DESIGN OF A MONITORING SYSTEM FOR CURRENT, POWER, AND ELECTRIC ENERGY CONSUMPTION OF VARIOUS ROOM COUNTERS IN AIRPORTS WITH IOT-BASED FUZZY MULTIPLE ATTRIBUTE DECISION MAKING (FMADM) METHOD

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ABSTRACT

The use of electricity at the airport every concession / terminal tenant gets electricity supply and is directly connected to the kWh meter. Therefore, the technician checks the kWh meter to determine the amount of electricity. This research focuses on the use of kWh meters at airports to monitor energy use by consumers. This research aims to develop a system for collecting data on energy usage and usage costs, by utilizing data collected from kWh meters connected to the internet. The system includes Power Supply, LM 2596, PZEM 004T Sensor, ESP32, switches, lights, and sockets. The way it works is that the 220 volt voltage is reduced to 12 VDC by the power supply, then the LM2596 reduces it again to 5 VDC to supply the NodeMCU ESP32. The PZEM 004T sensor reads the load and sends data to the NodeMCU ESP32. The NodeMCU ESP32 processes the data and sends it to the server via internet/wifi. The data on the server is processed using the FMADM method and displayed on the web interface. Users can monitor the data by logging into the webserver via the internet network. This study concluded that the IoT-based kWh monitoring system can provide accurate and timely information about energy consumption, the toolkit with NodeMCU ESP32 and the PZEM-004T sensor works well and accurately (97.74%) so it is worth using. Categories of electricity consumption: power (low <50, moderate 50-100, high >100), energy (low<50 kWh, medium 50-150 kwh, high >150 kWh), and cost (low≤150, moderate 150-200, high>200). The use of this FMADM helps technicians and consumers monitor electricity use remotely with an accuracy rate of over 95%.

Keywords: Fuzzy MADM, Listrik, PZEM 004T, ESP32

1. INTRODUCTION

The airport is a region used for the landing and takeoff of aircraft, the boarding and disembarking of passengers, the loading and unloading of goods, and the transfer between different modes of transportation. The airport has electrical facilities that support the smooth operation of air travel, ensuring the safety and comfort of air transportation users and the aircraft itself. Electricity is one of the most essential needs in human life, as almost all human activities today are not separate from electronic devices. The use of electricity at the airport for each concession/tenant terminal receives electricity supply and is directly connected to the kWh meter. Therefore, technicians check the kWh meter

When carrying out On the Job Training (OJT) the author found a problem, namely in monitoring and collecting data on the use of electricity costs at the canteen booth at the airport. So the technicians there are still monitoring and recording the use of electrical energy consumption power manually, so checking and collecting data still has to be done to the kWh meter panel room spread across the airport terminal. In checking and collecting data, technicians experience difficulties such as the far location of kWh meters and quite a lot of kWh meters that must be recorded so that it is less efficient,

ineffective and takes quite a long time. Of the many kWh meters installed in the panel rooms, it is certainly less effective if the officer checks and if he wants to monitor the panel rooms if he needs data at any time.. technicians is certainly still not said to be effective and efficient in terms of time calculation. Of course technicians will also have difficulty checking and collecting data. Not only that, with the research of this tool it can make it easier for technicians to monitor the use of electric power if there are problems or errors.

From the research in the field, it is necessary to have a tool that can assist technicians in monitoring and recording the use of electric power in each concession at the airport terminal to get accurate results and save time and energy for electricians. For this reason, from the problems that exist at the airport, the author pours out a solution in the form of a Final Project with the title "DESIGN OF A MONITORING SYSTEM OF CURRENT, POWER AND ELECTRIC ENERGY CONSUMPTION FROM VARIOUS ROOM COUNTERS AT THE AIRPORT BY FUZZY MULTIPLE ATRIBUTE DECISION MAKING (FMADM) METHOD BASED ON IOT" which discusses system management that can collect and display the amount of current, power and electrical energy consumption used, and can be monitored via android smartphones of technicians at the airport. So that electricians do not need to go directly to each counter at the terminal to monitor and record the use of electric power at each counter at the airport terminal. However, the activity of monitoring and recording electricity usage is still carried out manually by technicians, which often encounters challenges due to the large number of concessions and the uncertain number of electrical technicians at the airport. It is not uncommon for tenants to complain to electrical technicians about the increase in electricity payment tariffs.

This research aims to develop a system for collecting data on energy usage and usage costs by utilizing data collected from kWh meters connected to the internet. The system includes Power Supply, LM 2596, PZEM 004T Sensor, ESP32, switches, lights, and sockets. The operation involves reducing the 220-volt voltage to 12 VDC by the power supply, then further reducing it to 5 VDC by LM2596 to supply the NodeMCU ESP32. The PZEM 004T sensor reads the load and sends data to the NodeMCU ESP32. The NodeMCU ESP32 processes the data and transmits it to the server via internet/wifi. The data on the server is processed using the FMADM method and displayed on a web interface. Users can monitor the data by logging into the web server via an internet network.

The study concludes that the IoT-based kWh monitoring system can provide accurate and timely information about energy consumption, with an accuracy rate of over 95%. The categories of electricity consumption include power (low 100), energy (low 150 kWh), and cost (low ≤150, moderate 150-200, high >200). The use of FMADM helps technicians and consumers monitor electricity use remotely with high accuracy. This system optimizes energy usage, reduces electricity costs, and enhances energy efficiency.

The benefits of this research include creating a useful design at the airport as a system for managing data collection regarding current, power, and electrical energy consumption. The system can be accessed by technicians and consumers to accurately determine energy usage. Additionally, it facilitates monitoring of current, voltage, and power consumption anywhere and checking tariffs as needed through an Android smartphone. With these features, technicians can monitor high electricity usage and prevent overload.

In summary, this research aims to optimize electrical energy usage at airports, reduce electricity costs, and enhance energy efficiency. Furthermore, the IoT-based monitoring system using fuzzy logic multiple attribute decision making implemented on an Android system will have several advantages such as being customizable according to user needs, accessible from a distance, and providing more detailed real-time information about electricity usage..

1.1. Problem Formulation

1. How can technicians and consumers monitor current, power and total electrical energy consumption and electricity costs incurred through a web server?
2. How is the performance system of data collection and monitoring tools for current, power and total electrical energy consumption and costs with fuzzy multiple attribute decision making method based on Iot at the airport?

1.2 Research Objectives

1. This design is made by the author simply to monitor or monitor the collection of data on the use of current, power and total cost of electrical energy consumption with the Iot-based fuzzy multiple attribute decision making method at the airport.
2. The value set from the fuzzy multiple attribute decision making algorithm process in this tool is only used for decision making to determine low, medium. and high electricity usage and the fuzzy data is processed through the network interface.

1.3 Research Objectives

1. Creating a monitoring system or monitoring the use of electrical energy consumption in real time including power, current and costs that can be accessed by technicians and consumers via cellular phones using an android-based web.
2. Knowing how to monitor current, power and electrical energy consumption and costs at airports based on android with the Fuzzy Multiple Attribute Decision Making (FMADM) algorithm

1.4 Research Benefits

Design a useful tool at the airport as a data collection management system for current, kWh meter power and the cost of electrical energy that has been used. So that it can be accessed by technicians and consumers so that they can find out the electrical energy used. Another expected benefit is to make it easier for users to monitor the current, voltage and power of the kWh meter anywhere and check the tariff used at any time if needed via an android cellphone. In addition, if an error occurs, it will be monitored in real time and can be controlled. The benefit of using this fuzzy is to know the consumption with low, medium, or high levels. With this as a technician can monitor the use of electricity that is already high and can avoid overload.

2. LITERATURE REVIEW

1. Power supply is the main component in the monitoring system of current, power, and electrical energy consumption. The main function of the power supply is to reduce the voltage of 220 volts to 12 VDC. Thus, this lower voltage can be used by other devices in the system. This 12 VDC voltage is then reduced again to 5 VDC by the LM2596 component to supply the NodeMCU ESP32, which is the microcontroller used to process data from the PZEM 004T sensor.

Figure 1. Adaptor

2. NodeMCU ESP32 is a microcontroller used to process data that has been taken from the PZEM 004T sensor. The main function of NodeMCU ESP32 is to process the data received from the PZEM 004T sensor and then the data results are sent to the server via internet / wifi. Thus, the system can monitor electricity usage in real-time and provide accurate information about energy consumption.ESP32 is a Wi-Fi and Bluetooth microcontroller developed by Espressif Systems. ESP32 is used in the current, power, and electrical energy consumption monitoring system to process the data sent by the PZEM 004T sensor. The received data is then sent to the server via internet/wifi and processed using the Fuzzy Multiple Attribute Decision Making (FMADM) method.

Figure 2. ESP 32

3. The PZEM 004T sensor is a very important component in the current, power, and electrical energy consumption monitoring system. The main function of this sensor is to read the electrical load and then the data is sent to the NodeMCU ESP32. The data sent includes current, power, and total electrical energy consumption. Thus, the system can monitor electricity usage in real-time and provide accurate information about energy consumption. PZEM 004T is used in the current, power, and electrical energy consumption monitoring system to collect the required data. The collected data is then processed by NodeMCU ESP32 and sent to the server via internet/wifi.

Figure 3. PZEM 004T

4. The LM 2596 functions as a voltage regulator that reduces the 12 VDC voltage to 5 VDC. This 5 VDC voltage is very important because it is used to supply the NodeMCU ESP32, which requires a stable and low voltage to operate properly. By using the LM 2596, the system can ensure that the NodeMCU ESP32 receives the appropriate voltage and is not disturbed by unstable electrical disturbances. LM 2596 in the current, power, and electrical energy consumption monitoring system, LM 2596 is used to reduce the voltage from 12VDC to 5VDC to supply the NodeMCU ESP32

Figure 4. LM 2596

5. Arduino IDE is a software development platform used to program Arduino microcontrollers. In the context of research on current, power, and electrical energy consumption monitoring systems at airports, the Arduino IDE is not directly used because this research uses the NodeMCU ESP32 which is usually programmed using platforms such as Arduino IDE or PlatformIO. In IoT projects such as monitoring systems for current, power, and electrical energy consumption, the Arduino IDE can be used to program the microcontrollers used in the system. Although the NodeMCU ESP32 is used in this research, the basic concepts of microcontrollerbased system development learned from the Arduino IDE can be applied. Thus, an understanding of the Arduino IDE can help in developing a more sophisticated and efficient monitoring system, although in this research a more specific NodeMCU ESP32 was used.

Figure 5. Arduino IDE

6. XAMPP

In the context of developing a monitoring system for current, power, and electrical energy consumption at airports, XAMPP can be used as a platform to develop web applications that monitor real-time electricity usage data. XAMPP is a package that allows developers to build complex web applications easily. Apache is a web server used to handle HTTP requests, while MySQL is a data-based management system that functions to manage and store data. PHP is a programming language used to develop dynamic web applications, and Perl is a programming language used for specific tasks. In the development of web applications to monitor electricity usage data, XAMPP can be used to develop web applications that allow users to monitor data in real-time. For example, users can access the web application through a browser and view the current electricity usage data. Thus, an understanding of XAMPP can help in developing complex web applications that allow users to monitor electrical energy usage data in real-time

Figure 6. XAMPP

7. Fuzzy Multiple Attribute Decision Making can be concluded is a method to find alternatives from a number of alternatives with certain criteria. The FMADM method determines the weight value for each attribute, then proceeds with a ranking process that will select alternatives that have been given. Fuzzy multiple attribute decision making is an approach to decision making that considers several attributes or criteria and uses fuzzy logic to handle uncertainty and vagueness in decision makers' preferences.

3. METHODS

3.1 Research Design

Figure 7. Research Steps

a. Test Planning

This stage involves determining what will be tested, how the test will be conducted, and what the purpose of the test is. It can involve determining performance metrics, determining test conditions, and determining test methods.

b. Manufacture of Testing Instruments

This stage involves creating or selecting the instruments that will be used in testing. These instruments can be tools, software, or procedures that will be used to perform.

c. Testing Implementation

This stage involves conducting the test in accordance with the plan. It can involve operating the system or device under test, collecting data, and monitoring the testing process.

d. Data Analysis

This stage involves analyzing the data that has been collected to obtain useful information. This analysis could involve using statistics, data analysis methods, or other techniques to extract information from the data

e. Interpretation of Results

This stage involves making interpretations or conclusions from the results of data analysis. These interpretations should reflect the test objectives and provide insight into the performance of the system under test.

f. Result Reporting

This stage involves creating a report that describes the testing process, data collection, data analysis, and interpretation of results. This report should provide a clear picture of what has been done, what has been found, and what it means for the purpose of the test.

3.2 Tool Design

The use of electricity at the airport for each concession/tenant terminal receives electricity supply and is directly connected to the kWh meter. Therefore, the technician checks the kWh meter to determine the amount of electricity. This research focuses on the use of kWh meters at airports to monitor energy use by consumers. This study employs an experimental design with a system development method. The primary objective of this research is to develop a system for monitoring current, power, and electrical energy consumption from various room counters at the airport using the Fuzzy Multiple Attribute Decision Making (FMADM) method based on IoT.

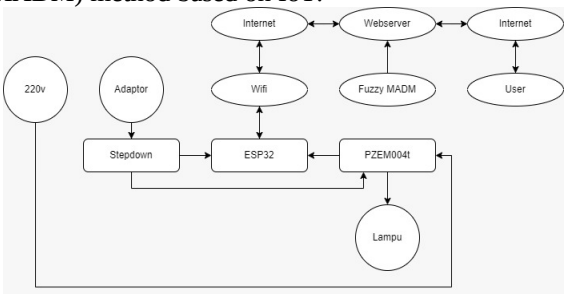

Figure 8. Block Diagram of the Tool Design

The way this monitoring tool works is that the 220 volt voltage is channeled to the power supply and will be reduced to a voltage from 220 VAC to 12 VDC. Then the 5 volt DC voltage is used to supply the NodeMCU ESP32 and connected to the input of the PZEM004T network cable so that it can work and receive the sensor results read. If the PZEM 004T sensor module reads the load, the results read by the sensor are sent to the NodeMCU ESP32. Then NodeMCU ESP32 will process the data. Then the data received by NodeMCU ESP32 will be sent to the server using the internet / wifi. On the server side, the data received will be processed using the Fuzzy Multiple Attribute Decision Making (FMADM) method and then displayed on the web interface. Users can monitor data by logging into the webserver via the internet network.

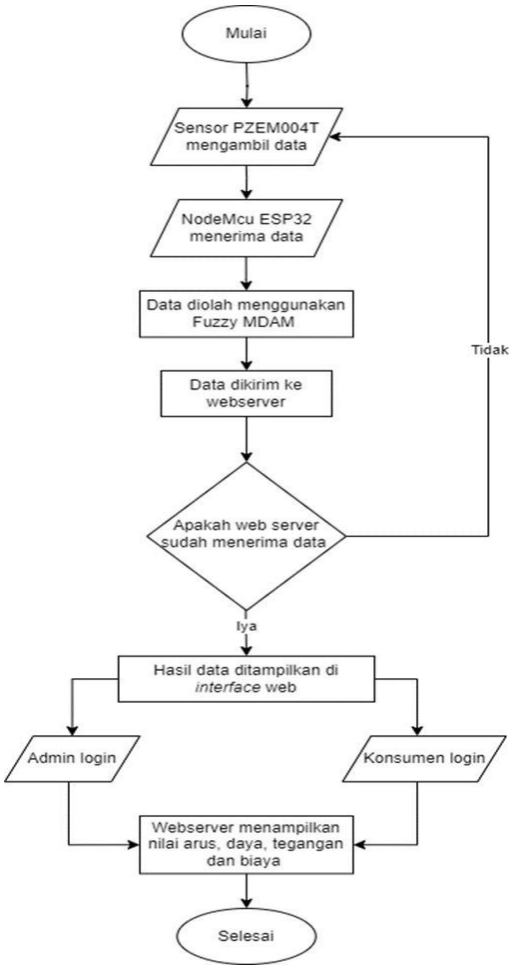

Figure 9. Flowchart

Based on the flowchart or work flowchart of Based on the flowchart or work flowchart of the tool that has been made, it can be concluded that the way this tool works is when the tool is on, the PZEM 004T sensor will take data including the current, power and voltage used. Then the data will be sent to the NodeMcu ESP 32 and then sent to the web server. Here the web server will analyze whether it has received data or not, if not then PZEM 004T will

retrieve the data. However, if the web server has received it, the data will be processed using FMDAM. In processing data using the FMADM algorithm, it will analyze which power usage and electricity costs are low, medium and high. Then the processed data results will be displayed on the web interface. The specialty of this tool is that admins or technicians as well as consumers can access it but for limited consumers can only see their own data. After logging in the web server will display the value of current, power, voltage and cost of electricity usage.

3.3 Tool Components

In making this tool, several components are needed which are designed to produce the desired tool. The components include

Hardware

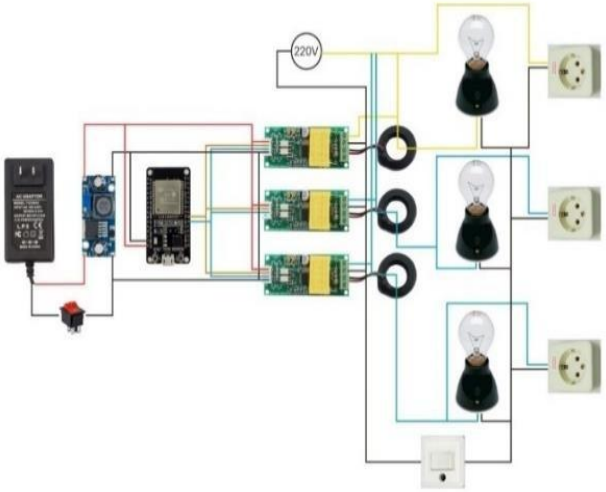

Figure 10. Hardware Circuit Design

1. Adaptor

   Power supply is the main component in the monitoring system of current, power, and electrical energy consumption. The main function of the power supply is to reduce the voltage of 220 volts to 12 VDC. Thus, this lower voltage can be used by other devices in the system. This 12 VDC voltage is then reduced again to 5 VDC by the LM2596 component to supply the NodeMCU ESP32, which is the microcontroller used to process data from the PZEM 004T sensor.

2. LM 2596

   The LM 2596 functions as a voltage regulator that reduces the 12 VDC voltage to 5 VDC. This 5 VDC voltage is very important because it is used to supply the NodeMCU ESP32, which requires a stable and low voltage to operate properly. By using the LM 2596, the system can ensure that the NodeMCU ESP32 receives the appropriate voltage and is not disturbed by unstable electrical disturbances.

3. ESP 32

   NodeMCU ESP32 in this project is installed by getting power input from LM 2596. Then connected to the output of the PZEM 004T sensor network which is used to read the current, power and voltage sensors which then the results of the use of electrical energy will be sent to the arduino IDE then managed by XAMMP and displayed on the website that has been created. NodeMCU ESP32 as a control center as well as a wifi module which is used to measure electrical parameters such as voltage, current, power and energy used. This module also functions to monitor electrical energy consumption in real time via the connected internet network which will later be accessed through the webserver dashboard. Then it is also used for energy data analysis where data will be collected by the PZEM004T sensor stored and analyzed to identify which electricity usage is low, medium and high.

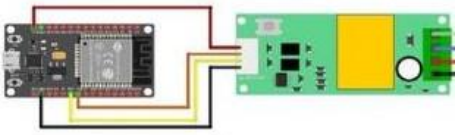

Figure 11. Design ESP 32

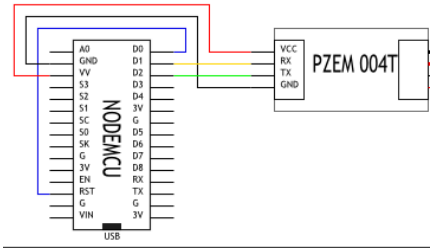

Figure 12. Wiring ESP 32

4. PZEM 004T

   This PZEM 004T sensor is installed by getting power input from PLN. Then the output is channeled to ESP 32 for the communication network cable while in making hardware the tool is used as a current, power and voltage meter used. Where from this sensor information is able to provide information that there is electrical energy usage in each concession / tenant..

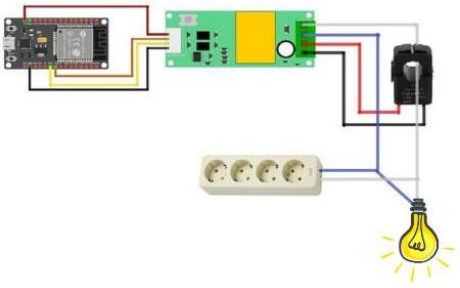

Figure 13. Design PZEM 004T

Software

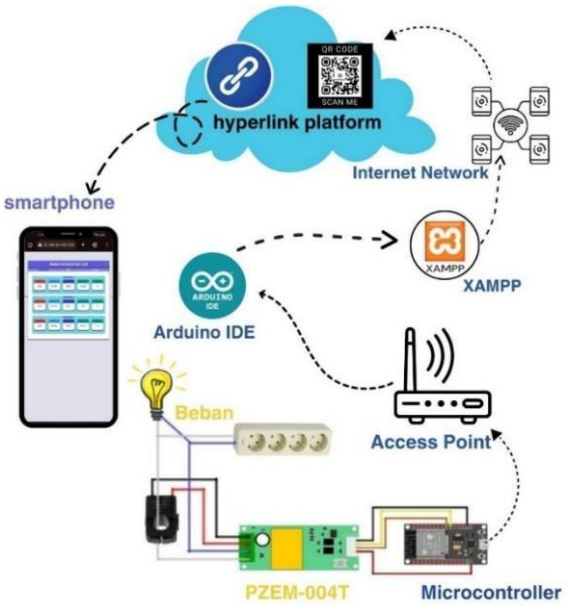

Figure 14. Software Design

1. Software Arduino IDE

   This software design aims to create coding that is injected into the microcontroller. NodeMCU ESP32 is a microcontroller component that is used to process data and regulate so that the tool system can work according to what has been conceptualized.

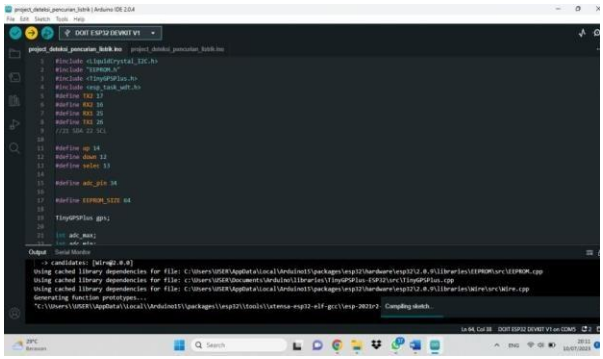

Figure 15. Compail Arduino IDE data

2. XAMMP

   XAMMP is software used to develop a webserver that can communicate with ESP 32, store and display data from sensors connected to ESP 32. So data from sensors can be sent by ESP32 to the XAMMP server running MySQL to be stored in basic data. Then the data can be displayed with the PHP application on XAMPP in an easy-to-understand format such as a graph or table

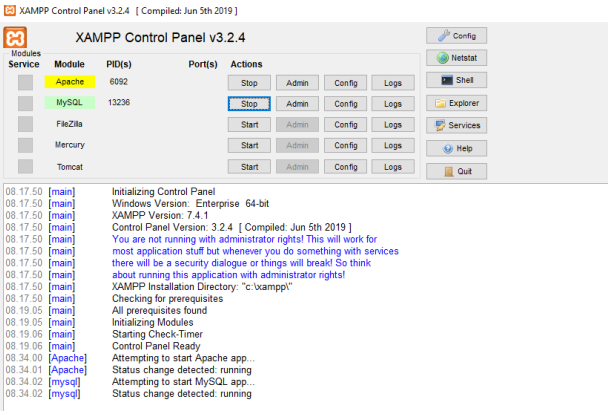

Figure 16. Display of XAMPP application

3. The creation of webserver software in this study aims to develop a monitoring system for current, power, and electrical energy consumption at airports using the IoT-based Fuzzy Multiple Attribute Decision Making (FMADM) method. This webserver software is designed to display real-time and accurate electricity usage data, so that technicians and consumers can monitor electricity usage remotely. This webserver software can provide accurate and timely information about electrical energy consumption, so that technicians and consumers can optimize the use of electrical energy, reduce electricity costs, and increase energy usage efficiency.

Figure 17. Code Barcode

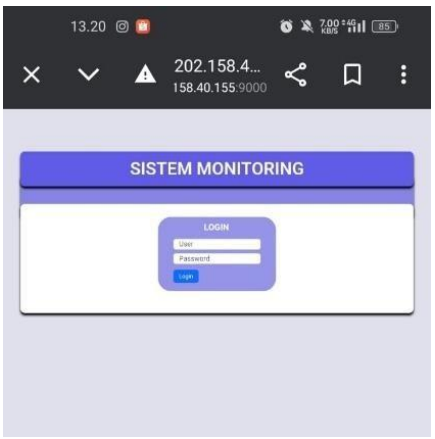

Figure 18. Tampilan Login Webserver

Figure 19. Monitoring system webserver view

Figure 20. Fuzzy MADM monitoring webserver view

Figure 21 Real-time usage history monitoring

3.4 Testing Technique

The testing technique is carried out to determine the work of the tool that has been made and to ascertain whether the tool works according to its function. In this test, researchers will test this tool with each stage and the end result can monitor the electrical energy used. After running well with proof that the tool can monitor electrical energy. Then the results are read by the microcontroller which will be sent to the web. At this stage, tool testing is carried out on the entire circuit both for the block circuit or its parts and the components that will be used.

1. Adapter Testing Technique

Table 1. Adapter Testing Technique

Purpose	It serves to ensure that it can drain and reduce the voltage to 12 VDC..
Indication of success	The measurement results are as desired.

2. LM 2596 Testing Technique

Table 2. LM 2596 Testing Technique

Purpose	To ensure that the LM 2596 can drain the electric current and reduce the voltage to 5 VDC..
Indication of success	The measurement results are as desired

3. ESP 32 Testing Technique

Table 3.ESP 32 Testing Technique

Purpose	Knowing the NodeMCU ESP32 can work well
Indication of success	The indicator light on the NodeMCU ESP32 lights up. The codding creation and upload was successful

4. PZEM 004T Testing Technique

Table 4.PZEM 004T Testing Technique

Purpose	Knowing PZEM 004T can work properly
Indication of success	The indicator light on the PZEM 004T lights up and the measurement results between the webserver and the actual measurement are similar/close.

5. Arduino IDE Testing Technique

Table 5. Arduino IDE Testing Technique

Purpose	To find out whether the coding that has been made can be used
Indication of success	It can be uploaded to the ESP 32 module and it says "campling"

6. XAMPP Testing Technique

Table 6.XAMPP Testing Technique

Purpose	To find out whether the coding that has been made can be used and the webserver can be accessed.
Indication of success	The coding upload process is successful and the Webserver can be accessed.

7. Webserver Testing Technique

Table 7.Webserver Testing Technique

Purpose	Knowing the web server can be accessed properly and correctly.
Indication of success	The web server can be accessed by technicians and consumers

4. RESULTS AND DISCUSSION

This sub chapter will explain the results and discuss the final design of the project tool implemented, the discussion of the results of this research starts from making hardware, then assembling the supporting components of the tool, the sensors used and the software. In this study, testing is used to determine how the device works and analyze the level of reliability, deficiencies and limitations of the functional specifications of the device and the applications made. In addition, this test aims to determine the state of this system, so that this application can be used normally and optimally. This test begins by testing the adapotor which functions as the main source, then testing the supporting hardware, then testing is carried out on the components used, including power supply, LM 2596, ESP32, PZEM 004T, Arduino IDE, XAMPP and webserver.

1. Power Supply

Testing on this adapter aims to find out whether the adapter used can drain the electric current and can reduce the voltage from 220 VAC to 12 VDC.

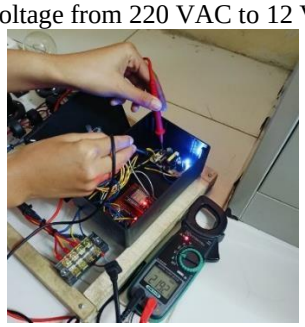

Figure 22. Adaptor Testing

Table 8. Adapter testing results

Testing	Input Voltage	Output Voltage	Description.
1	218,6 VAC	12,21 VDC	Normal
2	222,2 VAC	12,26 VDC	Normal
3	220,3 VAC	12,24 VDC	Normal

Analysis: After testing the adapter by measuring the flowing voltage, it can be confirmed that the adapter is able to change the voltage from 220 VAC to 12 VDC.

2. LM 25

Testing the LM 2596 aims to find out whether the components used can drain the electric current and can reduce the voltage from 12 VDC to 5 VDC.

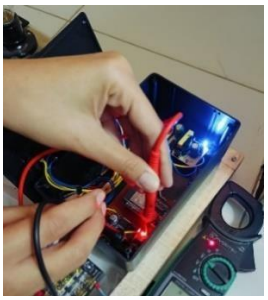

Figure 23. LM 2596 Testing

Table 9. Test results LM 2596

Testing	Input Voltage	Output Voltage	Description.
1	8,26 VDC	5,04 VDC	Normal
2	12.21 VDC	5,01VDC	Normal
3	12,20 VDC	5,03VDC	Normal

Analysis: After testing by measuring the flowing voltage, it can be concluded that the LM 2596 is able to change the voltage from 12 VDC to 5 VDC.

3. ESP 32

Testing on the NodeMCU ESP32 aims to find out whether the NodeMCU ESP32 used can work properly or not.

Figure 24. ESP 32 Testing

Table 10. Test results ESP 32

Testing	Input Voltage	Output Voltage	Description.
1	5,1 VDC	Light up	Normal
2	5,1 VDC	Light up	Normal
3	5,1 VDC	Light up	Normal

Analysis: After testing the NodeMCU by measuring the flowing voltage, it is obtained that the voltage flowing is 5.1V DC and is able to connect to the wifi that has been determined.

4. PZEM 004T

Testing on PZEM 004T aims to find out whether the PZEM 004T used can work properly or not. Analysis: After testing the PZEM 004T by measuring the flowing voltage, a voltage of 222.2 VAC was obtained and the sensor was able to collect data properly and accurately.

Figure 25. PZEM 004T Testing

5. Arduino IDE

   From the tests carried out, the results obtained that the program in the Arduino IDE application works properly and normally, and is ready to be uploaded to the NodeMCU board used in this tool.

Figure 26. Arduino IDE Testing

Analysis Results: From the above tests, it is obtained that the program in the Arduino IDE application works properly and normally, and is ready to be uploaded to the NodeMCU board used in this tool.

6. XAMPP

Figure 27. XAMPP Testing

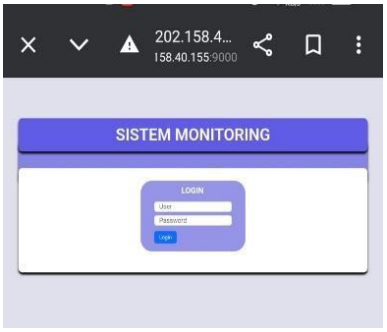

Figure 28. Webserver Display

The test results show that XAMPP can run well and there are no significant compatibility issues. The data sent by NodeMCU ESP32 is tested to ensure that XAMPP can process the data correctly using the FMADM method. The test results show that XAMPP can process data with a high level of accuracy (more than 95%). XAMPP test results show that XAMPP can be used properly in the monitoring system of current, power, and electrical energy consumption using the IoT-based FMADM method. This system can provide accurate and timely information about electrical energy consumption, as well as help technicians and consumers monitor electricity usage remotely with a high level of accuracy.

7. Webserver

   The results of web server testing show that the monitoring system for current, power, and electrical energy consumption using the IoT-based FMADM method can provide accurate and timely information about electrical energy consumption, as well as help technicians and consumers monitor electricity usage remotely with a high level of accuracy.

Overal Testing of the tool

Testing steps :

1. Connect the mockup to 220 VAC electricity and make sure it is in good condition and ready to use.
2. Then connect the ESP 32 module output to the laptop using a USB connector cable. Here it is used to check and ensure that the program in the Arduino IDE application works properly and normally, and is ready to be uploaded to the NodeMCU board used in this tool.
3. After that, open the XAMPP application on a laptop to activate the internet network and webserver so that it can be accessed.
4. Access the webserver that has been created to monitor the use of electrical energy.
5. Then login with the user and password that has been created.
6. Then switc on the switch to turn on the load.
7. After the load is on we can monitor the use of the electricity used

Test Result Data

Admin				
Monitor User 1				
Electrical load	Current (A)	Power (Watt)	Energy (KwH)	Cost (Rp)
No electrical load	0	0	0,014	20
1 lamp 100 W	0,443	95,7	0.018	26
1 lamp 100 W + 1 iron	2,052	447,4	0.024	35
1 socket	1,63	358	0,032	46
Monitor User 2				
Electrical load	Current (A)	Power (Watt)	Energy (KwH)	Cost (Rp)
No electrical load	0	0	0,013	19
1 5 watt lamp	0.272	60,2	0.015	22
1 5 watt lamp + 1 laptop charger	0,455	89,6	0,018	26
1 socket (laptop charger)	0,266	34,6	0,019	27
Monitor User 3				
Electrical load	Current (A)	Power (Watt)	Energy (KwH)	Cost (Rp)
No electrical load	0	0	0,018	26
1 lamp 100 W	0,432	95,6	0,022	32
1 lamp 100 W + (cellphone charger)	0,551	116,4	0,024	35
1 socket (cellphone charger)	0,156	20,1	0,025	36

Figure 29. Electrical energy usage testing (admin monitor)

Admin			
Fuzzy MADM Category User 1			
No electrical load	Energy Weight	Energy (KwH)	Cost Weight
1 lamp 100 W	Low	Low	Low
1 lamp 100 W + 1 iron	Currently	Low	Low
1 socket	High	High	High
No electrical load	High	High	High
Fuzzy MADM Category User 1			
Load	Energy Weight	Energy (KwH)	Cost Weight
No burden	Low	Low	Low
1 5-watt lamp	Low	Low	Low
1 5-watt lamp and laptop case	Medium	Low	Low
1 laptop case	Low	Low	Low
Fuzzy MADM Category User 3			
Load	Energy Weight	Energy (KwH)	Cost Weight
No burden	Low	Low	Low
1 100 W lamp	Medium	Medium	Medium
1 lamp 100 W + hp case	High	High	Medium
1 hp case	Low	Low	Low

Figure 30. Fuzzy MADM Category Testing (admin)

Admin					
Log User 1					
Time/second	Voltage	Current	Power	Energy	Cost
09:14:16 21-07-2024	219	0,273	59,6	0,084	121
09:13:14 21-07-2024	218	0,272	59,3	0,083	120
09:12:12 21-07-2024	218	0,272	59,3	0,082	118
09:11:11 21-07-2024	218	0,272	59,3	0,081	117
09:10:09 21-07-2024	220	0,273	60	0,08	116
09:09:08 21-07-2024	220	0,273	60	0,079	114
09:08:06 21-07-2024	220	0,273	60,1	0,078	113
09:07:05 21-07-2024	220	0,273	60,2	0,077	111
09:06:03 21-07-2024	219	0,272	60,4	0,076	110
09:05:01 21-07-2024	220	0,273	60	0,075	108
Log User 2					
Time/second	Voltage	Current	Power	Energy	Cost
09:14:16 21-07-2024	219	0,273	59,6	0,084	121
09:13:14 21-07-2024	218	0,272	59,3	0,083	120
09:12:12 21-07-2024	218	0,272	59,3	0,082	118
09:11:11 21-07-2024	218	0,272	59,3	0,081	117
09:10:09 21-07-2024	220	0,273	60	0,08	116
09:09:08 21-07-2024	220	0,273	60	0,079	114
09:08:06 21-07-2024	220	0,273	60,1	0,078	113
09:07:05 21-07-2024	220	0,273	60,2	0,077	111
09:06:03 21-07-2024	219	0,272	60,4	0,076	110
09:05:01 21-07-2024	220	0,273	60	0,075	108

Figure 31. Electricity Usage History Testing

Pros and Cons Of Tools

After conducting several tests on several components and testing the entire integrated system, the following summarizes the results of the discussion through an explanation of the advantages and disadvantages of the tool as follows:

Tool Advantages:

1. Can monitor remotely using a smartphone.
2. This plan is already IOT-based.
3. Technicians and customers can access the web server
4. Using the Fuzzy MADM algorithm to determine the category of low, medium and high electrical energy usage.
5. Can be used for 1 phase or 3 phase electricity
6. The output can display the total current, power, voltage and cost of electrical energy used.

Tool Shortages:

1. Can not be used outdoors / outdoor
2. Using the internet network

AUTHORS' CONTRIBUTIONS

In this tool research successfully developed a monitoring system for current, power, and electrical energy consumption from various counter rooms at the airport using the IoT-based Fuzzy Multiple Attribute Decision Making (FMADM) method. This system includes Power Supply, LM 2596, PZEM 004T Sensor, NodeMCU ESP32, and server connected via internet/wifi. The test results show that this system can process data with a high level of accuracy (more than 95%) and display data clearly on the web interface. This

system can also help technicians and consumers remotely monitor real-time electricity usage, reduce electricity costs, and improve energy use efficiency.

The whole series of tools can work well, using NodeMCU ESP32 to monitor the use of electrical energy from the results of the PZEM-004T sensor. As well as the results of sensor readings displayed on the samrtphone on a webserver that can help technicians and consumers monitor remotely. By connecting the mockup to a 220 VAC power source and making sure all devices are in good condition and ready to use. Then, connect the ESP32 module to a laptop using a USB cable to ensure the program in the Arduino IDE application runs properly before uploading it to the NodeMCU board. After that, open the XAMPP application on the laptop to activate the internet network and webserver, then access the webserver that has been created to monitor the use of electrical energy. Log in to the webserver with the username and password that has been created, then turn on the switch to turn on the connected load. After the load turns on, monitor the use of electric power used through the webserver. This research concludes that the IoT-based kWh monitoring system can provide accurate and timely information about energy consumption, The device circuit with NodeMCU ESP32 and PZEM-004T sensor works well and accurately (97.74%) so it is feasible to use. Electricity usage categories: power (low <50, medium 50-100, high >100), energy (low <50 kWh, medium 50-150 kWh, high >150 kWh), and cost (low <150, medium 150-200, high >200). The use of FMADM helps technicians and consumers monitor electricity usage remotely with more than 95% accuracy.

REFERENCES

[1] Lotfi A. Zadeh. Fuzzy Sets. Information and Control, vol. 8, no. 3, pp. 338-353, 1965. (Referensi dasar teori fuzzy set)

[2] K. J. Raydan. Fuzzy Multiple Attribute Decision Making: Methods and Applications. Springer, 2011. (Referensi tentang metode FMADM)

[3] Espressif Systems. ESP32 Datasheet. Espressif Systems, 2020. (Referensi tentang NodeMCU ESP32)

[4] PZEM 004T Datasheet. PZEM 004T Datasheet. (Referensi tentang sensor PZEM 004T)

[5] LM 2596 Datasheet. LM 2596 Datasheet. (Referensi tentang regulator tegangan LM 2596)

[6] Wikipedia. Fuzzy Logic. Wikipedia, 2023. (Referensi singkat tentang teori fuzzy logic)

[7] IoT Journal. IoT in Energy Management: A Review. IoT Journal, 2022. (Referensi tentang penggunaan IoT dalam manajemen energi)

[8] Abdullah, K., Jannah, M., Aiman, U., Hasda, S., Fadilla, Z., Taqwin, N., Masita, Ardiawan, K. N., & Sari, M. E. (2021). Metodologi Penelitian Kuantitatif. In PT Rajagrafindo Persada (Vol. 3, Issue 2).

[9] Ali, M. (2018). Aplikasi Elektronika Daya pada Sistem Tenaga Listrik. UNY Pers, 1–149.

[10] ANDROID. Jurnal Sistem Informasi Dan Teknologi Informasi, 2(3), 13–24.