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Smart kWh Meter Model with Energy Control and Monitoring on Low Voltage Electricity

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ABSTRACT
This research makes a smart kWh (kilowatt-hour) electricity meter system to complement the conventional kWh model household electricity meter. The purpose of this study is to monitor and control the use of electrical energy at low voltage and industrial groups to obtain efficient patterns in the use of electrical energy. In this model using sensors as current and voltage readers, microcontrollers as data senders to the webserver contained in raspberries as one of the main components of the concept of the Internet of Things (IoT). The advantage of this control and monitoring system is that the measurement results of each sensor can be processed directly and displayed graphically in real-time conditions and can monitor this capability remotely or via the internet. The implementation of IoT by applying the fuzzy method in monitoring electricity usage is needed as a tool to determine conditions of low (0-0.1), moderate (0.8 - 0.2), and high (> 0.18), with determination based on determining the level of membership in a linear curve downward, triangles and up. Establishment of a monitoring model for household and industrial electrical energy usage with the fuzzy implementation that can control usage and provide real-time history and information about electricity usage to its users on a web server that can help users to be able to control their use of electrical energy. Based on the results of the significance test, the difference between the voltmeter test results with the sensor used difference current less than 0.5, so the model used can be said to be significant.

Keywords: *Smart meter, electricity, control, Internet of Things, monitoring*

1. INTRODUCTION

In this research, the development of automation devices in the reading system of electrical energy use is carried out by calculating the kWh (kilowatt-hours) of the electricity meter. Systems with prepaid and postpaid electricity payment models as well as monitoring the condition of electric power systems and control systems with the help of artificial intelligence as an assessment of equipment conditions using a computerized system with artificial intelligence techniques based on data classification [1] [2] [3]. The model proposed for automatic kWh meter reading is to develop kWh meter reading and control using telecommunication transmission media and installing an embedded system on the kWh meter so that it can be read and entered into the database, stored and accessible immediately online with meter recording, so the results are recorded. kWh meter is more accurate and can be accessed in real-time [4]. The model of controlling and monitoring the use of electrical energy can help determine usage to save and consume electrical energy, remote use calculation, and control, and determine the power stored and processed in real-time by applying artificial intelligence methods with the application of IoT (Internet of things) [5]. This method is very useful in today's era that can help the community a lot in any way, one of which is monitoring electricity usage in real-time regardless of distance [6]. The concept of the Internet of Things is a technology that is of concern and uses in human life in the face of revolution 4.0 [7] [8] [9] [10]. The development of meter reading tools with better capabilities (smart metering), from conventional ones, has several weaknesses, including requiring a large amount of human labor and digital development that does not automatically have many weaknesses such as errors and takes a lot of time to correct, gives the risk of an incorrect unit read, the second provides a digital read with some accuracy but cannot be sent to the billing point directly. The Smart Energy Meter is designed to use a reference voltage and current to self-calibrate the price of power consumed. However, this approach does not consider the influence of the frequency of supply but rather concentrates on the power consumption patterns of consumers [11]. Research [4] is to make a model for charging electric pulses with a smart card as an alternative to filling digit numbers into prepaid electricity meters which are currently done manually. The proposed smart home meter prototype with a system architecture consisting of several components which includes several functions as a base station, control unit, and user interface. Targets are devices developed that can be used by users to monitor and control electricity usage.

1.1. Related Work

Previous research proposed using GSM (Global System for Mobile) technology as a transmission medium in energy readings that this proposed system could replace traditional energy meter reading methods and allow remote access of existing energy meters by energy providers. Managers can monitor reading regularly without visiting a person's home [10]. The Smart Energy Meter is designed to use a reference voltage and current to self-calibrate the price of power consumed. However, this approach does not consider the influence of the frequency of supply but rather concentrates on the power consumption patterns of consumers [11]. In this study, the concept of a smart meter as a substitute for a kWh meter, where this smart meter allows consumers to get statistical data on electrical energy consumption by using the ACS712 sensor on the current sensor. This study uses the Backpropagation Neural Network method where the method is used for feedforward Neural Networks [12] [13]. According to data from PT PLN, 48% still use mechanical meters, and 51.22% use digital prepaid meters [14]. The development of a smart meter is a proposal for a device that is smart and capable of carrying out the many functions of the currently used electric meter models. Besides being able to record the use of electrical energy automatically, then record and store for a predetermined duration of time, with the transmission media module communication connected in a two-way communication system, not only sends readings from the meter to the data center but also to provide control information or commands from the data center to meter [10] [15] [16] [14]. Fuzzy logic is a two-value logic known as Boolean, which is a well-defined and used theory that has advantages when a system that has a high level of complexity makes mathematical modeling of the system more difficult, then controlling this fuzzy logic system can support decisions in the development of a proper system of reasoning [17]. The membership function is a curve that shows the mapping of data input points into membership values or membership degrees which have values ranging from 0 to 1 [18].

2. METHODOLOGY

The approach method used is to make observations or observations. Observation is data collection by directly observing the running system by finding problems that often occur. The proposed system is an attempt to solve problems that can help and narrow down problems arising from the system being analyzed. In this case, the proposed system is created by designing a monitoring model for household electricity use with the Internet of Things. The system proposed in the research process aims to obtain meter recording accuracy, easy and fast electricity bill calculation, operational cost efficiency, and customer satisfaction.

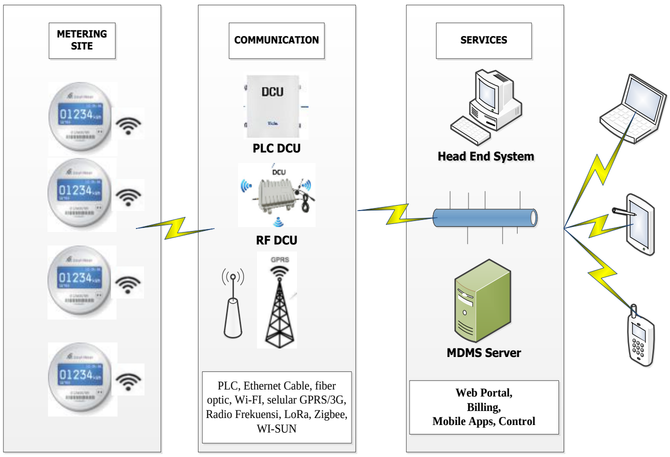

Figure 1 Proposed System Scenario

Based on Figure 1, the system proposed in this research effort includes:

1. Measurement location: meter reading placement tool. Electric energy consumption sensor reader.
2. Communication: Communication transmission media as a communication gateway between meters that can be implemented by kWh meters such as PLC, ethernet cable, fiber optic, Wifi, GPRS / 3G, RF, Zigbee, etc.
3. Services: Head End System (HES), as an application for meter reading and an application for meter operation, for example: connecting/disconnecting, power limit; Audit trail, events, alarm log, status & history. Meter Data Management System (MDMS) as:
    a. Storage area for meter reading, alarms, events, status data;
    b. Validation, Estimation, Editing (VEE);
    c. Asset management, device lifecycle management, and reporting;
    d. Measured data functionality (analysis, meter changes, audit history & trail).

Based on the system scenario, a research framework is proposed which can be illustrated. This research framework will consist of four stages. The purpose of this research framework is to hypothesize the development of an electric energy meter model. The research framework is divided into 4 parts, namely indicators, proposed methods, objectives, and measurements, which are illustrated in Figure 2.

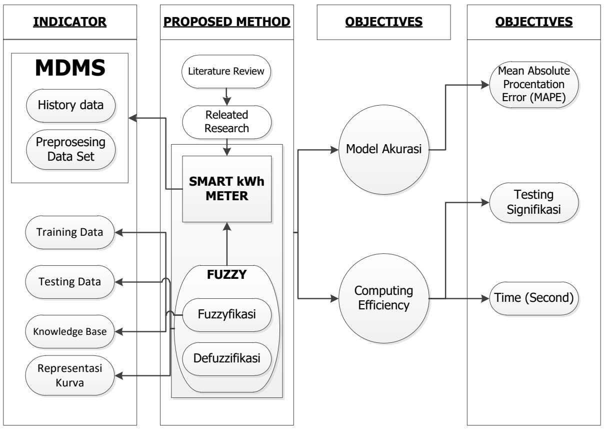

Figure 2 Research Framework

Based on the schematic scenario designed, the proposed system analysis is to define, monitor, and control the real-time that can be used directly without any time and space limitations.

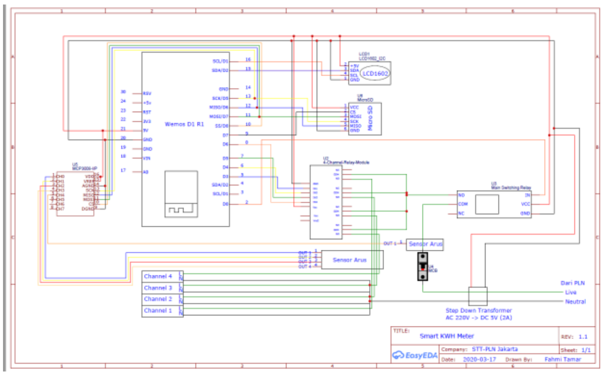

Figure 3 Smart kWh Meter Rev Model Schematic: 1.1.0

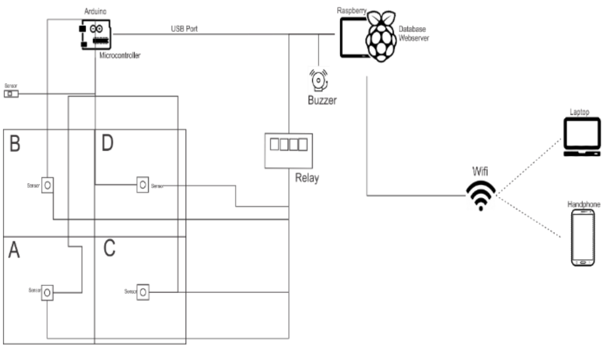

Figure 4 Channel Scenario System

The following is a proposed function of electricity use with the Internet of Things approach. With the fuzzy logic method approach, electricity consumption can be grouped into 3 (three) categories, namely: low, medium or high. Testing with an approach using the Fuzzy Logic method. This method serves to provide an exact value from the data collected to become recommendations and decisions in the pattern of electrical energy use.

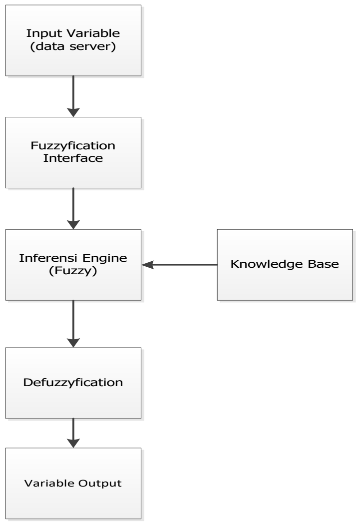

Figure 5 Fuzzy Inference Procedure

Calculating Membership Function. The next process is to calculate the degree of membership in the use of electrical energy in channel A based on the membership function. To perform calculations, a formula is needed, as for the formula as below:

a. Using the formula for a descending linear curve

$$\mu\ Low[x,a,b] = \begin{cases} 1 & ; \quad x \le a \\ (b-x)/(b-a) & ; \quad a < x \le b \\ 0 & ; \quad x > b \end{cases}$$

b. Using the Triangle Curve Formula

$$\mu\ Mid[x,a,b,c] = \begin{cases} 0 & ; \quad x \le a \text{ or } x \ge b \\ (x-a)/(b-a) & ; \quad a < x \le b \\ (c-x)/(c-b) & ; \quad b < x \le c \end{cases}$$

c. Using the formula for linear ascending curve

$$\mu\ high[x,a,b] = \begin{cases} 0 & ; \quad x \le a \\ (x-a)/(b-a) & ; \quad a < x \le b \\ 1 & ; \quad x > b \end{cases}$$

Based on the function on the trapezoid curve, the choice of representation of the trapezoidal membership function will read the data pattern from the right and left, that the function x is the value of the variable being sought, a is the lower bound, b and c is the middle boundary, and d is the upper bound, in the representation trapezium curve. Where for the Membership Functions use the trapezium curve formula as shown below:

$$\mu[x] \begin{cases} 0; & x \le a \text{ or } x \ge d \\ (x-a)/(b-a) & a < x \le b \\ 1; & b < x \le c \\ (d-x)/(d-c) & c < x \le d \end{cases}$$

The membership function based on the input current and voltage variables is carried out in the following steps: The first step in the formation of fuzzification, Current:

a) Parameters {0 350 450 600}
b) Low {0, 600}

$$\mu Low[x]\begin{cases} 0; & x \le 0 \; or \; x \ge 600 \\ (x-0)/(350-0) & 0 < x \le 350 \\ 1; & 350 < x \le 450 \\ (600-x)/(600-450) & 450 < x \le 600 \end{cases};$$

c) Parameter {400 500 550 650}
d) Normal {400 - 650}

$$\mu normal[x]\begin{cases} 0; & x \le 400 \; or \; x \ge 650 \\ (x-550)/(600-550) & 400 < x \le 500 \\ 1; & 500 < x \le 550 \\ (750-x)/(750-650) & 550 < x \le 650 \end{cases};$$

e) Parameter {600 650 750 1000}
f) High {≥600}

$$\mu High[x]\begin{cases} 0; & x \le 700 \; or \; x \ge 1000 \\ (x-600)/(650-600) & 700 < x \le 850 \\ 1; & 850 < x \le 900 \\ (1000-x)/(1000-750) & 900 < x \le 1000 \end{cases};$$

a) Voltage

a) Parameter {0 4 7 10.5}
b) Low {≤10.5}

$$\mu Low[x]\begin{cases} 0; & x \le 0 \; or \; x \ge 10.5 \\ (x-0)/(4-0) & 0 < x \le 4 \\ 1; & 4 < x \le 7 \\ (10.5-x)/(10.5-7) & 7 < x \le 10.5 \end{cases};$$

c) Parameter {9 10 13 14}
d) Normal {9 - 14}

$$\mu normal[x]\begin{cases} 0; & x \le 9 \; or \; x \ge 14 \\ (x-9)/(10-9) & 9 < x \le 10 \\ 1; & 10 < x \le 13 \\ (14-x)/(14-13) & 13 < x \le 14 \end{cases};$$

e) Parameter {13 14 15 16}
f) High {≥13}

$$\mu High[x]\begin{cases} 0; & x \le 13 \; or \; x \ge 16 \\ (x-13)/(14-13) & 13 < x \le 14 \\ 1; & 14 < x \le 15 \\ (16-x)/(16-15) & 15 < x \le 16 \end{cases};$$

b) Electric Power Load:

a) Parameter {0 30 45 60}
b) Low {≤60}

$$\mu Low[x]\begin{cases} 0; & x \le 0 \; or \; x \ge 60 \\ (x-0)/(30-0) & 0 < x \le 30 \\ 1; & 30 < x \le 45 \\ (60-x)/(60-45) & 45 < x \le 60 \end{cases};$$

c) Parameter {60 65 75 80}
d) Normal {60 - 80}

$$\mu normal[x]\begin{cases} 0; & x \le 60 \; or \; x \ge 80 \\ (x-60)/(65-60) & 60 < x \le 65 \\ 1; & 65 < x \le 75 \\ (80-x)/(80-75) & 75 < x \le 80 \end{cases};$$

a) Parameter {75 80 95 100}
b) High {≥75}

$$\mu High\,[x]\begin{cases} 0; & x \le 75 \; or \; x \ge 100 \\ (x-75)/(80-75) & 75 < x \le 80 \\ 1; & 80 < x \le 95 \\ (100-x)/(100-95) & 95 < x \le 100 \end{cases};$$

3. RESULTS

The device design model to be tested as a whole is made into several channels. Some channels will be conditioned with room/part conditions in the utilization of electrical energy for the type of household or low voltage network group.

Figure 6 Meter Device Model kWh 5 Channel Rev 1.0

Based on test results with simulation, the implementation of fuzzy logic testing is carried out using Matlab as shown below:

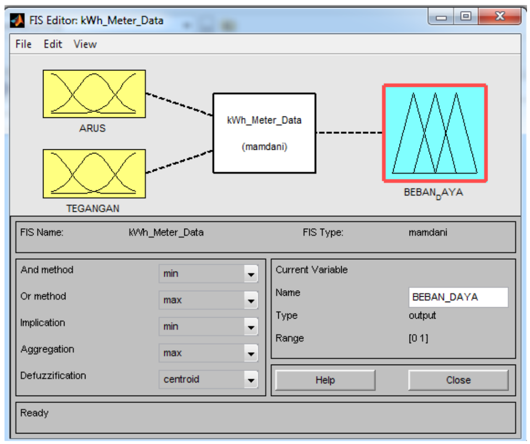

Figure 7 Input Variable Current, Voltage and Power Load

The curve representation used for the current is a trapezoidal curve which includes Low, Normal, and High as shown in Figure 5 which is a current curve image with the parameters Low [0 350 450600], Normal [400 500 550 650], and High [600 650 750 1000].

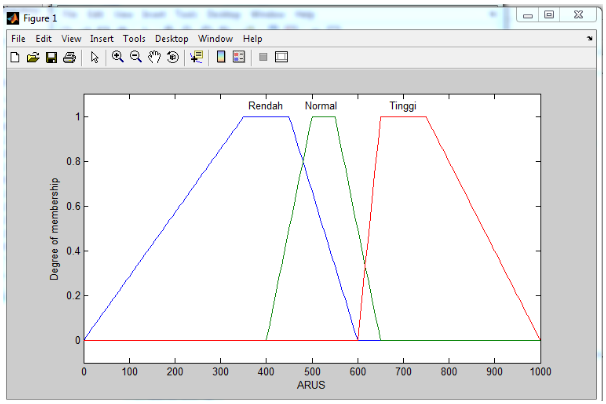

Figure 8 Current Curve Representation

Furthermore, the input process will be carried out on a voltage which includes Low, Normal, and High. Figure 4.15 is a voltage curve with parameter Low [0 4 7 10.5], normal voltage with parameter [9 10 13 14] and High with parameter [13 14 15 16].

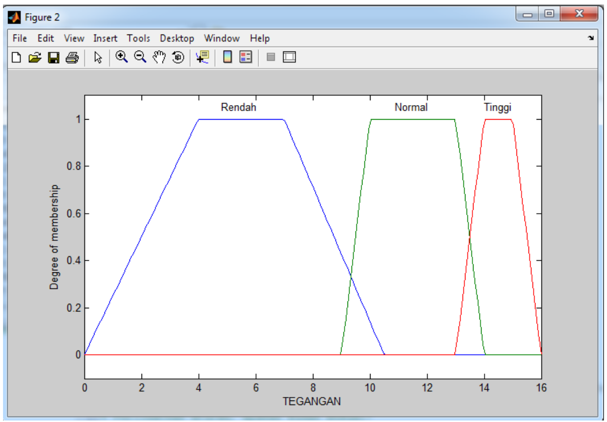

Figure 9 Voltage Curve Representation

Then the power load curve determination was carried out with the Low parameter, namely ≤10.5 [0 4 7 10.], Standard 9 - 14 [9 10 11 13], and Wasteful ≥13 [13 14 15 16], shown in Figure 7.

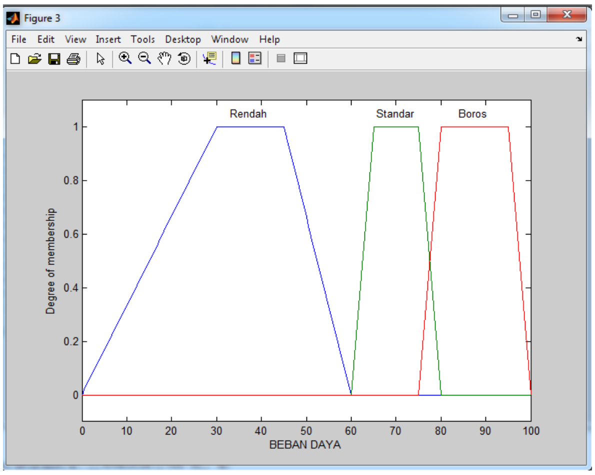

Figure 10 Power Load Curve Representation

After the rules are made, the next step is to test the power loading output on the Matlab from the current and voltage sensor input device, the results obtained are according to rule [8] with inference.

IF (Normal Current; (630) AND (High Voltage; (13.2) THEN (High Power / Wasteful Load).

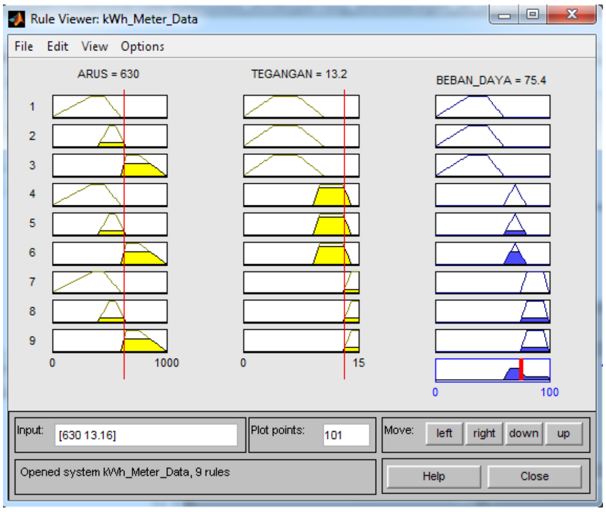

Figure 11 Rule Base Model IF-THEN

Inferential Statistical Testing, is done using a calibrated voltmeter to measure the voltage and current in the socket on each channel.

Table 1. Signification Test Results

T	(V)		(C)		(W)		Error		
	A	S	A	S	W	S	V	C	L
1	219	217	0.15	0.15	32.89	32.55	2	0	0.34
2	218	217	0.15	0.15	32.70	32.55	1	0	0.15
3	218	217	0.15	0.15	32.70	32.55	1	0	0.15
4	217	217	0.15	0.15	32.55	32.55	0	0	0
5	217	217	0.16	0.15	34.72	32.55	0	0.01	2.17
6	218	217	0.15	0.15	32.70	32.55	1	0	0.15
7	217	217	0.15	0.15	32.55	32.55	0	0	0
8	217	217	0.15	0.15	32.55	32.55	0	0	0
9	217	217	0.15	0.16	32.55	34.72	0	0.01	2.17
10	217	217	0.15	0.16	32.55	34.72	0	0.01	2.17

Based on the results of the significance test, the difference between the voltmeter test results and the sensor used is less than 0.5, so the model used can be said to be significant.

4. CONCLUSION

The device can process data access in real-time to find out the history of usage and control the device by determining the distribution flow according to the capacity specified by the user, using telecommunications network media with flexible and mobile devices. Based on the results of the significance test, the difference between the voltmeter and sensor test results on the meter reading tool from the current user with the average value obtained is the difference (error) from the test of 0.5 with a test time of 10 minutes. Testing the power loading output on the *Matlab* from the input of the current sensor and the device voltage is obtained according to the rule [8] with the conclusion that the results obtained are Normal Current; (630), High Voltage; (13.2), and (High / Wasteful Load). Based on the functions on the trapezium curve, the choice of trapezium membership function representation will read the data pattern from the right and the left by determining the Fuzzy Logic current and voltage with low, normal and high criteria, while the load criteria are low, standard and extravagant/high.

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