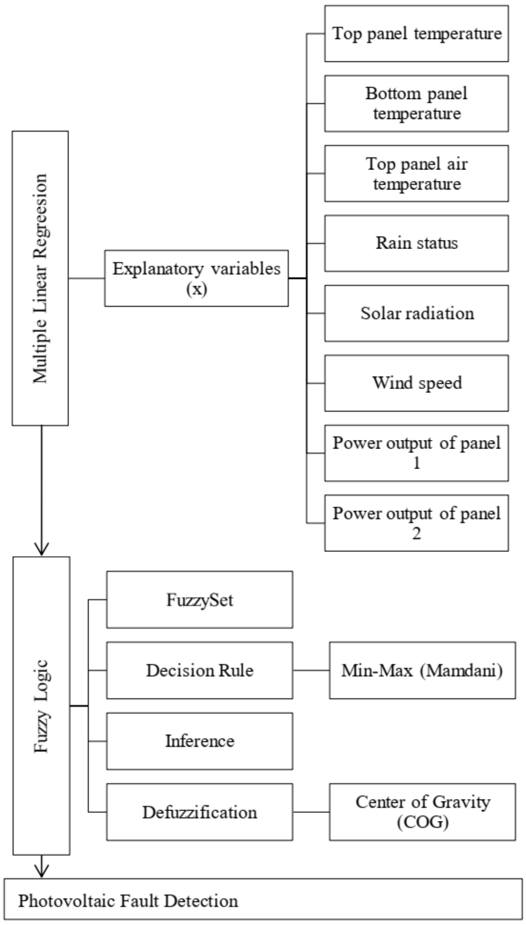


Figure 5. DSS Model Based on FL and MLP

The DSS model based on Fuzzy Logic (FL) and Multiple Linear Regression (MLR) for the PV system is used to optimize energy management in the solar panel system. In the first stage, this model uses MLR to predict the output power of the solar panels. MLR combines several explanatory variables, such as the upper panel temperature, lower panel temperature, air temperature, rain status, solar radiation, and wind speed, to calculate the output power from two PV panels (P_1 and P_2). The predicted results are then used to determine battery charging decisions, which are further processed using Fuzzy Logic (FL).

Fuzzy Logic in this model serves to process uncertainty within the system by converting uncertain or linguistic input data into precise decisions. FuzzySets are used to define categories such as low, medium, or high for input variables like temperature and solar radiation. Then, Decision Rules are generated using a Min-

Max (Mamdani) approach to determine the battery charging level based on input variables. Inference is then used to combine these fuzzy rules and determine an interim output, which is finally converted into a more precise value through the Defuzzification process using the Center of Gravity (COG) method. In this way, the DSS based on FL and MLR can efficiently provide optimal battery charging recommendations based on environmental conditions and the detected power of the PV system.

In the monitoring and performance prediction system for photovoltaic (PV) systems, several environmental and system variables are used to estimate the output power of the solar panels. These variables include: X_1 as the temperature on the upper panel, X_2 as the temperature on the lower panel, and X_3 as the temperature on the upper panel, which affect the energy conversion efficiency of the solar panels. X_4 represents the rain status (yes/no), which can influence the amount of solar radiation the panel receives, while X_5 represents the detected solar radiation, a key factor in solar energy production. X_6 is the wind speed, which plays an important role in cooling the panels and preventing overheating. Based on these variables, P_1 and P_2 are the output powers produced by panels 1 and 2, which are calculated using multiple linear regression and fuzzy logic to provide power estimates based on the current environmental and system conditions. Using the MLR formula, the model for the output power of Panel 1 and Panel 2 can be expressed as:

P1: -1.0389 + 0.1656 * X1 + -0.0754 * X2 + -0.0688 * X3 + 0.4500 * X4 + -0.0025 * X5 + 13.6189 * X6

P2: -55.9447 + 0.6757 * X1 + 5.0193 * X2 + -3.5212 * X3 + -0.9017 * X4 + 0.2040 * X5 + 4.6400 * X6

Based on the calculations above, a comparison is made between the actual data and the predictions of the MLR model, illustrating the relationship between the observed output power values and those predicted by the model. The first graph shows the actual data for P_1 (x-axis) compared with the predicted P_1 values (y-axis), where the data points, shown in blue, are very close to the dashed diagonal line (y = x). This pattern indicates that the model has achieved high accuracy, with minimal error in predicting P_1. Meanwhile, the second graph compares the actual data for P_2 (x-axis) with the predicted values (y-axis), where the data points, shown in green, appear more scattered, although most still follow the diagonal line y = x. The visualization of the MLR model predictions is depicted in Figure 6.

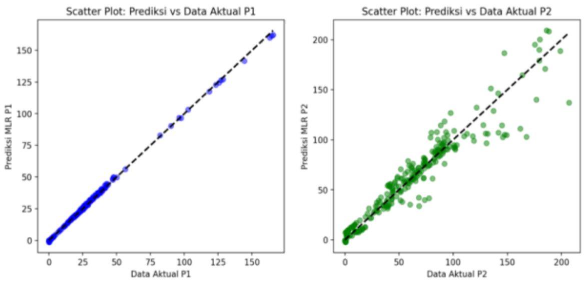


Figure 6. Comparison of Actual Data and MLR Model Predictions

The fuzzy rules for predicting the output Daya_Panel1_P1 and Daya_Panel2_P2, along with other input data (such as Temperatur_Panel_Atas, Temperatur_Panel_Bawah, Suhu_Udara, Hujan, Radiasi_Matahari, and Kecepatan_Angin), involve several key steps. First, the fuzzy sets for the variables Daya_Panel1_P1 and the charging variable charging_P3 are defined. Then, fuzzy rules are formulated that link Daya_Panel1_P1 and other input variables to the output charging_P3. The predicted results from the MLR model for P_1 and P_2 are then classified into fuzzy categories for the predictions of P_1 and P_2 (Low, Medium, High), as shown in Figure 5.6. This classification helps in providing a clear understanding of the system's performance in terms of battery charging and panel efficiency based on various environmental and system parameters in Figure 7.

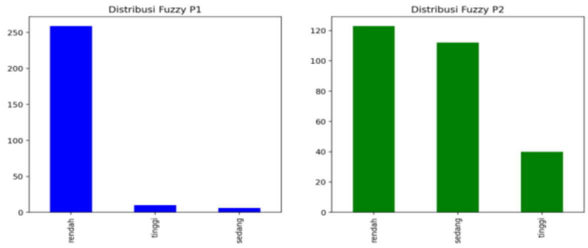


Figure 7. Fuzzy Classification for P1 and P2

The *decision support system* (DSS) for fault detection in photovoltaic systems uses input data from the Multiple Linear Regression (MLR) model. The prediction results from the MLR model are used as input data for the Fuzzy Logic (FL) model. The data, including Temperatur_Panel_Atas (X1), Temperatur_Panel_Bawah (X2), Suhu_Udara (X3), Hujan (X4), Radiasi_Matahari (X5), and Kecepatan_Angin (X6), are input into the DSS criteria. These results are then used as input data for the Fuzzy Logic model, enabling the system to make more accurate predictions and decisions regarding fault detection and performance optimization of the photovoltaic system.

4. CONCLUSION

This research successfully developed an IoT-based PV system in Pandan Arang Village, Kandis District, Ogan Ilir Regency. The system is equipped with various sensors, such as the DHT-22, PZEM-017, BH1750, and DS18B20, to monitor important environmental and system parameters including temperature, humidity, wind speed, light intensity, and electrical load. These sensors were integrated with the Adafruit platform to enable data communication between the server and data logger, facilitating the collection of research data. The system integrated data from various environmental sensors and PV components to monitor the performance of solar panels, batteries, and inverters in real-time. Using the Multiple Linear Regression (MLR) model, the system predicted the output power of the solar panels based on environmental variables and the PV system. The prediction models generated equations for Panel 1 (P1) and Panel 2 (P2), with variables such as upper and lower panel temperatures, air temperature at the upper panel, rain status, solar radiation, and wind speed analyzed to determine the output power of the panels. These results were then analyzed using Fuzzy Logic (FL) to account for changing environmental conditions and system behavior. FL classified the system's conditions based on the MLR predictions and input parameters like unstable weather or temperature. The fuzzification, inference, and defuzzification processes in FL successfully provided decision-making recommendations for battery charging and fault detection, such as identifying when panel temperatures are too high or low.

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Lampiran 3 - Publikasi Konferensi ICIMCIS (Scopus)

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A Preliminary Study of Decision Support Model of Photovoltaic for Village Area in South of Sumatera

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***Abstract*—Indonesia has a very high potential for solar energy irradiation, including in 66 countries in the sunbelt area. This can be alternative for power generation system that converts energy sources from solar radiation into electricity through solar cells or photovoltaic cells. This research goal is to develop an initial decision support model for the photovoltaic village area in South Sumatra, Indonesia. This research was conducted six months in Pandan Arang Village, Kandis District, Ogan Ilir Regency, South Sumatra. As the result, the proposed model is consisted of four sub- system, including photovoltaic system, data logger, database management and decision support system. Based on the results of experiments on solar panels with the parameters of current, voltage and light intensity, the highest value of light intensity was 1989.1 W/m2, while the voltage and current of 15.49V and current of 14.91 A were displayed through a 16x2 LCD display which served as information display in real time. The expected result in this study is an alternative fault detection PV system in the form of normal conditions, shadows, and overloads.**

Keywords*— *photovoltaic, microcontroller, decision support system, conceptual model

I. INTRODUCTION

Indonesia has a very high potential for solar energy irradiation, including in 66 countries in the sunbelt area. Utilization of solar energy by converting its rays into electrical energy through solar cells (photovoltaic or solar power plants). Based on Indonesian National Standard (SNI) 8395:2017, photovoltaic or solar power plants is a power generation system that converts energy sources from solar radiation into electricity through solar cells or photovoltaic cells. The higher the solar radiation that hits the photovoltaic cell, the higher the electrical power produced [1], [2].

PLTS components consist of a photovoltaic (PV) module, battery, charger controller, and inverter [3][4]. Seven types of PV are often used, namely, monocrystalline silicon (mono-Si, multicrystalline silicon (multi-Si), ribbon silicon (ribbon-Si), cadmium telluride (CdTe), copper indium gallium selenide solar cell (or CIGS cell, sometimes CI(G)S or CIS cell), amorphous thin-film silicon (a-Si, TF- Si), gallium arsenide (GaAs) [5]–[8]. The batteries are an energy source that can convert the stored chemical energy into electrical energy that can be used, such as electronic devices. Each battery consists of a positive terminal (cathode) and a negative terminal (anode), as well as an electrolyte that serves as a conductor [9]–[11].

A charger controller is electronic equipment used to regulate direct current, which is charged to the battery and taken from the battery to the load, solar charge controller regulates overcharging (excess charging because the battery is full) and excess voltage from the solar panel or solar cell [12]–[15]. The inverter supplies direct current (DC) to alternating current (AC) and also works to convert DC voltage into AC. Pulse Width Modulation (PWM) circuit in the process of converting DC voltage to AC voltage [15]– [17].

Solar power plants and system components are used in the decision-making system regarding system performance and reliability—input data using current, voltage, and temperature sensors placed on photovoltaics (PV) components. The installed sensors are connected to the internet of things to produce multivariable outputs [18]– [20].

A decision support system (DSS) is a collection of models based on procedures for processing data and assessments to assist in decision-making and achieve goals. The system must be simple, easy to control, and adaptable so that this understanding implicitly assumes that the system can provide problem-solving abilities for its use [21]–[23].

The decision support system (DSS) manages input data from sensors stored in the system database with the help of computer software. Such as voltage, current, and temperature sensors are used. The voltage sensor uses a voltage transformer as a voltage reducer from 220 to 5 volts AC rectified using a diode bridge to change the AC voltage to DC voltage. The filter uses a capacitor and enters a voltage divider circuit to lower the voltage. The resulting voltage is not more than 5-volt DC, so it becomes the input to the microcontroller [24]–[26].

The current sensor using ACS712 is an overcurrent sensor whose device is up to 5× the overcurrent requirement. The conductive line terminals are electrically isolated from the signal cable (pins 5 to 8). This allows ACS712 to be used without needing electrical isolation [27]–[29]. The temperature sensor uses a BH1750 sensor. This BH1750 digital light sensor can measure without having to perform

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calculations. The data output from this sensor is directly in lux (Lx) units [30], [31].

The sensors used in the photovoltaics system are integrated with the Arduino UNO microcontroller board based on Atmega328 has 14 digital input/output pins (of which six can be used as PWM outputs), six analog inputs, 16 MHz ceramic resonators, USB connection, a power jack, ICSP header, and reset button [32]–[34]. In addition, Arduino UNO is connected to a data logger shield that functions as the internet of things that functions as information storage (logging information) on the Secure Digital (SD) card, automatically collecting and recording information for data archiving or analysis purposes [35], [36].

In this context, the paper presents the implementation of a decision support system for a photovoltaic panel. The goal of the decision-based control system is to satisfying the electricity consumed in village area. The decision-making system designed will have 4 functions such as monitoring, diagnosis, prediction and decision making for photovoltaic fault detection.

II. Methodology

This research was conducted six months in Pandan Arang Village, Kandis District, Ogan Ilir Regency, South Sumatra. This research aims to develop an initial decision support model for the photovoltaic village area in South Sumatra, Indonesia. This research consists of five stages of research, as shown in the Figure 1 below.

Fig. 1. Research methdology

Based on the Figure 1 above, the first stage is the initial identification of research objectives and looking for photovoltaics parameters and decision support from the situation in the village area in South Sumatra. The second stage is to collect data in Pandan Arang Village, Kandis District, Ogan Ilir Regency, South Sumatra. The third stage is to develop an initial decision support model for the photovoltaic village area. This model was developed by adapting the rules from research by Stamatescu et al. (2017) [37]. The next step is to ensure that the hardware equipment is by the developed architecture, such as the Arduino IDE for programming, Proteus to help with simulations, and using fritzing to make it easier to assemble the pins connected to the Arduino. The last stage is displaying the results in scientific reports and publications.

III. Result And Discussion

A. Architecture

The proposed architecture is initial decision support model for the photovoltaic village area in South Sumatra, Indonesia. The model is contained of four sub-system, including photovoltaic system, data logger, database management and decision support system as depicted in Figure 2 below.

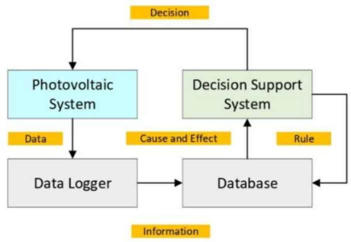

Fig. 2. Architecture of initial decision support model

1) Photovoltaic System

In a photovoltaic system, solar panels store energy from the sun. Therefore, a voltage sensor, a current sensor, and a BH1750 sensor were added. Voltage sensors, BH1750 sensors, and current sensors can measure a solar panel's voltage, current, and light intensity.

A microcontroller made by Arduino is also part of the photovoltaic system. In this design, the microcontroller is the central part of the system that controls everything else. The current and voltage sensor will send an analog signal to the microcontroller. The microcontroller will then send the signal to the information logger, using the values to make a table or graph.

The photovoltaic system is also linked to batteries, which are not usually used to store electricity. In this study, a lead acid battery model is used, which has good features and costs less than other models. The battery is made to last and work well for five years. Also, the Liquid Crystal Display (LCD) serves as an indicator or shows data from the DSS output, such as current, voltage, and light intensity. The electrical design circuit used to make solar cell monitoring using the Arduino Uno R3 microcontroller consists of several components: one solar cell, Arduino Uno microcontroller, current sensor, BH1750, voltage sensor, LCD, and information logger shield. The following Figure 3 shows the electrical design of the solar cell monitoring.

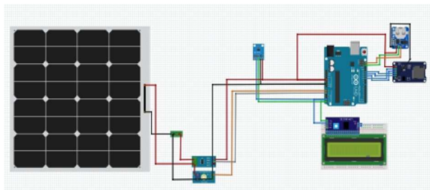

Fig. 3. Circuit design of photovoltaic system

2) Data Logger

The data logger shield stores information from the Arduino and is stored in memory card, where the information will later be viewed via Microsoft Excel.

3) Database

For the proposed system, the database is based on MySQL. It can set and store rules based on the decision algorithm and store data from sensors in the photovoltaic system with a time stamp.

4) Decision Support System

Decision support systems' purpose is to represent and process explicit knowledge. Knowledge must be procedural, consisting of a collection of methods for completing a variety of activities in order to reach a conclusion [38]–[40]. The rules in this DSS are an adaptation of rules derived from prior research. The adopted and proposed rules are as follows:

a) PCS is the consumed electricity from a rural home

b) PPP is the energy generated by photovoltaic panels.

c) PBS is the stored energy in batteries.

The following criterion must always be met by the electric network:

$$P_{PP} + P_{BS} = P_{CS} \quad (1)$$

A set of decision rules are listed in the decision table below (Table 1).

TABLE I. DECISION RULE

Rule	Condition	Decision
1	PCS > PPP	Connection to the battery power source
2	PCS < PPP	Connector for loading batteries

The decision rule above will be implemented in decision support model. There are four sections of decision support model including PV design, monitoring, data design, and DSS component as depicted in Figure 4 below.

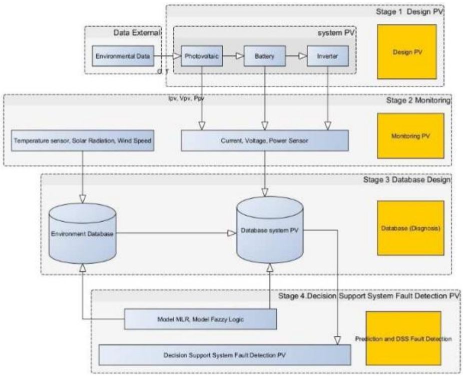

Fig. 4. Decision support model for the photovoltaic village area in South Sumatra

Stage 1 is PV design by installing PV systems such as photovoltaics, batteries, inverters, and other supporting equipment. **Stage 2** is done by designing a monitoring system using sensors. There are two data, namely: external data and PV system data. **Stage 3** is database design for creating tables to store sensors' input. There are two databases designed: the environmental database and the PV system database. **Stage 4** is the decision-making system for fault detection PV using a database component and the MLR model for predictions on the PV system, which is used as input criteria for the decision-making system for the fault detection system PV.

B. Experiment

We designed tools for experiment consists of an input section in the form of a BH1750, voltage sensor, and current sensor. Each sensor functions according to its function. BH1750 functions to read the value of light intensity, voltage, and current sensors to read voltage and current with data in the form of signals. The output block consists of a 16x2 LCD and a data logger with storage of sensor reading information and time via a memory card.

In the measurement data of voltage, current, and light intensity, data collection uses the Arduino microcontroller system. Voltage, current, and light intensity tests on solar panels were measured for 10 hours per day. The important component of tools is data logger because it is used for recording and monitoring systematically parameter values of this research. The results of the design of the data logger on the photovoltaic system based on the Arduino microcontroller produced are presented in Figure 4 below.

Fig. 5. Data logger on photovoltaic system

The data logger on the design of the voltage and current monitoring system on the Arduino microcontroller-based solar panel applies a memory card in the form of an SD card which functions to store data from the measurements made by the sensor. Monitoring the data logger results is used as input data in predicting the PV system using the MLR model. The prediction results will become the criteria for the DSS fault detection system for the PV so that two results are obtained, namely the actual fault detection data (monitoring) and the fault detection data prediction. The example of data logger result is depicted in Figure 6.

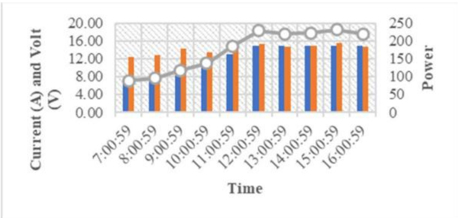

Fig. 6. Data statistics of voltage, current and power using data logger

The data above stored in this memory card uses a text-based format, which a computer can access through a text-processing program such as Notepad or WordPad. Furthermore, this data recording is parallel to the reading time variable, making accessing the reading data for different purposes easier. The script program to save and read data from data logger on an SD card can be seen Figure 7 below.

```
#include <SPI.h>
#include <SD.h>
Serial.print("Initializing SD card...");
if (!SD.begin(chipSelect)) {
 Serial.println("Card   failed,   or   not
present");
 lcd.setCursor(0,0);
 lcd.print("Card failed,!");
 // don't do anything more:
 while (1);}
Serial.println("card initialized.");
Void loop(){
  //1  menit  interval,  ,  RESULT  SCANNING
  SENSOR
  if(tm.Second>=59){
        // DELETE SECOND
  Serial.println("WRITE MEM!!");
  File dataFile = SD.open("datalog.txt", FILE_WRITE);
  if (dataFile) {
    dataFile.println(dataString);
    dataFile.close();
    Serial.println(dataString);
  }
  else {
```

Fig. 7. Codes for stroring to SD card

Then the data stored in the data logger from Arduino is stored in a MySQL-based database used. This data is then processed to make decisions based on the rules below.

```
IF Pcs > Ppp
THEN Connection to the battery
supply ELSE IF Pcs < Ppp
THEN Battery connection for loading
```

Fig. 8. Decision rule

In the process of taking this measurement data using data logger component, testing was carried out for seven days to obtain data on the accuracy and validity of the measurement. The results of this test are then presented in Table 2 below.

TABLE II. MEASUREMENT OF LIGHT INTENSITY W/M2

Time	Day						
	1	2	3	4	5	6	7
7:00:59	210.2	243.8	98.0	421.8	477.3	521.3	533.5
8:00:59	211.9	250.1	121.1	450.5	673.3	652.5	741.2
9:00:59	221.5	273.5	231.2	359.4	681.6	731.0	561.8
10:00:59	240.0	333.3	1238.3	425.1	818.3	957.2	730.2
11:00:59	255.8	415.0	1189.1	520.0	850.8	1478.3	1161.6
12:00:59	283.3	421.6	1721.4	795.8	357.5	1033.3	1091.6
13:00:59	950.8	339.1	1425.5	712.5	1454.1	977.5	1375.8
14:00:59	1593.3	332.5	1281.1	800.0	1469.1	897.5	227.5
15:00:59	521.2	497.5	704.1	541.6	1781.6	**1989.1**	63.3
16:00:59	325.4	345.8	624.2	328.3	673.3	724.1	132.5

The measurement results in Table 2 above show when testing the BH1750 sensor on the solar panel using the Arduino microcontroller to determine the input power on the solar panel. The highest light intensity value is on the sixth day, with a value of 1989.1 at 03:00 PM. This is because the weather is sweltering, while the lowest light intensity value is on the seventh day, with an intensity value of 63.3 due to rainy or dark weather. The example of light intensity is depicted in Figure 9 below.

Fig. 9. Condition of light intensity

After this test is carried out to determine the ability of the panel to absorb energy from the sun, this test uses a measuring instrument in the form of a BH1750 sensor and a solar power meter. After the measurement results are obtained, the amount of input power from the solar panel is calculated using the equation below.

$$P_{in} = I_{rad} X\ A \quad (2)$$

Fig. 10. The cross-sectional area of the panel

Whereas Pin = Power on photovoltaic (W), Irad = Intensity of sunlight (W/) and A = photovoltaic cross-sectional area ( ). The cross-sectional area is panel area that is used in this research. The panel area is depicted in Figure 10.

Based on Figure 6, the cross-sectional area of the panel then we can calculate as below.

$$A - width\ x\ height \quad (3)$$

$$A = 263\ X\ 300 = 78.900\ m^2$$

By using equation (2), we obtained result below.

$$P_{in} = I_{rad} XA \quad (4)$$

$$P_{in} = 457.5\ W/m^2 x 78.900\ m^2$$

$$P_{in} = 36.096.750\ W$$

After looking at the calculation of the input power on the panel above, it can be concluded that the higher the light intensity on the panel, the greater the power obtained. The of management process of Pin= 36.096.750 W is illustrated in Figure 11 below.

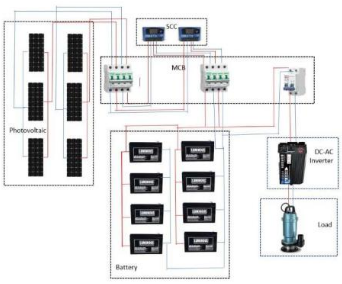

Fig. 11. Development of photovoltaic system electronic scheme

Based on Figure 11 above, photovoltaic captures sunlight and transmits DC electrical power to the solar charge controller (SCC), the power generated by the SCC is used to charge the battery with a total Pin = 36.096.750 W. In hot sun conditions, the DC electricity generated can be used directly to the load through an inverter to convert DC electricity into AC electricity. However, if the sun is cloudy, the battery's electrical power is used for workloads. If this condition occurs continuously (PCS < PPP but battery (PBS) is in low capacity), then the battery capacity is limited (drained) so that overload can occur.

IV. CONCLUSION

This research aims to develop an initial decision support model for the photovoltaic village area in South Sumatra, Indonesia. The model is contained of four sub-system, including photovoltaic system, data logger, database management and decision support system. Based on the results of experiments on solar panels with the parameters of current, voltage and light intensity, the highest value of light intensity was 1989.1 W/m2, while the voltage and current of

15.49 V and current of 14.91 A were displayed through a 16x2 LCD display which served as information display in real time. The expected result in this study is an alternative fault detection PV system in the form of normal conditions, shadows, and overloads.

The future research of this add more component of DSS. The variables of DSS will be more complex by upgrading several components such as photovoltaic panels, wind turbine, batteries and public electricity supply.

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Subject : Letter of Acceptance as Submission at ICIMCIS 2022

Jakarta, November 8th, 2022

Feby Ardianto
Universitas Muhammadiyah Palembang, Indonesia

Dear author,
Congratulation, your final manuscript submission **#1570839272** with the title **(A Conceptual Decision Support Model of Photovoltaic for Village Area in South of Sumatera)** has been ACCEPTED as part of the technical program for the 2022 International Conference on Informatics, Multimedia, Cyber and Information Systems (ICIMCIS). Hopefully, this paper will be presented (oral or online) at the conference as our technical program reports. The conference organizers and our attendees expect each and every accepted paper to be presented which contributes to the success of the event.

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Please be noticed, only registered and presented papers will proceed to IEEE explore. Upon receipt of your registration, we appreciate taking this opportunity to thank you for your participation in the 4th ICIMCIS 2022. Please do not hesitate to contact us for further information or visit our link below :

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We look forward to meeting you at the 4th ICIMCIS on November 16th – 17th , 2022 at **Virtual Conference, in Horison Grand Serpong, Indonesia.** For more info please join this WhatsApp Group:
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Sincerely,

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Chair


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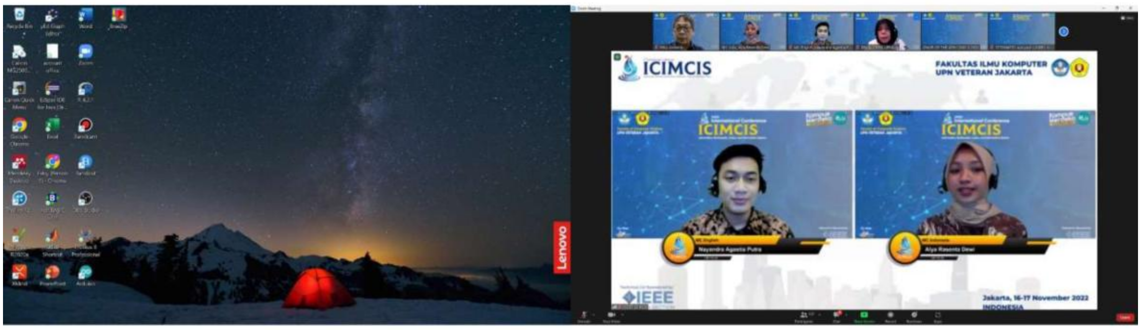
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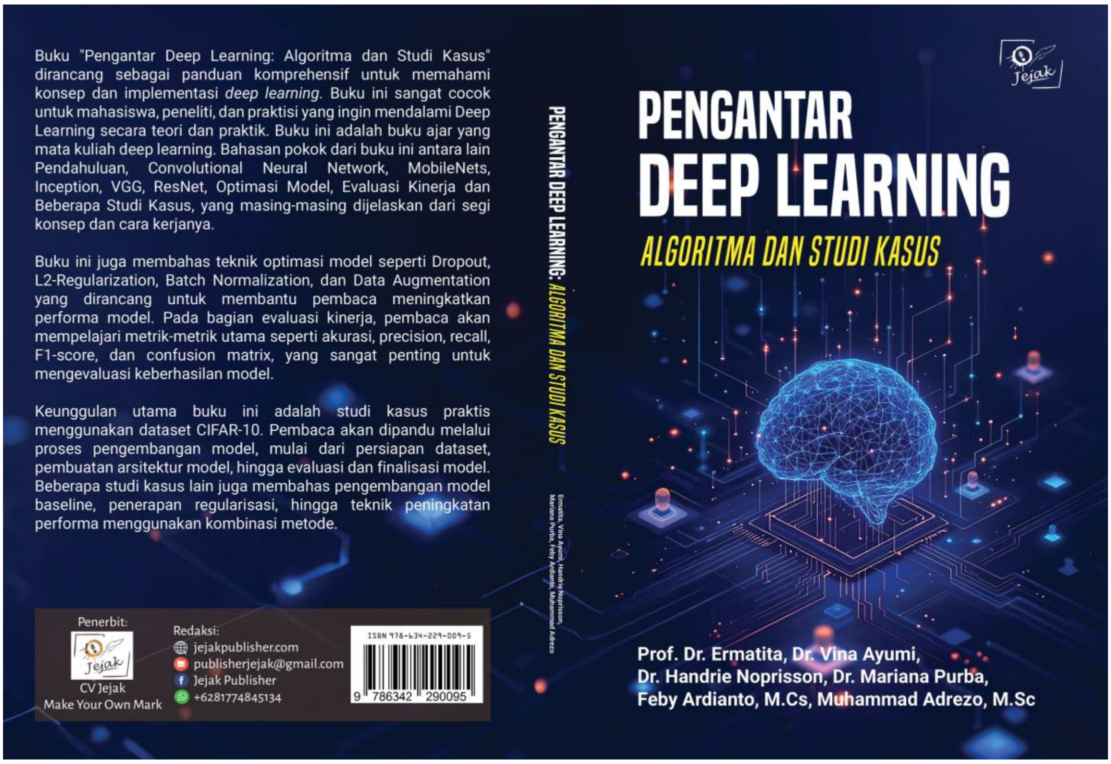
Lampiran 4 - Buku ISSN



Pengantar Deep Learning:
Algoritma dan Studi Kasus

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Dr. Handrie Noprisson, Dr. Mariana Purba,
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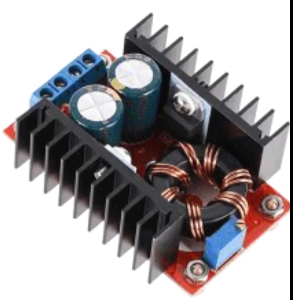
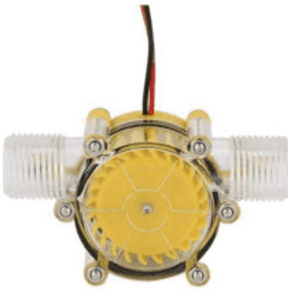
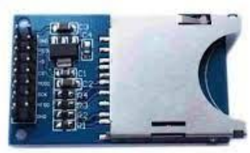
197 halaman; 15,5 x 23 cm

Lampiran 5 – Log Pengumpulan Data

No.	Tanggal	Kegiatan	Hasil	Dokumentasi
1.	30 Januari 2023	Pembelian kompoenen Low Voltage Disconnect Baterai Battery Charging Control Module XH-M609 Lithium Proteksi LVD Modul Over	melakukan pembelian kompoen melalui toko online shofee pesanan diterima pada tanggal 03 Februari 2023	
2.	30 Januari 2023	Pembelian Modul Pelindung DC6-60V Saklar Pelindung Charger Baterai Lead-acid 12V 24V 48V	melakukan pembelian kompoen melalui toko online shofee, pesanan diterima pada tanggal 04 Februari 2023	
3.	31Januari 2023	Pembelian MCB SCHNEIDER ORANGE 2A 4A 6A 10A	melakukan pembelian kompoen melalui toko online shopee pesanan diterima pada tanggal	
4.	02 Februari 2023	Pembelian box plastik	melakukan pembelian box plastik yang digunakan sebagai prototype pemapungan air untuk pompa	

5.	04 Februari 2023	Pembelian Pompa WATERPUMP 1500 LPH POMPA CELUP AQUARIUM	Melakukan pembelian pompa air yang dipergunakan untuk beban pada pembangkit listrik tenaga surya melalui toko online shopee pesanan diterima 07 Februari 2023	
6.	05 Februari 2023	Pembelian Kabel panel / solar cable visero 2250 TWIN 18m	Melakukan pembelian kabel panel solar melalui toko online shopee pesanan diterima 08 Februari 2023	
7.	05 Februari 2023	Pembuatan tiang dan dudukan panel surya menggunakan baja ringan	melakukan pembuatan tiang dan dudukan panel surya dengan menggunakan baja ringan dengan posisi box dipasang dibawah panel yang diperlukakan sebagai prototype PLTS di desa Pandan Arang. pembuatan prototype dilakukan untuk peralatan uji kendali jarak jauh (IoT) sebelum dilakukan pemasangan di lokasi PLTS roop dan floating di desa Pandan Arang	
8.	06 Februari 2023	Pembelian Boost Converter 10-32V to 12-35V Step Up Charger 150W DC-DC	melakukan pembelian Boost Converter toko online shopee pesanan diterima 08 Februari 2023 yang dipergunakan sebagai converter DC to DC 150 W inputan mini PLTHM 12 V yang diletakan pada output pompa air celup untuk hybrib energi listrik	

			PLTMH dan PLTS	
9.	06 Februari 202	Pembelian mini PLTMH 12v Pembangkit Listrik Tenaga Air Generator Hydroelectric Turbin	melakukan pembelian mini PLTMH 12v Pembangkit Listrik Tenaga Air Generator Hydroelectric melalui toko online shopee pesanan diterima 14-02-2023. dipergunakan unutk hybrib energi listrik PLTMH dan PLTS sebagai tambahan suplay energi listrik untuk pengecsaan baterai yang memanfaatkan output air pompa celup sebagai sumber	
10.	06 Februari 202	Pembelian MPPT Solar Panel Battery Regulator Charge Controll	Melakukan Pembelian Solar Panel Battery Regulator Charge Controll melalui toko online shopee pesanan diterima 10-02-2023	
11	08 Februari 2023	Pembelian Mini inverter 12V to 220v Up to 300watt max	melakukan pembelian Mini inverter 12V to 220v Up to 300 watt max melalui online shopee pesanan diterima 13-02-2023, yang dipergunakan sebagai sumber inverter 220 Vac, 300 Watt untuk sumber hybrib energi listrik PLTMH dan PLTS	
12	11 Februari 2023	Pengujian PLTS dengan menggunakan 3 Panel surya 50 WP	melakukan pengujian PLTs dengan pompa air. video dapat dilihat dengan mengklik link : https://drive.google.com/file/d/1OsInMAz0i6MZ4a-	

			tu9kfgz2Sl9bdYHem/ view?usp=sharing	
13	13 Februari 2023	Pembelian DHT22 DHT-22 AM2302 HUMIDITY & TEMPERATURE SENSOR SUHU DHT22	melakukan pembelian HUMIDITY & TEMPERATURE SENSOR SUHU DHT22 melalui toko online tokopedia. sensor yang digunakan untuk mengukur suhu dan kelembapan. Sensor ini juga dikenal sebagai AM2302. Sensor DHT22 menggunakan teknologi digital untuk mengukur suhu dan kelembapan, sehingga hasil pengukurannya lebih akurat daripada sensor analog.	
14	13 Februari 2023	Pembelian SD-MMC Card Module	melakukan pembelian SD-MMC Card Module melalui toko online tokopedia. SD-MMC Card Module adalah perangkat keras yang digunakan untuk membaca dan menulis data pada kartu SD dan MMC. Fungsi utama dari modul ini adalah untuk menyediakan antarmuka antara kartu memori dan mikrokontroler atau komputer untuk mengakses dan memanipulasi data pada kartu memori.	

15	13 Februari 2023	pembelian GY-302 Light Intensity BH1750 Module Sensor Intensitas Cahaya	melakukan pembelian GY-302 Light Intensity BH1750 Module Sensor Intensitas Cahaya melalui toko online tokopedia. sebuah sensor intensitas cahaya yang dapat mengukur tingkat kecerahan lingkungan dalam satuan lux. Sensor ini bekerja dengan menggunakan teknologi fotoelektrik yang mengubah energi cahaya menjadi sinyal listrik. nilai intensitas cahaya dapat ditampilkan pada sebuah display atau disimpan pada sebuah memori. Selain itu, sensor ini juga dapat dihubungkan dengan sebuah sistem mikrokontroler seperti Arduino untuk melakukan pengolahan data lebih lanjut.	
16	13 Februari 2023	Pembelian PZEM-017 0-300V RS485 Modbus DC Meter Current Voltage Power Energy - 50A	melakukan pembelian PZEM-017 0-300V RS485 Modbus DC Meter Current Voltage Power Energy - 50A melalui toko online tokopedia. PZEM-017 adalah perangkat yang dapat digunakan untuk mengukur konsumsi energi pada sistem listrik DC, dan dapat diintegrasikan ke dalam sistem pemantauan energi yang lebih besar melalui protokol	

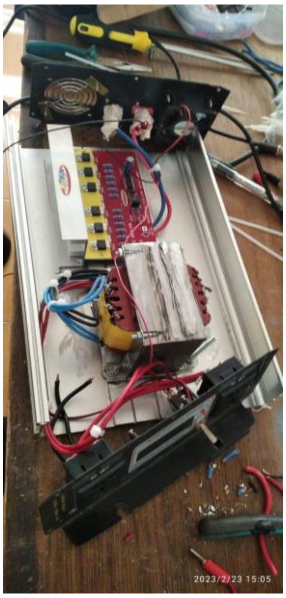
			komunikasi RS485 Modbus. perangkat metering yang digunakan untuk mengukur tegangan, arus, daya, dan energi pada sistem listrik DC. Perangkat ini dapat beroperasi pada rentang tegangan 0-300V dan arus hingga 50A.	
17	13 Februari 2023	Pembelian DS18B20 Water Proof Temperature	melakukan pembelian DS18B20 Water Proof Temperature melalui toko online tokopedia. Water Proof Temperature Sensor adalah sensor suhu digital yang dirancang untuk memberikan pembacaan suhu yang akurat dalam berbagai lingkungan. Sensor ini dilindungi dengan bahan waterproof sehingga dapat digunakan dalam lingkungan yang lembab atau basah, seperti dalam air atau di luar ruangan.	
18	13 Februari 2023	Pembelian MAX485 TTL TO RS485 CONVERTER MODULE	melakukan pembelian MAX485 TTL TO RS485 CONVERTER MODULE melalui toko online tokopedia. Modul elektronik yang berguna untuk mengubah sinyal TTL (Transistor-Transistor Logic) menjadi sinyal RS485 (Recommended Standard 485) yang lebih handal dan dapat digunakan untuk komunikasi serial	

			jarak jauh. Berikut adalah fungsi dan cara kerja MAX485 TTL to RS485 Converter Module: Fungsi: Mengubah sinyal TTL menjadi sinyal RS485, Meningkatkan jangkauan komunikasi serial antar perangkat, Mengurangi noise dan interferensi yang terjadi pada transmisi data, Meningkatkan kehandalan dan integritas data yang dikirimkan	
19	13 Februari 2023	Pembelian LCD 20x4 LCD 2004 2004A BIRU BLUE	melakukan pembelian LCD 20x4 LCD 2004 2004A BIRU BLUE melalui toko online tokopedia. LCD 20x4 (2004) adalah sebuah display atau tampilan visual yang dapat menampilkan teks dan karakter pada empat baris dan 20 kolom. Display ini biasanya digunakan pada berbagai perangkat elektronik, seperti pengukur suhu, alat ukur, dan perangkat elektronik lainnya.	
20	13 Februari 2023	Pembelian Raindrop Module Sensor Hujan Module	melakukan pembelian Raindrop Module Sensor Hujan Module melalui toko online tokopedia.Raindrop module atau modul sensor hujan adalah sebuah perangkat elektronik yang digunakan untuk	

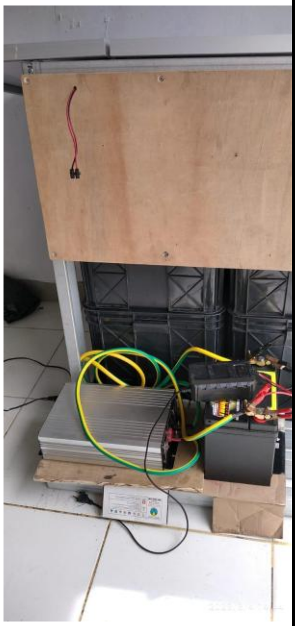
			mendeteksi keberadaan air atau hujan pada permukaan sensor. Modul ini dapat digunakan untuk mengontrol sistem irigasi, penutup jendela otomatis, atau sistem lain yang terkait dengan kelembaban atau keberadaan air. Fungsi dari modul sensor hujan adalah untuk mendeteksi apakah hujan sedang turun atau tidak. Modul ini biasanya terdiri dari dua pin atau lebih yang terhubung ke permukaan sensor, dan sebuah rangkaian elektronik yang mengolah sinyal yang diterima oleh sensor. Ketika permukaan sensor terkena air, sinyal yang diterima oleh modul akan berubah, dan modul akan memberikan output yang sesuai. Cara kerja modul sensor hujan adalah dengan memanfaatkan sifat listrik air yang dapat menghantarkan arus listrik. Ketika permukaan sensor terkena air, sinyal listrik akan mengalir melalui air dan melalui pin sensor, sehingga menghasilkan perubahan pada sinyal yang diterima oleh modul. Modul ini kemudian akan mengolah sinyal	

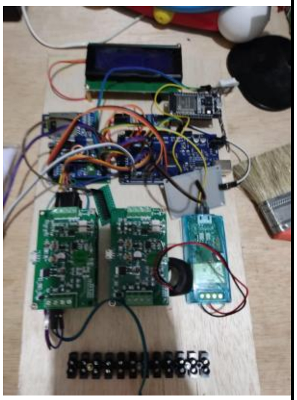
			tersebut dan memberikan output yang sesuai, misalnya dalam bentuk sinyal digital atau analog. Untuk menggunakannya, modul sensor hujan dapat dihubungkan ke mikrokontroler atau sistem elektronik lainnya, dan diatur untuk mengendalikan sistem terkait dengan kelembaban atau keberadaan air. Dalam aplikasi yang lebih kompleks, modul ini dapat digunakan bersama dengan sensor lainnya, seperti sensor suhu dan kelembaban, untuk memonitor kondisi lingkungan yang lebih lengkap.	
21	13 Februari 2023	melakukan pembelian Modul IIC I2C Serial Interface LCD 1602A 2004A	melakukan pembelian Raindrop Module Sensor Hujan Module melalui toko online tokopedia. Modul I2C Serial Interface LCD 1602A 2004A adalah modul eksternal yang digunakan untuk menampilkan karakter pada layar LCD dengan menggunakan protokol komunikasi I2C (Inter-Integrated Circuit). Modul ini memiliki fungsi untuk memudahkan proses tampilan karakter pada layar LCD, terutama dalam aplikasi mikrokontroler atau sistem embedded.	

22	13 Februari 2023	Pembelian arduino mega	melakukan pembelian arduino mega melalui toko online tokopedia. Arduino Mega adalah salah satu jenis papan pengembangan mikrokontroler yang populer digunakan dalam proyek-proyek elektronik. Papan ini menggunakan mikrokontroler ATMega2560 sebagai inti sistemnya, yang memiliki lebih banyak pin input/output (I/O) dan memori yang lebih besar dibandingkan dengan Arduino Uno. Fungsi utama dari Arduino Mega adalah untuk mengontrol dan memproses data dari berbagai sensor dan aktuator pada proyek elektronik. Papan ini dapat diprogram menggunakan bahasa pemrograman Arduino yang cukup mudah dipelajari dan digunakan. Cara kerja Arduino Mega adalah dengan memasukkan kode program melalui software Arduino IDE, yang kemudian di-upload ke papan Arduino Mega melalui koneksi USB. Setelah di-upload, program tersebut akan dijalankan oleh mikrokontroler ATMega2560, dan papan Arduino Mega	

			akan mulai mengontrol sensor dan aktuator yang terhubung ke pin input/output-nya sesuai dengan instruksi dalam program tersebut.	
23.	15 Februari 2023	Pembelian KIT INVERTER DC TO AC 220V 1000W	Melakukan pembelian KIT INVERTER DC TO AC 220V 1000W melalui toko online shopee pesanan diterima 17-02-2023, inverter dipergunakan sebagai sumber utama dari PLTS 100 WP untuk sumber energi listrik pompa celup	
24.	22 Februari 2023	Pembuatan BOX Inverter 1000 Watt	Melakukan pembuat box inverter 1000 Watt yang sumber utama dari PLTS 100 WP untuk sumber energi listrik pompa celup	
25.	23 Februari 2023	instalasi dan perakaitan inverter	melakukan instalasi dan perakitan inverter 1000 watt untuk dibebani pompa air celup	

				
26	25 Februari 2023	instalasi komponen kendali Internet of Thing (Iot) pada sistem PLTS untuk data lingkungan dan sistem photovoltaik	Untuk menginstalasi data lingkungan dan sistem photovoltaic, terlebih dahulu dibutuhkan beberapa sensor yang dapat mengukur intensitas cahaya, suhu, kecepatan angin, arus, dan tegangan. Sensor-sensor tersebut kemudian dapat dihubungkan ke papan mikrokontroler seperti Arduino Mega untuk membaca dan memproses data yang dihasilkan oleh sensor. Dalam program, pengguna dapat menentukan cara pembacaan data dari sensor-sensor tersebut, seperti melalui koneksi serial atau tampilan di layar LCD. Data yang dihasilkan oleh sensor-sensor dapat juga disimpan pada media penyimpanan eksternal seperti kartu SD atau dikirim ke server melalui koneksi internet untuk pemantauan jarak jauh.	percoaba dengan dengan 11 volt https://drive.google.com/file/d/1b3jkgkqf_q6IQyy7gGATSePRi_jw_mbS/view?usp=sharing percoaba dengan dengan 12,9 volt https://drive.google.com/file/d/1kF4Ve6ODR8ndqo7LFi851cshswfKpCmR/view?usp=sharing

27	4 Maret 2023	Instalasi komponen sistem photovoltaic dengan beban pompa air	melakukan instalasi seluruh komponen PLTS seperti modul photovoltaic, MCB, SCC baterai dan inverter	 
28	6 Maret 2023	pengujian dan pengukuran arus, tengan pada photovoltaic, baterai dan beban	melakukan pengujian dan pengukuran sistem PLTS beban pompa air dengan menggunakan tang amper	https://drive.google.com/file/d/1VNoM3qR1HjsSMnm7DOu9j4QOsH3zVlOR/view?usp=sharing
29	16 Maret 2023	Intaslasi Ardunio dengan komponen sistem	melakukan instalasi seluruh komponen kedalam ardunio mega	

				 
30	30 Maret 2023	Intalasi komponen kendali ke dalam box panel	melakukan intalasi komponen kendali kedalam box panel	
29	7 April 2023	pengujian sistem kendali	melakukan pengujian sistem kendali dengan output LCD, data Logger dan IoT	

Lampiran 6 – Dataset Penelitian

waktu	Suhu_Panel_Atas	Suhu_Panel_bawah	Suhu_Udara	Hujan	Radiasi_Matahari	Kecepatan_Angin	daya_panel1_P1	daya_panel2_P2	charging_P3	discharging_P4	Beban_P5
5:57:14	25.75	25.62	25	0	10.27	0.06	0.7482	1.116	0	1.4844	0
5:57:45	25.81	25.69	25.1	0	10.48	0	0	1.5036	0	1.4844	0
5:58:15	25.94	25.69	25.1	1	10.75	0	0	1.86	0	1.4844	0
5:58:44	25.94	25.75	25.2	1	11.42	0	0	2.356	0	1.4844	0
5:59:14	26	25.75	25.2	1	12.24	0	0	3.732	0	1.4868	0
5:59:44	25.94	25.87	25.2	1	13.09	0	0	4.8789	0	1.612	0
6:00:14	25.94	25.87	25.3	1	13.98	0	0	6.6303	0	1.4904	0
6:06:18	26.25	26.37	25.7	0	19.87	0	0	9.2796	0	1.4316	35.44
6:08:18	26.37	26.44	25.8	0	21.91	0	0	10.1426	0	1.4328	35.376
6:15:00	26.44	26.56	25.9	0	22.01	0.04	0.4812	9.856	0	1.5509	35.344
6:15:31	26.56	26.62	26.3	0	26.72	0.03	0.3609	10.998	0	1.5509	35.344
6:17:50	26.5	26.56	26.3	0	26.79	0.03	0.3606	10.6227	0	1.5483	33.12
6:19:50	26.5	26.69	26.5	0	27.79	0.03	0.3603	9.135	0	1.5483	35.328
6:25:30	26.62	26.81	27	0	28.52	0.03	0.3603	10.37	0	1.5483	35.344
6:26:00	26.56	26.75	27	0	29.57	0.03	0.3603	12.3523	0	1.6674	33.12
6:30:49	26.62	27	27.2	0	34.48	0.03	0.3603	12.8415	0	1.5483	33.105
6:33:19	26.69	27.06	27.3	0	33.77	0.03	0.3603	12.8415	0	1.6674	33.135
6:35:19	26.75	27.06	27.3	0	35.35	0.03	0.3603	14.0875	0	1.6674	35.344
6:37:49	26.94	27.31	27.7	0	39.18	0.03	0.3603	15.8283	0	1.6674	35.328
6:40:01	26.94	27.56	27.9	0	41.3	0.03	0.3603	15.8283	0	1.6674	33.12
6:42:31	27	27.75	28.1	0	40.63	0.03	0.36	15.7568	0	1.666	33.105
6:44:31	27	27.81	28.2	0	42.47	0.03	0.36	16.8236	0	1.666	33.105
6:47:02	27.06	28	28.5	0	48.22	0.03	0.3603	18.5881	0	1.666	35.344
6:49:02	27.25	28.25	28.7	0	47.85	0.02	0.24	18.675	0	1.666	33.12
6:56:26	27.75	29.5	29.5	0	72.11	0.03	0.3603	24.4083	0	1.666	35.328
6:58:43	27.75	29.87	30.1	0	72.77	0.03	0.36	23.1319	0	1.666	35.328
7:06:10	28.12	31	30.5	0	113.68	0.03	0.3606	36.7628	0	1.6688	35.328
7:09:42	28.37	31.56	30.8	0	81.5	0.02	0.24	29.6548	0	1.666	35.328
7:13:01	28.31	31.31	30.4	0	66.86	0.02	0.2398	26.3961	0	1.6646	35.328
7:14:31	28.19	31.25	30.1	0	73.31	0.02	0.2398	27.5946	0	1.6646	35.328

waktu	Suhu_Panel_Atas	Suhu_Panel_bawah	Suhu_Udara	Hujan	Radiasi_Matahari	Kecepatan_Angin	daya_panel1_P1	daya_panel2_P2	charging_P3	discharging_P4	Beban_P5
7:16:31	28.12	31.19	30.2	0	75.61	0.02	0.24	29.4056	0	1.666	35.328
7:21:31	28.37	31.62	30.2	0	89.34	0.02	0.2402	36.0185	0	1.666	35.328
7:24:00	28.56	32.13	30.5	0	108.16	0.02	0.2408	51.2478	0	1.6702	35.344
7:28:31	29.12	33.06	32.1	0	129.26	0.02	0.2404	42.942	0	1.788	35.328
7:31:40	29.25	32.63	33.8	0	136.68	0.02	0.2404	43.1365	0	1.6688	35.312
7:32:10	29.12	32.5	34	0	137.97	0	0	60.1606	0	1.6744	35.328
7:34:10	29.25	32.56	33.1	0	142.53	0.02	0.242	73.5471	0	1.68	35.344
7:39:17	30	33.44	35	0	159.59	0.02	0.2424	77.6704	0	1.803	35.36
7:42:26	30.06	33.5	35.2	0	164.27	0.02	0.242	68.3274	0	1.6786	35.36
7:43:35	29.44	33.75	34.7	0	131.61	0.02	0.2408	52.9125	0	1.791	35.344
7:46:04	28.75	33.25	33.7	0	75.95	0.02	0.2398	31.4503	0	1.782	35.328
7:48:43	28.56	33.06	33.3	0	92.96	0.02	0.2398	35.75	0	1.7835	35.328
7:50:02	28.75	33.25	33.5	0	105	0.02	0.2412	68.4607	0	1.794	35.344
7:52:42	29.19	33.69	34.8	0	101.9	0.02	0.24	39.339	0	1.6646	35.312
7:58:01	28.69	33.69	33.2	0	93.41	0.02	0.2398	35.4474	0	1.6632	35.328
8:05:08	28.75	33.63	31.7	0	144.9	2.38	29.4644	53.0728	14.945	1.836	35.568
8:08:08	28.69	33.94	31.6	0	152.1	3.36	41.9664	68.5676	20.6245	1.851	33.06
8:10:38	29	33.94	31.6	0	124.12	2.13	26.3055	46.155	0	1.6772	35.344
8:12:41	28.94	34	32	0	131.33	2.13	26.3055	60.6177	0	1.7985	35.344
8:15:16	28.94	33.69	31.9	0	155.2	2.13	26.3055	72.7632	0	1.803	35.344
8:18:23	29.31	34.5	32.6	0	166.11	3.78	47.5146	76.7625	23.3684	1.863	33.015
8:20:24	29.5	34.63	33.5	0	133.83	3.29	41.1908	62.1888	19.9318	1.8555	33.045
8:23:02	29.31	34.31	33.5	0	132.79	3.1	38.812	58.918	18.3224	1.8555	33.045
8:25:15	29.37	34.31	33.8	0	150.93	3.4	42.772	66.5328	20.8992	1.8645	32.985
8:27:56	29.56	34.19	34.3	0	134.82	3.04	38.2128	59.355	18.645	1.863	33.015
8:30:42	29.5	34.19	34.4	0	152.18	2.13	26.4546	42.0849	12.915	1.8435	33.06
8:32:42	29.19	34.06	33.7	0	199.81	3.68	46.9936	72.0384	22.716	1.8915	32.94
8:38:24	28.87	33.38	32.4	0	99.44	2.09	25.6861	43.7503	12.2816	1.824	35.36
8:41:25	29.06	33.69	32.8	0	137.49	2.63	32.5068	55.9	15.899	1.833	35.328
8:43:25	29.06	33.75	32.6	0	113.35	1.99	24.3775	44.1842	11.8874	1.818	35.328
8:46:47	29.31	34.06	33.1	0	121.18	2.24	27.4848	49.6908	13.365	1.8195	33.105

waktu	Suhu_Panel_Atas	Suhu_Panel_bawah	Suhu_Udara	Hujan	Radiasi_Matahari	Kecepatan_Angin	daya_panel1_P1	daya_panel2_P2	charging_P3	discharging_P4	Beban_P5
8:48:05	29.31	34.25	33.3	0	132.71	2.47	30.4304	54.0892	14.628	1.8285	33.09
8:51:28	29.44	34.5	33.3	0	131.4	2.43	29.8647	55.642	14.3606	1.7024	35.344
8:53:28	29.5	34.5	33.3	0	138.09	2.75	34.0175	61.9157	16.524	1.8345	35.328
8:56:58	29.5	34.88	33.4	0	165.39	2.88	35.9136	66.8932	17.3994	1.8495	33.045
8:59:18	29.75	35.38	33.7	0	146.13	2.49	30.9507	62.087	15.129	1.8435	33.06
9:01:18	29.81	35.63	34	0	155.14	2.86	35.6356	70.3575	17.5228	1.848	33.06
9:03:48	30.06	36.38	34.1	0	204.56	3.77	47.9921	89.9535	23.5433	1.887	32.94
9:06:18	30.19	36.88	34.3	0	153.98	3.08	39.116	77.4144	18.4632	1.8825	32.97
9:08:18	30.69	37.31	34.2	0	145.29	2.27	28.5793	61.6824	13.9664	1.869	33
9:10:48	30.31	37.06	34.6	0	171.48	2.91	36.8406	72.5152	17.9036	2.0032	32.97
9:13:18	30.31	37.25	35	0	168.48	2.86	36.2648	73.0792	17.6814	1.881	32.955
9:15:38	30.5	37.44	35.6	0	154.4	2.39	30.1618	64.4436	14.625	1.9984	33
9:19:43	30.56	37.19	35.3	0	171.65	2.84	36.068	73.3224	17.598	1.884	32.955
9:22:13	30.75	37.94	35.5	0	342.2	6.25	82.0625	137.2736	39.7258	2.0688	32.895
9:24:13	31.12	38.75	36.2	0	190.13	3.31	42.5004	83.6035	20.828	2.0304	32.94
9:26:43	31.56	39.25	37	0	173.82	2.84	36.2668	73.81	17.5557	2.0192	32.94
9:29:13	31.44	39.25	37	0	171.78	2.75	34.98	73.9442	17.3742	1.887	32.97
9:31:43	30.94	39.63	35.5	0	431.44	9.46	127.1424	184.9232	62.3604	2.1136	32.835
9:34:44	32.13	41.81	36.9	0	221.56	3.66	47.214	93.2159	22.95	2.0384	32.91
9:37:21	33.25	43.06	38.1	0	431.44	9.2	123.28	179.4892	56.019	2.104	32.865
9:39:21	33.88	44.5	39.9	0	207.31	3.38	43.6358	84.861	21.1982	2.0416	32.91
9:44:22	33.38	44.13	41.1	0	166.2	7.26	96.0498	162.0512	52.4	2.0816	32.865
9:45:22	33.81	43.94	43.1	0	431.44	8.84	118.456	163.704	57.9919	2.2406	32.835
9:47:50	33.44	43.81	43.8	0	180.05	7.75	102.765	147.2716	45.71	2.2134	32.85
9:50:29	32.88	41.44	43.3	0	97.18	1.66	20.916	44.03	10.1088	1.9952	32.985
9:51:49	32.25	40	42.2	0	109.17	1.9	23.902	50.2848	11.703	1.992	32.985
9:55:47	31.56	38.19	40	0	116.47	1.9	23.845	51.76	11.5599	1.9872	33.015
9:58:48	31.75	37.81	40	0	120.18	1.87	23.4311	51.2527	11.408	1.984	33.03
10:03:24	31.56	38	39.5	0	161.47	2.49	31.3989	72.6642	15.3504	1.8705	32.985
10:08:02	32.44	40.81	39.5	0	431.44	6.81	90.0963	134.7672	36.8183	2.0688	32.835
10:10:02	33.38	44.38	40.9	0	431.44	11.95	163.1175	198.8042	79.9832	2.1424	32.79

waktu	Suhu_Panel_Atas	Suhu_Panel_bawah	Suhu_Udara	Hujan	Radiasi_Matahari	Kecepatan_Angin	daya_panel1_P1	daya_panel2_P2	charging_P3	discharging_P4	Beban_P5
10:12:39	35.19	48.63	41.9	0	431.44	12.05	164.4825	188.3569	82.3259	2.1392	32.82
10:15:09	35.25	48.94	42.5	0	431.44	9.34	125.5296	175.3016	55.0924	2.2389	32.85
10:17:39	34.63	49.44	42.8	0	431.44	12.12	165.5592	186.2399	80.8486	2.278	32.82
10:21:20	35.25	50.06	43.9	0	431.44	7.31	97.5154	147.2156	55.0023	2.2304	32.835
10:23:20	34.56	48.5	43.2	0	223.53	3.03	39.0264	91.7952	18.7278	2.0368	32.925
10:25:50	34.13	48.13	42.9	0	431.44	9.56	128.4864	179.365	52.337	2.2406	32.88
10:27:50	34.31	49.5	43.4	0	431.44	10.62	144.2196	179.9172	71.4492	2.1344	33.225
10:29:50	33.81	48	42.7	0	268.66	4.33	56.4632	121.5657	24.7104	2.0576	33.165
10:33:20	32.5	43.69	40.3	0	209.26	3.04	39.3984	85.7168	16.0902	2.04	33.135
10:35:20	32.44	42.25	39.2	0	157.15	1.48	18.7368	58.2084	9.0288	1.881	33.135
10:37:27	31.75	40.13	38	0	165.63	1.59	20.0817	59.4286	9.7578	2.0016	33.12
10:39:27	31.62	39.13	37.2	0	171.75	1.61	20.3182	61.2144	9.875	1.8735	33.12
10:41:30	31.44	38.31	36.6	0	158.34	1.55	19.5145	57.7229	9.3525	1.8705	33.135
10:45:30	31.12	36.69	35.3	0	126.95	1.08	13.5	41.4732	6.4428	1.7332	33.12
10:49:30	30.62	34.81	34.3	0	95.06	0.93	11.5785	33.098	5.553	1.7262	33.105
10:51:30	30.12	33.94	33.6	0	83.17	0.87	10.8141	29.5444	5.1744	1.7234	33.135
10:53:30	29.87	33.25	33.3	0	78.53	0.9	11.178	29.44	5.2933	1.6003	33.135
10:55:30	29.81	33.06	32.9	0	74.21	0.93	11.5413	28.336	5.535	1.599	33.12
10:57:30	30	33.06	32.9	0	90.14	1.08	13.4136	32.334	6.4012	1.599	33.12
10:59:30	30	33.13	32.9	0	98.37	1.3	16.172	39.284	7.7616	1.6016	33.105
11:01:30	30	33	32.7	0	105.3	1.55	19.313	47.434	9.386	1.6042	33.105
11:03:30	30.19	33.38	32.8	0	128.33	1.8	22.5	55.212	10.8944	1.6081	33.135
11:05:31	30.12	33.69	33.2	0	134.56	1.9	23.769	58.185	11.5227	1.6094	33.12
11:10:09	30.5	34	34.1	0	89.74	1.49	18.5505	43.1626	9.0009	1.6016	33.12
11:12:09	30.44	34	34.2	0	85.55	1.38	17.1396	38.4144	8.2477	1.599	33.12
11:14:09	30.06	33.5	34.3	0	83.69	1.34	16.6294	37.7487	7.995	1.5977	33.12
11:16:41	29.87	32.75	34.4	0	93.17	1.44	17.8848	39.6864	8.617	1.599	33.12
11:18:10	30	32.63	34.1	0	96.56	1.38	17.1396	39.866	8.364	1.5977	33.12
11:20:42	29.94	32.44	34.1	0	99.91	1.26	15.624	38.735	7.4969	1.4736	33.12
11:22:43	30.06	32.75	34.3	0	105.29	1.26	15.624	40.9596	7.4969	1.4736	33.12
11:24:43	30.5	33.5	34.3	0	112.13	1.32	16.3812	43.5708	7.8656	1.5977	33.12

waktu	Suhu_Panel_Atas	Suhu_Panel_bawah	Suhu_Udara	Hujan	Radiasi_Matahari	Kecepatan_Angin	daya_panel1_P1	daya_panel2_P2	charging_P3	discharging_P4	Beban_P5
11:26:43	30.56	34.31	33.8	0	114.14	1.37	17.0017	44.625	8.2343	1.4748	33.135
11:28:43	30.69	34.94	33.4	0	111.59	1.36	16.864	43.4434	8.1114	1.5964	33.12
11:31:13	30.94	35.63	33.3	0	105.67	1.24	15.3636	41.4346	7.362	1.5951	33.105
11:32:13	31.19	35.69	33.4	0	106.19	1.17	14.4846	40.894	6.9939	1.5938	33.12
11:35:27	31.12	35.69	32.6	0	99.53	1.15	14.2255	40.0014	6.743	1.47	33.135
11:37:27	30.87	35.38	32.6	0	102.6	1.13	13.9781	39.308	6.7375	1.47	33.15
11:39:29	30.75	35.25	32.8	0	105.51	1.15	14.2255	41.2425	6.86	1.47	33.15
11:42:29	30.81	35.25	32.3	0	109.21	1.28	15.8464	45.972	7.6074	1.5925	33.135
11:46:35	31.06	36.13	32.7	0	116.34	1.41	17.4699	48.3604	8.4663	1.4724	33.12
11:47:54	31.25	36.44	32.9	0	115.48	1.56	19.344	48.6156	9.4556	1.4724	33.12
11:50:33	31.37	36.25	33.4	0	113.17	1.86	23.1012	51.84	11.193	1.4748	33.135
11:51:53	31.5	35.69	33.6	0	117.42	2.08	25.896	57.0984	12.5766	1.4784	33.105
11:53:15	31.37	35.63	34	0	119.32	2.21	27.5808	65.268	13.4724	1.482	33.12
12:00:34	31.12	34.06	34.5	0	170.78	2.55	32.079	80.9424	15.5625	1.4928	33.345
12:05:10	30.62	34.25	33.8	0	223.5	2.74	34.7432	91.9721	16.929	1.5048	33.06
12:09:45	31.56	38	35.2	0	218.61	2.94	37.632	101.8654	18.3715	1.5192	33.135
12:10:34	31.81	38.38	35.5	0	219.8	2.89	37.0498	101.5952	18.0056	1.6471	33.135
12:11:04	31.81	38.69	35.5	0	217.68	2.84	36.4088	100.2442	17.766	1.6484	33.135
12:13:34	32.13	39.56	35.8	0	201.72	2.92	37.4928	101.625	18.161	1.5228	33.015
12:16:35	32.31	40	35.7	0	193.89	2.76	35.4108	96.4949	17.272	1.5216	33.045
12:18:35	32.63	40.69	35.8	0	185.75	2.53	32.3587	89.1765	15.8375	1.6445	33.045
12:20:35	32.19	39.81	35.8	0	182.13	2.4	30.648	85.504	14.9152	1.5156	32.985
12:23:22	31.81	38.88	34.3	0	179.01	2.32	29.58	82.3176	14.3868	1.5144	33.015
12:25:22	31.75	38.69	34	0	185.12	2.28	29.0472	80.731	14.1232	1.512	33.06
12:31:45	31.75	38.5	34.2	0	192.44	2.39	30.4964	83.4458	14.9034	1.5144	32.94
12:33:46	31.69	38.25	33.6	0	198.16	2.4	30.648	85.6376	14.9152	1.5156	33.15
12:35:46	31.56	38.06	34.1	0	204.68	2.37	30.2886	88.9045	14.8005	1.5168	33.12
12:38:06	31.56	38.31	34.2	0	206.14	2.28	29.1156	85.9691	14.1568	1.5168	33.12
12:40:36	31.94	39.06	34.4	0	205.18	2.27	28.9652	84.372	14.0304	1.5144	33.105
12:44:38	31.62	38.31	34.5	0	207.47	2.49	31.872	89.0424	15.5841	1.5192	33.09
12:47:52	32.13	39.19	34.5	0	212.62	2.52	32.2812	89.5114	15.7232	1.5204	33.135

waktu	Suhu_Panel_Atas	Suhu_Panel_bawah	Suhu_Udara	Hujan	Radiasi_Matahari	Kecepatan_Angin	daya_panel1_P1	daya_panel2_P2	charging_P3	discharging_P4	Beban_P5
12:49:52	31.94	39.44	34.6	0	210.02	2.57	32.9474	90.986	15.9894	1.5216	33.12
12:51:56	31.69	39.06	34.3	0	219.5	2.58	33.1014	91.0565	16.129	1.5228	33.045
12:53:56	31.81	39	34.6	0	207.49	2.51	32.2033	92.3356	15.748	1.5228	33.06
12:56:04	31.75	38.56	34.8	0	210.19	2.43	31.1769	94.9978	15.113	1.5228	33.06
12:58:04	32.13	39.25	34.7	0	208.57	2.52	32.4072	100.548	15.7852	1.5264	32.94
13:00:34	32.19	39.5	35.3	0	207.69	2.76	35.5764	103.224	17.4812	1.53	32.97
13:02:34	32.5	40.31	35.7	0	208.89	3	38.88	119.0373	18.9736	1.5372	33
13:05:04	33.13	41.44	36.1	0	209.07	2.93	37.9728	118.0946	18.4752	1.5384	32.97
13:07:34	33.94	43.13	37.1	0	189.94	3.09	40.2009	131.6832	19.6911	1.5432	32.955
13:09:34	34.19	44	37.9	0	186.03	3.15	41.1075	141.6644	19.995	1.5468	33
13:11:34	34.06	44	38.2	0	178.97	3.21	41.9868	149.3471	20.5746	1.4223	32.955
13:13:34	34.94	45.81	39.2	0	163.79	2.88	37.5552	129.7803	18.1749	1.4179	32.895
13:16:17	35	45.88	38.8	0	149.65	2.18	28.013	91.3231	13.6104	1.3992	32.94
13:20:17	34.75	45.13	38.7	0	150.02	3.15	41.265	167.5298	20.4926	1.4256	32.94
13:22:22	34.88	46.25	39.8	0	149.72	2.7	35.235	145.839	17.1703	1.419	32.97
13:25:22	35.06	46.13	39.5	0	187.3	2.25	29.025	100.7636	14.1747	1.5312	32.835
13:27:22	34.88	45.56	39.3	0	178.55	2.24	28.8288	94.57	14.014	1.4003	32.91
13:29:53	34.56	44.5	37.5	0	209.78	2.79	36.2979	144.9	18.046	1.5432	32.865
13:32:23	36.31	48.13	38.3	0	217.11	3.79	50.1796	206.9697	24.6092	1.4388	32.91
13:34:26	37.44	52.44	41.3	0	193.83	2.9	38.106	176.8531	18.85	1.4289	32.865
13:37:26	38.19	54.38	42.7	0	214.42	2.22	28.9044	141.3585	13.9104	1.4168	32.835
13:39:26	37.06	52.63	43.7	0	188.42	1.95	25.1355	97.4916	12.2496	1.4025	32.85
13:42:06	36.25	49.31	42.5	0	191.96	1.92	24.6336	88.346	11.938	1.524	32.985
13:44:44	36.06	47.13	40.9	0	185.52	1.82	23.2596	79.7742	11.2585	1.3915	32.985
13:46:04	35.75	45.75	40.8	0	194.21	1.83	23.3508	78.9515	11.2407	1.3893	33.015
13:50:02	34.69	43.25	39.3	0	203.91	1.95	24.9405	87.6799	12.1536	1.3926	33.03
13:51:22	34.69	43.19	39.4	0	203.93	2.03	26.2276	130.5978	12.79	1.4069	32.985
13:54:01	34.94	43.75	39.9	0	239.27	1.73	22.2651	110.0868	10.8375	1.4025	32.835
13:58:29	35.5	45.5	40.6	0	255.45	1.99	25.8302	127.7892	12.4742	1.4135	32.79
14:01:29	35.19	44.81	40.6	0	226.72	2.12	27.4328	112.586	13.3224	1.408	32.82
14:03:29	35.06	44.19	39.8	0	196.49	2.09	26.9401	95.2038	13.1428	1.4025	32.85

waktu	Suhu_Panel_Atas	Suhu_Panel_bawah	Suhu_Udara	Hujan	Radiasi_Matahari	Kecepatan_Angin	daya_panel1_P1	daya_panel2_P2	charging_P3	discharging_P4	Beban_P5
14:05:59	34.94	43.38	39.3	0	192.27	1.85	23.754	90.1784	11.439	1.3981	32.82
14:08:29	34.06	41.63	38.9	0	187.34	1.63	20.864	85.358	10.0093	1.3937	32.835
14:10:30	33.88	40.94	38.6	0	181.79	1.53	19.5381	82.1025	9.4875	1.3904	32.925
14:13:01	33.88	40.88	37	0	196.34	1.52	19.3952	86.4348	9.3536	1.263	32.88
14:15:31	33.56	40.5	37	0	145.02	1.46	18.5128	62.7614	8.9176	1.256	32.94
14:18:05	33.5	39.88	36.4	0	125.93	1.33	16.758	51.4008	8.112	1.248	33.015
14:22:35	32.88	37.94	35.4	0	133.31	1.45	18.2265	55.6288	8.8466	1.245	33.03
14:24:34	32.81	37.69	34.6	0	140.04	1.55	19.5145	61.94	9.3525	1.247	35.232
14:27:35	32.94	37.63	35.1	0	162.94	1.59	20.0499	68.0409	9.6173	1.1241	33
14:29:35	33	37.94	35.2	0	156.26	1.63	20.5706	68.3031	10	1.249	33.015
14:32:05	33	38.44	35.4	0	173.94	1.69	21.3785	73.9398	10.3916	1.251	32.985
14:34:35	33.31	38.94	35.1	0	169.77	1.73	21.9018	73.3155	10.6505	1.1277	32.955
14:36:35	33.5	39.25	35.7	0	175.91	1.77	22.4082	72.8088	10.7758	1.1277	32.985
14:38:35	33.25	38.69	36	0	166.38	1.84	23.3128	73.92	11.286	1.1286	32.97
14:41:35	32.88	38.25	36.1	0	212.96	1.91	24.3334	86.84	11.8628	1.1349	32.955
14:44:05	33.38	39.19	36.3	0	194.97	1.94	24.7738	87.77	12.0175	1.1376	32.94
14:48:35	33.63	40.19	36.5	0	191.64	1.95	24.9795	90.9225	12.046	1.1412	32.955
14:51:05	33.69	40.5	36.7	0	198.3	1.95	24.9795	89.9805	12.046	1.1412	32.94
14:52:35	33.5	40.06	36.8	0	210.68	1.94	24.8902	93.15	12.065	1.143	32.94
14:57:11	33.31	39.69	37.3	0	190.69	1.88	24.064	83.1519	11.6564	1.1403	32.94
14:58:41	33	38.88	37.1	0	189.8	1.86	23.7894	83.9553	11.5297	1.1394	32.94
15:01:11	32.94	38.56	36.9	0	178.22	1.83	23.3508	78.3216	11.2496	1.1367	32.955
15:03:45	33.13	38.88	37	0	184.84	1.8	22.986	81.2896	11.1232	1.1367	32.94
15:06:15	33	38.63	36.9	0	161.99	1.77	22.5498	73.3278	10.8446	1.134	32.955
15:08:46	33	38.38	36.9	0	142.11	1.73	21.971	69.1367	10.5588	1.1304	32.955
15:11:16	33.38	38.81	37.1	0	141.76	1.66	21.0156	65.9817	10.1493	1.1277	32.985
15:13:46	32.69	37.81	36.5	0	138.99	1.59	20.0817	63.6174	9.6327	1.125	32.97
15:16:17	32.63	37.5	36.3	0	131.55	1.5	18.885	60.7664	9.1031	0.9976	33
15:18:47	32.44	37.06	36.1	0	121.61	1.43	17.9608	57.5457	8.5836	0.9952	33.03
15:20:47	32.38	36.94	35.8	0	140.27	1.38	17.3328	63.0652	8.3348	1.1196	33.03
15:23:17	32.63	37.44	36.2	0	143.94	1.34	16.8304	65.25	8.086	0.9952	33

waktu	Suhu_Panel_Atas	Suhu_Panel_bawah	Suhu_Udara	Hujan	Radiasi_Matahari	Kecepatan_Angin	daya_panel1_P1	daya_panel2_P2	charging_P3	discharging_P4	Beban_P5
15:25:47	32.88	38.06	36.4	0	148.3	1.31	16.4405	64.4985	7.8309	0.9944	33.03
15:28:17	32.81	38.06	37.1	0	103.69	1.19	14.8631	47.288	7.0509	0.9896	35.248
15:30:47	32.5	37.38	36.9	0	86.45	0.97	12.0765	38.918	5.7998	0.9864	35.248
15:32:47	32.38	36.56	36.4	0	71.59	0.74	9.1834	31.0415	4.428	0.984	35.296
15:35:17	32.31	36	36.2	0	45.67	0.66	8.1708	22.26	3.8037	0.9816	35.28
15:37:47	31.75	34.63	35.4	0	43.1	0.62	7.6694	20.7075	3.5554	0.9808	35.312
15:40:18	31.56	33.81	34.8	0	38.31	0.55	6.798	18.9203	3.185	0.98	35.312
15:43:16	31.25	33.25	34.2	0	29.37	0.4	4.932	13.8417	2.1996	0.9784	35.328
15:45:56	31.19	32.88	33.8	0	22.85	0.31	3.8192	10.6984	1.7094	0.9768	35.328
15:48:34	30.87	32.44	33.4	0	20.89	0.28	3.4468	9.315	1.464	0.976	35.312
15:51:13	30.87	32.31	33.3	0	20.01	0.27	3.321	9.0593	1.4628	0.9752	35.344
15:53:52	30.81	32	33	0	19.76	0.27	3.3183	8.804	1.4628	0.9744	35.36
15:57:24	30.62	31.69	32.5	0	17.64	0.25	3.07	7.9232	1.3387	0.9736	35.312
15:59:54	30.31	31.37	32.2	0	16.83	0.24	2.9448	7.2924	1.3376	0.9728	35.312
16:02:24	30.12	31.06	31.8	0	15.89	0.24	2.9424	6.916	1.215	0.972	35.344
16:04:54	30.19	31	31.6	0	15.56	0.22	2.695	6.4168	1.0935	0.9712	35.344
16:07:24	29.81	30.75	31.3	0	14.96	0.2	2.448	5.9184	1.0926	0.9704	35.344
16:09:54	29.81	30.56	30.9	0	13.07	0.18	2.2014	5.2933	0.9704	0.9704	35.344
16:12:29	29.5	30.31	30.7	0	11.03	0.15	1.833	4.2262	0.7272	0.9688	35.344
16:14:59	29.25	30.06	30.5	0	10.07	0.12	1.4652	3.3156	0.4844	0.9688	35.36
16:17:30	29.06	29.81	30.1	0	8.32	0.1	1.22	2.8221	0.3627	0.968	35.36
16:20:30	28.75	29.56	29.6	0	7.76	0.07	0.8533	2.45	0.2416	0.9664	35.344
16:23:00	28.81	29.5	29.5	0	8.9	0.09	1.0962	3.0625	0.3624	0.9664	35.36
16:25:30	28.81	29.44	29.5	0	9.24	0.11	1.3387	3.1824	0.4828	0.9656	35.344
16:27:00	28.69	29.31	29.4	0	9.18	0.11	1.3387	3.06	0.4824	0.9648	35.36
16:30:36	28.5	29.06	29.1	0	9.09	0.11	1.3376	2.9352	0.4824	0.9648	35.36
16:33:06	28.37	28.94	29	0	8.74	0.11	1.3365	2.9328	0.482	0.964	35.344
16:35:36	28.44	28.94	29	0	7.39	0.09	1.0926	2.3199	0.3612	0.9632	35.36
16:37:36	28.37	28.87	28.9	0	7.72	0.09	1.0917	2.466	0.3609	0.9624	35.36
16:40:06	28.31	28.81	28.8	0	6.83	0.08	0.9696	2.074	0.2404	0.9616	35.344
16:42:03	28.31	28.81	28.7	0	4.99	0.06	0.7272	1.3387	0	0.9608	35.36

waktu	Suhu_Panel_Atas	Suhu_Panel_bawah	Suhu_Udara	Hujan	Radiasi_Matahari	Kecepatan_Angin	daya_panel1_P1	daya_panel2_P2	charging_P3	discharging_P4	Beban_P5
16:45:33	28.19	28.75	28.6	0	4.93	0.05	0.6055	1.3387	0	0.9608	35.36
16:47:33	28.12	28.75	28.6	0	5.39	0.06	0.726	1.5808	0	0.96	35.344
16:50:03	28.19	28.75	28.6	0	3.11	0.05	0.6045	0.8505	0	0.9592	35.328
16:52:33	28.06	28.69	28.5	0	2.17	0.02	0.2418	0.3642	0	0.9584	35.328
16:55:04	28.06	28.75	28.6	0	3.6	0.03	0.3624	0.8568	0	0.9584	35.328
16:57:34	28.12	28.69	28.6	0	3.39	0.04	0.4828	0.8491	0	0.9576	35.328
16:59:34	28.19	28.75	28.6	0	3.78	0.04	0.4824	0.9696	0	0.9568	35.344
17:04:39	28.12	28.37	28.6	0	4.46	0.05	0.6205	1.3552	0	0.9848	35.312
17:07:08	27.75	27.25	28.4	0	4.32	0.05	0.6215	1.1097	0	0.9864	35.312
17:09:13	27.56	26.87	28.3	0	3.84	0.04	0.4976	0.9872	0	0.9864	35.344
17:11:15	27.44	26.69	28.2	0	3.3	0.03	0.3732	0.8666	0	0.9872	35.344
17:13:17	27.31	26.62	28.1	0	3.14	0.03	0.3732	0.741	0	0.9872	35.344
17:15:36	27.25	26.44	27.9	0	3.06	0.03	0.3732	0.741	0	0.9872	35.344
17:18:06	27.12	26.44	27.8	0	2.82	0.03	0.3732	0.619	0	0.9872	35.344
17:20:37	27.06	26.44	27.6	0	2.41	0.03	0.3732	0.3705	0	0.9872	35.36
17:22:07	27	26.31	27.5	0	2.28	0.02	0.2488	0.3705	0	0.9872	35.36
17:24:52	26.75	26.25	27.3	0	1.87	0	0	0.2468	0	0.9872	35.344
17:26:52	26.69	26.25	27.2	0	1.64	0.02	0.2488	0	0	0.9872	35.36
17:28:54	26.69	26.19	27.1	0	1.43	0	0	0	0	0.9872	35.344
17:31:40	26.62	26.31	27	0	1.24	0	0	0	0	0.9872	35.36
17:33:10	26.62	26.31	27	0	1.07	0	0	0	0	0.9872	35.36
17:36:40	26.56	26.25	26.9	0	0.85	0	0	0	0	0.9864	35.344
17:38:40	26.5	26.19	26.8	0	0.73	0	0	0	0	1.1097	35.36
17:42:10	26.37	26.12	26.7	0	0.57	0	0	0.2466	0	1.1097	35.36
17:45:34	26.37	26.12	26.7	0	0.4	0	0	0.2466	0	1.1097	35.344
17:46:53	26.37	26.06	26.6	0	0.34	0	0	0	0	1.1097	35.36
17:50:52	26.37	26.12	26.6	0	0.2	0	0	0	0	1.1097	35.36
17:53:47	26.37	26.06	26.5	0	0.13	0	0	0	0	1.1097	35.344

Lampiran 7 – Kode Pemrograman Python

```
import streamlit as st
import pandas as pd
import numpy as np
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_squared_error, r2_score
import matplotlib.pyplot as plt
# Daftar aturan dalam bentuk list of dictionaries
fuzzy_rules = [
    {"P1": "rendah", "P2": "tinggi", "X4": "tidak", "X1": "tinggi", "X2": "tinggi", "X3": 
"tinggi", "X5": "tinggi", "X6": "sedang", "charging_P3": "tinggi"},
    {"P1": "tinggi", "P2": "tinggi", "X4": "tidak", "X1": "tinggi", "X2": "tinggi", "X3": 
"sedang", "X5": "tinggi", "X6": "rendah", "charging_P3": "tinggi"},
    {"P1": "sedang", "P2": "sedang", "X4": "tidak", "X1": "sedang", "X2": "sedang", "X3": 
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    {"P1": "rendah", "P2": "rendah", "X4": "tidak", "X1": "rendah", "X2": "rendah", "X3": 
"rendah", "X5": "rendah", "X6": "rendah", "charging_P3": "rendah"},
    {"P1": "tinggi", "P2": "sedang", "X4": "ya", "X1": "tinggi", "X2": "sedang", "X3": 
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    {"P1": "rendah", "P2": "rendah", "X4": "ya", "X1": "sedang", "X2": "rendah", "X3": 
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    {"P1": "rendah", "P2": "rendah", "X4": "ya", "X1": "rendah", "X2": "rendah", "X3": 
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    {"P1": "sedang", "P2": "tinggi", "X4": "tidak", "X1": "sedang", "X2": "sedang", "X3": 
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    {"P1": "sedang", "P2": "sedang", "X4": "tidak", "X1": "tinggi", "X2": "sedang", "X3": 
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    {"P1": "rendah", "P2": "rendah", "X4": "tidak", "X1": "rendah", "X2": "rendah", "X3": 
"rendah", "X5": "tinggi", "X6": "sedang", "charging_P3": "rendah"},
    {"P1": "tinggi", "P2": "tinggi", "X4": "tidak", "X1": "tinggi", "X2": "sedang", "X3": 
"tinggi", "X5": "tinggi", "X6": "rendah", "charging_P3": "tinggi"},
    {"P1": "sedang", "P2": "sedang", "X4": "tidak", "X1": "sedang", "X2": "tinggi", "X3": 
"sedang", "X5": "tinggi", "X6": "sedang", "charging_P3": "tinggi"},
    {"P1": "rendah", "P2": "sedang", "X4": "ya", "X1": "sedang", "X2": "sedang", "X3": 
"rendah", "X5": "sedang", "X6": "rendah", "charging_P3": "rendah"},
    {"P1": "tinggi", "P2": "tinggi", "X4": "tidak", "X1": "tinggi", "X2": "tinggi", "X3": 
"tinggi", "X5": "sedang", "X6": "tinggi", "charging_P3": "tinggi"},
    {"P1": "sedang", "P2": "sedang", "X4": "tidak", "X1": "sedang", "X2": "sedang", "X3": 
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    {"P1": "rendah", "P2": "tinggi", "X4": "tidak", "X1": "rendah", "X2": "tinggi", "X3": 
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    {"P1": "rendah", "P2": "rendah", "X4": "ya", "X1": "sedang", "X2": "tinggi", "X3": 
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    {"P1": "rendah", "P2": "sedang", "X4": "tidak", "X1": "rendah", "X2": "sedang", "X3": 
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    {"P1": "tinggi", "P2": "tinggi", "X4": "tidak", "X1": "sedang", "X2": "sedang", "X3": 
"tinggi", "X5": "sedang", "X6": "sedang", "charging_P3": "tinggi"},
    {"P1": "tinggi", "P2": "sedang", "X4": "tidak", "X1": "tinggi", "X2": "tinggi", "X3": 
"sedang", "X5": "sedang", "X6": "tinggi", "charging_P3": "tinggi"},
    {"P1": "rendah", "P2": "rendah", "X4": "ya", "X1": "rendah", "X2": "rendah", "X3": 
"sedang", "X5": "sedang", "X6": "tinggi", "charging_P3": "rendah"},
    {"P1": "tinggi", "P2": "sedang", "X4": "tidak", "X1": "tinggi", "X2": "sedang", "X3": 
"sedang", "X5": "tinggi", "X6": "sedang", "charging_P3": "tinggi"},
    {"P1": "rendah", "P2": "rendah", "X4": "tidak", "X1": "sedang", "X2": "sedang", "X3": 
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    {"P1": "tinggi", "P2": "sedang", "X4": "ya", "X1": "tinggi", "X2": "tinggi", "X3": 
"sedang", "X5": "tinggi", "X6": "rendah", "charging_P3": "sedang"},
    {"P1": "tinggi", "P2": "tinggi", "X4": "tidak", "X1": "sedang", "X2": "tinggi", "X3": 
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    {"P1": "rendah", "P2": "rendah", "X4": "ya", "X1": "tinggi", "X2": "rendah", "X3": 
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    {"P1": "tinggi", "P2": "tinggi", "X4": "tidak", "X1": "tinggi", "X2": "tinggi", "X3": 
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"sedang", "X5": "tinggi", "X6": "sedang", "charging_P3": "sedang"},
    {"P1": "tinggi", "P2": "tinggi", "X4": "tidak", "X1": "tinggi", "X2": "tinggi", "X3": 
"rendah", "X5": "tinggi", "X6": "tinggi", "charging_P3": "tinggi"}
]
```

```
# Fungsi untuk memprediksi nilai MLR berdasarkan input manual
def predict_mlr(X, model):
    return model.predict([X])[0]
# Fungsi untuk klasifikasi fuzzy dari nilai input X
def fuzzy_input_classification(value, var_type):
    if var_type == "temperature":
        if value <= 25:
            return "rendah"
        elif 25 < value <= 35:
            return "sedang"
        else:
            return "tinggi"
    elif var_type == "radiation":
        if value <= 10:
            return "rendah"
        elif 10 < value <= 100:
            return "sedang"
        else:
            return "tinggi"
    elif var_type == "wind_speed":
        if value <= 1:
            return "rendah"
        elif 1 < value <= 3:
            return "sedang"
        else:
            return "tinggi"
    elif var_type == "rain":
        return "tidak" if value == 0 else "ya"

# Fungsi untuk klasifikasi fuzzy dari hasil MLR
def fuzzy_classification(value):
    if value <= 50:
        return "rendah"
    elif 50 < value <= 100:
        return "sedang"
    else:
        return "tinggi"

# Fungsi untuk menentukan hasil charging_P3 berdasarkan aturan fuzzy
def fuzzy_logic_charging_p3(fuzzy_rules, P1_fuzzy, P2_fuzzy, X1_fuzzy, X2_fuzzy, X3_fuzzy,
X4_fuzzy, X5_fuzzy, X6_fuzzy):
    # Loop melalui setiap aturan dalam fuzzy_rules
    for rule in fuzzy_rules:
        # Cek apakah semua kondisi aturan terpenuhi
        if (rule["P1"] == P1_fuzzy and rule["P2"] == P2_fuzzy and
            rule["X1"] == X1_fuzzy and rule["X2"] == X2_fuzzy and
            rule["X3"] == X3_fuzzy and rule["X4"] == X4_fuzzy and
            rule["X5"] == X5_fuzzy and rule["X6"] == X6_fuzzy):
            return f"charging_P3 {rule['charging_P3']}"
    # Jika tidak ada aturan yang cocok
    return "charging_P3 tidak terdefinisi"

# Streamlit UI untuk input manual dan proses prediksi
st.title("Prediksi dan Fuzzy Logic dengan Input Manual")

# Proses 1: Mempersiapkan model MLR untuk P1 dan P2
uploaded_file = st.file_uploader("Unggah file CSV data PLTS", type="csv")
if uploaded_file:
    data = pd.read_csv(uploaded_file)
    X    =    data[['Suhu_Panel_Atas',    'Suhu_Panel_bawah',    'Suhu_Udara',    'Hujan',
'Radiasi_Matahari', 'Kecepatan_Angin']]
    y_P1 = data['daya_panel1_P1']
    y_P2 = data['daya_panel2_P2']

    # Melatih model MLR
    model_P1 = LinearRegression().fit(X, y_P1)
    model_P2 = LinearRegression().fit(X, y_P2)

    # Prediksi MLR
    y_pred_P1 = model_P1.predict(X)
    y_pred_P2 = model_P2.predict(X)
```

```
    st.subheader("Proses 1: Prediksi MLR untuk P1 dan P2")
    st.write("Data yang diunggah:")
    st.write(data.head())  # Tampilkan tabel data awal

    # Persamaan model dan cost function
    mse_P1 = mean_squared_error(y_P1, y_pred_P1)
    mse_P2 = mean_squared_error(y_P2, y_pred_P2)
    st.write("### Hasil Prediksi MLR")
    st.markdown(f"**Persamaan model untuk P1:** {model_P1.intercept_:.4f} + {' + '.join([f'{coef:.4f} * X{i+1}' for i, coef in enumerate(model_P1.coef_)])}")
    st.markdown(f"**Mean Squared Error (MSE) untuk P1:** {mse_P1:.4f}")
    st.markdown(f"**Persamaan model untuk P2:** {model_P2.intercept_:.4f} + {' + '.join([f'{coef:.4f} * X{i+1}' for i, coef in enumerate(model_P2.coef_)])}")
    st.markdown(f"**Mean Squared Error (MSE) untuk P2:** {mse_P2:.4f}")

    # Simpan koefisien dan intercept untuk penggunaan di Proses 3
    intercept_P1, coef_P1 = model_P1.intercept_, model_P1.coef_
    intercept_P2, coef_P2 = model_P2.intercept_, model_P2.coef_

    # Scatter plot untuk membandingkan prediksi dan data aktual
    fig, ax = plt.subplots(1, 2, figsize=(12, 5))
    ax[0].scatter(y_P1, y_pred_P1, color="blue", alpha=0.5)
    ax[0].plot([y_P1.min(), y_P1.max()], [y_P1.min(), y_P1.max()], 'k--', lw=2)
    ax[0].set_xlabel("Data Aktual P1")
    ax[0].set_ylabel("Prediksi MLR P1")
    ax[0].set_title("Scatter Plot: Prediksi vs Data Aktual P1")

    ax[1].scatter(y_P2, y_pred_P2, color="green", alpha=0.5)
    ax[1].plot([y_P2.min(), y_P2.max()], [y_P2.min(), y_P2.max()], 'k--', lw=2)
    ax[1].set_xlabel("Data Aktual P2")
    ax[1].set_ylabel("Prediksi MLR P2")
    ax[1].set_title("Scatter Plot: Prediksi vs Data Aktual P2")
    st.pyplot(fig)

    # Proses 2: Klasifikasi fuzzy untuk P1 dan P2
    fuzzy_P1 = [fuzzy_classification(val) for val in y_pred_P1]
    fuzzy_P2 = [fuzzy_classification(val) for val in y_pred_P2]

    st.subheader("Proses 2: Klasifikasi Fuzzy untuk P1 dan P2")
    st.write("### Hasil Fuzzy Klasifikasi")
    st.write("Kategori Fuzzy untuk Prediksi P1 dan P2 (Rendah, Sedang, Tinggi)")

    # Visualisasi hasil fuzzy dengan bar chart
    fuzzy_counts_P1 = pd.Series(fuzzy_P1).value_counts()
    fuzzy_counts_P2 = pd.Series(fuzzy_P2).value_counts()

    fig, ax = plt.subplots(1, 2, figsize=(12, 5))
    fuzzy_counts_P1.plot(kind='bar', ax=ax[0], color='blue', title="Distribusi Fuzzy P1")
    fuzzy_counts_P2.plot(kind='bar', ax=ax[1], color='green', title="Distribusi Fuzzy P2")
    st.pyplot(fig)

    # Proses 3: Input Manual untuk Prediksi MLR dan Penentuan `charging_P3`
    st.subheader("Proses 3: Hasil Status `charging_P3`")
    X1 = st.number_input("Masukkan nilai untuk Suhu Panel Atas (X1):", min_value=0.0)
    X2 = st.number_input("Masukkan nilai untuk Suhu Panel Bawah (X2):", min_value=0.0)
    X3 = st.number_input("Masukkan nilai untuk Suhu Udara (X3):", min_value=0.0)
    X4 = st.selectbox("Apakah Hujan? (X4)", options=[0, 1])
    X5 = st.number_input("Masukkan nilai untuk Radiasi Matahari (X5):", min_value=0.0)
    X6 = st.number_input("Masukkan nilai untuk Kecepatan Angin (X6):", min_value=0.0)

    # Mengonversi input manual ke bentuk linguistik
    X1_fuzzy = fuzzy_input_classification(X1, "temperature")
    X2_fuzzy = fuzzy_input_classification(X2, "temperature")
    X3_fuzzy = fuzzy_input_classification(X3, "temperature")
    X4_fuzzy = fuzzy_input_classification(X4, "rain")
    X5_fuzzy = fuzzy_input_classification(X5, "radiation")
    X6_fuzzy = fuzzy_input_classification(X6, "wind_speed")

    # Menggunakan model fungsi cost dari Proses 1
    P1 = intercept_P1 + sum(coef * val for coef, val in zip(coef_P1, [X1, X2, X3, X4, X5, X6]))
```

```
    P2 = intercept_P2 + sum(coef * val for coef, val in zip(coef_P2, [X1, X2, X3, X4, X5,
X6]))


    st.write("Nilai Prediksi MLR untuk P1:", P1)
    st.write("Nilai Prediksi MLR untuk P2:", P2)

    # Klasifikasi fuzzy dari hasil MLR
    P1_fuzzy = fuzzy_classification(P1)
    P2_fuzzy = fuzzy_classification(P2)

    st.write("Kategori Fuzzy untuk P1:", P1_fuzzy)
    st.write("Kategori Fuzzy untuk P2:", P2_fuzzy)

    # Menjalankan logika fuzzy untuk menentukan charging_P3
    charging_P3  =  fuzzy_logic_charging_p3(fuzzy_rules,  P1_fuzzy,  P2_fuzzy,  X1_fuzzy,
X2_fuzzy, X3_fuzzy, X4_fuzzy, X5_fuzzy, X6_fuzzy)
    st.write("### Status `charging_P3` Berdasarkan Fuzzy Logic:")
    st.markdown(f"**{charging_P3}**")
```

Lampiran 8 – Kode Pemrograman Arduino

```
#include "FS.h"
#include "SD.h"
#include "SPI.h"
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 20, 4);

unsigned long previousMillis = 0;  // will store last time LED was updated
const long interval = 1000;

#include <OneWire.h>
#include <DallasTemperature.h>
#define ONE_WIRE_BUS 27
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);
int deviceCount = 0;

float ds1;
float ds2;

float cahaya;
float suhu, kelembaban;
float hujan;
float kec_angin;

float v1;
float v2;
float v3;
float v4;
float v5;

float i1;
float i2;
float i3;
float i4;
float i5;

char inChar;
String data;

#include "WiFi.h"
#include <NTPClient.h>
#include <WiFiUdp.h>
#include "Adafruit_MQTT.h"
#include "Adafruit_MQTT_Client.h"

WiFiUDP ntpUDP;
NTPClient timeClient(ntpUDP);

// Variables to save date and time
String formattedDate;
String dayStamp;
String timeStamp;

/************************* WiFi Access Point *********************************/

#define WLAN_SSID "KOPILATEN"
#define WLAN_PASS "sitibalqis"

/************************* Adafruit.io Setup *********************************/

#define AIO_SERVER "io.adafruit.com"
#define AIO_SERVERPORT 1883  // use 8883 for SSL
#define AIO_USERNAME "febya81"
#define AIO_KEY "aio_EHfT171UQqJF2Ak0NguqYSE8ec3K"

/************ Global State (you don't need to change this!) ******************/

WiFiClient client;
Adafruit_MQTT_Client mqtt(&client, AIO_SERVER, AIO_SERVERPORT, AIO_USERNAME, AIO_KEY);
```

```
/****************************** Feeds ***************************************/

//Adafruit_MQTT_Publish   post_radiasi   =   Adafruit_MQTT_Publish(&mqtt,   AIO_USERNAME
"/feeds/radiasi");
Adafruit_MQTT_Publish    post_pzem1    =    Adafruit_MQTT_Publish(&mqtt,    AIO_USERNAME
"/feeds/pzem1");
Adafruit_MQTT_Publish    post_pzem2    =    Adafruit_MQTT_Publish(&mqtt,    AIO_USERNAME
"/feeds/pzem2");
Adafruit_MQTT_Publish    post_pzem3    =    Adafruit_MQTT_Publish(&mqtt,    AIO_USERNAME
"/feeds/pzem3");
Adafruit_MQTT_Publish    post_pzem4    =    Adafruit_MQTT_Publish(&mqtt,    AIO_USERNAME
"/feeds/pzem4");
Adafruit_MQTT_Publish    post_pzem5    =    Adafruit_MQTT_Publish(&mqtt,    AIO_USERNAME
"/feeds/pzem5");
Adafruit_MQTT_Publish    post_cahaya    =    Adafruit_MQTT_Publish(&mqtt,    AIO_USERNAME
"/feeds/cahaya");
Adafruit_MQTT_Publish    post_angin    =    Adafruit_MQTT_Publish(&mqtt,    AIO_USERNAME
"/feeds/angin");
Adafruit_MQTT_Publish    post_hujan    =    Adafruit_MQTT_Publish(&mqtt,    AIO_USERNAME
"/feeds/hujan");
Adafruit_MQTT_Publish    post_udara    =    Adafruit_MQTT_Publish(&mqtt,    AIO_USERNAME
"/feeds/suhu-udara");
Adafruit_MQTT_Publish    post_panel    =    Adafruit_MQTT_Publish(&mqtt,    AIO_USERNAME
"/feeds/suhu-panel");

/*************************** Sketch Code ************************************/

void MQTT_connect();
int count_wifi = 0;
#define hijau 15
#define biru 2
#define merah 4
void setup() {
  lcd.begin();
  lcd.backlight();
  Serial.begin(115200);
  Serial2.begin(9600);
  delay(10);
  pinMode(15, OUTPUT);
  pinMode(2, OUTPUT);
  pinMode(4, OUTPUT);
  digitalWrite(hijau, LOW);   // hijau
  digitalWrite(biru, LOW);    //biru
  digitalWrite(merah, HIGH);  //red
  Serial.println(F("Adafruit MQTT demo"));
  Serial.println();
  Serial.println();
  Serial.print("Connecting to ");
  Serial.println(WLAN_SSID);
  WiFi.begin(WLAN_SSID, WLAN_PASS);
  while (WiFi.status() != WL_CONNECTED) {
    count_wifi++;
    lcd.home();
    lcd.print("Connecting : ");
    lcd.print(count_wifi);
    lcd.print("  ");
    Serial.print(count_wifi);
    digitalWrite(merah, HIGH);
    delay(250);
    digitalWrite(merah, LOW);
    delay(250);
    if (count_wifi > 20) {
      digitalWrite(hijau, HIGH);
    }
    if (count_wifi > 30) {
      ESP.restart();
    }
  }
  lcd.clear();
  digitalWrite(hijau, HIGH);
  Serial.println();
```

```
  Serial.println("WiFi connected");
  Serial.println("IP address: ");
  Serial.println(WiFi.localIP());
  sensors.begin();
  deviceCount = sensors.getDeviceCount();
  Serial.print(deviceCount, DEC);
  Serial.println(" devices.");
  Serial.println("");
  if (!SD.begin(5)) {
    Serial.println("Card Mount Failed");
    return;
  }
  uint8_t cardType = SD.cardType();

  if (cardType == CARD_NONE) {
    Serial.println("No SD card attached");
    return;
  }

  Serial.print("SD Card Type: ");
  if (cardType == CARD_MMC) {
    Serial.println("MMC");
  } else if (cardType == CARD_SD) {
    Serial.println("SDSC");
  } else if (cardType == CARD_SDHC) {
    Serial.println("SDHC");
  } else {
    Serial.println("UNKNOWN");
  }
  uint64_t cardSize = SD.cardSize() / (1024 * 1024);
  Serial.printf("SD Card Size: %lluMB\n", cardSize);

  timeClient.begin();
  timeClient.setTimeOffset(25200);
}
String data1, data2, data3, data4, data5, data6, data7, data8;
uint32_t x = 0;
int count;
int berhasil;
String sbuff;
char dmdBuff[200];
long s;
uint16_t string_length;
void loop() {
  while (!timeClient.update()) {
    timeClient.forceUpdate();
  }
  formattedDate = timeClient.getFormattedDate();
  //  Serial.println(formattedDate);
  int splitT = formattedDate.indexOf("T");
  dayStamp = formattedDate.substring(0, splitT);
  timeStamp = formattedDate.substring(splitT + 1, formattedDate.length() - 1);
  MQTT_connect();
  sensors.requestTemperatures();
  for (int i = 0; i < deviceCount; i++) {
    if (i == 0) {
      ds1 = sensors.getTempCByIndex(i);
    } else if (i == 1) {
      ds2 = sensors.getTempCByIndex(i);
    }
  }
  while (Serial2.available()) {
    inChar = (char)Serial2.read();
    //    Serial.println(inChar);
    if (inChar == 'A') {
      v1 = data.toFloat();
      data = "";
    } else if (inChar == 'B') {
      i1 = data.toFloat();
      data = "";
    } else if (inChar == 'C') {
      v2 = data.toFloat();
```

```
      data = "";
    } else if (inChar == 'D') {
      i2 = data.toFloat();
      data = "";
    } else if (inChar == 'E') {
      v3 = data.toFloat();
      data = "";
    } else if (inChar == 'F') {
      i3 = data.toFloat();
      data = "";
    } else if (inChar == 'G') {
      v4 = data.toFloat();
      data = "";
    } else if (inChar == 'H') {
      i4 = data.toFloat();
      data = "";
    } else if (inChar == 'I') {
      v5 = data.toFloat();
      data = "";
    } else if (inChar == 'J') {
      i5 = data.toFloat();
      data = "";
    } else if (inChar == 'K') {
      kelembaban = data.toFloat();
      data = "";
    } else if (inChar == 'L') {
      suhu = data.toFloat();
      data = "";
    } else if (inChar == 'M') {
      cahaya = data.toFloat();
      data = "";
    } else if (inChar == 'N') {
      hujan = data.toFloat();
      data = "";
    } else if (inChar == 'O') {
      kec_angin = data.toFloat();
      data = "";
    } else {
      data += inChar;
    }
  }
  unsigned long currentMillis = millis();
  if (currentMillis - previousMillis >= interval) {
    //    sbuff = "v1," + String(v1) + ",i1," + String(i1) + ",v2," + String(v2) + ",i2," + String(i2) + ",v3," + String(v3) + ",i3," + String(i3) + ",v4," + String(v4) + ",i4," + String(i4) + ",v5," + String(v5) + ",i5," + String(i5) + ",radiasi," + String(cahaya) + ",suhu udara," + String(suhu) + ",kelembaban," + String(kelembaban) + ",hujan," + String(hujan) + ",suhu p1," + String(ds1) + ",suhu p2," + String(ds2) + ",angin," + String(kec_angin) + "\n";

    previousMillis = currentMillis;
    count++;
    data1 = String(v1) + "," + String(i1);
    data2 = String(v2) + "," + String(i2);
    data3 = String(v3) + "," + String(i3);
    data4 = String(v4) + "," + String(i4);
    data5 = String(v5) + "," + String(i5);
    data6 = String(suhu) + "," + String(kelembaban);
    data7 = String(ds1) + "," + String(ds2);
    Serial.print("data 7  ");
    Serial.println(data7);
    if (count < 10) {
      tampil(1);
    }
    else if (count == 10) {
      lcd.clear();
    }
    else if (count > 10 && count < 20) {
      tampil(2);
    }
    else if (count == 20 ) {
      lcd.clear();
```

```
    }
    else if (count > 20 && count < 30) {
      tampil(3);
    }
    else if (count == 40) {
      lcd.home();
      lcd.print("Berhasil = ");
      lcd.print(berhasil);
      lcd.print("  ");
      berhasil = 0;
    }
    else if (count > 40) {
      count = 0;
      lcd.clear();
    }
    Serial.print("DATE: ");
    Serial.println(dayStamp);
    Serial.print("HOUR: ");
    Serial.println(timeStamp);
    Serial.print("Count: ");
    Serial.print(count);
    Serial.print(" || v1: ");
    Serial.print(v1);
    Serial.print(" || i1: ");
    Serial.print(i1);
    Serial.print(" || v2 : ");
    Serial.print(v2);
    Serial.print(" || i2 : ");
    Serial.print(i2);
    Serial.print(" || v3 : ");
    Serial.print(v3);
    Serial.print(" || i3 : ");
    Serial.print(i3);
    Serial.print(" || v4 : ");
    Serial.print(v4);
    Serial.print(" || i4 : ");
    Serial.print(i4);
    Serial.print(" || v5 : ");
    Serial.print(v5);
    Serial.print(" || i5 : ");
    Serial.print(i5);
    Serial.print(" || hum : ");
    Serial.print(kelembaban);
    Serial.print(" || suhu : ");
    Serial.print(suhu);
    Serial.print(" || ds18b20 1 : ");
    Serial.print(ds1);
    Serial.print(" || ds18b20 2 : ");
    Serial.print(ds2);
    Serial.print(" || radiasi : ");
    Serial.print(cahaya);
    Serial.print(" || hujan : ");
    Serial.print(hujan);
    Serial.print(" || kec : ");
    Serial.print(kec_angin);
    Serial.println();
  }
  if (count == 40) {
    sbuff = "time," + String(timeStamp) + ",date," + String(dayStamp) + ",v1," + String(v1)
+ ",i1," + String(i1) + ",v2," + String(v2) + ",i2," + String(i2) + ",v3," + String(v3) +
",i3," + String(i3) + ",v4," + String(v4);
    s = sbuff.length() + 1;
    dmdBuff[s];
    sbuff.toCharArray(dmdBuff, s);
    appendFile(SD, "/hello.csv", dmdBuff);
    sbuff = ",i4," + String(i4) + ",v5," + String(v5) + ",i5," + String(i5) + ",radiasi,"
+ String(cahaya) + ",suhu udara," + String(suhu) + ",kelembaban," + String(kelembaban) +
",hujan," + String(hujan) + ",suhu p1," + String(ds1) + ",suhu p2," + String(ds2) +
",angin," + String(kec_angin) + "\n";
    s = sbuff.length() + 1;
    dmdBuff[s];
    sbuff.toCharArray(dmdBuff, s);
```

```
    appendFile(SD, "/hello.csv", dmdBuff);
//    readFile(SD, "/hello.csv");

    string_length = data1.length();
    char ADC_value_char[string_length + 1];
    data1.toCharArray(ADC_value_char, string_length + 1);
    Serial.println(ADC_value_char);
    if (!post_pzem1.publish(ADC_value_char)) {
      Serial.println(F("Failed"));
    } else {
      berhasil++;
      Serial.println(F("OK 1"));
    }
    string_length = data2.length();
    ADC_value_char[string_length + 1];
    data2.toCharArray(ADC_value_char, string_length + 1);
    Serial.println(ADC_value_char);
    if (!post_pzem2.publish(ADC_value_char)) {
      Serial.println(F("Failed"));
    } else {
      berhasil++;
      Serial.println(F("OK 2"));
    }
    string_length = data3.length();
    ADC_value_char[string_length + 1];
    data3.toCharArray(ADC_value_char, string_length + 1);
    Serial.println(ADC_value_char);
    if (!post_pzem3.publish(ADC_value_char)) {
      Serial.println(F("Failed"));
    } else {
      berhasil++;
      Serial.println(F("OK 3"));
    }
    string_length = data4.length();
    ADC_value_char[string_length + 1];
    data4.toCharArray(ADC_value_char, string_length + 1);
    Serial.println(ADC_value_char);
    if (!post_pzem4.publish(ADC_value_char)) {
      Serial.println(F("Failed"));
    } else {
      berhasil++;
      Serial.println(F("OK 4"));
    }
    string_length = data5.length();
    ADC_value_char[string_length + 1];
    data5.toCharArray(ADC_value_char, string_length + 1);
    Serial.println(ADC_value_char);
    if (!post_pzem5.publish(ADC_value_char)) {
      Serial.println(F("Failed"));
    } else {
      berhasil++;
      Serial.println(F("OK 5"));
    }

    string_length = data6.length();
    ADC_value_char[string_length + 1];
    data6.toCharArray(ADC_value_char, string_length + 1);
    Serial.println(ADC_value_char);
    if (!post_udara.publish(ADC_value_char)) {
      Serial.println(F("Failed"));
    } else {
      berhasil++;
      Serial.println(F("OK 6"));
    }
    string_length = data7.length();
    ADC_value_char[string_length + 1];
    data7.toCharArray(ADC_value_char, string_length + 1);
    Serial.println("Data 7 setelah :");
    Serial.println(ADC_value_char);

    if (!post_panel.publish(ADC_value_char)) {
      Serial.println(F("Failed"));
```

```
    } else {
      berhasil++;
      Serial.println(F("OK 7"));
    }
    if (!post_cahaya.publish(cahaya)) {
      Serial.println(F("Failed"));
    } else {
      berhasil++;
      Serial.println(F("OK 8"));
    }
    if (!post_hujan.publish(hujan)) {
      Serial.println(F("Failed"));
    } else {
      berhasil++;
      Serial.println(F("OK 9"));
    }
    if (!post_angin.publish(kec_angin)) {
      Serial.println(F("Failed"));
    } else {
      berhasil++;
      Serial.println(F("OK 10"));
    }
    count = 0;
  }
}

void MQTT_connect() {
  int8_t ret;

  if (mqtt.connected()) {
    return;
  }

  Serial.print("Connecting to MQTT... ");
  lcd.setCursor(0,1);
  lcd.print("connect mqtt");
  uint8_t retries = 3;
  while ((ret = mqtt.connect()) != 0) {  // connect will return 0 for connected
    Serial.println(mqtt.connectErrorString(ret));
    Serial.println("Retrying MQTT connection in 5 seconds...");
    mqtt.disconnect();
    delay(5000);  // wait 5 seconds
    retries--;
    if (retries == 0) {
      while (1)
        ;
    }
  }
  lcd.clear();
  Serial.println("MQTT Connected!");
}

void readFile(fs::FS &fs, const char * path) {
  Serial.printf("Reading file: %s\n", path);
  File file = fs.open(path);
  if (!file) {
    Serial.println("Failed to open file for reading");
    return;
  }
  Serial.print("Read from file: ");
  while (file.available()) {
    Serial.write(file.read());
  }
  file.close();
}

void appendFile(fs::FS &fs, const char * path, const char * message) {
  Serial.printf("Appending to file: %s\n", path);

  File file = fs.open(path, FILE_APPEND);
  if (!file) {
    Serial.println("Failed to open file for appending");
```

```
    return;
  }
  if (file.print(message)) {
    Serial.println("Message appended");
  } else {
    Serial.println("Append failed");
  }
  file.close();
}
```

KEPUTUSAN
DEKAN FAKULTAS TEKNIK UNIVERSITAS SRIWIJAYA

Nomor : 0385/UN9.FT/TU.SK/2025

Tentang

PANITIA, PENGUJI, PROMOTOR DAN KO-PROMOTOR UJIAN DISERTASI
PROGRAM STUDI ILMU TEKNIK PROGRAM DOKTOR
FAKULTAS TEKNIK UNIVERSITAS SRIWIJAYA
PERIODE SEMESTER GENAP TAHUN AKADEMIK 2024/2025

DEKAN FAKULTAS TEKNIK UNIVERSITAS SRIWIJAYA

Menimbang :
a. bahwa sesuai surat Koordinator Program Studi Ilmu Teknik Program Doktor No 0243/UN9.1.3/PSD/KM/2025 tanggal 28 April 2025 tentang penetapan SK Penguji dan Panitia, Penguji, Promotor dan Ko-Promotor Ujian Disertasi Program Studi Ilmu Teknik Program Doktor.
b. bahwa untuk kepentingan administrasi dalam pelaksanaan Ujian Disertasi Program Studi Ilmu Teknik Program Doktor Fakultas Teknik Universitas Sriwijaya Periode Genap Tahun Akademik 2024/2025, dipandang perlu membentuk Panitia, Penguji, Promotor dan Ko-Promotor Ujian tersebut.
c. bahwa berdasarkan pertimbangan huruf a dan b, perlu menetapkan Keputusan Dekan Fakultas Teknik Universitas Sriwijaya sebagai pedoman dan landasan hukumnya.

Mengingat :
1. Undang-Undang Nomor 12 tahun 2012 tentang Pendidikan Tinggi (LNRI Tahun 2012 Nomor 158);
2. Peraturan Pemerintah Nomor 4 Tahun 2014 tentang Penyelenggaraan Pendidikan Tinggi dan Pengelolaan Perguruan Tinggi (LNRI Tahun 2014 Nomor 16);
3. Peraturan Pemerintah Nomor 32 Tahun 2024 tentang Perguruan Tinggi Negeri Badan Hukum Universitas Sriwijaya (LNRI Tahun 2024 Nomor 169, TLN Nomor 6983);
4. Peraturan Presiden Republik Indonesia Nomor 189 Tahun 2024 tentang Kementerian Pendidikan Tinggi, Sains, dan Teknologi;
5. Peraturan Menteri Pendidikan, Kebudayaan, Riset, dan Teknologi Nomor 53 Tahun 2023 tentang Penjaminan Mutu Pendidikan Tinggi (Berita Negara Tahun 2023 Nomor 638);
6. Keputusan Menteri Pendidikan, Kebudayaan, Riset dan Teknologi RI Nomor 53540/M/06/2023 Tentang Pengangkatan Rektor Universitas Sriwijaya Periode Tahun 2023-2027;
7. Keputusan Rektor Universitas Sriwijaya Nomor 0206/UN9/SK.BUK.KP/2025 tanggal 3 Maret 2025 tentang Pengangkatan Dekan Fakultas Teknik Universitas Sriwijaya Masa Tugas 2025-2030;

Paraf	✓	

MEMUTUSKAN

Menetapkan	:	KEPUTUSAN DEKAN FAKULTAS TEKNIK UNIVERSITAS SRIWIJAYA TENTANG PANITIA, PENGUJI, PROMOTOR DAN KO-PROMOTOR UJIAN DISERTASI PROGRAM STUDI ILMU TEKNIK PROGRAM DOKTOR FAKULTAS TEKNIK UNIVERSITAS SRIWIJAYA PERIODE GENAP TAHUN AKADEMIK 2024/2025
KESATU	:	Mengangkat Panitia, Penguji, Promotor dan Ko-Promotor Ujian Disertasi Program Studi Ilmu Teknik Program Doktor Fakultas Teknik Universitas Sriwijaya Periode Semester Genap Tahun Akademik 2024/2025 yang namanya seperti tertera dalam Lampiran I dan II Surat Keputusan ini, yang dilaksanakan pada tanggal 5 Mei 2025.
KEDUA	:	Segala biaya yang timbul akibat dikeluarkannya Surat Keputusan ini dibebankan pada anggaran Fakultas Teknik Universitas Sriwijaya, atau anggaran yang disediakan khusus untuk itu.
KETIGA	:	Keputusan ini berlaku sejak tanggal ditetapkan sampai berakhirnya kegiatan tersebut, dengan ketentuan bahwa segala sesuatu akan diubah dan diperbaiki sebagaimana mestinya apabila terdapat kekeliruan dalam Keputusan ini.

Ditetapkan di : Inderalaya
Pada tanggal : 30 April 2025

DEKAN,

BHAKTI YUDHO SUPRAPTO
NIP 197502112003121002

Tembusan :
1. Rektor
2. Koorprodi Ilmu Teknik Program Doktor Fakultas Teknik Universitas Sriwijaya

LAMPIRAN I
KEPUTUSAN DEKAN FT UNSRI
NOMOR : 0385/UN9.FT/TU.SK/2025
TANGGAL : 30 APRIL 2025

PANITIA UJIAN DISERTASI
PROGRAM STUDI ILMU TEKNIK PROGRAM DOKTOR
FAKULTAS TEKNIK UNIVERSITAS SRIWIJAYA
PERIODE SEMESTER GENAP TAHUN AKADEMIK 2024/2025

Pengarah	:	Dr. Ir. Bhakti Yudho Suprapto, S.T., M.T., IPM
Penanggung Jawab	:	1. Ir. Irsyadi Yani, S.T, M.Eng, Ph.D., IPM 2. Dr. Ir. Bimo Brata Adhitya, S.T, M.T 3. Dr. Ir. David Bahrin, S.T, M.T
Ketua	:	Prof. Dr. Ir. Nukman, M.T.
Anggota	:	1. Yuni Erika, SE 2. Arief Soltarianda, S.Ud., M.Si

DEKAN,

BHAKTI YUDHO SUPRAPTO
NIP 197502112003121002

ADMPPs_FT

LAMPIRAN II
KEPUTUSAN DEKAN FT UNSRI
NOMOR : 0385/UN9.FT/TU.SK/2025
TANGGAL : 30 APRIL 2025

PENGUJI, PROMOTOR DAN KO-PROMOTOR UJIAN DISERTASI
PROGRAM STUDI ILMU TEKNIK PROGRAM DOKTOR
FAKULTAS TEKNIK UNIVERSITAS SRIWIJAYA
PERIODE SEMESTER GENAP TAHUN AKADEMIK 2024/2025

Hari	:	Senin
Tanggal	:	5 Mei 2025
Ketua Ujian	:	Dr. Ir. Bhakti Yudho Suprapto, S.T., M.T., IPM
Anggota	:	1. Dr. Eng. Tresna Dewi, ST., M. Eng
		2. Dr. Fathoni, S.T., M. MSI
		3. Dr. Rossi Passarella, S.T., M.Eng
Promotor	:	1. Prof. Dr. Ermatita, M.Kom
Ko-Promotor	:	2. Dr. Ir. Armin Sofijan, M.T
Mahasiswa	:	Feby Ardianto
NIM	:	03013682126020
Judul	:	Model *Decision Support System* Untuk *Fault Detection* Pada Operasional Sistem *Photovoltaic* Berbasis *Internet Of Things* Di Wilayah Desa Terpencil.

DEKAN,

BHAKTI YUDHO SUPRAPTO
NIP 197502112003121002

ADMPPs_FT

KEMENTERIAN PENDIDIKAN TINGGI,
SAINS, DAN TEKNOLOGI
UNIVERSITAS SRIWIJAYA
FAKULTAS TEKNIK
Jalan Raya Palembang-Prabumulih, KM 32 Inderalaya Kabupaten Ogan Ilir 30662
Laman: www.ft.unsri.ac.id

Nomor : 0124/UN9.FT/TU.UN/2025 30 April 2025
Perihal : ***Undangan***

Yth. . ...
Dosen Penguji Prodi Ilmu Teknik Program Doktor
Fakultas Teknik Universitas Sriwijaya

Dengan Hormat, mengharapkan kehadiran Saudara pada acara Ujian Disertasi Program Studi Ilmu Teknik Program Doktor Fakultas Teknik Universitas Sriwijaya pada :

Hari	:	Senin
Tanggal	:	5 Mei 2025
Waktu	:	10.00 WIB s/d Selesai
Tempat	:	Ruang Rapat Lantai II Fakultas Teknik Universitas Sriwijaya Kampus Palembang

Atas kehadirannya disampaikan ucapan terima kasih.

DEKAN,

BHAKTI YUDHO SUPRAPTO
NIP 197502112003121002

ADMPPs_FT

KEMENTERIAN PENDIDIKAN TINGGI, SAINS, DAN TEKNOLOGI
UNIVERSITAS SRIWIJAYA
FAKULTAS TEKNIK
PROGRAM STUDI ILMU TEKNIK PROGRAM DOKTOR
Jalan Srijaya Negara, Bukit Besar, Palembang 30139
Laman: https://pps.unsri.ac.id/ilmu-teknik/

No : 0244/UN9.1.3/PSD/DT/2025 April 2025
Perihal : Undangan Ujian Disertasi

Yth. Promotor (Prof. Dr. Ermatita, M.Kom)
Universitas Sriwijaya
di
Tempat

Dengan hormat, Kami sangat mengharapkan kehadiran Ibu sebagai Promotor pada Ujian Disertasi dari Mahasiswa Program Studi Ilmu Teknik Program Doktor Fakultas Teknik Universitas Sriwijaya :

Nama	: Feby Ardianto
NIM	: 03013682126020
Program Studi	: Ilmu Teknik Program Doktor
Bidang Kajian Utama	: Teknik Elektro
Judul Disertasi	: Model *Decision Support System* Untuk *Fault Detection* Pada Operasional Sistem *Photovoltaic* Berbasis *Internet of Things* di Wilayah Desa Terpencil

dilaksanakan pada	:
Tanggal	: 5 Mei 2025
Pukul	: 10.00 WIB s/d Selesai
Tempat	: Ruang Rapat Dekanat Fakultas Teknik Universitas Sriwijaya Kampus Palembang

Atas perhatian, kesediaan dan perkenannya, disampaikan ucapan terimakasih.

Koprodi,

Prof. Dr. Ir. Nukman M.T
NIP. 195903211987031001

Pakaian :
***Jas Untuk Ketua Sidang, Penguji, Promotor, Ko promotor & Guru Besar**
***Mahasiswa menggunakan almamater dan kemeja**
***Penguji yang Offline Hadir 15 menit sebelum acara dimulai**
**** Penguji dan Pembahas serta Promotor dan Ko-Promotor, sangat dianjurkan membawa Laptop karena sudah memakai simak Versi 3.0***

KEMENTERIAN PENDIDIKAN TINGGI,
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Jalan Srijaya Negara, Bukit Besar, Palembang 30139
Laman: https://pps.unsri.ac.id/ilmu-teknik/

No : 0244/UN9.1.3/PSD/DT/2025 April 2025
Perihal : Undangan Ujian Disertasi

Yth. Ko-Promotor (Dr. Ir. Armin Sofijan, M.T)
Universitas Sriwijaya
di
Tempat

Dengan hormat, Kami sangat mengharapkan kehadiran Bapak sebagai Ko-Promotor pada Ujian Disertasi dari Mahasiswa Program Studi Ilmu Teknik Program Doktor Fakultas Teknik Universitas Sriwijaya :

Nama	: Feby Ardianto
NIM	: 03013682126020
Program Studi	: Ilmu Teknik Program Doktor
Bidang Kajian Utama	: Teknik Elektro
Judul Disertasi	: Model *Decision Support System* Untuk *Fault Detection* Pada Operasional Sistem *Photovoltaic* Berbasis *Internet of Things* di Wilayah Desa Terpencil

dilaksanakan pada :

Hari	: Senin
Tanggal	: 5 Mei 2025
Pukul	: 10.00 WIB s/d Selesai
Tempat	: Ruang Rapat Dekanat Fakultas Teknik Universitas Sriwijaya Kampus Palembang

Atas perhatian, kesediaan dan perkenannya, disampaikan ucapan terimakasih.

Koprodi,

Prof. Dr. Ir, Nukman M.T
NIP. 195903211987031001

Pakaian :
****Jas Untuk Ketua Sidang, Penguji, Promotor, Ko promotor & Guru Besar***
****Mahasiswa menggunakan almamater dan kemeja***
****Penguji yang Offline Hadir 15 menit sebelum acara dimulai***
**** Penguji dan Pembahas serta Promotor dan Ko-Promotor, sangat dianjurkan membawa Laptop karena sudah memakai simak Versi 3.0***

KEMENTERIAN PENDIDIKAN TINGGI,
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Laman: https://pps.unsri.ac.id/ilmu-teknik/

No : 0244/UN9.1.3/PSD/DT/2025 April 2025
Perihal : Undangan Ujian Disertasi

Yth. Penguji (Dr. Rossi Passarella, S.T., M.Eng)
Universitas Sriwjaya

di
Tempat

Dengan hormat, Kami sangat mengharapkan kehadiran Bapak sebagai penguji pada Ujian Disertasi dari Mahasiswa Program Studi Ilmu Teknik Program Doktor Fakultas Teknik Universitas Sriwijaya :

Nama	: Feby Ardianto
NIM	: 03013682126020
Program Studi	: Ilmu Teknik Program Doktor
Bidang Kajian Utama	: Teknik Elektro
Judul Disertasi	: Model *Decision Support System* Untuk *Fault Detection* Pada Operasional Sistem *Photovoltaic* Berbasis *Internet of Things* di Wilayah Desa Terpencil

dilaksanakan pada :

Hari	: Senin
Tanggal	: 5 Mei 2025
Pukul	: 10.00 WIB s/d Selesai
Tempat	: Ruang Rapat Dekanat Fakultas Teknik Universitas Sriwijaya Kampus Palembang

Promotor	: Prof. Dr. Ermatita, M.Kom
Ko Promotor	: Dr. Ir. Armin Sofijan, M.T

Atas perhatian, kesediaan dan perkenannya, disampaikan ucapan terimakasih.

Koprodi,

Prof. Dr. Ir. Nukman M.T
NIP. 195903211987031001

Pakaian :
****Jas Untuk Ketua Sidang, Penguji, Promotor, Ko promotor & Guru Besar***
****Mahasiswa menggunakan almamater dan kemeja***
****Penguji yang Offline Hadir 15 menit sebelum acara dimulai***

KEMENTERIAN PENDIDIKAN TINGGI,
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Jalan Srijaya Negara, Bukit Besar, Palembang 30139
Laman: https://pps.unsri.ac.id/ilmu-teknik/

No : 0244/UN9.1.3/PSD/DT/2025 April 2025
Perihal : Undangan Ujian Disertasi

Yth. Penguji (Dr. Fathoni, S.T., M. MSI.)
Universitas Sriwijaya

di
Tempat

Dengan hormat, Kami sangat mengharapkan kehadiran Bapak sebagai penguji pada Ujian Disertasi dari Mahasiswa Program Studi Ilmu Teknik Program Doktor Fakultas Teknik Universitas Sriwijaya :

Nama	: Feby Ardianto
NIM	: 03013682126020
Program Studi	: Ilmu Teknik Program Doktor
Bidang Kajian Utama	: Teknik Elektro
Judul Disertasi	: Model *Decision Support System* Untuk *Fault Detection* Pada Operasional Sistem *Photovoltaic* Berbasis *Internet of Things* di Wilayah Desa Terpencil

dilaksanakan pada :

Hari	: Senin
Tanggal	: 5 Mei 2025
Pukul	: 10.00 WIB s/d Selesai
Tempat	: Ruang Rapat Dekanat Fakultas Teknik Universitas Sriwijaya Kampus Palembang

Promotor	: Prof. Dr. Ermatita, M.Kom
Ko Promotor	: Dr. Ir. Armin Sofijan, M.T

Atas perhatian, kesediaan dan perkenannya, disampaikan ucapan terimakasih.

Koprodi,

Prof. Dr. Ir. Nukman M.T
NIP. 195903211987031001

Pakaian :
****Jas Untuk Ketua Sidang, Penguji, Promotor, Ko promotor & Guru Besar***
****Mahasiswa menggunakan almamater dan kemeja***
****Penguji yang Offline Hadir 15 menit sebelum acara dimulai***

KEMENTERIAN PENDIDIKAN TINGGI, SAINS, DAN TEKNOLOGI
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PROGRAM STUDI ILMU TEKNIK PROGRAM DOKTOR

Jalan Srijaya Negara, Bukit Besar, Palembang 30139
Laman: https://pps.unsri.ac.id/ilmu-teknik/

No : 0244/UN9.1.3/PSD/DT/2025 April 2025
Perihal : Undangan Ujian Disertasi

Yth. Penguji (Dr. Eng. Tresna Dewi, ST., M. Eng)
Politeknik Negeri Sriwijaya

di
Tempat

Dengan hormat, Kami sangat mengharapkan kehadiran Ibu sebagai penguji pada Ujian Disertasi dari Mahasiswa Program Studi Ilmu Teknik Program Doktor Fakultas Teknik Universitas Sriwijaya :

Nama	: Feby Ardianto
NIM	: 03013682126020
Program Studi	: Ilmu Teknik Program Doktor
Bidang Kajian Utama	: Teknik Elektro
Judul Disertasi	: Model *Decision Support System* Untuk *Fault Detection* Pada Operasional Sistem *Photovoltaic* Berbasis *Internet of Things* di Wilayah Desa Terpencil

dilaksanakan pada	:
Hari	: Senin
Tanggal	: 5 Mei 2025
Pukul	: 10.00 WIB s/d Selesai
Tempat	: Ruang Rapat Dekanat Fakultas Teknik Universitas Sriwijaya Kampus Palembang

Promotor	: Prof. Dr. Ermatita, M.Kom
Ko Promotor	: Dr. Ir. Armin Sofijan, M.T

Atas perhatian, kesediaan dan perkenannya, disampaikan ucapan terimakasih.

Koprodi,

Prof. Dr. Ir. Nukman M.T
NIP. 195903211987031001

Pakaian :
****Jas Untuk Ketua Sidang, Penguji, Promotor, Ko promotor & Guru Besar***
****Mahasiswa menggunakan almamater dan kemeja***
****Penguji yang Offline Hadir 15 menit sebelum acara dimulai***

SURAT KETERANGAN
PERBAIKAN DISERTASI

Dosen Penguji Disertasi pada Program Studi Doktor Ilmu Teknik Fakultas Teknik Universitas Sriwijaya:

Nama	: Dr. Ir. Bhakti Yudho Suprapto, S.T., M.T., IPM
NIDN	: NIP. 197502112003121002

menyatakan bahwa mahasiswa sebagai berikut:

Nama	: Feby Ardianto
NIM	: 03013682126020
BKU	: Teknik Elektro
Judul Disertasi	: Model *Decision Support System* Untuk *Fault Detection* Pada Operasional Sistem *Photovoltaic* Berbasis *Internet Of Things* Di Wilayah Desa Terpencil

telah melakukan perbaikan laporan disertasi sesuai dengan yang telah disarankan oleh Dosen Penguji pada berita acara laporan disertasi.
Demikian Surat Keterangan ini dibuat untuk dipergunakan sebagaimana mestinya.

Palembang, Mei 2025
Dosen Penguji,

Dr. Ir. Bhakti Yudho Suprapto, S.T., M.T., IPM.
NIP. 197502112003121002

KEMENTERIAN PENDIDIKAN DAN KEBUDAYAAN
UNIVERSITAS SRIWIJAYA
FAKULTAS TEKNIK
PROGRAM STUDI ILMU TEKNIK PROGRAM DOKTOR
Jl. Srijaya Negara Kampus FT Unsri Bukit Besar Palembang (30139)
Telp. (0711) 370178 - 354222 Fax. (0711) 352870
Pos El s3ilmuteknik@ft.unsri.ac.id

DAFTAR TUGAS DAN PERBAIKAN
UJIAN DISERTASI

Nama : Feby Ardianto
NIM : 03013682126020
BKU : Teknik Elektro
Judul Disertasi : Model *Decision Support System* Untuk *Fault Detection* Operasional *Photovoltaic* di Wilayah Desa Terpencil

Hari : Senin
Tanggal : 05 Mei 2025
Pukul : 08.30 s/d selesai
Tempat : Ruang Rapat Prodi Doktor Ilmu Teknik Fakultas Teknik Unsri

Promotor : Dr. Ermatita, M.Kom.
Ko-Promotor : Dr. Ir. Armin Sofijan, M.T.

NO	KRITERIA	ISI	KETERANGAN
1.	Tugas	• Latar belakang kurang tajam • Permasalahan terlalu umum belum fokus pada yang ingin diselesaikan • Teori Fuzzy logic terlalu singkat • Belum ada pembanding untuk metode yang diajukan sebagai novelty	• Telah diperbaiki latar belakang sesuai dengan arahan • Telah ditambahankan pada rumusan masalah pengembangan rekayasa perangkat lunak (software) *decision support system* untuk *fault detection photovoltaic* pada wilayah desa terpencil dengan implementasi 4 fungsi menu monitoring, diagnosis, prediksi dan DSS *fault detection* untuk *fault detection* sistem PV dengan dua model MLR dan FL, terlihat pada halaman 7 point 4 • fuzzy digunakan sebagai salah satu model untuk klasifikasi pada data monitoring IoT dan digunakan juga untuk DSS pada hasil P3 daya *charger* merupakan • novelty penerapan kombinasi metode untuk

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Telp. (0711) 370178 - 354222 Fax. (0711) 352870
Pos El s3ilmuteknik@ft.unsri.ac.id

			fault detection pada sistem *photovoltaic* (PV) di wilayah desa terpencil, dengan menggunakan berbagai metode seperti *Fuzzy Logic, Multiple Linear Regression* (MLR), dan *Internet of Things* (IoT), dengan *photovoltaic* terpasang pada *rooftop* dan atas penampungan air (tendon).
2.	Perbaikan	• Istilah-istilah asing • Rumusan masalah	• telah diperbaiki istilah asing dicetak miring (*italic*) • telah ditambahankan pada rumusan masalah pengembangan rekayasa perangkat lunak (software) *decision support system* untuk *fault detection photovoltaic* pada wilayah desa terpencil dengan implementasi 4 fungsi menu monitoring, diagnosis, prediksi dan DSS *fault detection* untuk *fault detection* sistem PV dengan dua model MLR dan FL, terlihat pada halaman 7 point 4

Palembang, Mei 2025
Dosen Penguji,

Dr. Ir. Bhakti Yudho Suprapto, S.T., M.T., IPM.
NIP. 197502112003121002

SURAT KETERANGAN
PERBAIKAN DISERTASI

Dosen Penguji Disertasi pada Program Studi Doktor Ilmu Teknik Fakultas Teknik Universitas Sriwijaya:

Nama	: Dr. Fathoni, S.T., M. MSI.
NIDN	: 197210182008121001

menyatakan bahwa mahasiswa sebagai berikut:

Nama	: Feby Ardianto
NIM	: 03013682126020
BKU	: Teknik Elektro
Judul Disertasi	: Model *Decision Support System* Untuk *Fault Detection* Pada Operasional Sistem *Photovoltaic* Berbasis *Internet Of Things* Di Wilayah Desa Terpencil

telah melakukan perbaikan laporan disertasi sesuai dengan yang telah disarankan olehDosen Penguji pada berita acara laporan disertasi.
Demikian Surat Keterangan ini dibuat untuk dipergunakan sebagaimana mestinya.

Palembang, 09 Mei 2025
Dosen Penguji,

Dr. Fathoni, S.T., M. MSI.
NIP. 197210182008121001

KEMENTERIAN PENDIDIKAN DAN KEBUDAYAAN
UNIVERSITAS SRIWIJAYA
FAKULTAS TEKNIK
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DAFTAR TUGAS DAN PERBAIKAN
UJIAN DISERTASI

Nama : Feby Ardianto
NIM : 03013682126020
BKU : Teknik Elektro
Judul Disertasi : Model *Decision Support System* Untuk *Fault Detection* Operasional *Photovoltaic* di Wilayah Desa Terpencil

Hari : Senin
Tanggal : 05 Mei 2025
Pukul : 10.00 s/d selesai
Tempat : Ruang Rapat Dekanan Fakultas Teknik Unversitas Sriwijaya

Promotor : Prof. Dr. Ermatita, M.Kom.
Ko-Promotor : Dr. Ir. Armin Sofijan, M.T.

NO	KRITERIA	ISI	KETERANGAN
1.	Tugas	• Bagaimana dengan fuzzy logic (rendah, sedang, tinggi) • Rumusan masalah yang berkaitan dengan DSS • Hubungan dengan suhu, Cahaya dan kecepatan angin dengan desa terpencil • Arsitektur DSS • Hubungan Gambar 3.6 dengan Gambar 5.1 • Komponen DSS • Mode pengisian dengan Tabel 5.1 • Kesimpulan yang berkaitan dengan DSS	• Penentuan bobot disesuiakan dengan data yang digunakan melalui sensor yang mempengaruhi sistem PV seperti intensitas Cahaya, kecepatan angin, hujan dan temperature panel atas dan bawah • Telah ditambah pada point ke 4 rumusan masalah "pengembangan rekayasa perangkat lunak (software) *decision support system* untuk *fault detection photovoltaic* pada wilayah desa terpencil dengan implementasi 4 fungsi menu monitoring, diagnosis, prediksi dan DSS *fault detection* untuk *fault detection* sistem PV" terlihat pada halaman 7. • Implemtasi sistem PV diletakan di desa Pandan Arang Kecamatan Kandis Kabupaten Ogan Ilir yang terhubung dengan robot statis yang memonitoring parameter lingkungan seperti intensitas

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			Cahaya, kecepatan angin, hujan dan temperature panel atas dan bawah • Gambar 3.6 merupakan rancangan sistem yang akan dikembangkan dengan 4 menu sistem PV, diagnosis melalui sistem monitoring, DSS fault detection dengan model MLR dan Fuzzy logic. Gambar 5.1 implentasi dari DSS dari 4 menu yang di kembangkan. • Telah ditambahkan komponen DSS yang dapat dilihat pada gambar 2.3 halaman 17. • Mode pengisian merupakan implementasi dari SCC ke baterai, merupakan inputan daya panel 1 dan panel 2. Pada sistem monitoring menggunakan entitas Pzem 3 dan varibael P3. (charging) • DSS *fault detection* untuk *fault detection* sistem PV berhasil memberikan rekomendasi pengambilan keputusan mengenai pengisian baterai dan *fault detection*, seperti suhu panel yang terlalu tinggi atau rendah. terlihat pada Kesimpulan point ke 4
2.	Perbaikan	• Perbaikan sesuai dengan pembahasa	• Telah dilakukan perbaikan sesuai dengan arahan.

Palembang, 7 Mei 2025
Dosen Penguji,

Dr. Fathoni, S.T., M. MSI.
NIP. 197210182008121001

SURAT KETERANGAN
PERBAIKAN DISERTASI

Dosen Penguji Disertasi pada Program Studi Doktor Ilmu Teknik Fakultas Teknik Universitas Sriwijaya:

Nama	: Dr. Rossi Passarella, S.T., M.Eng.
NIDN	: 197806112010121004

menyatakan bahwa mahasiswa sebagai berikut:

Nama	: Feby Ardianto
NIM	: 03013682126020
BKU	: Teknik Elektro
Judul Disertasi	: Model *Decision Support System* Untuk *Fault Detection* Pada Operasional Sistem *Photovoltaic* Berbasis *Internet Of Things* Di Wilayah Desa Terpencil

telah melakukan perbaikan laporan disertasi sesuai dengan yang telah disarankan olehDosen Penguji pada berita acara laporan disertasi.
Demikian Surat Keterangan ini dibuat untuk dipergunakan sebagaimana mestinya.

Palembang, 16 Mei 2025
Dosen Penguji,

Dr. Rossi Passarella, S.T., M.Eng.
NIP. 197806112010121004

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UJIAN DISERTASI

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NIM : 03013682126020
BKU : Teknik Elektro
Judul Disertasi : Model *Decision Support System* Untuk *Fault Detection* Operasional *Photovoltaic* di Wilayah Desa Terpencil

Hari : Senin
Tanggal : 05 Mei 2025
Pukul : 10.00 s/d selesai
Tempat : Ruang Rapat Dekanan Fakultas Teknik Unversitas Sriwijaya

Promotor : Prof. Dr. Ermatita, M.Kom.
Ko-Promotor : Dr. Ir. Armin Sofijan, M.T.

NO	KRITERIA	ISI	KETERANGAN
1.	Tugas	• Gambar model DSS berbasis MLR dan FL untuk P1 dan P2, response • literature review	• Telah di perbaiki gambar model DSS berbasis MLR sesuai dengan arahan, P1 dan P2 merupakan keluaran dari model MLR, terlihat pada gambar 5.2 halaman 65. ✓ • Bab 2 Telah dibuatkan penelitian terkait pada tabel 2.1 dan dibuatkan Sota dalam bentuk gambar seperti Gambar 2.4 ✓
2.	Perbaikan	• Dalam tulisan ilmiah citasi tidak boleh mix atau ada dua, IEEEdan Harvard atau yang lain • Bagaimana infrastruktur jaringan IoT • Keterkaitan tabel 5.1 himpunan fuzy dan 5.2 aturan fuzzy	• Telah diperbaiki sesuai arahan, tidak ada lagi yang citasi yang mix atau dua style. ✓ • Jaringan menggunakan jaringan seluler ✓ • Telah dibuatkan perubahan pada tabel 5.1 dan 5.2 disesuikan dengan outputan MLR yaitu P1 dan P2 yang menjadi inputan fuzzy dengan ouputan P3 charging ✓

Palembang, 16 Mei 2025
Dosen Penguji,

Dr. Rossi Passarella, S.T., M.Eng.
NIP. 197806112010121004

SURAT KETERANGAN
PERBAIKAN DISERTASI

Dosen Penguji Disertasi pada Program Studi Doktor Ilmu Teknik Fakultas Teknik Universitas Sriwijaya:

Nama	: Dr. Eng. Tresna Dewi, ST., M. Eng.
NIDN	: 197711252000032001

menyatakan bahwa mahasiswa sebagai berikut:

Nama	: Feby Ardianto
NIM	: 03013682126020
BKU	: Teknik Elektro
Judul Disertasi	: Model *Decision Support System* Untuk *Fault Detection* Pada Operasional Sistem *Photovoltaic* Berbasis *Internet Of Things* Di Wilayah Desa Terpencil

telah melakukan perbaikan laporan disertasi sesuai dengan yang telah disarankan olehDosen Penguji pada berita acara laporan disertasi.
Demikian Surat Keterangan ini dibuat untuk dipergunakan sebagaimana mestinya.

Palembang, 09 Mei 2025
Dosen Penguji,

Dr. Eng. Tresna Dewi, ST., M. Eng
NIP. 197711252000032001

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Nama : Feby Ardianto
NIM : 03013682126020
BKU : Teknik Elektro
Judul Disertasi : Model *Decision Support System* Untuk *Fault Detection* Operasional *Photovoltaic* di Wilayah Desa Terpencil

Hari : Senin
Tanggal : 05 Mei 2025
Pukul : 10.00 s/d selesai
Tempat : Ruang Rapat Dekanan Fakultas Teknik Unversitas Sriwijaya

Promotor : Prof. Dr. Ermatita, M.Kom.
Ko-Promotor : Dr. Ir. Armin Sofijan, M.T.

NO	KRITERIA	ISI	KETERANGAN
1.	Tugas	• Bab 1. Rumusan masalah terlalu umum, kontribusi belum jelas dan tidak ada novelty • Bab 2 Tidak terlihat research gap • Bab 3 Pemilihan MLR dan FL tidak dijustifikasi, tidak ada pembanding matematis, tidak cukup untuk S3 • Bab 4 tidak ada evaluasi performace sistem • Bab 5 tidak ada matrik statistic performace (RMSE, MAE, R^2) • Bab 6 kesimpulan terlalu umum tidak berbasis data.	• Terdapat 4 rumusan masalah yang telah disajikan pada bab 1 halaman 7 • Novelty telah dijelaskan pada bab 1 dan bab 2 "menggunakan dua parameter monitoring yaitu parameter lingkungan seperti intesitas matahari, suhu, dan kecepatan angin. Parameter sistem PV seperti arus, tegangan, daya dan suhu dengan pengguna sensor. DSS dirancangan memiliki 4 fungsi seperti monitoring, diagnosis, prediksi dan DSS *fault detection*, dengan pasangan PV array *hybrid* dengan *Rooftop* (atap) dan floating (diatas air). • Bab 2 Telah dibuatkan penelitian terkait pada tabel 2.1 dan dibuatkan Sota dalam bentuk gambar seperti gambar 2.4 • Bab 3 telah dijelaskan bahwa MLR merupakan metode awal dalam DSS. Hasil model dijadikan inputan pada DSS sebagai data input FL dengan

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			model MLR dapat diubah-ubah sesuai dengan inputan user. • Bab 4 telah ada implementasi internet of things yang dirancang menggunakan sensor dengan 2 Parameter yang mempengaruhi sistem PV. Parameter lingkungan dan sistem PV. IoT menggunakan koneksi jaringan seluler untuk dapat di simpan cloud pada adafruid, logger SSD, layer LCD. Data dapat didownload dalam format CSV dan Json. • Telah ditambahkan dalam DSS untuk MSE dan RMSE dalam bentuk grafik pada bab 5 • Bab 6 Telah ada 4 kesimpulan untuk menjawab tujuan penelitian telihat pada halaman 79-80
2.	Perbaikan	• Bab 1. Tegaskan hipotesa dan novelty dan Batasan penelitian • Bab 2. Buatlah tabel perbandingan literatur (state of the art) sehingga terlihat research gap • Bab 3 buatkan justifikasi metode sertakan perbandingan baseline. • Bab 4. Pertegas visualisasi arsitektur DSS • Bab 5 tambahkan matrik evaluasi, model dan evaluasi performa proposed metode secara kuantitatif • Buat analisis scientic dengan include future work	• Kebaruan penelitian ini terletak pada penerapan kombinasi metode untuk *fault detection* pada sistem *photovoltaic* (PV) di wilayah desa terpencil, dengan menggunakan berbagai metode seperti *Fuzzy Logic, Multiple Linear Regression* (MLR), dan *Internet of Things* (IoT), dengan *photovoltaic* terpasang pada *rooftop* dan atas penampungan air (tendon dengan Penelitian ini diharapkan dapat mengimplemtasikan rakayasa perangkat "model *decision support system* untuk *fault detection* pada operasional sistem *photovoltaic* di wilayah desa terpencil" dengan implementasi 4 fungsi menu monitoring, diagnosis, prediksi dan DSS *fault detection* sistem PV. • Bab 2 telah ada tabel peneltian terkait dan gambar SoTA terlihat pada gambar 2.4 halaman 26.

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			• Pada bab 3 telah diberikan penjelasan dalam bentuk gambar tahapan penelitian untuk menyelesaikan tujuan penelitin seperti kompoen PV, rancangan monitoring IoT untuk diagnosis, predikasi dengan MLR & FL dan DSS dengan 2 inputan model MLR dan FL. • Bab 4 ada implementasi internet of things yang dirancang menggunakan sensor dengan 2 Parameter yang mempengaruhi sistem PV. Parameter lingkungan dan sistem PV. IoT menggunakan koneksi jaringan seluler untuk dapat di simpan cloud pada adafruid, logger SSD, layer LCD. Data dapat didownload dalam format CSV dan Json. • Telah di tambahkan narasi terkaitan arsitektur DSS. • Telah ditambahkan dalam DSS untuk MSE dan RMSE dalam bentuk grafik pada bab 5 • Bab 6 telah ada Penelitian lebih lanjut dapat memperbaiki akurasi model prediksi dengan menggunakan teknik lain dengan diuji pada skala lebih besar dengan lebih banyak sensor dan panel PV, serta hybrid sistem PV dengan sumber energi lainnya seperti turbin angin, mikrohidro untuk membangun sistem energi terbarukan berbasis IoT

Palembang, 7 Mei 2025
Dosen Penguji,

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LEMBAR PENGESAHAN ABSTRAK PAPER

Nama : Feby Ardianto
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Judul Artikel : Photovoltaic Fault Detection in Remote Areas Using Fuzzy-Based Multiple Linear Regression (FMLR)
Terbit pada : International Journal of Advanced Computer Science and Applications(IJACSA), Volume 16 Issue 4, 2025.
URL : https://thesai.org/Publications/ViewPaper?Volume=16&Issue=4&Code=IJACSA&SerialNo=25

***Abstract*—This research focused on developing and implementing a fault detection model for photovoltaic (PV) systems in remote areas, utilizing a Fuzzy-Based Multiple Linear Regression (FMLR) approach. The study aimed to address the challenges of monitoring PV systems in locations with limited access to conventional power grids and technical resources. The fault detection system integrated environmental parameters such as solar radiation, temperature, wind speed, and rainfall, alongside PV system parameters like panel voltage, current, battery voltage, and inverter performance. Data collection and preprocessing were conducted over a specified period to identify operational patterns under both normal and faulty conditions, ensuring data accuracy through cleaning, normalization, and categorization. The research was conducted in *Pandan Arang* Village, *Kandis* District, *Ogan Ilir* Regency, South Sumatera, Indonesia, contributing to the improvement of reliability and sustainability of renewable energy sources in isolated communities. The total number of data points for 276 rows with 6 attributes each was 1656 records. The MLR model was developed to predict the output power of the PV system, while fuzzy logic was employed to handle uncertainties in the data, offering a more flexible and adaptive decision-making process. The system applied fuzzy rules to determine the charging status (P3), categorizing it into Optimal Charging, Adjusted Charging, Charging Delay, or Fault Alert. The model was tested with real-time data, and its performance was validated through comparison with manual inspections. The results showed that the FMLR-based fault detection system effectively identified faults and optimized the performance of the PV system, making it suitable for remote areas in South Sumatera.**

***Keywords*—Photovoltaic; multiple linear regression; fuzzy; fault detection; remote areas**

Palembang, 9 Mei 2025

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