Implementation of Fuzzy Sugeno Method for Power Efficiency
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Abstract— Energy is one of the basic needs for human being. One of the most vital energy sources is electricity. Electricity is a type of energy that sustains survival of human being, more particularly in industrial sector. Efficiency in industrial sector refers to a state where electricity is used to as little as possible to produce the same amount of product. The case study was conducted in marine commodity sector, anchovy and jellyfish supplier. The supplier was classified as SME that installed 33,000 VA electric powers (B2). The data were in the form of energy consumption intensity (ECI) and specific energy consumption (SEC) to determine the energy efficiency level. The objective of the study was to classify the efficiency level of electricity consumption using Sugeno Fuzzy method. The findings of the study were 1) the average ECI between January, 2016 and April, 2017 was 1,949 kWh/m²; it was classified as efficient; 2) the average SEC at the same period was 126,108 kWh/ton; it was classified as excessive. Sugeno Fuzzy logic was implemented to determine efficiency level of electricity in this company. Based on the average ECI and SEC, the electricity consumption of the company was categorized as excessive with FIS Sugeno output of 0.803.

Keywords— Electrical Power, Efficiency, Fuzzy Sugeno, ECI, SEC

I. INTRODUCTION
Energy is one of the basic needs for human being. One of the most vital energy sources is electricity. Electricity is a type of energy that sustains survival of human being, more particularly in industrial sector. Efficiency in industrial sector refers to a state where electricity is used to as little as possible to produce the same amount of product. The case study was conducted in marine commodity sector, anchovy and jellyfish supplier. The supplier was classified as SME that installed 33,000 VA electric powers (B2). In 2015, the marine commodity supplier consumed 14,534 kWh of electricity and produced 133,460 kilograms of anchovy and jellyfish.

This study described the use of electricity during production, the energy consumption intensity (ECI) and specific energy consumption (SEC) to determine efficiency level of electricity. The findings were efficiency level of electricity consumption in the company (marine commodity supplier) as well as to evaluate whether or not Sugeno FIS algorithm was applicable in this case study. The supplier may use the findings to evaluate how much electricity they use during production, maintenance and for operating their electrical appliances.

II. METHODOLOGY
Electrical Energy
Electrical energy is type of energy generated from the flow of electrical charges. Energy is ability to do an activity or apply certain power to move an object. In terms of electrical energy, force is the attraction of electricity or repulsion between charged particles. Electrical energy can be either potential energy or energy, which is usually stored as potential energy, stored in relative positions of charged particles or electric fields. Charged particles moves through wires or other media called current or electricity. In addition, there is static electricity, which results from an imbalance or separation of positive and negative charges on an object. Static electricity is a form of electrical potential energy. If enough charge accumulates, electrical energy can be released to form sparks (or even lightning), which have electrical kinetic energy.

Energy Consumption Intensity (ECI)
Energy Consumption Intensity (ECI) is the division between energy consumption and total area of a building (SNI 03-6196, 2000). Energy consumption refers to the amount of energy consumption of both electrical energy and other energy sources in one building within one year.
Electricity consumption for one year (KWH / year) is obtained from electricity bill, while other energy consumption is obtained from records of fuel consumption or consumption of other energy sources. Energy Consumption Intensity (ECI) is term used to describe the amount of energy used per square meter of gross total area of a building within certain period of time (per year or per month).

\[ \text{ECI} \left( \frac{kWh}{m^2} \right) = \frac{\text{total energy consumption (kWh)}}{\text{total area of a building (m}^2\text{)}} \]

Specific Energy Consumption
Specific energy consumption (SEC) is the amount of energy used for production. These elements are used to measure specific energy consumption (SEC) of an industry.

1. Energy consumption of an industry for certain period of time (kWh/period of time, GJ/period of time)
2. Total production for certain period of time (ton/period)

The following equation can be used to measure the specific energy consumption (SEC) of an industry.

\[ \text{SEC} = \frac{\text{total energy consumption (kWh)}}{\text{total production (ton)}} \]

Fuzzy Sugeno
Sugeno Fuzzy method is fuzzy inference method for rules represented in the form IF-THEN, where system output (consequently) is not in the form of fuzzy set, but rather a constant or a linear equation. This method was introduced by Takagi-Sugeno Kang in 1985. [6] Sugeno model uses the Singleton membership function, membership function of which membership degree is 1 on a single crisp value and 0 on another crisp value.

Zero-Order Sugeno Fuzzy Model
In general, the equation for the zero-order Sugeno Fuzzy model is IF (X1 is A1) • (X2 is A2) • (X3 is A3) • ... • (Xn is AN) THEN z = k. A1 is the set of 1st fuzzy as antecedent and k is a constant as a consequence. Advantage of the Sugeno-type FIS is zero-order is often sufficient for various modeling purposes. [7].

III. RESULT AND IMPLEMENTATION
Data Management
This study uses Fuzzy Logic, particularly Fuzzy Inference System (FIS) with zero-order Sugeno Method. Fuzzy logic is often used to calculate vague score. In accordance to the Fuzzy Logic theory, the theory requires input score, input variable and linguistic variable. This study involves various processes or stages of the zero-order Sugeno method, from the start until the end. The stages are as follow:

A. Preparation
Prior to ECI and SEC data input to Sugeno FIS method, the researchers should do these steps.

1. Calculating ECI and SEC score
Table 1 described the 2015 ECI and SEC score of the marine commodity supplier.

| No | Month       | ECI (kWh/m²) | SEC (kWh/ton) |
|----|-------------|--------------|---------------|
| 1  | January     | 3,504        | 125,824       |
| 2  | February    | 4,574        | 110,997       |
| 3  | March       | 5,522        | 97,637        |
| 4  | April       | 1,880        | 107,033       |
| 5  | May         | 1,864        | 106,955       |
| 6  | June        | 1,249        | 85,853        |
| 7  | July        | 2,125        | 111,385       |
| 8  | August      | 2,078        | 118,159       |
| 9  | September   | 1,419        | 97,652        |
| 10 | October     | 4,762        | 111,935       |
| 11 | November    | 3,793        | 122,810       |
| 12 | December    | 1,438        | 100,892       |
| 13 | Total       | 34,207       | 108,932       |

Minimum: 1,249 (kWh/ton), Maximum: 5,522 (kWh/ton)

2. Classifying the ECI and SEC variables
Having obtained the ECI and SEC scores, the following stage was to classify ECI and SEC variables. Standardized ECI for non air conditioned room from the Department of Education and Culture was used as reference for ECI variable classification since the supplier did not use any air conditioner. Table 2 described the criteria for the ECI variable.

| Kriteria          | Range of ECI |
|-------------------|--------------|
| Very efficient    | 0.84 s/d 1.67|
| efficient         | 1.67 s/d 2.50|
| Excessive         | 2.50 s/d 3.34|
| Really Excessive  | 3.34 s/d 4.17|

Table 3. SEC Variable Criteria

| Kriteria     | Range of SEC |
|--------------|--------------|
| very good    | ≤ 85,853     |
| good         | 85,853 s/d 108,094 |
| poor         | 108,094 s/d 125,824 |
| Very poor    | ≥ 125,824    |

Data Input Process
The ECI and SEC were used as the input for the Sugeno
FIS method. The input was conducted manually into the system. Both data were used as the required parameter to determine how much electricity the company used.

**Sugeno Fuzzy Process**

In using the FIS sugeno method required some process done, namely the formation of membership functions for input variables, formation of combination rules (fuzzyfikasi), and affirmation (defuzzyfikasi).

There were several steps in the Sugeno FIS method, namely membership function for the input variable, fuzzyfication and defuzzyfication.

1. **Membership Function**

   Based on the literature related to fuzzy membership function and the criteria of ECI and SEC in Table 2 and 3, the membership function for ECI variable was as follow (Figure 1).

   ![Fig 1. Membership Function of ECI Variable](image)

   **2. Combination and Weighting**

   Table 4 described the combination used in this study.

   **Table 4. Combination for Electricity Consumption**

   | No | Input  | Output                |
   |----|--------|-----------------------|
   | 1  | Very efficient | Very efficient        |
   | 2  | Very efficient | good                 |
   | 3  | Very efficient | poor                 |
   | 4  | Very efficient | Very poor             |
   | 5  | efficient      | Very good             |
   | 6  | efficient      | good                 |
   | 7  | efficient      | poor                 |

2. **Defuzzyication**

   To determine electricity consumption in the company, combination of the two variables as described in Table 4 was the requirement. The following formula was used to determine the output.

   \[
   Z = \frac{\alpha_1(w_1) + \alpha_2(w_2) + \alpha_3(w_3) + \ldots + \alpha_n(w_n)}{\alpha_1 + \alpha_2 + \alpha_3 + \ldots + \alpha_n}
   \]

   Description:
   - \(Z\) = weighted average output and the constant (k), \(\alpha\) = \(\alpha\)-predicate = minimum score from the \(n\)th fuzzyfication
   - \(W\) = Weights for each determination in the fuzzyfication

   Based on the rules in Table 4 and the calculation of Z score after calculating the average weighting, it was confirmed the criteria described in Table 5 should be used to determine the electricity consumption.

   **Table 5 Criteria for Electricity Consumption**

   | Kriteria   | Range          |
   |------------|----------------|
   | Very efficient | \(Z \leq 0.25\) |
   | efficient    | \(0.25 < Z \leq 0.375\) |
   | quite efficient | \(0.375 < Z \leq 0.5\) |
   | quite Excessive | \(0.5 < Z \leq 0.625\) |
   | Really Excessive | \(0.625 < Z \leq 0.875\) |
   | Excessive     | \(0.875 < Z \leq 1\) |

3. **Result**

   This stage is the last stage, which displays the results of the processing of two input data into FIS sugeno method in the form of Z value and grouped according to criteria according to table 5. Manual calculation for sample training data from CV. Mahera 2015 in determining the
use of electricity with two variables of ECI and SEC is as in table 6 below:

| Month | ECI (kWh/m²) | SEC (kWh/ton) | FIS Manual | Electricity Consumption |
|-------|-------------|----------------|------------|------------------------|
| Jan   | 3,504       | 125,824        | 1          | Really Excessive       |
| Feb   | 4,574       | 110,997        | 0.875      | Excessive              |
| Mar   | 5,522       | 97,637         | 0.875      | Excessive              |
| Apr   | 1,880       | 107,033        | 0.4375     | Quite Efficient        |
| May   | 1,864       | 106,955        | 0.4375     | Quite Efficient        |
| Jun   | 1,249       | 85,853         | 0.25       | Sangat Efficient       |
| Jul   | 2,125       | 111,385        | 0.625      | Quite Excessive        |
| Aug   | 2,078       | 118,159        | 0.75       | Excessive              |
| Sep   | 1,419       | 97,652         | 0.375      | Efficient              |
| Oct   | 4,762       | 111,935        | 0.875      | Excessive              |
| Nov   | 3,793       | 122,810        | 0.9375     | Really Excessive       |
| Dec   | 1,438       | 100,892        | 0.375      | Efficient              |

The last stage referred to describing the result of processing two inputs into the Sugeno FIS method. The result was Z score which was later classified based on the criteria described in Table 5. Table 6 described manual data analysis for electricity consumption in CV. Mahera in 2015 using two variables, ECI and SEC.

Table 6. The 2015 Training Data Result using Sugeno FIS Manual Calculation

System Implementation

Figure 3 described the real implementation in the matlab.

Figure 3 showed that when user entered the ECI of 1.9 kWh/m² and SEC of 129 kWh/ton, the electricity consumption (output) was 0.775, which was categorized as excessive. To replace the input, the user put a score on the input column between brackets ([ECI SEC]) and pressed the enter button. The program would automatically display the output. Another method was to shift the red line in the ECI and/or SEC variables in order to automatically change the electricity consumption score. Analysis of the Test Result

Based on the testing using matlab in Table 7, the Sugeno FIS method was able to provide satisfying results or expected outcome.

IV. CONCLUSION

Based on the data related to the system implementation and testing obtained from the company between January, 2015 to April 2017, the average Energy Consumption Intensity (ECI) for January, 2016 to April 2017 is 1.949 kWh/m²; the score is categorized as efficient. On the other hand, the average of Specific Energy Consumption (SEC) from January, 2016 to April, 2017 is 126.108 kWh/ton; it is categorized as excessive.

Based on the average of ECI and SEC between January, 2016 and April, 2017, the consumption of electricity in CV. Mahera is categorized as excessive with the Sugeno FIS output 0.803. The Fuzzy logic with the zero-order Sugeno method is applicable for determining efficiency level of electricity consumption in a company. The efficiency level is shown based on the result of processing, analysis, and accuracy testing of the data obtained from the company.

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