Field computation with finite element method applied for diagnosis eccentricity fault in induction machine

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Abstract—This paper deals with analysis of the magnetic field by using FEM and numerical computation of the electromagnetic characteristics of Induction machine. The knowledge of electromagnetic characteristics is very important in performance analysis of electrical machines. The purpose of this investigation is to use the field computation by finite element model to evaluate, detect and diagnosis fault of the static eccentricity effect on the vector potential and field magnetic. The result of simulation of our model allows us to clearly see the effect of the eccentricity on the electromagnetic quantities of the induction squirrel machine.

Keywords—Induction machine, modelisation, finite element methode, eccentricity, diagnosis, simulation.

I. INTRODUCTION

The sudden damage of the induction motors, which are generally used as part of the product line in the industry, can lead to stop the whole process. Therefore, the diagnosis of the lack of time is important to prevent the spread of the fault on the product range. Energy conversion in an induction motor (converting electrical energy into mechanical energy) is through the magnetic energy in the air gap. However, the displacement effect of the rotor (eccentricity) directly affects the course of the magnetic flux (magnetic reluctance) [1,2].

According to the model developed in this work, we could introduce and study the consequences of the eccentricity phenomenon on the magnetic quantities of the machine through the magnetic vector potential. The complexity related to the spatial distribution of local forces [3,4] to calculate a resultant force has been surmounted due to the flexibility of our program allows us to consider the effect of changing the rotor position by adjusting its coordinates in the program.

In the following sections, we propose the problematic will be resolved by our proposed model in this paper.

In the third section, we consider the development of the model using the formulation of magnetic vector potential. Next, we present the simulation results and their interpretations.

II. STATEMENT OF THE PROBLEM

Our study is to see the evolution of magnetic variable (magnetic field and vector potential) along the axis of movement (x) of the rotor for 25% of the value of the airgap. Comparing the simulation results in the default case (with eccentricity) with those of the healthy case, we can see the impact of eccentricity on the magnetic quantity of the asynchronous machine.

Figure.1 Balanced of the rotor along x axis.
III. MODEL OF INDUCTION MACHINE

To determine the field distribution at each time-step, a two dimensional transverse section of the induction motor is represented, in reducing the problem to two dimensions [5,6]. The transient magnetic field in terms of magnetic vector potential (A); The permeability of air is defined by $\mu_0 = 4 \pi \cdot 10^{-7} \text{H/m}$; Conductivity (\(\sigma\)) and current density (\(J_s\)), can be expressed as:

$$\sigma \cdot \frac{\partial A}{\partial t} + \text{curl} \left( \frac{1}{\mu_0} \cdot \text{curl} (A) \right) = J_s$$

(1)

The constitutive linear relationship of ferromagnetic material is:

$$B = \mu_0 \mu_r \cdot H$$

(2)

Where,

- \(B\): flux density;
- \(H\): magnetic field;
- \(\mu_r\): permeability relative.

To solve the general diffusion equation (1) a classical weighted residual method with first order shape functions we obtain the following integral form [7,8]:

$$\omega_i \\left[ \text{curl}(\text{curl} A) + \mu_0 \sigma \frac{\partial A}{\partial t} \right] d\Omega = \omega_i \mu_0 J_s \cdot d\Omega$$

(3)

\(\omega_i\): ponduration function.

With the following linear approximation for the vector potential:

$$A = \sum \omega_i \cdot A_i$$

(4)

Then, we obtain the following algebraic form:

$$[K] \left[ \frac{\partial A}{\partial t} \right] + [M] \cdot [A] = [F]$$

(5)

$$K_{ij} = \int_{\Omega} \sigma \mu_0 \omega_i \omega_j \ d\Omega$$

$$M_{ij} = \int_{\Omega} \left( \frac{\partial \omega_i}{\partial x} \frac{\partial \omega_j}{\partial y} + \frac{\partial \omega_i}{\partial y} \frac{\partial \omega_j}{\partial x} \right) \ d\Omega$$

(6)

$$F_i = \int_{\Omega} \omega_i \cdot \mu_0 \cdot J_s \cdot d\Omega$$

IV. SIMULATIONS AND DISCUSSION

The finite element model described above to evaluate the effects of rotor eccentricity in the air gap on the vector potential magnetic and the magnetic field [9,10]. The figure 2 shows the geometry of the induction machine with four poles, 36 slots in the stator and 32 rotor bars.

The discretization of the geometry with finite element is shown in figure 3.

The equipotential of potential vector magnetic is shown by the figure 4.
V. EFFECT OF THE ECCENTRICITY

A) Potential vector magnetic

The figure 5 shows the spatial distribution of the potential vector magnetic for each element of the geometry.

The projection of the spatial distribution of magnetic vector potential presented in Figure 5 on the plane “zx” allows us to obtain the potential vector magnetic in the healthy case (figure 6.a) and with fault, that is to say that the rotor is balanced along the “x” axis (figure 6.b) is illustrated by figure 6.

In the healthy cases (Figure 6.a) we find that the shape of the spatial distribution of the magnetic vector potential is symmetrical. Furthermore, the same figure shows that we have the same absolute amplitude on the four poles of the induction machine.

Against by, in the case with defect (Figure 6.b), the thickness of the air gap is not uniform, then the shape of the magnetic potential is not symmetrical and the absolute value of magnetic potential is not uniform in the four poles.

The change in the position of the rotor (eccentricity) occurs with the change of magnetic reluctance. Indeed, when the air gap reduces, so, the magnetic reluctance also reduces, therefore the amplitude of the magnetic vector potential increases.

By against, when the air gap increases we see the opposite effect.
B) Magnetic field

The figure 7 shows the spatial distribution of the magnetic field (absolute values) for each element of the geometry.

The projection of the spatial distribution of magnetic field presented in Figure 7 on the plane “zx” allows us to obtain the magnetic field in the healthy case (figure 8.a) and with fault, where the rotor is balanced along the “x” axis (figure 8.b), is illustrated by figure 8.

In healthy cases, the air gap is healthy, therefore uniform along the contour of the air gap. This is expressed by the symmetry of the shape of the magnetic field distribution observed in Figure 8.a.

By against, the figure 8.b (with eccentricity case), there is no symmetry in the evolution plane of the magnetic field.

The effect of the eccentricity of the magnetic field is opposite with respect to their effect on the potential vector, when the reduced air gap, therefore, the magnetic reluctance also therefore reduces the amplitude of the magnetic field decreases. For against, when the air gap increases the magnetic reluctance also increases, therefore, the amplitude of the magnetic field increases.

VI. CONCLUSION

The results of simulations enables us to introduce and clearly see the impact of eccentricity on the magnetic behavior of the machine (magnetic field and vector potential) for the rotor position change of 25% from its initial position, it is found that the effect of the eccentricity influences first places on the magnetic reluctance (the course of the field in the air gap), the
variation of the latter, causes a variation of the magnetic properties (magnetic quantities), mechanics (mechanical quantities) and electrical (electrical quantities).

VII. REFERENCES


