Asynchronous machine end windings characterisation with FLUX3D.

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Introduction

The knowledge of the end windings inductance is necessary to determine the voltage-current characteristics in motors.
The 3D finite element model allows to represent precisely the three-dimensional geometry of end windings with which it can be obtained a complete analysis of electromagnetic fields in the extremities of machines, for the computations of losses and electromechanical efforts on end windings.
Among the leakage inductance, one distinguished:

- The 2D leakage, located in the straight part of the machine where the magnetic field is bi-dimensionnal: Slot leakage, differential leakage, harmonic leakage
- The 3D leakage at the extremities of the machine where the looping of the conductors induce "3D" leakage flux: Two 3D leakage inductance are defined, the end ring inductance at the rotor and the end winding inductance at the stator. This latter is the parameter studied in the following Finite Element Method.

The model

The model is based from a classical type of asynchronous machine (LS180). This machine is voluntary simple in order to validate the calculation method on clear basis but the study can be applied with more complicated machines (with screen and mounting flanges). The geometry of the model is shown in figure 1.

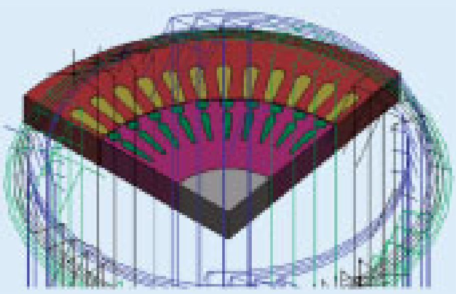

Figure 1: Modele of machine extrimity.

The symmetries allow to represent only one pole of the machine, i.e. the quarter of the machine. Moreover, the calculated value being an extremity parameter, one extremity of the machine has only been modelled. Results have proved that a 15cm iron length is sufficient to obtain good values. The volume mesh of the system has been realised with the FLUX3D extrusive mesh generator. The total number of nodes is around 53900, the mesh is shown in figure 2.

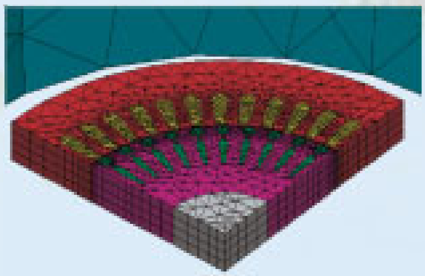

Figure 2: Meshed model.

Results

The calculation of end winding inductance has been performed with four different finite element methods by using energy and flux computations. Whatever the hypothesis, the four methods give very close results with only 4% of maximal variance.

The computation has first been completed with hypothesis inspired from the existing IEC norms concerning the experimental determination of end winding cyclic inductance (L-M). The computations have been executed for several lengths of iron in order to show that the value is independent of it. This confirms that the computed value is an extremity parameter. The results founded with the four methods with this reference simulation are presented in the following graph:
The study has been completed with other simulations:

- Single phase (configuration which gives the self and the mutual inductance),
- Influence of the geometric variations of the end windings and the airgap,
- Influence of the magnetic saturation,
- Influence of the lamination,
- Influence of the rotor,
- Influence of the induced currents.

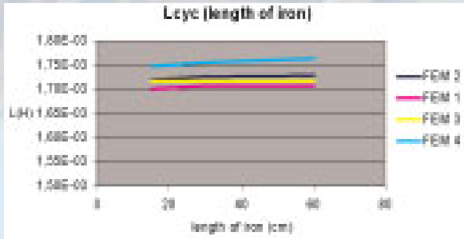

Figure 3: Results according to the length of iron.

Owing to the large possibility of parameterisation of FLUX3D, these simulations are easily obtained from the reference case and allow to model effects that classical analytic formulae cannot take into account.

The detail of this study and its computations are presented in the CEDRAT technical paper ***"Characterisation of end windings with FLUX3D"*** available at CEDRAT (you have the possibility to realise easily the study supported by this technical paper).

The computing time are presented in the following table (Pentium4).

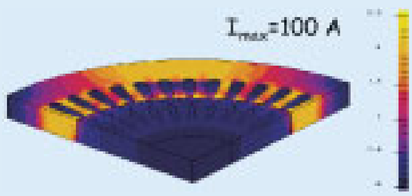

Figure 4: Simulation with magnetic saturation.

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Asynchronous machine end windings characterisation with FLUX3D. (continued from page 2)

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Connections with a FLUX2D study

The computed value can be introduced in the CIRFLU module of FLUX2D in order to realise a complete study on motors. With the knowledge of the end winding inductance, your study will take into account the extremity leakage, which are important in transient.

You can see below the representation of the electrical circuit with the components which represents the end winding leakage.

Studied device.

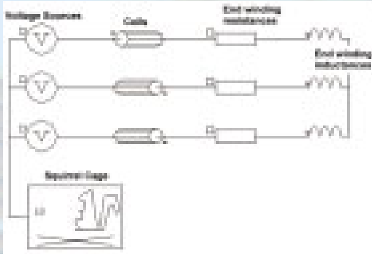

Figure 5: Representation of the asynchronous machine with CIRFLU.

Table 1: Computing times

Method	FEM 1		FEM 2	
Simulation	Number of solves	Total solving time (mn)	Number of solves	Total solving time (mn)
Reference case	1	3	2	5
Monophase	1	1	2	2
With saturation	X		X	
Rotor	1	4	2	6
Method	FEM 3		FEM 4	
Simulation	Number of solves	Total solving time (mn)	Number of solves	Total solving time (mn)
Reference case	2	6	2	5
Monophase	1	2	1	2
With saturation	X		4	28
Rotor	2	8	2	6

FLUX STUDIO: Dimensioning of an electromagnet at Schneider Electric.

Ph.Schuster – J.C.Ramirez – D.Savall - *SCHNEIDER ELECTRIC.*

Circuit breakers of the Schneider range.

Most often forgotten in a cupboard, their existence being generally not remarked (except for the case when the fuses blow…), the miniature circuit breakers are however high technology devices, with a complex design and able to show amazing performances considering their reduced size (switching short-circuit power of about 10000 A in less than a hundred of cm^3 !).

The heart of this equipment is an electromagnet with a plunger core, having a twofold purpose: to allow the unlock of the mechanism in case of short-circuit, and to impose an opening speed of the mobile contacts high enough to limit the instantaneous value of the current to a value that can be supported by the installation.

The optimal dimensioning of this electromagnet is therefore a key element in the design of circuit breakers.
Firstly, this dimensioning is important at the anticipation phase (elaboration of new apparatus), then at the development and adjusting phases.
Finally, the existent and already commercialised products can be the object of new studies in order to evaluate the impact on the performances of a partial re-design carried out to increase efficiency and reduce costs.

Thus, the dimensioning of a magnetic actuator is not an infrequent event; however, it is not so frequent as to make it possible, for a designer, to have a day-by-day competence on tools of FLUX2D type (not speaking of FLUX3D). Experience has shown that, in fact, these tools require regular practice, so that all their efficiency and reliability be exploited. In any case, the constraints of in-project work do not allow designers enough time for this practice.

Besides the understanding of the physical principles involved, the difficulties arise mainly in the logic of using the software tools (the new interfaces ease this task) and especially in the mastering of the notions linked either to the theory (for example the boundary conditions), or to the finite element method (for instance, the quality of the mesh).
For someone who is not a specialist, it is not easy to decide which modifications and simplifications can be made, for example, in order to use a 2D axi-symmetrical model for a 3D object.
Thus, the major benefit of Flux Studio consists in the possibility of hiding the specific technical part of the finite element analysis: boundary conditions, mesh, etc.

On the other hand, the parameterisation feature allows the user to make use of the quantities at hand (dimensions, material references). Moreover, one can take into account the possible modifications that are necessary in order to pass from the real 3D geometry to a 2D axi-symmetric representation.

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