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Article

Electric parameters analysis for the detection of possible failures in the insulation of electric motor windings

Análisis de parámetros eléctricos para la detección de posibles fallas en el aislamiento de los devanados de motores eléctricos

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Abstract

Knowledge of electric motors is of utmost importance in the industry. Knowing the anticipated data on the good or bad functioning of the equipment we work with allows us to make better decisions for their optimal development. This article presents a proposal for analyzing electrical data in induction motors, allowing a study of their behavior to be carried out to detect a possible failure in the windings due to a short circuit, defect or degradation of the insulation. With the help of a simulator, it is easier to develop this analysis. The Simulink software provided by the Matlab software shows us graphic results that we can view to predict and take preventive measures for the equipment.

Objetives	Methodology	Contribution
Detection of possible faults in the electric motor windings.	• Engine data analysis • Develop simulation model • Result comparison	The development of a simulation model predicts the detection of a short circuit in the winding of an electric motor.

Induction, Circuit, Windings

Resumen

El conocimiento en los motores eléctricos, es de suma importancia en el área de la industria, conocer los datos anticipados del buen o mal funcionamiento de los equipos con los que se trabaja nos permite tener mejores tomas de decisiones para el óptimo desarrollo de los mismos. Este artículo presenta una propuesta de análisis de datos eléctricos en los motores de inducción permitiendo que se realice un estudio de su comportamiento para detectar una posible falla en los devanados a causa de un corto circuito, por defecto o degradación del aislamiento. Con ayuda de un simulador se facilita desarrollar dicho análisis. El software simulink que nos brinda el software de Matlab nos muestra resultados gráficos que podemos visualizar para predecir y tomar medidas de prevención del equipo.

Objetivos	Metodología	Contribución
Detección de posibles fallas en los devanados de los motores eléctricos.	• Análisis de datos del motor • Desarrollo del modelo de simulación • Comparación de resultado	El desarrollo de un modelo de simulación predice la detección de un corto circuito en el devanado de un motor eléctrico.

Inducción, Circuito, Devanados

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Introduction

Most processes in industry use induction motors. Due to the various activities, they carry out, as well as the electrical and mechanical stresses to which they are subjected, they cause failures in the motors.

It is necessary to know the status of the induction motors on a daily basis, in order to detect any faults that may occur, even when they are in a stationary state. There are numerous circumstances due to which failures occur in electric motors, for example short circuits between turns, insulation losses and insulation degradation (Marot, 2022).

Failures in induction motors are caused by breakdowns that occur in their components, one of these components is the highly relevant winding turns located in the stator of induction motors. This breakdown is caused by progressive wear or degradation of the insulation between the winding conductors (Yuchechen Guillermo.D., 2020).

With a model, the behavior of the electrical parameters will be analyzed and possible failures in the windings of the electric motors detected.

The contribution of this work is to simulate a short circuit in the motor winding and analyze the value of the electrical parameters.

Equations will be used to find the values of the electrical parameters and be able to substitute them in a simulator and be able to observe graphical results of the behavior of the electric motor.

Model

An equivalent electrical circuit will be used for the analysis of the motor parameters, which has 2 circuits: one for the stator and another for the rotor.

Figure 1 shows the circuit for the analysis of the electric motor, with this circuit an analysis can be carried out to find the values of the parameters of the electric motor (Pozueta, 2018).

Box 1

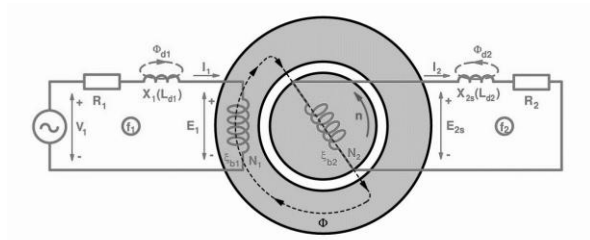

Figure 1
Equivalent circuit of an induction motor

Source: Rodríguez Pozueta Miguel Ángel

Figure 2 shows the equivalent circuit with the variables that will be used for the study of the electric motor. The analysis of the electrical parameters is based on this equivalent circuit.

Box 2

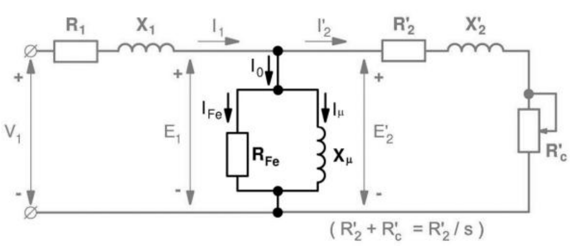

Figure 2
Equivalent diagram of an induction motor

Source: Rodríguez Pozueta Miguel Ángel

To find the value of these parameters it is necessary to perform the following tests on the induction motor:

- Vacuum test.
- C.D. test.
- Locked rotor test.

Vacuum test

The vacuum test consists of energizing the motor without any load, the factors that act on the motor would be friction losses and air friction losses. In these tests, the magnetization reactance XM and the losses in the core Rc are determined. This test also provides the magnetization current. To this test, the wattmeters, voltmeters and three ammeters are connected to the motor.

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In this case, as the motor rotates without any load, other than friction and air friction, the speed of the rotor is similar to the speed of the field, the slip of the motor is very small. Therefore, the losses in the stator copper are:

$$P_{PCE} = 3I_1^2 R_1 \quad [1]$$

Therefore, the input power will be:

$$P_{entr} = P_{PCE} + P_{nucl} + P_{FyR} + P_{misc} \quad [2]$$

Rotor losses are defined as:

$$P_{rot} = P_{nucl} + P_{FyR} + P_{misc} \quad [3]$$

Substituting equations 2 and 3 we are left with:

$$P_{entr} = 3I_1^2 + P_{rot} \quad [4]$$

So, by having the input power and obtaining the rotational losses. According to the equivalent circuit, the magnetization reactance X_M is in parallel with RC and R2 (1-s) /s, the approximate equivalent input impedance is obtained (Chapman, 2012):

$$|Z_{eq}| = \frac{V_\varphi}{I_{1,sc}} \approx X_1 + X_M \quad [5]$$

C. D. Test

The DC test consists of applying direct current voltage to the stator windings of an induction motor. Since it is direct current, there is no induced voltage to the rotor circuit, this means that there is no resulting current in the rotor. Therefore, the reactance of the rotor is zero, this provides that the only measure of current flow existing in the motor is that of the resistance of the stator windings, with this test we determine the resistance of the stator. Since the current passes through the two windings, the total resistance is 2R1, so we have:

$$2R_1 = \frac{V_{CD}}{I_{CD}} \quad [6]$$

Solving R1 we obtain:

$$R_1 = \frac{V_{CD}}{2I_{CD}} \quad [7]$$

But if the motor is connected in delta, then the equation is:

$$R_1 = \frac{3V_{CD}}{2I_{CD}} \quad [8]$$

Locked rotor test

In this test the rotor is locked, an A.C. voltage is applied. to the stator, but it is taken into account that it should not exceed the full load current, when setting the voltage and frequency the amperage is adjusted so that it is close to the nominal, and the power, amperage and voltage are measured quickly, trying not to overheat the engine. Then the magnitude of the total impedance of the circuit is (Chapman, 2012).

$$|Z_{RB}| = \frac{V_\emptyset}{I_1} = \frac{V_T}{\sqrt{3}I_L} \quad [9]$$

An example taken from Chapman's book is presented to calculate parameters that will be used in the equivalent circuit where they will be substituted in the simulation in Matlab-Simulink, and will give us values that will be graphed which we can interpret and thus identify if there is a possible failure in the induction motor.

Methodology

An exercise will be used to calculate the electrical parameters that are taken from the tests carried out on the electric motor, to obtain the values that will be used in the equivalent circuit of Figure 3, obtaining these parameters they will be substituted in the simulator, from the which we will obtain graphic results, to analyze the behavior of said equipment (Chapman, 2012).

Figure 3 shows the equivalent circuit used for the calculations and the values to be used.

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Box 3

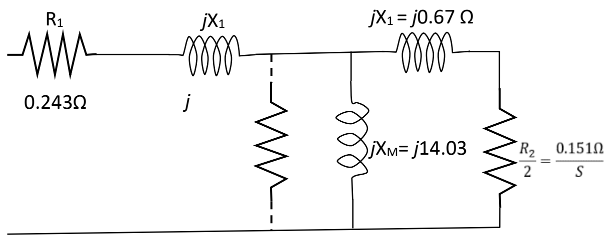

Figure 3
Equivalent circuit with parameters obtained from the calculations made to the induction motor
Source: Máquinas eléctricas Stephen J. Chapman

According to the formula for calculating the approximate full load current of a three-phase induction motor (Wildi, 2007), the following formula is used:

$$I = \frac{600\ P_h}{E} \qquad [10]$$

For the no-load current it is:

$$I_o = 0.3\ I \qquad [11]$$

And for the starting current it is:

$$I_{LR} = 6\ I \qquad [12]$$

Figure 4 shows graphically the result obtained from the simulator, with the data that was calculated in the exercise in Figure 3, when the motor is working in a normal state, the current values that the motor takes at the same time are observed. start-up, as well as the response time it takes to stabilize without current variations or alterations.

Box 4

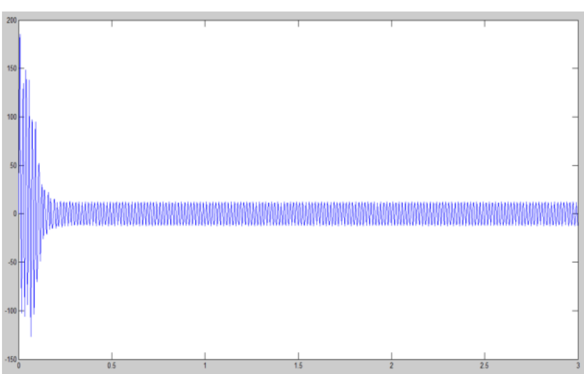

Figure 4
Amperage graph obtained in the simulator, where the motor starting amperage is observed with respect to time, and the stabilized amperage, in normal state.
Source: Own elaboration

Figure 5 shows the enlarged graph and the value of the current can be better observed when it stabilizes, as well as the time it takes to do so, with the motor in good condition.

Box 5

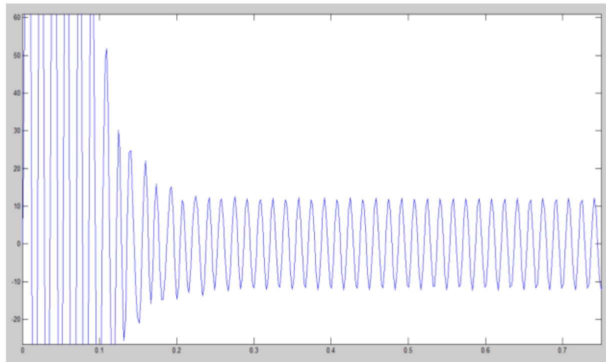

Figure 5
Graph of the simulator amperage with zoom, to be able to observe the current consumed by the motor.
Source: Own elaboration

Figure 6 shows the engine speed, and the variations it has with respect to time, up to the maximum revolution point.

Box 6

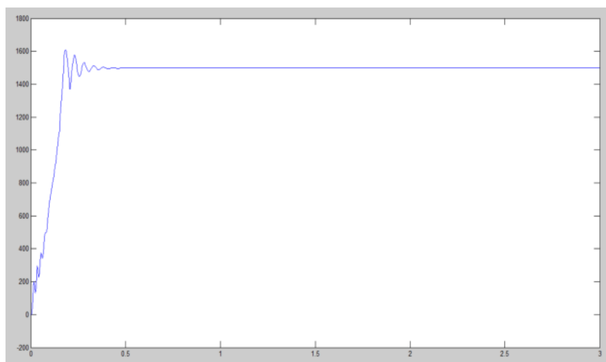

Figure 6
Graph of engine speed in RPM shown by the simulator, with the engine in good condition.
Source: Own elaboration

Figure 7 shows the maximum torque at which the motor breaks, starting in a state of rest until the motor reaches its state of stability, with the motor being in good condition.

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Box 7

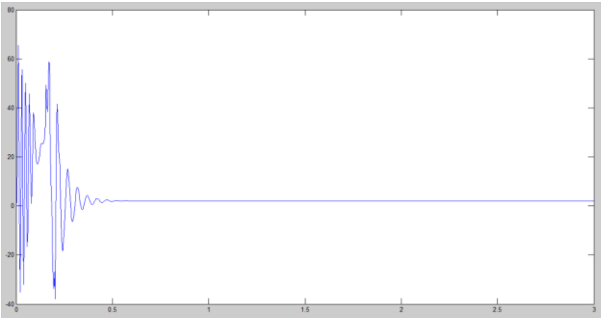

Figure 7
Mechanical torque graph showing engine simulator in good condition

Source: Own elaboration

Results

With the data obtained we can observe the behavior obtained from the motor, we observe the starting amperage which we can compare with the result we calculated, and we observe how the amperage stabilizes. Figure 6 and 7 show the speed and maximum torque of the motor which we can analyze and comparing with the data obtained, the result of the graph coincides with the calculated data.

Figure 8 shows the result of the motor, displaying the value of the current that the motor takes when reducing the resistance by 50%. The increase in current is observed, although it stabilizes but the current it consumes is more.

Box 8

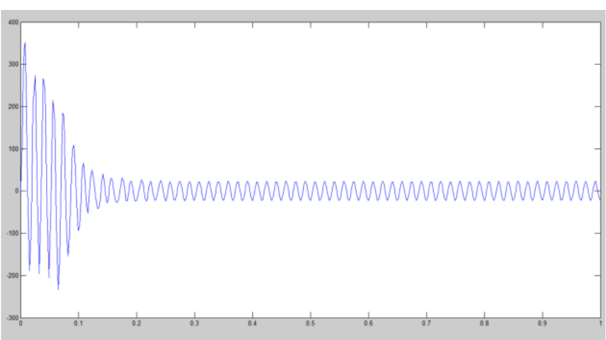

Figure 8
Motor result with 50% less resistance.

Source: Own elaboration

In Figure 9 you can better see the values obtained in the simulator, better visualizing the current value that the motor takes.

Box 9

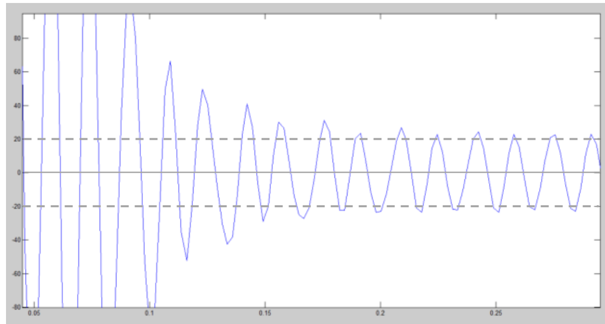

Figure 9
Amplified graph showing the amperage at 50% less resistance

Source: Own elaboration

Table 1 shows the values in the normal state of the motor and at 50% less, simulating a short circuit by reducing the parameters of the induction motor to 50%.

Box 10

Table 1
Engine values in normal state and values reduced to 50%.

	Engine values in normal state	Values reduced to 50%
R_1	0.243	0.1215
R_2	0.151	0.075
X_1	0.67	0.335
X_2	0.67	0.335
X_M	14.03	7.015

Source: Own elaboration

Conclusions

Having a tool that allows us to model failures in an electrical machine without affecting the equipment helps us to have good control of its operation. Simulation is that tool in which it is possible to carry out analysis with real parameters without that the engines are affected. In this research work, a methodology was presented to detect a short circuit in the windings of an induction motor through tests that are carried out on the motor to perform calculations of electrical parameters, and use them in an equivalent circuit in this way they will be analyzed and with the help of a simulator, interpret them graphically, observing how the engine behaves.

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According to the data obtained, we can make decisions to determine when it is necessary to apply preventive action to avoid generating a short circuit in the winding. Some of these failures in the windings are when the insulation stops doing its job and a short circuit occurs, then the current no longer circulates throughout the winding, generating a decrease in resistance, but at the same time an increase in current, which sometimes A certain time causes the engine to burn out or stop working and the process or activity it is carrying out stops.

Conflict of interest

The authors of this article declare that they have no conflict of interest. They have no known competing financial interests or personal relationships that could have influenced the work reported in this article.

Author contribution

The contribution to this work that each researcher made in developing this research was defined:

Terrazas-Flores, Luis Emilio: Contributed with the idea of the project, method and research technique. Support in writing the article and data analysis.

Melchor-Hernández, César Leonardo: Created the structure of the article, revised the writing, and analyzed the data.

Sánchez-Medel, Luis Humberto: Contributed to the study of documented research for publication, as well as data analysis.

González-Sobal, Martín: Carried out the research design, the type of research, and the writing of the article.

Availability of data and materials

The MATLAB-Simulink software was used, which is an element analysis tool that helps us understand the behavior of the electric motor through the analysis of parameters which can be graphed to better visualize its behavior.

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Antecedents

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Supports

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Differences

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