Proposal of tutorial for ICEM 2020

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Abstract

We propose a tutorial on the 23th August 2020 before ICEM 2020.
We would able to propose a half-day tutorial (5 hours), but, according to the number of requests and availability of the rooms, we could limit the tutorial to be 2.5 hours, including questions.
The speakers will be:

- Luigi Alberti (luigi.alberti@unipd.it)
- Nicola Bianchi (nicola.bianchi@unipd.it)
- Matteo Carbonieri (matteo.carbonieri@studenti.unipd.it)

1 Tutorial details

The tutorial title is "**A flux-oriented-based analysis of three-phase induction machines**".

The tutorial will describe a complete finite-element analysis procedure for induction motors, including squirrel cage motor. One of the main novelty of the proposed approach is that the machine performance is obtained performing only magneto-static finite element analyses. The synergy between analytical and finite element model leads to a rapid and precise estimation of the rotor induced current. In fact, the rotor currents are assigned as source and their value is adjusted in at maximum three simulation steps.

Adopting magneto-static analysis, saturation phenomena are carefully considered in any operating condition. In addition, computational time is quite low, since time-stepping analyses are avoided.

The procedure proposed allows the motor performance to be directly derived, without any preliminary knowledge of the machine equivalent circuit.

In the tutorial, how to apply this analysis procedure will be described in details. In addition, strategies to include the analysis of skewed rotors, MMF space harmonics, iron losses evaluation, ... will be explained.

The tutorial table of contents is described hereafter. The tutorial will contain technical details which could be appreciated by audience.

2 Brief summary of the contents

1. Theoretic introduction to highlight the equation of the induction machine in the useful form to highlight the rotor flux. $d-q$ model of the machine, where d-axis is oriented along the flux linkage of the rotor. Corresponding

equivalent circuit.
Such concepts, derived from the control of the motor, are adopted to the finite-element analysis of the machine.

2. Magneto-static analysis of the machine. Selection of the rotor current distribution. First selection according to the equivalent circuit. Iterative loop to adjust the rotor current amplitude, demonstrating the the maximum number of iterations is three.
   Advantages of the approach with respect other techniques: rapidity, proper consideration of iron saturation, easy implementation in any SW tool.

3. Experimental tests are reported to validate the analysis results. Experimental validation will be given durin the whole presentation.

4. How to consider the skewed rotor. Skewing effect is considered using the 2-D multi-slice technique. After a first analysis, static simulations are enough to account the skewing, imposing the rotor current distribution previously computed.

5. The procedure can be simply adjusted to consider the impact of the Magneto-Motive-Force (MMF) harmonics. These harmonics move at different speed with respect the fundamental one, so that for any rotor position, the rotor current distribution has to be adjusted. The technique will be deeply described.

6. Parameter and losses estimation is a key feature of the proposed procedure. In particular, the rotor parameters are easily determined, after the first analysis on the machine geometry.
   It is interesting to note that also the iron losses (including the rotor stray-load losses) can be determined by this analysis approach. The impact of the rotor skewing and the rotor slot tip on the rotor losses will be illustrated in detail.

7. Due to the rapidity of the magneto-static simulations, the procedure is adopted to determine the performance map of the machine (sometimes also referred to as efficiency map). A set of d- and q-axis stator currents are fixed. From the FE analysis the results are elaborated so as to achieve the corresponding torque, flux linkages, losses, thus maximum speed. Thise results are redrawn in the torque-speed plane, similarly to how is commonly done for synchronous machines, allowing a practical comparison between synchronous and induction machines.

8. Finally, some particular cases will be shown. At first, an industrial application: the analysis of induction motors for pumping applications. Then, the analysis of the induction machine design for an automotive traction application, where torque overload, flux-weakening, high speed are required. Finally, the analysis of the induction motor is carried out for an aeronautic application, where the operating frequency (around 400 Hz) is not fixed but can be change in a quite large range of values.