Identification of IM Parameters Using Finite Element Model for EVs application

Youssef Dhieb
National School of Engineers of Sfax Laboratory of advanced electronic system and sustainable energy, University of Sfax, 3038 Sfax, Tunisia
jousef.dh@hotmail.fr

Mohamed. Radhouan Hachicha
National School of Engineers of Sfax Laboratory of advanced electronic system and sustainable energy, University of Sfax, 3038 Sfax, Tunisia
radhouan.mail@gmail.com

Moez Ghariani
National School of Engineers of Sfax Laboratory of advanced electronic system and sustainable energy, University of Sfax, 3038 Sfax, Tunisia
moez.ghariani@gmail.com

Rafik Neji
National School of Engineers of Sfax Laboratory of electronics and information technology (LETI), University of Sfax, 3038 Sfax, Tunisia
rafik.neji@gmail.com

Abstract—This paper presents an induction machine (IM) assessment used for electric vehicle (EVs) applications. The purpose of the study focuses on the finite element (FE) analysis; by calculating the magnetic flux distribution to identify the parameters in the IM model. Due to the difficulty of accessing the real system, 2D FE model based on practice measurements is used to estimate the unmeasured states. The model is developed using Matlab and Lua script. Simulations are carried out to evaluate the IM performance and to identify stator and rotor induction, as well as rotor time constant and magnetic dispersion coefficient.

Index Terms—Induction machine, Parameters of IM, FEM.

1. NOMENCLATURE

D: electric flux density
B: Magnetic flux density
E: the electric field
H: the magnetic field
J: electric current density
ρ: electric charge density

2. INTRODUCTION

With market condition today, the economics are such that users and engineers are looking for the best fit for the application at the most reasonable cost. As a result, EVs is a great way for not only save money, but also help contribute towards a healthy and stable environment. The design of electrical machines in one of the most prestigious discoveries of the last century and today remains a popular research topic in research laboratories. The studies for electrical vehicles (EVS) have attracted attention of the necessity of developing electrical machine performance. IMs with squirrel cage rotor plays key role in industrial and commercial sectors, and have experienced in EVs and noteworthy improvement in their performance, especially in urban environments. Indeed a wise choice for work method, due to the difficulty of accessing real system. Second, analytics models are complex and not accuracy and third depends every stator winding and every rotor bar winding independent model winding. FEM has been achieved to create a numerical model of IM. Indeed, the modeling of electrical machines has experienced remarkable development in recent decades through the use of FEA. But also evaluating the performance of this motor depends on the accuracy of these parameters. The proposed method for calculating the machine parameters is FE field solution is not new but it might be useful alternative to the existing numerical and experimental method, because it eliminates some of their drawbacks. To carry out such design, we usually employ 2-D FEA software FEMM even it is time consuming. But, with the progress of technologies this method is very fast than in the past. In this paper, step by step simulation was made to determine field distribution. Which using for IM parameters estimation [1] [2][3].

3. MACHINE ARCHITECTURE

The three phase machine designed with 36 slots stator and 24 slots rotor. This motor is characteristic by P=1.8kW, f=50hz, 4 pairs of poles (i.e. p=2), running of a 220 Vrms line-to-line, 3 phase supply, implying that it will be running at slightly less than 1500 RPM. The air gap of the induction machine is 0.07 mm. The detailed dimensions presented in Table 1.

Table 1: Motor Dimensions

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor Radius</td>
<td>81.8/2 mm</td>
</tr>
<tr>
<td>Number of stator Slots</td>
<td>36</td>
</tr>
<tr>
<td>Number of rotor slots</td>
<td>24</td>
</tr>
<tr>
<td>Number of stator turns</td>
<td>46</td>
</tr>
<tr>
<td>Coil pitch</td>
<td>65/71 mm</td>
</tr>
<tr>
<td>Torque</td>
<td>12N.m</td>
</tr>
<tr>
<td>Weight</td>
<td>15 Kg</td>
</tr>
<tr>
<td>Rated current</td>
<td>4.1A</td>
</tr>
<tr>
<td>Peak efficiency</td>
<td>77 %</td>
</tr>
<tr>
<td>Power factor</td>
<td>0.85</td>
</tr>
</tbody>
</table>

An important feature of the stator is the shape of the slot.
There are two main types: slot which is open and the semi-open. The open type slots are the same width through their depth and teeth are trapezoidal. The semi-open slots are typically trapezoidal in shape, so the teeth are parallel walls. These slots let a minimum width of opening but still allow introducing small diameters conductors. The slots in the squirrel cage motor are copper bars or aluminum shorted at both ends of the stator by end rings. In low-medium power motors, the cages are made of cast aluminum partial vacuum and pressure, which prevents the presence of air bubbles and to the bars and the rings in the same operation. The slots in the engine are semi open type as presents in Figure 1.[4]

![Fig. 1. Semi open type of slot](image1)

The winding configuration for the machine is divided in three symmetric phases and rotor the cage rotor constitutes bars as pictured below in Figure 2 and Figure 3. To reduce noise and some harmonics during starting and for the accelerating is more uniform, the rotor is constructed so that the conductors are oblique with respect to the motor shaft. In order to model electrical rotor asymmetries the full topology of the rotor cage, respectively has to be taken into account. In order to understand how induction motors work it is necessary to have a good model.

![Fig. 2. Stator winding configuration](image2)

![Fig. 3. Squirrel rotor winding configuration](image3)

4. MODEL DESIGN

There are different methods used in the field of calculation and simulation of electrical devices including asynchronous machines [5].

The proposed method for estimating the machine parameters by using FE field solution is not completely new, but it might be useful as alternative to the existing numerical an experimental methods because it eliminates some of their drawbacks [6]. Their aim is to compute accurately the operating properties and characteristics of IM. This model is based on the calculation distribution of the electromagnetic field in the machine. This calculation is performed numerically using the finite element method which used several approaches have been explored for the spatial discretization of the field equations based in Maxwell equations:

\[
\nabla \times \vec{H} = \vec{j} \tag{1}
\]

\[
\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \tag{2}
\]

\[
\nabla \times \vec{D} = \vec{q}_s \tag{3}
\]

\[
\nabla \times \vec{B} = 0 \tag{4}
\]

These equations are coupled with the equations governing the boundary conditions to determine the distribution of the field in the machine.

Many studies can be performed on this machine is meant to represent field distribution in rotor bars and calculate rotor current directly as eddy current induced in rotor bars. But, the parameters are obtained from FE field solution by building and identifying an IM model and for the discretization triangular as well as quadrilateral finite elements can be used in 2D using FEMM. The main purpose of this software is to determine the mapping of the magnetic field in electrical machine with the aim of building and optimizing [7] [8].

For the study and modification of the various parameters of the machine, these settings may vary depending on the desired performance, they include as well the geometric dimensions, for all that is magnetic saturation, eddy current...etc [9].

Calculation and computer aided design of the IM is to size the squirrel machine. At first we used the generalized analytical calculation by a program reserved for the design of an engine, written in Matlab. Then specialized software based on the finite element method for the simulation of electrical machines like shown in figure 4.
The controls scripts are programmed in MATLAB that are required to call FEMM software and create the geometry of the IM. With geometry, we give him the materials as of each part; outline the conditions of the machine, and operating conditions. From a practical standpoint, it is very easy to vary the operating conditions of the machine (frequency and magnetizing flux), by simply changing the data calculation program where high flexibility. Materials are assigned in the models. After run the mesh, the flux distribution can be seen as in Figure 5 [10].

5. SIMULATION RESULT

The point of identifying these parameters via FE method is to validate the approximations and simplifications that automatically must be made in the derivation of analytical design formulas [11].

The principle of this method, the magnetic circuit of the machine is divided into several elements of small dimensions to allow considering the linear magnetic material on the corresponding surfaces. The use of the Maxwell equations, based on local forms, solves the problem. The 2d model of the Induction Machine has field linking with the stator phases or the rotor loops can be calculated from the vector magnetic potential as presented in figure 6, 7 and 8.
The analysis is run at a different values rotor speed and stator current. The main point to be considered when modeling IM at a single frequency is that the currents induced in the rotor bars will vary at the slip frequency rather than the armature frequency. This is important because the setup of the dynamic analysis needs to account for the difference between the frequencies in the stator windings and the rotor bars / conductors. Now, one could either attempt to base parameter identification by using a constant stator current over a range of frequencies.

The proposed method ensures the required separation of the rotor and stator leakage inductances in both saturated and unsaturated case. The described model of the induction motor with the complete known set of parameters can be used in the advanced control synthesis of the induction machine.

To calculate the stator induction, the model solved with the simulation were achieved for wide range rotor speeds while different stator current figure 9 present the stator inductance parameter for rotor speeds equal 2, 5, 12 and 25 rd/s.

![Fig. 9. Stator inductance](image)

The same process is adopted for rotor induction while varying stator current up reach high values (0 at 50 A) and for rotor speeds equal 2, 5, 12 and 25 rd/s like figure 10 displays.

![Fig. 10. Rotor inductance](image)

Figure 11 and 12 shows respectively rotor time constant and magnetic dispersion coefficient, the simulation and FE analysis were achieved with similar manner for wide range rotor speeds equal 2, 5, 12 and 25 rd/s while different stator current(0 at 50 A).

![Fig. 11. Rotor time constant](image)

![Fig. 12. Magnetic dispersion coefficient](image)

The developed program compute the circuit model parameters of squirrel cage IM using the solution of electromagnetic fields and take in account the saturation and skin effects. In addition, Analysis the performance of IMs and study of non-linear alternating filed, then, study the problems that are difficult to be solved by analytical methods. Indeed, other parameters may also be present using FEM calculation, such as stator and rotor resistance, mutual induction between rotor and stator, field by phase and electromagnetic torque can be computed with significantly good accuracy.

**CONCLUSION**

In this work, the geometric design of a IM is performed with 2-D FEM simulations to achieve diagnostic and optimization in next papers. The exclusive use of analytical methods has resulted to be not sufficiently accurate, here. As a result, a faster optimization process that includes the use of FEM is proposed. With the proposed magnetic field analysis based on the finite element method, it is possible to determine the motor parameters. The simulations of parameters identify for high performance IM drives was carried for wide range
stator currents and rotor speeds. So the application where the high performance is needed the ac motors are used so only the total performance depends in IM for use in electric cars.

ACKNOWLEDGMENT

University of Sfax

REFERENCES


