ScuDo

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XXXVI Cycle

Thermal-electromagnetic design and analyses of synchronous machines for traction applications

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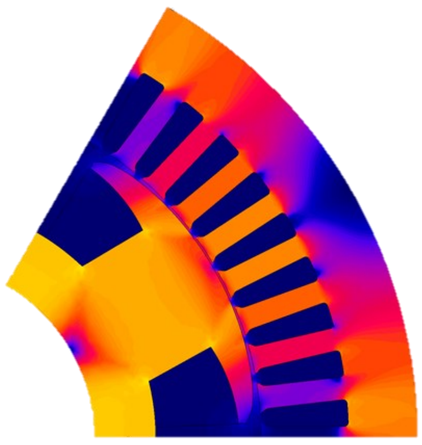
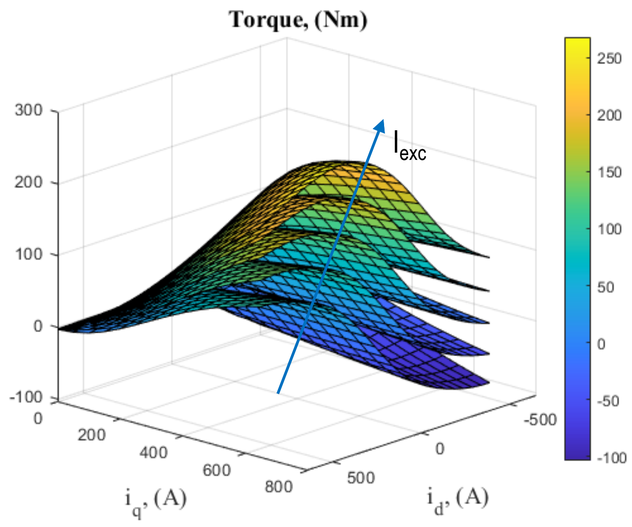
Supervisors: Prof. Silvio Vaschetto | Prof. Alberto Tenconi

Research context and motivation

- The electric traction represents the future of transportation and the electric motor is the crucial component of the drivetrain of hybrid and electric vehicles.
- Electric vehicles' producers are turning their attention to machines with reduced or completely without magnets.
- The wound field synchronous machines and the doubly excited synchronous machines have been identified as promising solutions.
- My research aims at developing a fast and reliable sizing tool for wound field synchronous machines for traction applications and at analyzing the motor performances from an electromagnetic and thermal point of view.



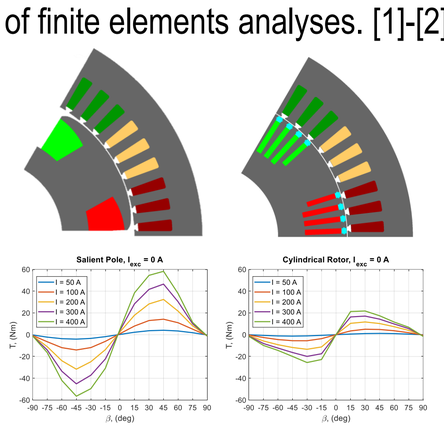


Addressed research questions/problems

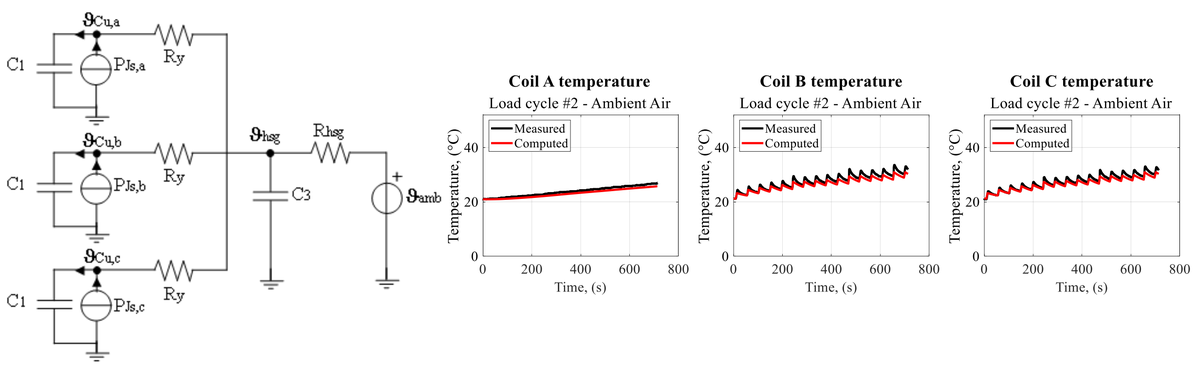
To date, my research has focused on:

- An extensive study of the state of the art about synchronous machines with reduced or completely without magnets, further explored by means of finite elements analyses. [1]-[2]

Sources location	PMs and EW both on the rotor side				PMs and EW both on the stator side	
Excitation paths	Parallel	Parallel	Parallel	Series	Series	Parallel
Machine						
Torque density	●	●	●	●	●	●
Topological complexity	●	●	●	●	●	●
Current on the rotor	Y	Y	Y	Y	N	N
Flux weakening	●	●	●	●	●	●
PM demagnetization	●	●	●	●	●	●
Level of investigation	FEM	-	Prototype	Prototype	Prototype	FEM



- Development of lumped parameters thermal networks for synchronous machines (with both computed and optimized parameters), validated through experimental thermal tests and 2D thermal finite element simulations [3]-[4]-[5]; laying the foundation for the application to the final topic machine.



Currently, the sizing tool of wound field synchronous motors is under development.

- The goal of the sizing code is to allow machine designers to obtain a preliminary wound field synchronous machine geometry, by simply inserting basic and well-known variable constraints and parameters.

Submitted and published works

[1] **F. Graffeo**, S. Vaschetto, M. Cossale, M. Kerschbaumer, E. C. Bortoni and A. Cavagnino, "Cylindrical Wound-Rotor Synchronous Machines for Traction Applications," 2020 International Conference on Electrical Machines (ICEM), 2020.

[2] **F. Graffeo**, O. Stiscia, S. Vaschetto, A. Tenconi and A. Cavagnino, "Doubly Excitated Synchronous Machines for Traction Applications," 2021 IEEE 30th International Symposium on Industrial Electronics (ISIE), 2021.

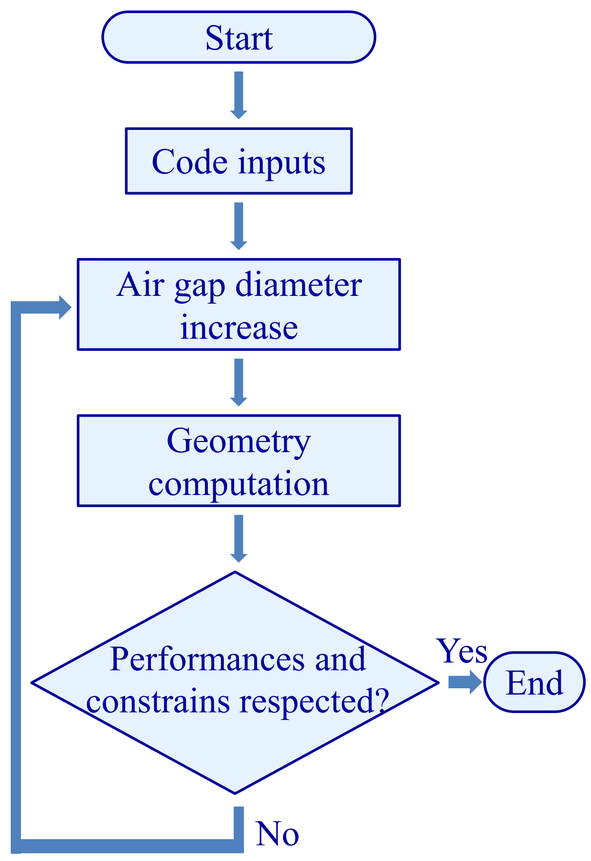
[3] **F. Graffeo**, S. Vaschetto, A. Miotto, F. Carbone, A. Tenconi and A. Cavagnino, "Lumped-Parameters Thermal Network of PM Synchronous Machines for Automotive Brake-by-Wire Systems," Energies 2021, 14, 5652.

[4] S. Vaschetto, E. Agamloh, **F. Graffeo** and A. Cavagnino, "Comparison of Superposition Equivalent Loading Methods for Induction Machine Temperature Tests", 2021 IEEE Energy Conversion Congress and Exposition (ECCE).

[5] **F. Graffeo**, S. Vaschetto, A. Miotto, F. Carbone, A. Tenconi and A. Cavagnino, "Simplified Thermal Model of Disk-Shaped Automotive Smart Braking Actuators", to be presented at 2022 IEEE Energy Conversion Congress and Exposition (ECCE).

Adopted methodologies

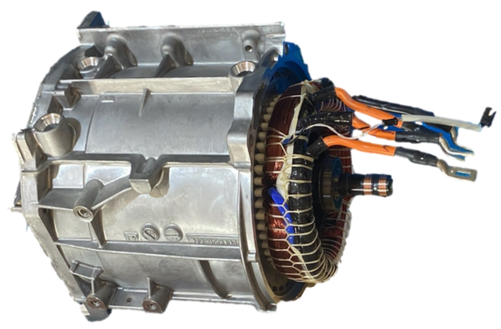
- The algorithm for the sizing of wound field synchronous machines is based on the concept of increasing the machine diameter until all the desired constraints are respected.
- The code is conceived to require a limited number of input variables and parameters (e.g., torque, speed, supply voltage, material exploitation indexes).
- At present, the developed code has only been tested for a well-known machine and good agreements have been found.
- The code is under development, especially for the rotor winding design.



Future work

The final code will be validated by means of two wound field synchronous machines:

- One traction motor whose main characteristics will be found by a work of reverse engineering.
- One standard grid-connected wound field synchronous generator.



List of attended classes

Hard skills:

- 02ITTRV–Generatori e impianti fotovoltaici (H, 23/4/2021, credits: 33.33)
- 01VFNRV–High Temperature Superconductors for Electrical Applications (H, 25/1/2021, credits: 16)
- 01DOBRV–Mathematical-physical theory of electromagnetism (H, 6/6/2022, credits: 20)
- 01LEVRV–Power system economics (H, 14/7/2021, credits: 26.67)
- 02SFURV–Programmazione scientifica avanzata in matlab (H, 25/5/2021, credits: 40)
- 01TSLRO–Soluzioni innovative per veicoli elettrici e/o ibridi (H, 19/5/2021, credits: 20)
- 02LGXRV–Valutazione di impatto ambientale di campi magnetici ed elettrici a frequenza industriale (H, 19/7/2021, credits: 26.67)

Soft skills:

- 01PJMRV–Etica informatica (3/5/2021, hours: 20)
- 01UNVRV–Navigating the hiring process: CV, tests, interview (23/9/2021, hours: 2)
- 01RISRV–Public speaking (24/9/2021 , hours: 5)
- 01SYBRV– Research integrity 29/9/2021, hours: 5)
- 01SWQRV–Responsible research and innovation, the impact on social challenges (28/9/2021, hours: 5)
- 01UNXRV–Thinking out of the box (S, 6/1/2021 , hours: 1)
- 01SWPRV–Time management (S, 29/9/2021 , hours: 2)

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