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SIMULATION OF THE INDUCTION MOTOR FAULTS USING FUZZY LOGIC TECHNIQUE

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ABSTRACT

Induction machines are commonly used in various applications. They have many uses compared to other motors, as 80% of the motors used in industries are induction motors. But due to their continuous working and movement, they are exposed to many faults. In this paper, we represent a new type of diagnosis technique which is called Fuzzy Logic to diagnose and detect the induction motor faults that may take place during the operation to help the operator to make the right decision to deal with this fault. This paper presents SIMULINK induction motor model using SIMULINK in MATLAB software, and also distinguishes between healthy and defective motor by analyzing three types of faults, Rotor Faults, Stator Faults, and Mechanical or Bearing Faults.

KEYWORDS: *Induction Motor, Fuzzy Logic, Rotor Faults, Stator Faults, Bearing Faults, MATLAB/SIMULINK*

Article History

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INTRODUCTION

Induction motors are one of the most used electric machines in the industry as a result of their reliable installation, low-cost, and high reliability in performance. This is in addition to their availability of operating capacities from parts of horsepower and up to very high capabilities. It is therefore important to take care of their maintenance in order to prevent possible breakdowns, and therefore extended work and studies related to monitoring the conditions of electric motors was carried out for several years. This research and new discoveries in un in the industry and academia have been able to provide means for predicting and monitoring the conditions of motors, and many different devices and systems are being developed and many of them have been widely used in industry and transportation [7].

COMMON FAULTS IN INDUCTION MOTORS

Bearing Fault

Bearing is made of two spheres of focus. A collection of rollers or balls in the raceways rotate between the inner and outer rings. Bearing defects are often referred to as "distributed" or “localized”. Distributed defects include rolling and off-scale elements of the misaligned races, waviness, and surface roughness. Localized defects include curses, holes, and cracks on the rolling surfaces.

Such localized faults produce a sequence of impact vibrations as a running roller runs over the surface of a defect, the length, and amplitude of which can be determined by the fault position, induction motor speed, and inner and outer ring measurements of the bearing. The faulted bearings produce mechanical vibrations. Those vibrations are at each component's rotational speed. The bearing dimensions and thus the machine's rotational speed is typically used to determine the characteristic frequencies associated with the raceways, and therefore the balls or rollers. Checking the frequencies can test the condition of the bearing. This activity is carried out using methods for the study of mechanical vibrations [8].

Rotor Faults

Electrical faults such as a bar of the rotor can cause rotor failures, breakage defects, or mechanical defects, such as rotor eccentric. The first thermal stress fault occurs, hot spots, or stresses of exhaustion during transient operations like Start-up, in particular with large motors. A broken bar significantly changes torque and has become dangerous to electrical machines' safety and consistent operation. The second rotor fault is due to the eccentricity of the air gap. This fault is a common effect associated with a number of mechanical problems in induction engines such as unbalance of load or shaft misalignment. Long-term unbalance in load can damage the bearings and the housing and influenced the symmetry of air gaps. Misalignment of the shaft implies a horizontal, vertical or radial misalignment between a shaft and its load. When the shaft is misaligned the rotor would be Displaced from their normal position by constant radial force [8].

Stator Faults

An induction motor undergoes various stresses such as thermal, electrical, mechanical, and environmental stresses. Many failures in the stator can be due to these stressful operating conditions. Some of the more prevalent and potentially destructive faults are failures in the stator winding such as turn-to-turn, coil-to-coil, open circuit, phase-to-phase, and coil-to-ground. If left undetected, these could result in a serious failure of the motor [8].

Eccentricity Faults

Unequal air distance between stator and rotor leads to induction motor eccentricity. Air-gap eccentricity can usually be of two types: the eccentricity of static air-gap and the eccentricity of the dynamic air gap. It absolutely was also accounted for a mix of both forms, called mixed eccentricity and the axial non-uniformity of the air gap called inclined eccentricity. For static air-gap eccentricity, the minimum radial air-gap length is about in space. On the other, for dynamic eccentricity, the middle of the rotor and the centre of rotation don't coincide. During this case, the minimum air gap position isn't set in space but is rotated by the rotor. Failure to position the rotor or stator during the commissioning phase may lead to static eccentricity. it should even be caused by the ovality of the core stator. A bent shaft, wears, and motion of the bearing or mechanical resonances at critical speeds could also be a source of dynamic eccentricity [8].

FUZZY LOGIC

Fuzzy logic is the study of methods and principles of deduction, where being used means obtaining new proposals from the existing ones in classical logic. The proposals must be either True or False, meaning that the value of the truth is either Zero or One. Fuzzy logic generalizes the two-valued logic that makes the value of truth take value in the field [1,0].

The theory of traditional totals, the element in the field of description (Universe of Discourse) either belongs to or does not belong to the group given and it is the world of black or white, yes or no, (1) or (0) If there is an element Xi belongs to group A it can be written :

$$A \in Xi$$

If this element does not belong to group B then it can be written:

$$B \notin Xi$$

Traditional groups (Crisp) are sufficient to categorize certain things such as classification of groups of odd and even numbers and these are not good for categorizing other real things in our world.

Groups of Fuzzy logic solved this problem by clarifying the mysterious nature of the real things in the universe instead of whether the variable belongs to or does not belong as it applies the members of the graded membership as each element in the field of description (Universe of discourse) (U) is marked as a member (membership) Arrange and specify from "0" (non-member) to "1" (full member), which represents the degree to which the object is bound to the Fuzzy logic set [5].

FUZZY LOGIC CONTROLLER

Fuzzy Logic controller consists of four parts; Fig. 1 shows the general steps of the fuzzy logic controller (FLC) [1].

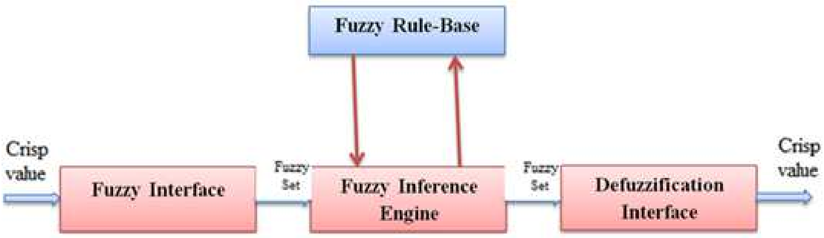

Figure 1: The General Steps of the Fuzzy Logic Controller (FLC) (Amuthameena S., Monisa S., 2017).

Fuzzy Interface

It converts measured crisp values to Fuzzy groups of input totals then move to a Fuzzy Inference sensor to calculate them and compare them with the control rules stored in the Fuzzy rule-base unit.

Fuzzy Rule-Base

It is a set of laws that linguistically define the laws of control, which draws a group of vague income groups and transforms into mysterious output groups. They are conditional laws such as:

It is usually built by the expert, where the largest number of obscure logic laws is calculated to the inputs and the various totals for the obscure logic present in these inputs are calculated by multiplying the number of totals for all the inputs.

Fuzzy Inference Engine

This unit makes the logical decision, which is a set of laws of the mysterious, and by applying the laws of ambiguity; the results are a group or several groups of mysterious groups known to have an effective action which means it generates the appropriate control command fuzzy control action according to the rules.

De-Fuzzy Interface

It generates the appropriate control command for the system by converting the linguistic variables that were concluded in the inference machine to only one value used as an entry for the system to be controlled as well as a re-weighing to convert the resulting values to the original range that you work with [1].

INITIAL PROCEDUREs

To achieve the objectives of this research, a model of a three-phase induction motor whose specifications are mentioned in Table 1 has been run on the computer using simulation software (MATLAB version 7).

Table 1: The Specifications of the Three-Phase Induction Motor

S. No.	Parameters	Specification
1.	1-HP (Three phase IM load)	745W
2.	Rated voltage (Line to line voltage)	220V
3.	No. of pair of poles	2
4.	Rated frequency	60Hz
5.	Power factor	0.7
6.	Rms current value	2.7051
7.	Stator winding resistance	3.36 Ω
8.	Stator leakage resistance	6.95 Ω
9.	Stator magnetizing reactance	163.63mH
10.	Rotor leakage reactance	6.95mH
11.	Rotor damping coefficient	0
12.	Rotor winding resistance	1.98Ω
13.	Rotor inertia constant	2.3688sec.
14.	Rotor inertia	0.15Kgm^2
15.	Base ampere voltage value	750VA

Here the work and behaviour of the motor are monitored in the correct operating state and case of faults by analyzing and checking the signal for the current and the rotor speed.

MONITORING THE INDUCTION MOTOR FAULTS

Monitoring the Rotor Fault Open Conductor

In this case, this fault was simulated by controlling the rotor's impedance to one of the windings by increasing its maximum value and Fig. 2 shows that [4].

$$rpr_1 = 1.99 \quad \Omega$$
$$rpr_2 = 1.99 * 1000 \quad \Omega$$
$$rpr_3 = 1.99 \quad \Omega$$

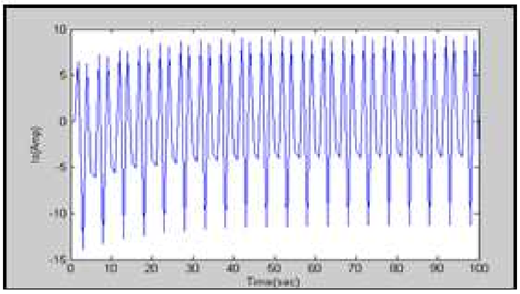

Figure 2: The Rotor Fault in the Case of (Open Conductor) (Ghassan Husien A. 2011).

Monitoring the Stator Fault

To represent the insulator damage between two adjacent windings in the coil, this type of fault is called a "turn-to-turn" fault or a short turn; It is represented by simulation, by reducing the static impedance of one of the windings to the lowest value as shown in Fig.3 (Ghassan Husien A. 2011).

$$R_{s1} = 3.35 \quad \Omega$$
$$R_{s2} = 3.35 \quad \Omega$$
$$R_{s3} = 3.35 \quad \Omega$$
$$Rs2 = 3.35 * 50/100 = 1.675 \ \Omega$$

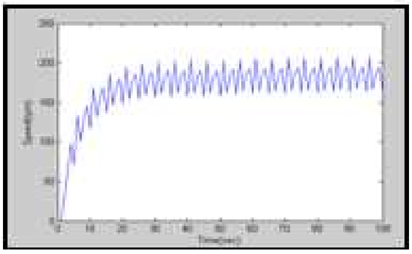

Figure 3: The Stator Fault Case of (turn-to-turn) (Ghassan Husien A. 2011).

Monitoring the Mechanical or Bearing Faults

In this case, random values for mechanical torque are set by increasing the load, which represents the mechanical rotor fault, as shown in Fig.4 [4].

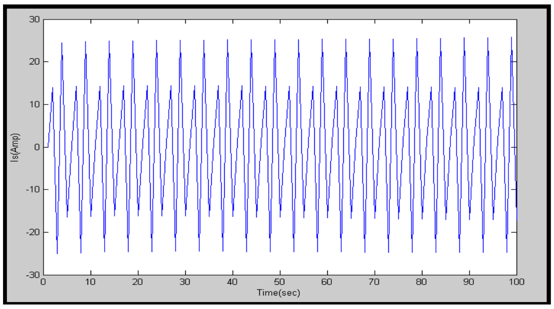

Figure 4: The Mechanical Rotor Fault (Ghassan Husien A. 2011).

FUZZY LOGIC ALGORITHM

A Fuzzy logic technique was introduced to diagnose the failure of the three-phase search engine, where the algorithm for the fuzzy logic was implemented as in the flowchart as shown in Fig. 5, where the algorithm was implemented using a simulation of the MATLAB 7 program as follows [4].

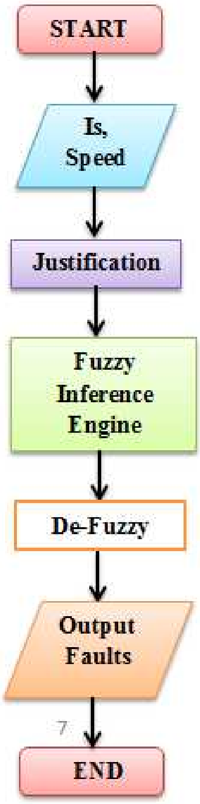

Figure 5: Flowchart for Implementing Fuzzy Logic (Ghassan Husien A. 2011).

The Algorithm included the following steps:

- Choosing the appropriate weight for the universe of discourse, which includes the variables that enter the mysterious logic represented by the stator current (Is) and the speed (Sr).

$$-L \leq X \leq L$$

Whereas, (L, -L) represents the lower and upper limits of the comprehensive set (U) of the variables and here in the research were as follows:

$$\text{Stator current}: 0 \leq Is \leq 100$$

$$\text{rotational speed}: 0 \leq \text{speed} \leq 2000$$

Choose the linguistic variables that represent the consonant current, and the speed, and they are three variables.

- Choose the appropriate rules that we can obtain from our prior knowledge of the system and the experiments that were conducted on it, and the shape of these will be as shown in the equation.

Is is L & speed is VL & Then FAULT is in rotor .

And therefore there are three linguistic variables for each of the consonant current (Is) and the rotational speed (Sr), and there are nine laws and then the process of eliminating ambiguity where we get a single value used to detect malfunctions in the engine system, after returning the weight to this value.

Connect the mysterious logic system to the engine system and perform the examination to ensure the correctness of the system's work in detecting faults for the engine by operating the engine in the normal state and in the case of malfunctions and watching the results on the screen.

RESEARC RESULTS

Simulation results were obtained for the stable state of the work of the motor and the condition of the presence of a fault and the values for the current and speed were recorded and as shown in the figure for all cases the expected faults of the motor and then linking the fuzzy logic system with the motor system to detect the usual state of the work of the motor and in the case of faults as shown in Fig.6.

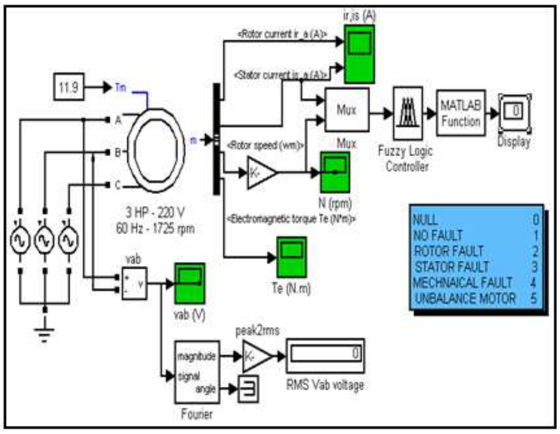

Figure 6: Motor System with Fuzzy Logic.

CONCLUSIONS AND FUTURE WORK

- The specification of the 3-phase induction motor used for testing and developing a fault detection220V, 60Hz, 0.745KW.
- Using Fuzzy Logic (FL) helps us to detect and diagnose all types of induction motor faults at high accuracy and speed up to more than 90% of accuracy.
- Accuracy in detecting and diagnosing faults of three-phase induction motors and showing them with one signal that helps the enhanced to take the appropriate decision, and therefore it can be applied to other systems and other types of the motor using simple algorithms and with high-efficiency.
- Using FL can be detected as a compound fault at the same time.
- Using a simulated model to diagnose motor failures in determining the system's response to changes in motor parameters that quickly and accurately represent failures.

The proposed method generates a Fuzzy Logic delay time with varying degrees of different fault combinations so that the adjustable and optimum delay time is obtained. In the next experiments the system can be improved by increasing the number of inputs to control different parameters of fault.

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