UNIVERSITY OF L'AQUILA - DIIIE

Francesco Parasiliti Collazzo, Marco Tursini, Marco Villani, Antonio Ometto, Giuseppe Fabri, Lino Di Leonardo, Marco Santececca, Andrea Credo, Alessio Di Tullio

---

RESEARCH TOPICS

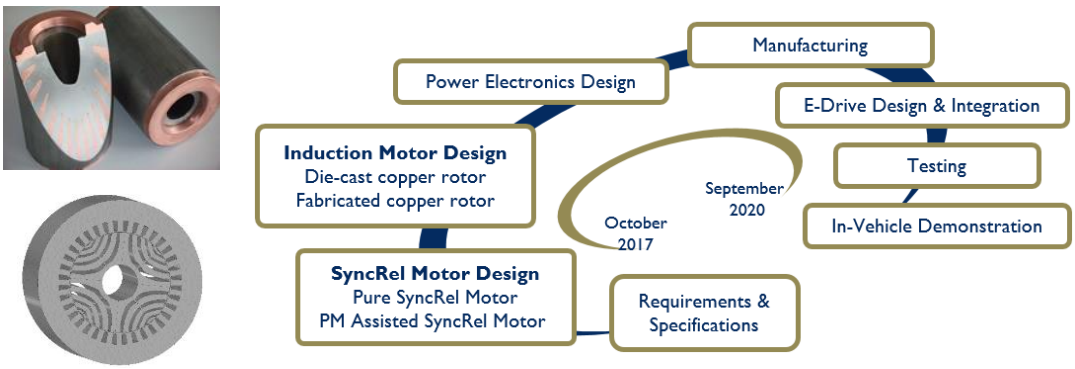
- Motors-drives solutions for aeronautical and automotive applications
- Modeling, simulation, and control of fault-tolerant machines
- Sensorless and optimum control of synchronous reluctance motors
- High-efficiency line-start SRM for industrial applications
- Modeling and simulation of hydrogen light-rail trains

MOTORS-DRIVES SOLUTIONS FOR AERONAUTICAL AND AUTOMOTIVE APPLICATIONS

Keywords: Motor design, fault-tolerant motor, PM motor, switched reluctance motor, flap actuator, helicopter, tail rotor, transient analysis, thermal analysis.

In aeronautical applications, the activity in has led to the design of multiphase motors and drives with "independent phases", i.e. conceived to be tolerant respect to faults which could happen on both the motor and drive phases. A 5-phase motor for "flap application", a 6-phase motor for "cabin elevator", and a 6-phase motor for the tail rotor of a helicopter (FP7 CleanSky/Airbus project) have been developed.

In automotive application, the H2020 ReFreeDrive project (2017-2020) has the objective to develop rare earth-free traction technologies beyond their current state-of-art, with a strong focus on industrial feasibility for mass production, targeting lower costs with higher specific torque and power density. Design and prototypes of induction motors and synchronous reluctance motors (pure and assisted by rare-earth free permanent magnets) for two power ranges electric vehicles (75 kW and 200 kW) are planned.



Highlights of the Horizon 2020 – ReFreeDrive project

References

[1] G. Fabri, F. Parasiliti Collazzo, M. Tursini, M. Villani, L. Castellini, "PM Brushless motor for helicopter electric tail rotor drive system", Proc. of IEMDC 2017, Miami, Usa, May 21-24, 2017.

[2] M. Tursini , M. Villani , G. Fabri , L. Di Leonardo, "A switched-reluctance motor for aerospace application: design, analysis and results", Electric Power Systems Research, Vol. 142, January 2017, pp. 74-83.

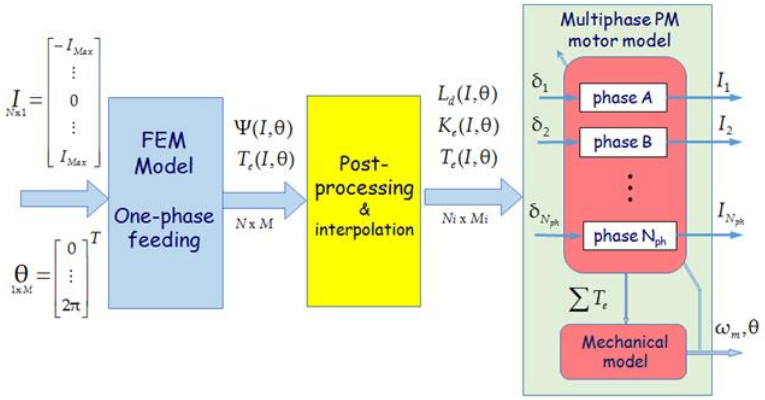
[3] L. Castellini, M. Villani, M. Tursini, M. Santececca, "Comparison of PM Brushless motors for helicopter tail rotor Fenestron type", Recent Advances in Aerospace Actuation Systems and Components (R3ASC), Toulouse, France, March 16-17, 2016.

[4] G. Fabri, E. Della Loggia, M. Tursini, M. Villani, "Fault-Tolerant Design of Motor-Drives for High Reliability Applications", Proc. of Int. Forum on Research and Technologies for Society and Industry (RTSI 2015), Turin, Italy, Sept. 16-18, 2015, pp. 219-225.

MODELING, SIMULATION, AND CONTROL OF FAULT-TOLERANT MACHINES

Keywords: Motor modeling, motor simulation, multiphase machines, fault-tolerant machines, finite element analysis, virtual prototyping, neuro-fuzzy controller.

This research has led to the development of dynamic models suitable for accurate co-simulation of fault-tolerant permanent-magnet motor drives featuring independent-phases structure. The model functions are pre-computed by a finite element method analysis of a single phase of the machine, once the magnetic independence among the phases has been verified. Then, the circuital model is solved by a dynamical simulator which implements also the drive system, converter and control, following on the off-line co-simulation approach. The methodology has been used for the development of a neuro-fuzzy controller with fault-tolerance capability.



Implementation steps of the fault-tolerant PM motor model

References

[5] M. Tursini, M. Villani, A. Di Tullio, G. Fabri and F. Parasiliti Collazzo, "Nonlinear model suitable for the offline cosimulation of fault-tolerant PM motors drives", IEEE Trans. on Industry Applications, Vol. 53, Issue. 4, July 2017, pp 3719-3729.

[6] M. Tursini, M. Villani, A. Di Tullio, G. Fabri and F. Parasiliti, "Off-line co-simulation of multiphase PM motor-drives", Proc. of ICEM 2016, Lausanne, Switzerland, Sept. 4-7, 2016, pp. 1138-1144.

[7] M. Tursini, L. Di Leonardo, A. Di Tullio, E. Della Loggia, "Transient analysis of multiphase PM motor-drives by non-linear modeling", Proc. of SPEEDAM 2016, June 22-24, 2016, Anacapri, Capri Island, Italy.

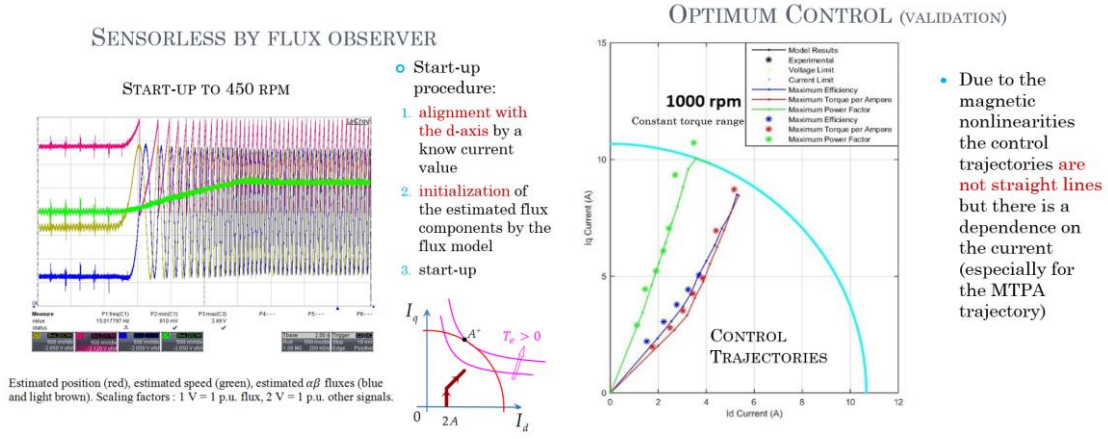
[8] A. Di Tullio, M. Tursini, F. Parasiliti Collazzo, K. Akatsu, "Five phase multi-layer drive with fault tolerant neuro-fuzzy features for safety critical applications", Proc. of ICEMS 2017, Sydney, Australia, 11-14 August 2017.

SENSORLESS AND OPTIMUM CONTROL OF SYNCHRONOUS RELUCTANCE MOTORS

Keywords: Synchronous reluctance motor, sensorless control, finite elements modeling, finite elements analysis, phase-locked loop algorithm, optimum control, MTPA.

A hybrid sensorless controller is developed, which includes an adaptive observer for not-zero speed operation and signal injection for standstill. The observer detects the flux linkages components in the two-phase stationary reference frame by the voltage model integration and closed loop correction feedback. This last is provided by a non-linear model of the rotor-fixed frame flux components achieved by finite elements computations. Maximum torque/current, maximum power factor, maximum torque/flux, and maximum efficiency are considered for optimum control. The optimizing control

trajectories are evaluated by means of a numerical Finite Elements model analysis and validated by experiments.



Test results of synchronous reluctance motor control

References

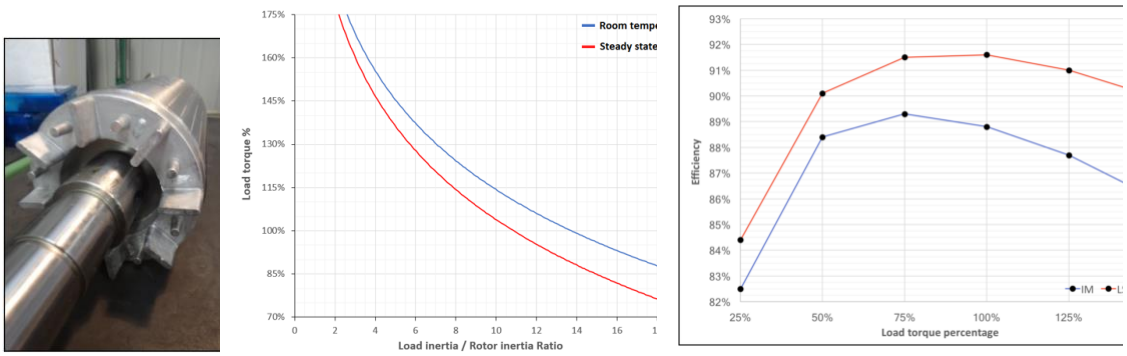
[1] M. Tursini, M. Villani, G. Fabri, S. Paolini, A. Credo, A. Fioravanti, "Sensorless control of a synchronous reluctance motor by finite elements model results", Proc. of SLED 2017, Catania, Italy, Sept. 18-19, 2017.

[2] M. Tursini, A. Credo, G. Fabri, F. Parasiliti, M. Villani, "Assessment of control strategies for synchronous reluctance motors", Proc. of EEMODS 2017, Rome, Italy, Sept. 6-8, 2017.

HIGH-EFFICIENCY LINE-START SRM FOR INDUSTRIAL APPLICATIONS

Keywords: Synchronous reluctance motor, line-start motor, finite elements design, fan application, pump application.

The design of high performance Line-Start Synchronous Reluctance motor should ensure a certain compromise between an adequate starting performance in the asynchronous operating region and efficiency at synchronous operation. A 4 kW, 4 poles, IE4. LSSRM has been realized and tested. The prototype presents satisfactory performance, reduced acoustic impact, low temperature increase in the stator winding and good behavior during start-up. The comparison with a same size IE3 Induction motor points out an effective save of about 20% of electrical steel volume and 10% of copper, despite the increment of efficiency.



Prototype and tests of the line-start SRM

References

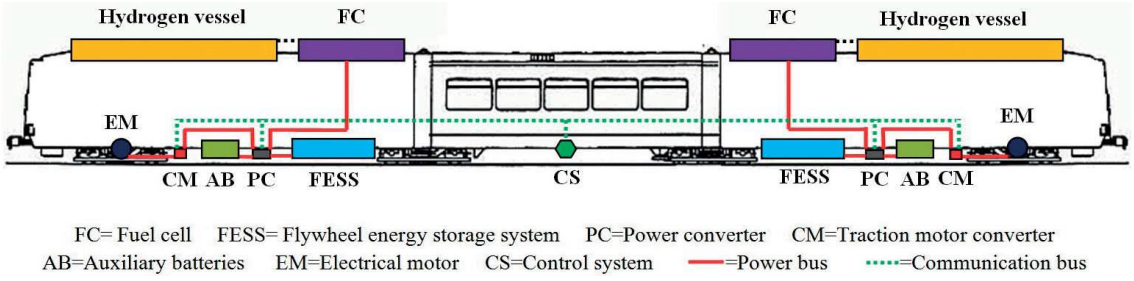
[3] M. Villani, M. Santececca, F. Parasiliti, "High-efficiency line-start synchronous reluctance motor for fan and pump applications", accepted for ICEM 2018.

MODELING AND SIMULATION OF HYDROGEN LIGHT-RAIL TRAINS

Keywords: Light-rail train modeling, fuel cells, flywheel, hybrid power train.

The business case for electrification of the "complementary" lines is almost always unfavorable and diesel traction is usually provided. New technological opportunities concerning advanced hybrid propulsion systems offer to realize a city railway transportation system environmental friendly able to operate at high energy efficiency also along non-electrified lines. An emission-free light-train (tram-train type) powered by a hybrid power unit consisting of hydrogen fuel cells and high-speed kinetic energy storage systems has been modeled and simulated. A numerical dynamic simulator of the proposed light-trail train has been developed in order to compute performance by varying system parameters with the aim to numerically verify the technical feasibility.

The simulation of the proposed light-train running along a re-designed non-electrified single-track line in the sub-urban territory of L'Aquila city (Italy) has been carried out. The numerical results show that a significant reduction of energy consumption and emissions can be achieved by using the hydrogen power-train and regenerative braking.



Power system simplified scheme of the LHE train

References

[4] A. Ometto, G. D'Ovidio, C. Masciovecchio, A. Carpenito "Preliminary analysis on advanced technologies for hydrogen light-rail trains application in sub-urban non electrified routes", Ingegneria Ferroviaria, Vol. 1, November 2017, pp 865-878.