DECISION SUPPORT SYSTEM FOR ELECTRICAL OSH INSPECTION AND TESTING BASED ON FUZZY LOGIC

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ABSTRACT

Conventional Electrical OSH inspection and testing usually only refers to one standard (SNI, IEC, IEEE or ANSI-NETA), this has an impact on analysis and a longer time besides the objectivity and subjectivity of the results is also a problem in itself. To overcome this, it is necessary to create an information system and validation of analysis based on Fuzzy Logic. The model is set as an Electrical OSH inspection and testing on the electricity distribution and utilization system. Parameters set include: assessment of administrative documents, assessment, measurement, calculation and testing. The results of the examination and testing are analyzed using the Fuzzy Logic method to improve its accuracy. The results of the development of this model produce a faster and more efficient analysis time and accurate results compared to conventional systems, this is evidenced by application testing on the factory X electricity distribution system which results in the conclusion that it meets the OSH requirements with an output value of 80,8 %. Meanwhile, the factory Y electricity utilization system concluded that it did not meet the OSH requirements with an output value of 40 %.

Keywords: *Inspection and Testing, Electrical OSH, Fuzzy Logic, Distribution System, Utilization System*

1. INTRODUCTION

Electrical hazards in the workplace are caused by improper installations, which leads to the inappropriate generation, transmission, distribution, maintenance, and use of electricity [1][2]. Electrical hazards can occur in the process of installing, maintaining, using and operating electricity [3][4]. This causes accidents, fire outbreaks, explosions, and occupational diseases [5][6][7]. One way to control is to inspect and test electrical OSH in the workplace [8][9][10]. However, conventional inspections and tests usually only refer to one standard, so the accuracy is not objective, plus the length of time the analysis of processed results becomes ineffective, this causes the company not to immediately implement efforts to prevent electrical hazards so that there is a potential for accidents in the workplace [11]. To overcome this, a practical and efficient information system in the field is proposed [9]. The addition of the Fuzzy Logic feature to improve accuracy with validation to the Indonesian National Standard (INS) document, the International Electrotechnical Commission (IEC), The Institute of Electrical and Electronics Engineers (IEEE) and the American National Standards Institute - International Electrical Testing Association (ANSI-NETA) are used [12][13].

Several previous studies, include testing distribution transformers, its oil characteristics, and switchgear, as well as the effect of unbalance loading, harmonics, as well as electrical hazards and testing on electrical utilization [14][15][16]. They succeeded in carrying out the inspection and testing of conventional electrical K3 using a specific standard although, none have applied artificial intelligence [17][18][19]. Therefore, this research focuses on improving the inspection and testing of electrical OSH information systems using several standards based on fuzzy logic to be able to obtain rapid and accurate results.

The purpose of this study is to design and build a decision support system that is integrated with all standards of electrical OSH inspection and testing and to apply Fuzzy Logic to a decision support information system for electrical OSH inspection and testing so as to increase the efficiency and effectiveness of the analysis results.

2. RESEARCH PROPOSED METHOD

Electrical OSH inspection and testing methods involve assessing, calculating, testing, and measuring electrically installed equipment to ensure the standard requirements are met, including the provisions of laws and regulations. It was carried

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out at the installation, generation, transmission, distribution, and utilization stages. This research focuses on electricity distribution and utilization systems in the workplace [13][20]. The process involves distributing electrical voltage, utilization section, including distributive networks, medium voltage distribution panel (cubicle), and transformers. Meanwhile, electrical energy is used for lighting and power installations, including main, branch, and load panels [21][22]. The research object is shown in Figure 1.

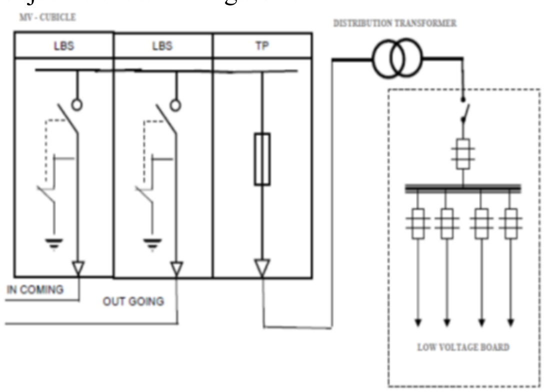

Figure 1: Electricity Distribution and Utilization Systems [1][23]

Based on Figure 1, electrical equipment involved in the distribution and utilization systems include:

a. Medium Voltage Distribution Panel or Cubicle
Cubicle is a piece of electrical equipment that functions as a controller, liaison, and protector as well as distributes power from its source. In addition, this consist of incoming and outgoing cubicles, and it contains various kinds of safety equipment, connectors, and electrical breakers, including Disconnecting Switch (DS), Load Break Switch (LBS), Circuit Breaker (CB), and Transformer Protection (TP) [24][23].

b. Distribution Transformer
A distribution transformer is a device for reducing a medium voltage of 20 kV to a lesser one of 400 V. The group vector types used for a 3-phase transformer are Yzn5, Dyn5, and Ynyn0. The neutral point is directly connected to the ground, while the outer-pair and inner-pair substation transformers are both equipped with ceramic insulator medium-voltage bushings or pre-molded plug-in insulators [1][23][25].

c. Low Voltage Distribution Panel.
Low-voltage Distribution Panel functions as controllers, connectors, and protectors as well as distributes electrical power from its generation to transformers. It comprises of several types, namely Main Panel (Main Distribution Panel), Branch Panel (Sub Distribution Panel), and Load Panel (Subbranch Distribution Panel). Electrical equipment utilized in distribution panel includes protective and separation facilities, fuses, conductors, and additional tools such as protection relays, measuring transformers, instruments, and phase indicator lights [24][23].

Data collection was carried out by inspecting and analyzing the Electrical OSH, including administrative documents, assessment, measurement, calculation, and testing. The results were further compared with the standard reference values of SNI, IEC, IEEE, and ANSI-NETA using fuzzy logic, which was subsequently analyzed to determine whether or not it meets the OSH requirements as shown in Figure 2.

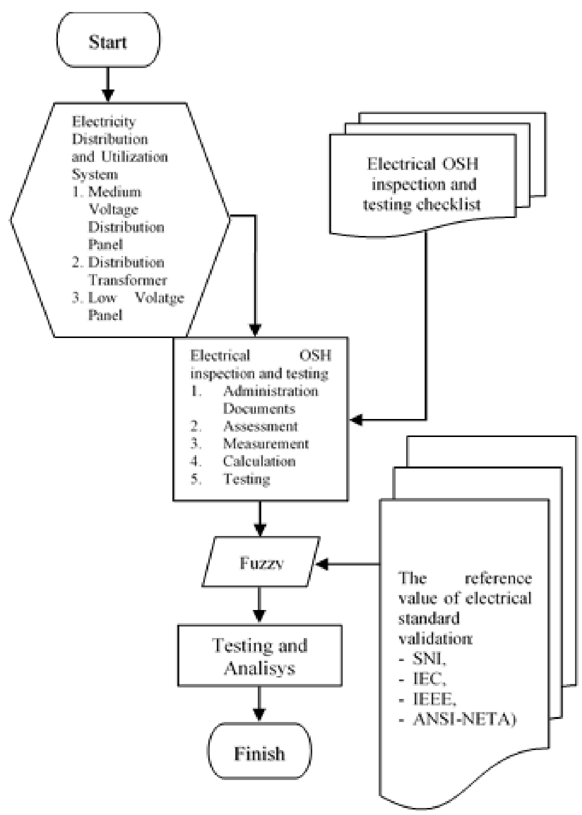

Figure 2: Proposed System for Inspection and Testing of Electrical [3][5]

The design of this research starts from determining the target object for electrical OSH inspection and testing, determining electrical OSH inspection and testing activities, carrying out

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electrical OSH inspection and testing activities, designing applications and implementing fuzzy logic, testing and analyzing [13][26][27]. Electrical OSH inspection and testing activities are shown in Table 1 and 2.

Table 1: Description of Electrical OSH Inspection and Testing Activities in Electrical Distribution System [13][16][26]

No	Input	Activity Form and Process	Description of Activities in Distribution System
1.	Administrative Document Assessment	Checking and reviewing administrative documents	It consists of 7 sub-activities, including inspecting electrical drawings, manufacturer certificates, manuals, maintenance and operation books, and OSH signs.
2.	Assessment	Visually assessing the condition of the installed, electrical fixtures, and equipment.	It consists of 50 sub-activities, including physical assessment of transformers, bushings, cooling systems, breathing apparatus, earthing installations, fire protection, and cubicle
3.	Measurement	Measuring the values of electrical quantities in installed fixtures and equipment.	It consists of 42 sub-activities, including measuring current, voltage, frequency, grounding, insulation, contact resistance, transformer oil breakdown voltage, conductor heat, ambient temperature, and lighting intensity.
4.	Calculation	Calculating the values of electrical quantities in installed fixtures, and equipment.	It consists of 5 sub-activities, including conductor rating calculation and protection, load and voltage imbalance, and transformer usage percentage.
5.	Testing	Individual and system testing of electrical installed fixtures, and equipment	It consists of 4 sub-activities, including testing protection equipment, relays, switches, and tripping voltage drops.

Table 2: Description of Electrical OSH Inspection and Testing Activities in Electrical Utilization System [13][16][26]

No	Input	Activity Form and Process	Description of Activities in Utilization System
1.	Administrative Document Assessment	Checking and reviewing administrative documents	It consists of 9 sub-activities, including checking electrical drawings, power recapitulation and short circuit current calculation documents, manufacturer certificates, maintenance and operation books, and OSH signs.
2.	Assessment	Visually assessing the condition of the installed, electrical fixtures, and equipment.	It consists of 37 sub-activities, including physical assessment of connection panels, neatness of installation, the identity of cables and busbars, protective devices, earthing systems, OSH signs, and ELCB ratings.
3.	Measurement	Measuring the values of electrical quantities in installed fixtures and equipment.	It consists of 46 sub-activities, including measuring current, voltage frequency, Total Harmonic Distortion, power factor, grounding, insulation and contact resistance, transformer oil breakdown voltage, conductor heat and size, ambient temperature, and lighting intensity.
4.	Calculation	Calculating the values of electrical quantities in installed fixtures, and equipment.	It consists of 6 sub-activities, including the calculation of the conductor and busbar current carrying capacity rating, protection rating, load and voltage imbalance, and voltage drop calculation.
5.	Testing	Individual and system testing of electrical installed fixtures, and equipment	It consists of 4 sub-activities, including testing protection equipment, relays, switches, and tripping voltage drops.

The reference value is determined based on the standard electrical validation in the administrative document process, assessment, measurement, calculation, and testing of electricity distribution and utilization systems, as shown in Table 3.

Table 3: Design of Reference Values from Validation of Electrical Standards [28][29][30][31]

No	Input	Reference Value of Electrical Standard Validation	Output
1.	Administrative Document Assessment	SNI; IEC [26]; IEEE [32][33]; ANSI-NETA [12][13]	Electrical OSH inspection and testing information system
2.	Assessnt		
3.	Measurement		
4.	Calculation		
5.	Testing		

2.1 Fuzzy Logic

A fuzzy logic method is used to prove that the electrical OSH inspection and testing results are accurate. In addition, this approach was adopted based on the Sugeno method [19][34][35]. The application process begins by entering the variables of the administrative document assessment, assessment, measurement, calculation and testing. From the parameter level data for the assessment of administrative documents, the assessment, measurement, calculation and testing above will result in a value of 0 (zero) if "Not Available" or "Not Suitable" or "Not Working" and a value of 1 (one) if "Available" or "Suitable" or “Working”. The process of determining the value is carried out by comparing the results of the inspection and testing of each activity description with the value of the electrical standard validation that has been set. The results of the calculation of activity variables will be used as input for the fuzzy logic process. Furthermore, the Fuzzy Logic process is carried out to get the conclusion that it does not meet the OSH requirements, meets the OSH requirements with notes or meets the K3 requirements. The application of Fuzzy Logic in the application of information systems for inspection and testing of Electrical OSH is described in Figure 3 and Figure 4.

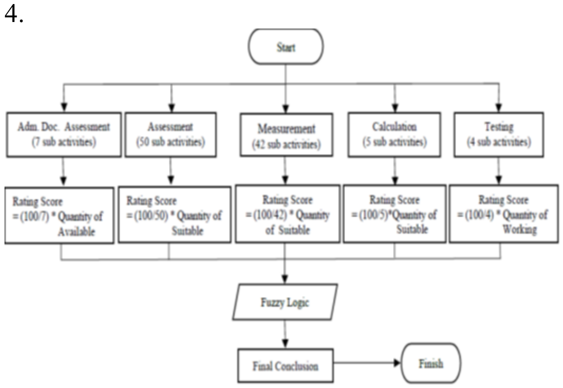

Figure 3: Flowchart of Application of Fuzzy Logic in Distribution System

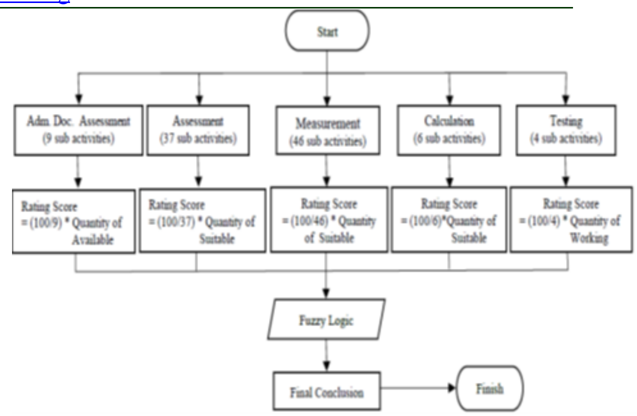

Figure 4: Flowchart of Application of Fuzzy Logic in Electrical Utilization System

Fuzzy logic output can be obtained through 4 stages as follows.

2.2.1 Fuzzification

At this stage the input and output values will be fuzzified into fuzzy sets and classified into several linguistic variables. Furthermore, the set of each linguistic variable is arranged to form a fuzzy membership function.

Table 4: Administrative Document Assessment Input Variables

Administrative Document Assessment (%)	Linguistic Variables
0-60	Does not meet OSH
40-100	Meets OSH

Tabel 5: Assessment Input Variables

Assessment (%)	Linguistic Variables
0-60	Does not meet OSH
40-100	Meets OSH

Tabel 6: Measurement Input Variable

Assessment (%)	Linguistic Variables
0-60	Does not meet OSH
40-100	Meets OSH

Tabel 7: Calculation Input Variable

Calculation (%)	Linguistic Variables
0-60	Does not meet OSH
40-100	Meets OSH

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Tabel 8: Testing Input Variables

Testing (%)	Linguistic Variables
0-60	Does not meet OSH
40-100	Meets OSH

Tabel 9: Output Variable Final Conclusion

Final Conclusion (%)	Variabel Linguistik
0-50	Does Not Meet OSH Requirements
40-70	Meet OSH Requirements with Notes
60-100	Meet OSH Requirements

From the data on the level of dministrative document assessment, assessment, measurement, calculation and testing above will be entered into the curve representation as follows:

1. The input variables for the assessment of administrative documents, assessments, measurements, calculations and testing consist of two fuzzy sets, namely "Does not Meet OSH" and "Meets OSH".

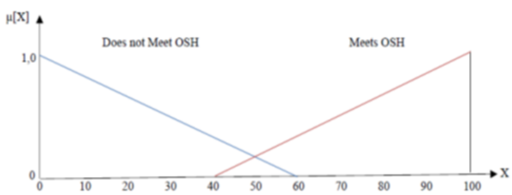

Figure 5: Activity Input Membership Curve

Membership Function "Does Not Meet OSH":

$$\mu \text{ Does not meet OSH } [x] = \begin{cases} 0 & X \geq 60 \\ \frac{60-X}{60-0}; & 0 \leq X < 60 \end{cases} \quad (1)$$

Membership Function Meets OSH:

$$\mu \text{ Meets OSH } [x] = \begin{cases} 0; & X \leq 40 \\ \frac{X-40}{100-40}; & 40 < X \leq 100 \\ 1; & X > 100 \end{cases} \quad (2)$$

2. The final conclusion output variable consists of three fuzzy sets, namely Does Not Meet OSH Requirements, Meets OSH Requirements with Notes and Meets OSH Requirements.

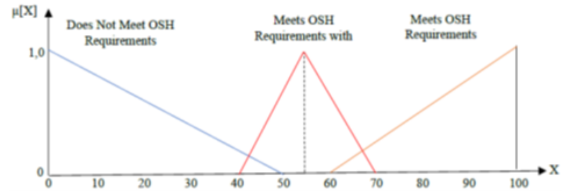

Figure 6: Output Membership Curve Final Conclusion

Membership Function Does Not Meet OSH Requirements:

$$\mu \text{ Does not meet OSH Requirements } [x] = \begin{cases} 0 & X \geq 50 \\ \frac{50-X}{50-0}; & 0 \leq X < 50 \end{cases} \quad (3)$$

Membership Function Meets OHS Requirements with Notes:

$$\mu \text{ Meet OSH Requirements with Notes } [x] = \begin{cases} \frac{X-40}{55-40}; & 40 \leq X \leq 55 \\ \frac{70-X}{70-55}; & 55 \leq X \leq 70 \end{cases} \quad (4)$$

Membership Function Meets OHS Requirements:

$$\mu \text{ Meets OSH Requirements } [x] = \begin{cases} 0; & X \leq 60 \\ \frac{X-60}{100-60}; & 60 < X \leq 100 \\ 1; & X > 100 \end{cases} \quad (5)$$

2.1.2 Fuzzy Rules Base

This stage is carried out by compiling the rules in the form of IF ... THEN. Propositions following IF in fuzzy logic are called antisendent, while propositions following THEN are called consequent. The implication function rules are obtained from 2 (two) membership values, namely Does not Meet OSH and Meets OSH on 5 (five) activity variables, including assessment of administrative documents, assessment, measurement, calculation and testing in distribution and utilization of electricity. Based on the results of the formation of the fuzzy set, it is described in 32 rules, some of which are shown in Figure 7.

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No		Adm. Doc. Assessment		Assessment		Measurement		Calculation		Testing		Results
1	IF	Does not meet OSH	AND	Does not meet OSH	AND	Does not meet OSH	AND	Does not meet OSH	AND	Does not meet OSH	THEN	Does not meet OSH
2	IF	Does not meet OSH	AND	Does not meet OSH	AND	Does not meet OSH	AND	Does not meet OSH	AND	Meets OSH	THEN	Meets OSH
3	IF	Meets OSH	AND	Meets OSH	AND	Meets OSH	AND	Does not meet OSH	AND	Meets OSH	THEN	Meets OSH
4	IF	Meets OSH	AND	Meets OSH	AND	Meets OSH	AND	Meets OSH	AND	Does not meet OSH	THEN	Meets OSH
5	IF	Meets OSH	AND	Meets OSH	AND	Meets OSH	AND	Meets OSH	AND	Memenuhi	THEN	Meets OSH

Figure 7: Final Conclusion Rules

2.1.3 Inference Engine

The inference engine is used to evaluate and interpret all the rules simultaneously to produce conclusions. Fuzzy Inference Engine uses two inputs to produce one output. In accordance with the illustration of the reading of the values above, the application of the implication function is obtained by selecting the minimum membership degree (MIN method) from the values obtained from the antisendent. The MIN function aims to find the α-predicate value of all rules. The implication function rule is as follows:

[R1] IF Administrative Document Assessment DOES NOT MEET OSH AND Assessment DOES NOT MEET OSH AND Measurement DOES NOT MEET OSH AND Calculation DOES NOT MEET OSH AND Testing DOES NOT MEET OSH THEN Final Conclusion DOES NOT MEET OSH REQUIREMENTS.

α1 = min (µ Administrative Document Assessment [DOES NOT MEET OSH]); (µ Assessment [DOES NOT MEET OSH]); (µ Measurement [DOES NOT MEET OSH]); (µ Calculation [DOES NOT MEET OSH]) ; (µ Testing [DOES NOT MEET OSH]).

[R32] IF Administrative Document Assessment MEETS OSH AND Assessment MEETS OSH AND Measurement MEETS OSH AND Calculation MEETS OSH AND Testing MEETS OSH THEN Final Conclusion MEETS OSH REQUIREMENTS.

α32 = min (µ Administrative Document Assessment [MEETS OSH]); (µ Assessment [MEETS OSH]); (µ Measurement [MEETS OSH]); (µ Calculation [MEETS OSH]) ; (µ Testing [MEETS OSH]).

2.1.4 Defuzzification

Defuzzification using the Sugeno Orde 0 method. This method takes the average value to get the crips value. The defuzzification value is:

$$x = \frac{(\alpha 1 * x1) + +(\alpha \cdots n * x \cdots n)\ (\alpha 32 * x32)}{x1 + x \ldots n + x32} \quad (6)$$

2.2 Research Flow

The research flow on the inspection and testing of Electrical OSH is shown in Figure 8.

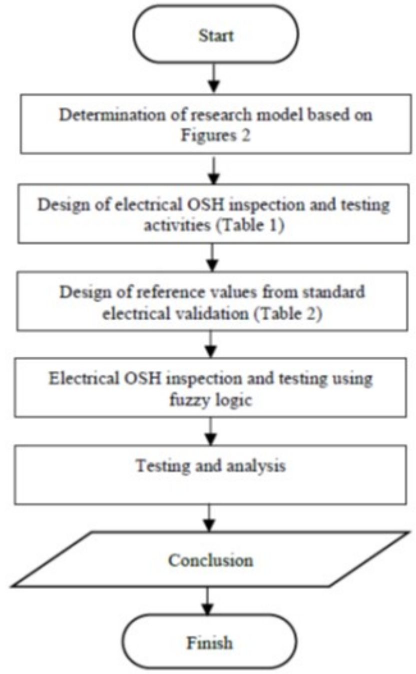

Figure 8: Electrical OSH Inspection and Testing Flow

The research flow starts with determining the target object of the electrical OSH inspection and testing, namely the electricity distribution and utilization systems. Furthermore, it is designed in accordance with administrative documents, assessment, measurement, calculation, and testing. The subsequent stage is the calculation of reference values from validated electrical measures based on the Indonesian National Standard (SNI), the International Electrotechnical Commission (IEC), The Institute of Electrical and Electronics Engineers (IEEE), and the American National Standards Institute - International Electrical Testing Association (ANSI-NETA). Furthermore, inspection and testing of electrical OSH is also carried out using fuzzy logic. The final stage is the testing and analysis phase to conclude whether or not the results meet the OSH requirements.

3. RESULT AND DISCUSSION

Based on flowchart of application of fuzzy logic in figure 3 and 4, and the research flow in Figure 8, a case study was carried out on factory X and Y electrical OSH inspection and testing based on quantitative method to ensure the application runs smoothly according to the expected needs and objectives.

3.1. Implementation of Fuzzy Logic in Electrical Distribution System

The inspection and testing of electrical OSH is carried out at Factory X by producing the input values per activity parameter as follows:

a. Administrative document assessment with a value of 29 %.
b. Assessment with a value of 76 %.
c. Measurement with a value of 95 %.
d. Calculation with a value of 100 %.
e. Testing with a value of 100 %.

Based on this value, it can be concluded that the final conclusion of the Electrical OSH examination and testing using fuzzy logic is as follows:A fuzzy logic method is used to prove that the electrical OSH examination and testing using fuzzy logic is as follows:

a. Fuzzification

Based on the activity input membership curve in Figure 5, the following is the input fuzzification:

- Administrative document assessment input variable with a value of 29 %.
  µ Does Not Meet OSH [29]= (60 – 29)/(60 - 0) = 0,52
  µ Meets OSH [29]= 0
- Assessment input variable with a value of 76 %.
  µ Does Not Meet OSH [76]= 0
  µ Meets OSH [76]= (76 – 40)/(100 - 40) = 0,6
- Measurement input variable with a value of 95 %.
  µ Tidak Memenuhi K3 [95]= 0
  µ Meets OSH [95]= (95 – 40)/(100 - 40) = 0,91
- Calculation input variable with a value of 100%.
  µ Does Not Meet OSH [100]= 0
  µ Meets OSH [100]= (100 – 40)/(100 - 40) = 1
- Testing input variable with a value of 100%.
  µ Does Not Meet OSH [100]= 0
  µ Meets OSH [100]= (100 – 40)/(100 - 40) = 1

b. Fuzzy Rules Base and Inference Engine

Based on the results of the formation of fuzzy set values above, the application of the implication function is obtained by selecting the minimum membership degree (MIN method) from the values obtained from the antisendent. The MIN function aims to find the α-predicate value of all rules.

Fuzzy Inference Engine is used to evaluate and interpret all rules simultaneously to generate conclusions. Fuzzy Inference Engine uses five inputs to produce one output as follows:

[R1]α1 = min (µ Administrative document assessment [0,52]); (µ Assessment [0]); (µ Measurement [0]); (µ Calculation [0]) ; (µ Testing [0]).

[R16]α16 = min (µ Administrative document assessment [0,52]); (µ Assessment [0,6]); (µ Measurement [0,91]); (µ Calculation [1]) ; (µ Testing [1]).

[R…]α… = min (µ Administrative document assessment [DOES NOT MEET OSH]); (µ Assessment [DOES NOT MEET OSH]); (µ Measurement [DOES NOT MEET OSH]); (µ Calculation [DOES NOT MEET OSH]) ; (µ Testing [DOES NOT MEET OSH]).

[R32]α32 = min (µ Administrative document assessment [0]); (µ Assessment [0,6]); (µ Measurement [0,91]); (µ Calculation [1]) ; (µ Testing [1]).

No		Adm. Doc. assessment		Assessment		Measurement		Calculation		Testing	MIN (α)		Result (x)
1	IF	0,52	AND	0	AND	0	AND	0	AND	0	0	THEN	0
2	IF	0,52	AND	0	AND	0	AND	0	AND	1	0	THEN	0
3	IF	0,52	AND	0	AND	0	AND	1	AND	0	0	THEN	0
4	IF	0,52	AND	0	AND	0	AND	1	AND	1	0	THEN	0
5	IF	0,52	AND	0	AND	0,91	AND	0	AND	0	0	THEN	0
6	IF	0,52	AND	0	AND	0,91	AND	0	AND	1	0	THEN	0
7	IF	0,52	AND	0	AND	0,91	AND	1	AND	0	0	THEN	0
8	IF	0,52	AND	0	AND	0,91	AND	1	AND	1	0	THEN	0
9	IF	0,52	AND	0,6	AND	0	AND	0	AND	0	0	THEN	0
10	IF	0,52	AND	0,6	AND	0	AND	0	AND	1	0	THEN	0
11	IF	0,52	AND	0,6	AND	0	AND	1	AND	0	0	THEN	0
12	IF	0,52	AND	0,6	AND	0	AND	1	AND	1	0	THEN	0
13	IF	0,52	AND	0,6	AND	0,91	AND	0	AND	0	0	THEN	0
14	IF	0,52	AND	0,6	AND	0,91	AND	0	AND	1	0	THEN	0
15	IF	0,52	AND	0,6	AND	0,91	AND	1	AND	0	0	THEN	0
16	IF	0,52	AND	0,6	AND	0,91	AND	1	AND	1	0,52	THEN	80,8
17	IF	0	AND	0	AND	0	AND	0	AND	0	0	THEN	0
18	IF	0	AND	0	AND	0	AND	0	AND	1	0	THEN	0
19	IF	0	AND	0	AND	0	AND	1	AND	0	0	THEN	0
20	IF	0	AND	0	AND	0	AND	1	AND	1	0	THEN	0
21	IF	0	AND	0	AND	0,91	AND	0	AND	0	0	THEN	0
22	IF	0	AND	0	AND	0,91	AND	0	AND	1	0	THEN	0
23	IF	0	AND	0	AND	0,91	AND	1	AND	0	0	THEN	0
24	IF	0	AND	0	AND	0,91	AND	1	AND	1	0	THEN	0
25	IF	0	AND	0,6	AND	0	AND	0	AND	0	0	THEN	0
26	IF	0	AND	0,6	AND	0	AND	0	AND	1	0	THEN	0
27	IF	0	AND	0,6	AND	0	AND	1	AND	0	0	THEN	0
28	IF	0	AND	0,6	AND	0	AND	1	AND	1	0	THEN	0
29	IF	0	AND	0,6	AND	0,91	AND	0	AND	0	0	THEN	0
30	IF	0	AND	0,6	AND	0,91	AND	0	AND	1	0	THEN	0
31	IF	0	AND	0,6	AND	0,91	AND	1	AND	0	0	THEN	0
32	IF	0	AND	0,6	AND	0,91	AND	1	AND	1	0	THEN	0

Figure 9: Fuzzy Inference Engine Results on Factory X

After obtaining the MIN value from each rule, then looking for the MAX value from rules 1 to 32. In rules 1 to 32, the MAX value is 0.52 on rule 16 with the results of meeting OSH. Furthermore, calculations are carried out according to the output fuzzification of the final conclusions as follows:

Meet OSH Requirements
[0,52]= x-60 / (100-60)
x= 60 + 0,52 (40) = 80,8

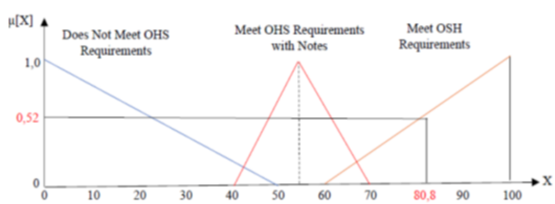

Figure 10: Output Result Curve Final Conclusion at Factory X

c. Defuzzification

In the fourth stage or defuzzification, the fuzzy set is transformed into a crisp set. In this study, the defuzzification of the composition of Sugeno's fuzzy logic rules was carried out using the centroid method. This method takes the average value using weighting in the form of membership degrees:

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$$x = \frac{(\alpha 1 * x1) + +(\alpha \cdots n * x \cdots n)\ (\alpha 32 * x32)}{x1 + x \ldots n + x32}$$

$$x = \frac{(0{,}52 * 80{,}8)}{0{,}52} = 80{,}8$$

Thus, testing the application on the electricity distribution system at Factory X's workplace resulted in the conclusion that it complies with OSH requirements with an output value of 80.8 %.

3.2. Implementation of Fuzzy Logic in Electricity Utilization System

Implementation of inspection and testing on the electricity utilization system of Factory Y produces the input values per parameter as follows:

a. Administrative document assessment with a value of 33%
b. Assessment with a value of 32%
c. Measurement with a value of 52%
d. Calculation with a value of 33%
e. Testing with a value of 55%

Based on this value, it can be concluded that the final conclusion of the Electrical OSH examination and testing using fuzzy logic is as follows:

a. Fuzzification

Based on the activity input membership curve in Figure 5, the following is the input fuzzification:

- Administrative document assessment input variable with a value of 33 %.
  µ Does Not Meet OSH [33]= (60 – 33)/(60 - 0) = 0,45
  µ Meets OSH [33]= 0
- Assessment input variable with a value of 32 %.
  µ Does Not Meet OSH [32]= (60 – 32)/(60 - 0) = 0,46
  µ Meets OSH [33]= 0
- Measurement input variable with a value of 52%.
  µ Does Not Meet OSH [52]= 0
  µ Meets OSH [52]= (52 – 40)/(100 - 40) = 0,2
- Calculation input variable with a value of 33 %.
  µ Does Not Meet OSH [33]= (60 – 33)/(60 - 0) = 0,45
  µ Meets OSH [33]= 0
- Testing input variable with a value of 55 %.
  µ Does Not Meet OSH [55]= 0
  µ Meets OSH [55]= (55 – 40)/(100 - 40) = 0,25

b. Fuzzy Rule Base and Inference Engine

[R1]α1 = min (µ Administrative document assessment [0,45]); (µ Assessment [0,46]); (µ Measurement [0]); (µ Calculation [0,45]) ; (µ Testing [0]).

[R6]α6 = min (µ Administrative document assessment [0,45]); (µ Assessment [0,46]); (µ Measurement [0,2]); (µ Calculation [0,45]) ; (µ Testing [0,25]).

[R…]α… = min (µ Administrative document assessment [DOES NOT MEET OSH]); (µ Assessment [DOES NOT MEET OSH]); (µ Measurement [DOES NOT MEET OSH]); (µ Calculation [DOES NOT MEET OSH]) ; (µ Testing [DOES NOT MEET OSH]).

[R32]α32 = min (µ Administrative document assessment [0]); (µ Assessment [0]); (µ Measurement [0,2]); (µ Calculation [0]) ; (µ Testing [0,25]).

No		Adm. Doc. assessment		Assessment		Measurement		Calculation		Testing	MIN (α)		Result (x)
1	IF	0,45	AND	0,46	AND	0	AND	0,45	AND	0	0	THEN	0
2	IF	0,45	AND	0,46	AND	0	AND	0,45	AND	0,25	0	THEN	0
3	IF	0,45	AND	0,46	AND	0	AND	0	AND	0	0	THEN	0
4	IF	0,45	AND	0,46	AND	0	AND	0	AND	0,25	0	THEN	0
5	IF	0,45	AND	0,46	AND	0,2	AND	0,45	AND	0	0	THEN	0
6	IF	0,45	AND	0,46	AND	0,2	AND	0,45	AND	0,25	0,2	THEN	40
7	IF	0,45	AND	0,46	AND	0,2	AND	0	AND	0	0	THEN	0
8	IF	0,45	AND	0,46	AND	0,2	AND	0	AND	0,25	0	THEN	0
9	IF	0,45	AND	0	AND	0	AND	0,45	AND	0	0	THEN	0
10	IF	0,45	AND	0	AND	0	AND	0,45	AND	0,25	0	THEN	0
11	IF	0,45	AND	0	AND	0	AND	0	AND	0	0	THEN	0
12	IF	0,45	AND	0	AND	0	AND	0	AND	0,25	0	THEN	0
13	IF	0,45	AND	0	AND	0,2	AND	0,45	AND	0	0	THEN	0
14	IF	0,45	AND	0	AND	0,2	AND	0,45	AND	0,25	0	THEN	0
15	IF	0,45	AND	0	AND	0,2	AND	0	AND	0	0	THEN	0
16	IF	0,45	AND	0	AND	0,2	AND	0	AND	0,25	0	THEN	0
17	IF	0	AND	0,46	AND	0	AND	0,45	AND	0	0	THEN	0
18	IF	0	AND	0,46	AND	0	AND	0,45	AND	0,25	0	THEN	0
19	IF	0	AND	0,46	AND	0	AND	0	AND	0	0	THEN	0
20	IF	0	AND	0,46	AND	0	AND	0	AND	0,25	0	THEN	0
21	IF	0	AND	0,46	AND	0,2	AND	0,45	AND	0	0	THEN	0
22	IF	0	AND	0,46	AND	0,2	AND	0,45	AND	0,25	0	THEN	0
23	IF	0	AND	0,46	AND	0,2	AND	0	AND	0	0	THEN	0
24	IF	0	AND	0,46	AND	0,2	AND	0	AND	0,25	0	THEN	0
25	IF	0	AND	0	AND	0	AND	0,45	AND	0	0	THEN	0
26	IF	0	AND	0	AND	0	AND	0,45	AND	0,25	0	THEN	0
27	IF	0	AND	0	AND	0	AND	0	AND	0	0	THEN	0
28	IF	0	AND	0	AND	0	AND	0	AND	0,25	0	THEN	0
29	IF	0	AND	0	AND	0,2	AND	0,45	AND	0	0	THEN	0
30	IF	0	AND	0	AND	0,2	AND	0,45	AND	0,25	0	THEN	0
31	IF	0	AND	0	AND	0,2	AND	0	AND	0	0	THEN	0
32	IF	0	AND	0	AND	0,2	AND	0	AND	0,25	0	THEN	0

Figure 11: Fuzzy Inference Engine Results at Factory Y

After obtaining the MIN value from each rule, then looking for the MAX value from rules 1 to 32. In rules 1 to 32, the MAX value is 0.2 in rule 6 with the result that OSH does not meet. Furthermore, calculations are carried out according to the output fuzzification of the final conclusions as follows:

Does not Meet OHS Requirements
[0,2] = 50-x / (50-0)
x = 50 - 0,2 (50) = 40

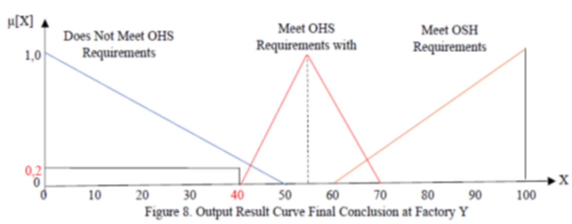

Figure 12: Output Result Curve Final Conclusion at Factory Y

c. Defuzzification

$$x = \frac{(\alpha 1 * x1) + +(\alpha \cdots n * x \cdots n)\ (\alpha 32 * x32)}{x1 + x \ldots n + x32}$$

$$x = \frac{(0{,}2 * 40)}{40} = 40$$

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Thus the application test on the factory Y workplace electricity utilization system resulted in the conclusion that it did not meet the OSH requirements with an output value of 40 %.

4. CONCLUSION

The development and testing of information systems (software) with the application of fuzzy logic algorithms showed the effectiveness and efficiency of the decision-making procedure. This was proven to be more rapid and accurate than the conventional type, which lasted for over a month. Therefore, it was recommended for inspecting and testing electrical OSH. Furthermore, a new fuzzy logic-based information system for inspection and testing of electricity, which can be applied to the distribution and utilization of electricity in the workplace, needs to be developed in the electricity generation and transmission section. To increase the accuracy of the results, the design of an information system for the inspection and testing of Electrical OSH can be developed using Fuzzy Logic SAW and AHP methods.

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REFERENCES:

[1] Von Meier, A. 2006. *Electric Power Systems*. USA: A John Wiley & Sons, Inc. Publication.
[2] Sclater, N; & Traister, E. J. 2003. *Handbook of Electrical Design Details*. USA: The McGraw-Hill Companies Inc.
[3] Mastrullo, K. 2012. *Electrical Safety in The Workplace*. USA: *ASSE Prof. Dev. Conf. Expo*.
[4] Gore, P.P; & Mane, A. 2018. *Electrical Hazards and Safety*. International Journal of Pure and Applied Mathematics, Volume 120 No. 6. India: Patil College of Engineering.
[5] Cadick, John; & Capelli-Schellpfeffer, M; & Neitzel, D. 2006. *Electrical Safety Handbook Third Edition*. USA: Mcgraw-Hill.
[6] Anonim. 2005. *Electrical Safety Hazards Handbook*. USA*: Littlefuse Inc.*
[7] Saba, T.M; & Tsado, J; & Raymond, E & Adamu, M. 2014. *The Level of Awareness on Electrical Hazards and Safety Measures Among Residential Electricity User's in Minna Metropolis of Niger State, Nigeria*. IOSR J. Electr. Electron. Eng. Vol. 9, No. 5. Nigeria: Electrical and Electronics Technology Education Department College of Education Minna.
[8] Structures, M.B. 2002. *Controlling Electrical Hazards*. USA: U.S. Department of LaborElaine L. Chao, Secretary.
[9] Garnham, E. 2020. Inspection and Testing of Electrical Equipments. *IEE Conf. Publ.*, no. 287. UK: Science and Technology Facilities Council.
[10] Anonim. 2012. *Managing Electrical Risk in The Workplace.* Australia: http://www.safeworkaustralia.gov.au.
[11] Anonymous. 2020. T*rain-the-Trainers Guide to Electrical Safety For General Industry*. Florida: The Workplace Safety Awareness Council
[12] ANSI; NETA; ATS and A. N. ATS. 2017. S*tandard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*. InterNational Electrical Testing Association 3050 Old Centre Avenue Suite 102.
[13] ANSI; NETA; ATS and A. N. ATS. 2009. S*tandard for Maintenance Testing Specifications for Electrical Power Equipment*. USA. InterNational Electrical Testing Association 3050 Old Centre Avenue Suite 10.
[14] Massey, G. W. 1995. *IEEE Standard Test Code for Dry-Type Distribution and Power Transformers.* IEEE Std C57.12.91-1995. USA: Institute of Electrical and Electronics Engineers, Inc.
[15] T. Committee. 1999. *IEEE Standard Test Code for Liquid-Inmersed Distribution, Power and Regulating Transformers. Std C57.12.90-1999*. USA: The Institute of Electrical and Electronics Engineers, Inc.
[16] Andrews, J.J; & Jones, R.A; & Bruce McClung. 2001. NFPA 70E 2000: Updating Electrical Safety Requirements for Employee Workplaces, *IEEE Ind. Appl. Mag.*, Vol. 7, No. 3, pp. 9–16. USA. National Fire Protection Association, Inc.
[17] Ross. T.J. 2010. *Fuzzy Logic With Engineering Application*. USA: A John Wiley and Sons, Ltd., Publication.

[18] Bhattacharyya, S; & Mahavidyalaya, R; & Dutta, P. 2012. *Handbook of Research on Industrial Informatics and Manufacturing Intelligence*. India: The University of Burdwan
[19] Ghani, A; & Tahour, A. 2012. *Application of Fuzzy Logic in Control of Electrical Machines*. *Fuzzy Log. - Control. Concepts, Theor. Appl.* Algeria: University of Mascara, Mascara.
[20] Robertson, C. R. 2008. *Electronic, Electrical, Fundamental Principles*. 2008. USA: Linacre House, Jordan Hill, Oxford OX2 8DP, UK.
[21] National Fire Protection Association. 2016. *National Electriacl Code*. USA. National Fire Protection Association, Inc.
[22] Earley, M.W; & Sargent, J.S; & Sheehan, J.V; & Caloggero, J.M. 2013. *National Electrical Code*, vol. 44, no. 11. USA: National Fire Protection Association, Inc.
[23] Short, T.A. 2004. *Electrical Distribution Handbook Short*. USA: CRC Press LLC
[24] Oza, B.A; & Mehta, R.P; & Nair, N; & Makwana, V. 2011. *Power System Protection and Switchgear*. India: Tata McGraw Hill Education Private Limited.
[25] T. Committee. 1999. *Guide for Loading Dry-Type Distribution and Power Transformers*. IEEE, Std C57.96-vol. 1999. USA: The Institute of Electrical and Electronics Engineers, Inc.
[26] ISO 527-2. 2006. *International Standard IEC 62337 Commissioning Of Electrical, Instrumentation And Control Systems In The Process Industry – Specific Phases and Milestones*. Switzerland: International Electrotechnical Commission.
[27] R. P. Ribas and F. H. Behrens. 1999. *IEEE Recommended Practice For Powering And Grounding Electronic Equipment. (Color Book Series - Emerald Book)*, vol 1999. USA: Institute of Electrical and Electronics Engineers, Inc.
[28] Institute of Electrical and Electronics Engineers, *IEEE Guide for Failure Investigation, Documentation, Analysis, and Reporting for Power Transformers and Shunt Reactors*, vol. 2015. 2015.
[29] T. Committee. 1999. *IEEE Standard Test Procedure for Thermal Evaluation of Liquid-Immersed Distribution and Power Transformers*, *Power*, vol. 1999. USA: The Institute of Electrical and Electronics Engineers, Inc.
[30] T. Committee. 1995. *IEEE Guide for the Design , Testing , and Application of Moisture- Impervious , Solid Dielectric , 5 – 35 kV Power Cable Using Metal-Plastic Laminates*. USA: The Institute of Electrical and Electronics Engineers, Inc.
[31] T. Committee. 1999. *IEEE Guide for Loading Dry-Type Distribution and Power Transformers*. USA: The Institute of Electrical and Electronics Engineers, Inc.
[32] T. Committee. 2002. IEEE Guide for Acceptance and Maintenance of Insulating Oil Equipment. USA: The Institute of Electrical and Electronics Engineers, Inc.
[33] J. V. H. Sanderson. 2001. *IEEE Recommended Practice for Protection and Co-ordination of Industrial and Commercial Power Systems*. USA: Institute of Electrical and Electronics Engineers, Inc.
[34] Voskoglou, M. G. 2020 *Fuzzy Sets, Fuzzy Logic and Their Applications*. Basel: MDPI St. Alban-Anlage 66.
[35] ZWICK, R: & ZIMMERMANN, H.J. 2001. *FUZZY SET THEORY AND ITS APPLICATIONS*, VOL. 106, NO. 2. NEW YORK: SPRINGER SCIENCE+BUSINESS MEDIA, LLC