UNIVERSITA' DEGLI STUDI DI TRIESTE
Faculty staff: Simone Castellan, Alfredo Contin, Roberto Menis, Alberto Tessarolo
Research fellows: Mario Mezzarobba, Mauro Bortolozzi, Nicola Barbini
Ph.D. students: Matteo Olivo, Nicola Barbini
Research assistant: Cesare Ciriani

RESEARCH TOPICS

- Design, development and prototyping of innovative electric machines
- Study of electric machines with analytical or semi-analytical methods
- Study and simulation of high-power drives through algebraic models
- Functional evaluation of oil-paper insulated power transformers
- Study of surge overvoltage impacts on dry-type transformers for static converter supply
- Torque ripple analysis and mitigation techniques in brushless DC electric drives

DESIGN, DEVELOPMENT AND PROTOTYPING OF INNOVATIVE ELECTRIC MACHINES

Keywords: design optimization, finite element analysis, linear motors, medium voltage machines, renewable energy generators, shipboard motors and actuators

The research group works in close cooperation with various electric machine manufacturers and final users assisting them in the study, design and prototyping of innovative electric machines, with a special focus on shipboard, oil-and gas and renewable energy applications. Examples of recently developed machines are: high-efficiency optimized permanent-magnet-assisted synchronous reluctance motors for household appliances; 500-kW 10.000-rpm motors with magnetically suspended rotor featuring a slotless stator and a Halback-array permanent magnet rotor arrangement; 700-kW 14-rpm prototype for direct-drive offshore wind generation featuring an interior permanent-magnet rotor design and a modular, fault-tolerant fractional-slot concentrated stator winding; prototypes for double-shaft rotary machines with innovative linear topology; prototype of an external permanent-magnet rim motor for boat outboard full-electric propulsion featuring a full integration between motor, propeller and power electronics; prototype of a synchronous permanent-magnet linear motor conceived as a full-electric alternative to hydraulic machinery for the full-electric actuation of large ship control surfaces.

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STUDY OF ELECTRIC MACHINES AND DRIVES WITH ANALYTICAL OR SEMI-ANALYTICAL METHODS

Keywords: analytical methods, magnetic equivalent circuits, modeling, reluctance networks, simulation, thermal networks

This line of inquiry is intended to investigate analytical or analytical-numerical approaches to the prediction of electric machine performance and parameters based on design data. The first-attempt solution consists of a direct solution of Maxwell's equations in the electric machine physical domain of interest; in case this is unfeasible, a minimal set of finite-element analysis simulations or experimental tests is defined to assist analytical procedures. The resulting calculation techniques are useful for their limited computational burden, which makes them suitable for incorporation into genetic-algorithm based design optimization programs.

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STUDY AND SIMULATION OF HIGH-POWER DRIVES THROUGH ALGEBRAIC MODELS

Analytical or even algebraic approaches are developed and validated to predict the steady-state behavior or large current-source-inverter-fed synchronous motor drives. With respect to the usual approach, requiring time-consuming and highly nonlinear simulations to be run until steady-state operation is reached, the proposed techniques are extremely fast, require a limited knowledge of electric motor parameters and directly provide the steady-state behavior of the drive in the desired operating conditions.

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FUNCTIONAL EVALUATION OF OIL-PAPER INSULATED POWER TRANSFORMERS

The research is carried out in cooperation with a national company and aims at assessing the condition of oil-paper insulation through partial discharge monitoring and analysis, dielectric spectroscopy, frequency response tests and examination of gases dissolved within the oil. The objective is to develop an advanced method for integrating the information obtained from different approaches, in order to support decisions relating to the functionality of the machine under examination. At present, the study covers the *in situ* condition monitoring of machines not connected to the grid.

STUDY OF SURGE OVERVOLTAGE IMPACTS ON DRY-TYPE TRANSFORMERS FOR STATIC CONVERTER SUPPLY

The goal of the study is to evaluate the impact on the transformer primary and secondary windings of surge overvoltage events caused by fast-acting circuit breakers or by solid-state device commutations. Following a pulse occurrence at machine terminals, the voltage distribution across the winding is highly non-uniform due to parasitic capacitances. This results in abnormal internal overvoltage events, which cause an early aging of the insulation system. The research activity intends to highlight overvoltage transmission mechanisms and then work out appropriate countermeasures to reduce the failure rate.

TORQUE RIPPLE ANALYSIS AND MITIGATION TECHNIQUES IN BRUSHLESS DC ELECTRIC DRIVES

The research activity developed in this field, in cooperation with some colleagues from the University of Padova, has led to elaborate a motor model in the space vector domain. The application of this model to the study of commutation-related torque disturbances has opened attractive perspectives and yielded effective solutions to mitigate the phenomenon in brushless DC motors. Along with the theoretical investigation, an experimental activity has been carried out by implementing the proposed control algorithms on a DSP-based development platform. Measurements have been collected on a test bench equipped with a braking device and a torque transducer.

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