Best Student Paper Award 2008.

Javier Rosero, Motion Control and Industrial Applications Group, Technical University of Catalonia.

Simulation and Fault Detection in PMSM under Dynamic Conditions.

J. Rosero, J. Romeral, Univ. of Catalonia.

The permanent magnet synchronous motor (PMSM) is becoming popular in high performance applications as compared to other types of AC motors. A short circuit between turns is the most critical fault in a machine, is quite difficult to detect and almost impossible to remove. There are a number of techniques used to detect turn-to-turn faults, the majority of them based on stator voltages and currents, axial flux and d-q current and voltage component analysis. The best way to analyze the content frequency of non-stationary stator current is with a joint time-frequency analysis.

The EMD method was motivated by computation of instantaneous frequency defined in terms of Hilbert transform. The Wigner-Ville distribution (WVD) is a time-frequency representation. If the signal analyzed contains more than one component, the WVD method suffers from cross-term interference as the Pseudo Wigner Ville Distribution (SPWVD) exists for applying the weighting function to the instantaneous correlation. Flux 2D is proposed for simulation of the system PMSM-Control-Drive because it involves non linear external circuit parts.

Simulation of Short Circuit

The fault of short turns of stator phase winding leads to two main effects on the machine flux. The first is that the large current in the shorted turns, leading to an increase in local leakage flux, particularly slot leakage. This changes the saturation conditions of the teeth locally. Secondly, the currents induced in the shorted coils oppose the establishment of the main, air-gap flux. They thus reduce that flux and the corresponding main flux path saturation along the winding axis of the shorted coil. There is a greater probability of flux density with the basic number of pole pairs now existing as shown in figure 2.

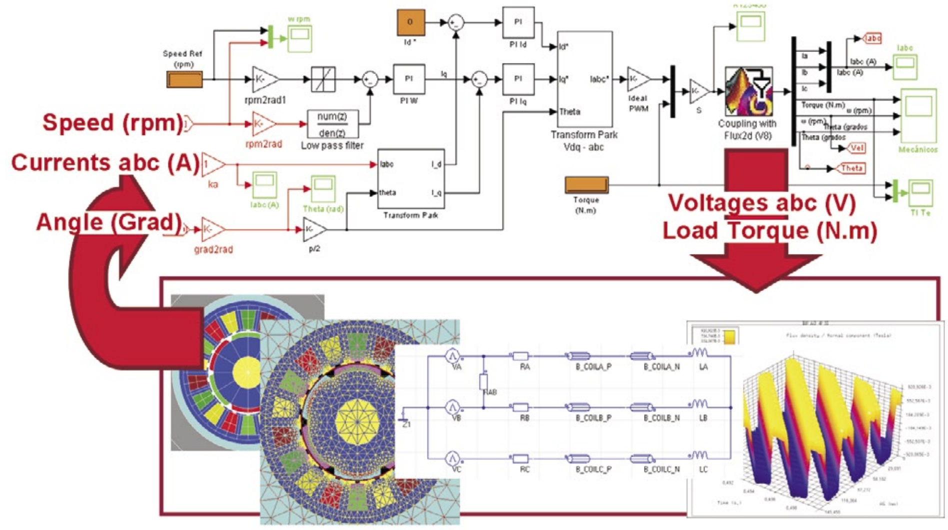

Fig. 1. Schematic of the finite element analysis (FEA) for a PMSM.

Result

The short circuit is analyzed under different speed conditions. Five intrinsic mode functions (IMF) are obtained from the stator current by means of EMD and afterwards WVD is calculated. IMF 3 contains the stator main current harmonic and IMF 1 and 2 together contain the failure harmonic. Now, the biggest harmonic is the 9th fault harmonic (900 Hz in this case); the main harmonic corresponding to power supply that is always higher to the other ones when it is analyzed with standard MCSA, has been eliminated.

(see continued on page 7)

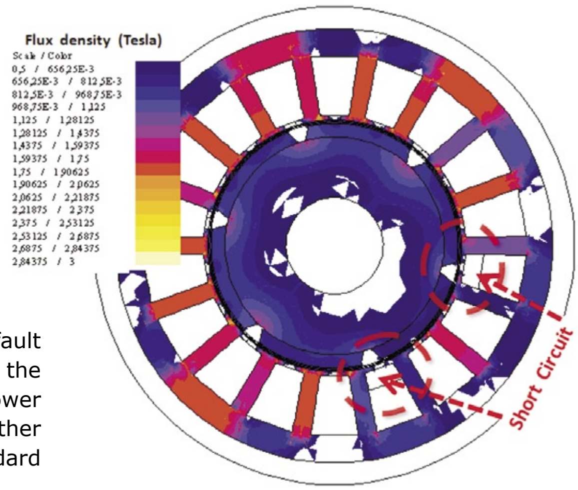

Fig. 2. Flux density of a PMSM with short circuit.

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Best Student Paper Award 2008. (continued)

Javier Rosero, Motion Control and Industrial Applications Group, Technical University of Catalonia.

Figure 3 shows SPWVD of IMF 1 and 2 of the stator currents of a PMSM with 12 short-circuit turns. Some experimental results are shown in figure 4.
These are the results for low speeds where the fault detection is more critical. The results for the whole speed range are also very satisfactory.

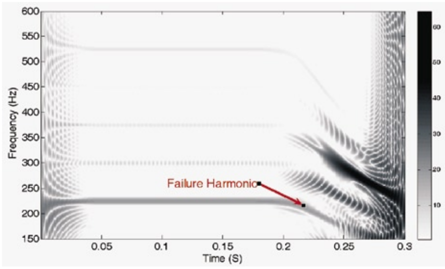

Fig. 3. SPWVD of IMF 1&2 in PMSM with 12 short circuit turns. Speed change from 1500 to 1000 rpm.

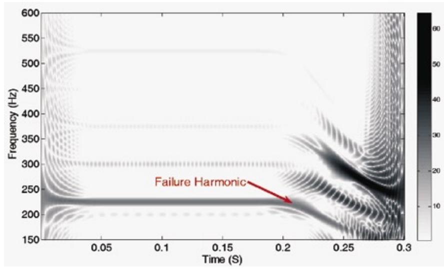

Fig. 4. SPWVD of IMF 1&2 in PMSM with 12 short circuit turns. Speed change from 1500 to 1000 rpm, Experimental results.

Conclusion

Flux 2D is an excellent tool for simulation of the PMSM under fault and for all speed range. This software allows the user to know the behaviour of the motor under different conditions and to analyze what has happened after a failure. The method by means of EMD and IMF, next WVD was applied to IMF 1 and 2 allows analysis of the characteristic failure and decreasing the computational burden; besides, it maximizes the failure relative value. The results show an increase in spectral resolution and also fault diagnosis reliability.

3D-Modelling of Circuit-breakers Cells.

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As part of a study for industry, CEDRAT Group has performed modelling of cells of circuit-breakers for Schneider-Electric.
This full parameterized model, was built in a 3D Flux environment.
Each basic component that constitutes the cells is parameterized and added to a library of components including arc control devices, linear actuators, magnetic screens and bi-metallic strips as well as the whole cell which can be associated with other cells.
The modelling of cells enables a simulation of the magnetic behaviour of the whole device for different working points. Here are the results one can extract:

- Evaluation of each cell's magnetic compatibility with its environment,
- Distribution of magnetic flux density inside and outside each cell,
- Computation of electro-dynamic strengths applied to the components inside the cells, including the force applied on the electric arc at the circuit-breaker opening,
- Computation of the magnetic flux embraced by the field coils.

In addition to the creation of macro functions to automatically build solenoids, this work has allowed us to very accurately define how to take into account the coupling between components such as coils (non-meshed coils) and solid conductors (meshed conductors) inside the geometry of the device as well as inside the corresponding electrical circuit.

Practically speaking, components of the electrical circuit are connected in series. This means that, inside our finite element model, the current can go from a coil (non-meshed coil) to a solid conductor (meshed conductor) and vice-versa.

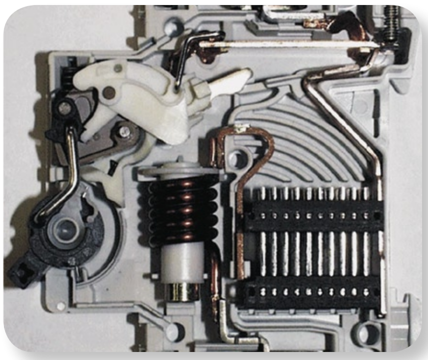

Fig. 1: One cell of a circuit-breaker.

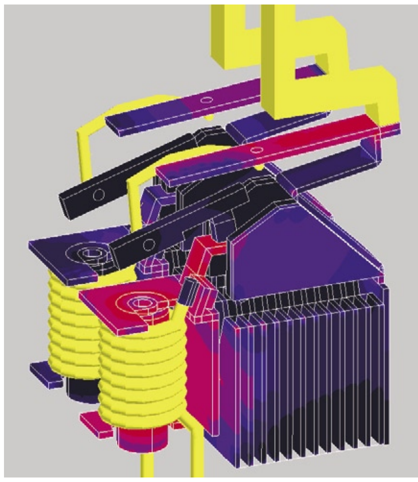

Fig. 2: Distribution of magnetic flux density inside circuit-breaker cells.

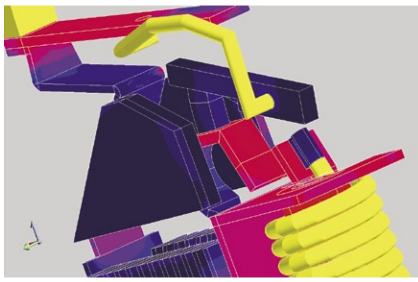

Fig.3: Connection between meshed solid conductors and non-meshed coils.