# ANALYSIS OF OPERATIONAL ANORMALITY IN 3 PHASE INDUCTION MOTORS USING THE FUZZY METHOD OF PLTU PELABUHAN RATU

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***Abstract*— In the steam power generation industry, three-phase induction motors have an important role. Therefore, the reliability of this motorbike needs to be maintained and monitored properly. In determining abnormal operations in three-phase induction motors, fuzzy logic can be an accurate method. With the parameters of voltage, current imbalance, and vibration, fuzzy logic determines the level of abnormality. The main objective of this research is the implementation of fuzzy mamdani simulation in detecting operating abnormalities in three-phase induction motors.**

***Keywords*— Fuzzy logic, three-phase induction motor, voltage, abnormality detection, decision making**

## I. INTRODUCTION

A 3-phase induction motor is a type of alternating current (AC) electric motor, which is the main equipment that uses electrical energy to drive industrial equipment. In generating units, induction motors usually operate continuously on a regular basis, so that if there is no maintenance or early detection of problems with the induction motor, various kinds of disturbances will arise. Some examples are overload disturbances, excessive current, vibration, short circuit disturbances. to ground and voltage or current imbalance disturbances on each motor phase. The sample in this research is a three-phase induction motor located in the West Java 2 Pelabuhanratu Steam Power Plant (PLTU) with a working voltage of 400VAC. These motors are Boiler Feedwater Booster Pump, Condensate Make Up Pump, Seal Air Fan and Vacuum Pump for generating equipment.

This analysis was made to detect abnormalities in 400 V 3-phase low voltage induction motors, such as what happened to the Seal Air Fan motor which has a power of 18kW whose function is to send air from the cold PAF to the pulvurizer/mill and coalfeader to seal the grinding roll mill. and coalheader. There were abnormalities in sound and vibration 3 times during the period August 2022 to February 2023, which resulted in vibrations on the motor and resulted in tripping/change over on the motor due to worn bearings.

Considering the frequent occurrence of damage to induction motors during operation which can disrupt generator productivity. Therefore, it is necessary to analyze problems and disturbances that arise in induction motors based on field data so that they can detect if abnormalities occur in induction motors, then carry out maintenance methods that are useful to prevent motor damage in the long term.

## II. RESEARCH BASIS

*3 phase induction motor

1. A 3 phase AC motor works by utilizing the source phase difference to create a rotating force on the rotor. If a 1 phase AC motor produces a phase difference, it is necessary to add a capacitor component to a 3 phase motor. The phase difference is obtained directly from the source.

A three-phase induction motor has two basic components, namely the stator and rotor, the rotor part is separated from the stator part by a narrow air gap with a distance of between 0.4 mm to 4 mm. The type of three-phase induction motor based on the windings on the rotor is divided into two types, namely the wound rotor, which is a type of induction motor that has a rotor made of the same windings as the stator windings, and the squirrel cage rotor, which is a type of induction motor. where the rotor construction is composed of several metal bars which are inserted through the slots in the induction motor rotor, then each part is joined by a ring so that the metal bars are briefly connected to other metal bars.

An induction motor is defined as a motor that works based on the induction of the stator magnetic field into the rotor. The rotor current of this motor is not obtained from a particular source, but is a current that is induced as a result of the relative difference between the rotor rotation and the rotating magnetic field produced by the stator current. (Gede, 2013).

So the definition of a three-phase induction motor is an electric machine that converts electrical energy into mechanical energy. This motor works based on the induction of a magnetic field from the stator to the stator, where the rotor current of this motor is not obtained from a particular source, but is a current that is induced as a result of relative differences. between the rotor rotation and the rotating magnetic field produced by the stator current, in the circuit connection there are 2 models. There are 2 connection models in the 3 phase motor circuit:


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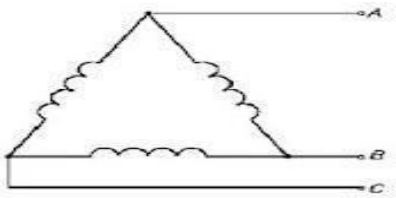
a. Star Connection
b. Triangle Connection




The delta or triangle connection is obtained by connecting the motor coils to form a triangle.
As machines generally show, induction motors also have the same construction, both DC and AC motors. The construction in question consists of 2 main parts, namely the stator and rotor.
2. Stators
The stator of an induction motor is the same as that of a synchronous motor and synchronous generator. The stator construction is made from laminations of silicon iron with a thickness of (4 to 5) mm with grooves made as a place to place the windings/coils. In the stator grooves, the stator windings are placed in different positions from one another, according to the phase. electrical degrees, namely 120° between phases (3 phase motor).

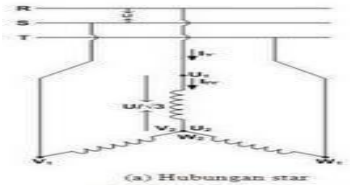
The number of windings on the stator is made according to the number of poles and the desired or specified number of turns. reels grouped into sets are called phases. The stator has one phase for each input power phase, and windings in the same phase receive power from the same phase (Matthew Scarpin, 2010)

Especially for stators on small electric motors, they are formed in whole pieces.
Meanwhile, large motorbikes are composed of a large number of laminated segments.
3. Rotor
This is the rotating part of the motor. As with the upper stator the rotor consists of a set of grooved steel laminations pressed together in the form of a cylindrical magnetic path and electrical circuit.
4. Bearings
A bearing is a machine element that supports the rotor shaft so that the rotation or movement of the rotor can take place smoothly, safely and have a long life. Bearings must be strong enough to allow the shaft and other machine elements to work properly.
5. Motorcycle Maintenance
Almost all motor cores are made from silicon steel or decarbonized cold rolled steel, their electrical properties do not change with age, however, poor maintenance can worsen motor efficiency due to motor age and unreliable operation.

*The Fuzzy Mamdani Method

The Fuzzy Mamdani Method is one part of the Fuzzy Inference System which is useful for drawing conclusions or the best decision in uncertain problems (Bova, 2010). The Fuzzy Mamdani Method was introduced by Ebrahim Mamdani in 1975. The Fuzzy Mamdani Method in the process uses linguistic rules and has a fuzzy algorithm that can be analyzed mathematically, making it easier to understand (McNeill, 1994).

The decision making process using the Fuzzy Mamdani Method to obtain the best decision is carried out through several stages, namely the formation of fuzzy sets; application of implication functions; composition of rules; defuzzification (Ebrahim Mamdani, 1975). The advantage of the Fuzzy Mamdani Method is that it is more specific, meaning that in the process the Fuzzy Mamdani Method pays more attention to the conditions that will occur for each fuzzy area, thus producing more accurate decision results (Bova, 2010). Apart from that, this method is more suitable when input is received from humans, so it is more accepted by many parties. The weakness of the Fuzzy Mamdani Method is that




this method can only be used for data in quantitative form, it cannot be used for data in qualitative form (Salman, 2010).

The Fuzzy Mamdani method is a method for drawing conclusions that is easiest for humans to understand, because it is most in line with human instincts. So using the Fuzzy Mamdani Method will produce the best decision for a problem (Salman, 2010). Compared to other methods of the Fuzzy Inference System, namely the Sugeno Method, this method does not go through the process of rule composition and defuzzification with the Centroid Method. This process is useful for knowing the output value from the center

fuzzy area. Apart from that, the Fuzzy Mamdani Method pays more attention to the condition of each fuzzy area, resulting in more accurate results. In the Fuzzy Mamdani Method the output produced is in the form of a value in the fuzzy set domain which is categorized into linguistic components, while in the Sugeno Method the output produced is in the form of a linear function or constant. The weakness of the output in the form of a linear function or constant is that the resulting output value must be in accordance with a predetermined value. Problems arise if the output value does not match the predetermined criteria. This output can be said to be correct if it can present the output determined by the antecedent (Salman, 2010).

*Profile of the Research Place Institution
Indonesia Power is a subsidiary of PT PLN (Persero) which was founded on October 3 1995 under the name PT PLN Pembangkitan Jawa Bali I (PT PJB I). On October 8 2000, PT PJB I changed its name to Indonesia Power as an affirmation of the Company's aim to become an independent power generation company with a pure business orientation. The Company's main business activities currently focus on providing electricity through electricity generation and as a provider of power plant operation and maintenance services that operate plants spread across Indonesia.
PLTU Palabuhanratu is a Steam Power Plant (PLTU) located on Jalan Raya Cipatuguran Jayanti Village, Citarik, Pelabuhanratu District, Sukabumi Regency, West Java, Indonesia. This PLTU has a total capacity of around 3 X 350 megawatts (MW), which is an important source of electrical energy in the Java and Bali islands. As a coal-fired PLTU, the Palabuhanratu PLTU uses coal as its main fuel to produce electrical energy. The process begins with burning coal in a boiler to produce heat. This heat is then used to convert water into steam in the boiler. The steam produced is channeled to a steam turbine, which will drive a generator to produce electricity.

## III. RESEARCH METHODS

3.1. Research methods
The method used in this research is an analysis method based on field data. And in the implementation the researcher applies measurements of an induction motor to determine the condition of the motor. The methods used in this research include:
a) The first step in this research is to carry out observations in the field to obtain the necessary data and look for problems that can be studied as research material.

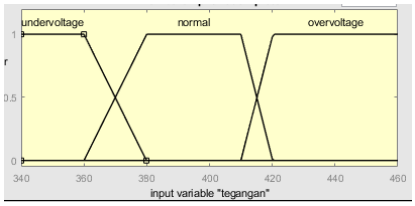
b) From the findings and collection of data obtained, it will be possible to determine the causes and consequences of abnormalities in the induction motor
c) The next step is monitoring through a series of tests and measurements, the results of which are then compared with the suitability of the normal condition.
d) From the results of tests and measurements, a guide material is created to determine whether the condition of the induction motor is still suitable for normal operation or not. Here are the steps:
*Fuzzification

The linguistic value of each parameter or fuzzy variable is categorized based on the fuzzy set. A fuzzy set is a collection of data with certain boundaries that is included in the universe of fuzzy variables. The fuzzy set was determined based on previous research. Table 1 shows the fuzzy set limits for each fuzzy variable.

Tabel 1. Batasan himpunan fuzzy

| No | Variabel | Kriteria | |
|---|---|---|---|
| 1 | Tegangan (Volt) | 340 - 380 | Undervoltage |
| | | 360 - 420 | Normal |
| | | 410 - 460 | Overvoltage |
| 2 | Ketidakseimbangan arus (%) | 0 – 5 | Imbang |
| | | 3 – 100 | Tak imbang |
| 3 | Vibrasi bantalan (mm/s) | 0 - 1,2 | Sangat rendah |
| | | 0,8 – 3,4 | Rendah |
| | | 2,4 – 12 | Tinggi |

*Voltage
In the voltage variable, the voltage value entered is the average voltage of all line to line voltages. There are three fuzzy sets in the voltage variable, namely undervoltage, normal, and overvoltage. The curve used in the fuzzy set graph is a trapezoid and is depicted as in Figure 2.

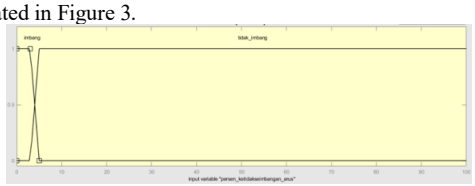



*In the current imbalance variable
the value entered is the percent of motor current imbalance. The percent current unbalance is obtained using the following formula.

$$a = \frac{I_R}{I_{avg}} ; b = \frac{I_S}{I_{avg}} ; c = \frac{I_T}{I_{avg}} ;$$

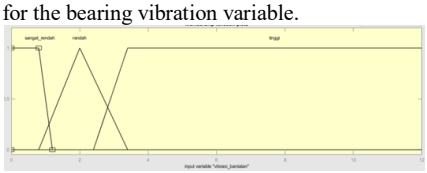
$$\frac{\{|a-1|+|b-1|+|c-1|\}}{3} x100\%$$

Ir = current in R phase;
Is = current in phase S;
It = current in phase T; And
Iavg = average current.
In the current imbalance variable, there are two fuzzy sets, namely balanced and unbalanced. Both sets use trapezoidal curves and are illustrated in Figure 3.



Bearing Vibration

In the bearing vibration variable, there are three fuzzy sets, namely very low, low and high [1]. The curve used is a trapezoid for very low and high, while for low it uses a triangle. Figure 4 is a fuzzy set graph for the bearing vibration variable.

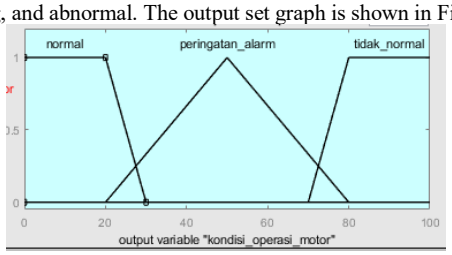


Evaluation Rules
References and instructions for evaluation rules are shown in Table 2. After going through the process, there are 25 evaluation rules available.

Table 2. Evaluation rules

| Rule No | Masukkan | | | Keluaran |
|---|---|---|---|---|
| | Tegangan | Arus | Vibrasi | |
| 1 | undervoltage | imbang | sangat rendah | tidak normal |
| 2 | undervoltage | tidak imbang | rendah | tidak normal |
| 3 | undervoltage | imbang | tinggi | tidak normal |
| 4 | undervoltage | tidak imbang | sangat rendah | tidak normal |
| 5 | undervoltage | imbang | rendah | tidak normal |
| 6 | undervoltage | tidak imbang | tinggi | tidak normal |
| 7 | normal | imbang | sangat rendah | normal |
| 8 | normal | tidak imbang | rendah | tidak normal |
| 9 | normal | imbang | tinggi | tidak normal |
| 10 | normal | tidak imbang | sangat rendah | peringatan alarm |
| 11 | normal | imbang | rendah | normal |
| 12 | normal | tidak imbang | tinggi | tidak normal |
| 13 | overvoltage | imbang | sangat rendah | peringatan alarm |
| 14 | overvoltage | tidak imbang | rendah | tidak normal |
| 15 | overvoltage | imbang | tinggi | tidak normal |
| 16 | overvoltage | tidak imbang | sangat rendah | tidak normal |
| 17 | overvoltage | imbang | rendah | peringatan alarm |
| 18 | overvoltage | tidak imbang | tinggi | tidak normal |

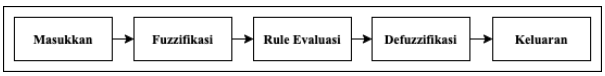
Defuzzification
In the defuzzification process, the three variables entered after going through each evaluation rule will be calculated into an output value using fuzzy logic. In this research, the fuzzy logic used is mamdani fuzzy with the defuzzification method being centroid. The resulting output values will be categorized based on the fuzzy output set. In this study, the output set is normal, alarm warning, and abnormal. The output set graph is shown in Figure 5.




## IV. Research Subject

The subject of this research is the air fan motor seal. The method used includes fuzzy logic analysis with three parameters used to detect operating abnormalities in three-phase induction motors. The three parameters are voltage, current imbalance, and bearing vibration. The voltage and current parameters or variables are obtained from readings on the Monitoring & Protection Relay which receives signals from the instrumentation transformer (current transformer & voltage transformer) which is integrated in the three-phase induction motor control circuit.
Fuzzy logic has three main stages, namely fuzzification, system inference, and defuzzification. The fuzzification stage is the stage of mapping crisp input values based on fuzzy set membership values. Then, the inference system will evaluate each input with evaluation rules obtained from factual data based on experts in the form of logical sentence statements. The final stage is defuzzification, namely producing evaluation result values which are then classified in the output set. The design of a fuzzy logic

system for detecting abnormal operations in a three-phase induction motor is depicted in Figure 1 below.




## V. Time And Place

This research will be carried out at the Pelabuhanratu PLTU which is located on Jalan Raya Cipatuguran, Jayanti Village, Citarik, Pelabuhanratu District, Sukabumi Regency, West Java, Indonesia. This research was conducted for five months from July to early November 2023.

## VI. Data Collection Thecnique

This data analysis is based on taking and collecting data from equipment in the field and comparing it with the data listed on the motorbike data sheet itself. One of them is observation. Observation involves direct observation of the research subject. Observations can be carried out directly (with the presence of researchers) or indirectly (using technology such as surveillance cameras or sensors). Data collected through observation can be the number, duration, frequency, or type of behavior observed.

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