UNIVERSITÀ DEGLI STUDI DI CASSINO E DEL LAZIO MERIDIONALE

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RESEARCH TOPICS

- Modeling of energy storage system and Battery Management System (BMS)
- Advanced control for Multi-Level power converters
- Multi-source charging infrastructure for Electric Vehicles (EVs)
- High-Performance E-Powertrains
- AC winding losses in high-speed motors
- Self-excited and Superconducting synchronous machines
- Automotive Inverter Test Bench System with Road Dynamics
- PCB motors with Passive Magnetic Bearings

MODELING OF ENERGY STORAGE SYSTEM AND BATTERY MANAGEMENT SYSTEM (BMS)

Keywords: Energy storage system, BMS

The characterization and the energy management of an energy storage system are relevant topics for the RU of the University of Cassino and Southern Lazio. The attention is mainly focused on the batteries, either for stationary applications or for the automotive ones. The development of an accurate battery model represents a fundamental key in this field. Several test procedures have been implemented with the aim to achieve an offline estimation of cell model parameters. Good results for both static and dynamic response of the battery cell have been achieved. In addition, the temperature of the cells under test during charging and discharging has been monitored by means of a thermo-camera. The RU is developing new algorithms for battery management system (BMS).

ADVANCED CONTROL FOR MULTI-LEVEL POWER CONVERTERS

Keywords: multi-level converter, modulation techniques

During the last years the RU has been developed several control techniques in the field of multi-level power converter. Starting from the three-level Neutral Point Clamped (NPC) inverters, the RU has proposed a new technique that allows taking into account the voltage variation of two capacitors of the dc-link during the modulation period, achieving an improvement of performance and the possibility of operating with unbalanced capacitor voltages as well. A novel power conversion structure for integrating different Battery Energy Storage Systems (BESSs) has been developed by the RU in collaboration with the RU of the University of Cagliari. A suitable control has been developed for optimizing the utilization of different types of battery units connected to power conversion system. A new high-efficiency modulation technique for a cascaded H-bridge (CHB) multi-level converter with an integrated battery energy storage system (BESS) used for electric vehicles (EVs) ultra-fast charging station has been developed.

The proposed modulation technique allows improving the conversion efficiency taking advantage of the several redundancies of the power conversion system.

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MULTI-SOURCE CHARGING INFRASTRUCTURE FOR ELECTRIC VEHICLES (EVS)

Keywords: multi-source EV charging station, optimal energy management

In the field of electro-mobility, the RU has developed several solutions that propose the utilization of multi-source power converter to minimize the cost of the charging process and the impact on the power grid as well. This goal is achieved by means of an optimal integration and control of renewable energy, stationary energy storage system, and V2G into the charging infrastructure. In particular, the optimal power flow management solves a stochastic multilayer optimization problem based on the definition of different priority levels representing the coordination of the ESS with the other sources.

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HIGH-PERFORMANCE E-POWERTRAINS

Keywords: electric vehicles, motorsport

This research activity deals with the design and implementation of high performances powertrain for electric vehicles used in motorsport application. These powertrains are based on high c-rate LiPo batteries, connected to PMSM based electrical drives. In the Laboratory of Industrial Applications several powertrains have been developed for different kind of vehicles. First prototypes have been focused on e-kart for competition. In particular, 30 hp and 50 hp powertrain have been implemented and mounted on 125cc kart body. Power management and onboard energy management have been deeply investigated, and some new traction control systems have been developed in order to optimize performances in terms of acceleration and braking (energy recovery). By means of CarSim software, the control algorithms have been tested in a HIL and SIL, before being implemented directly on the e-karts.

AC WINDING LOSSES IN HIGH SPEED MACHINES

Keywords: AC winding losses, brushless motors, permanent magnet machines, proximity effects, traction motors

This research investigates proximity and skin effects winding losses in a high performance and high frequency brushless permanent magnet machines for automotive and motorsport application. A new hybrid analytical-FEA method is proposed for speeding up the losses calculation and then validated against pure FEA method. The proposed method can be further used in accurate and fast estimation of the motor performance and in optimization procedures, avoiding heavy computational burden of full FEA simulations.

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SELF-EXCITED AND SUPERCONDUCTING SYNCHRONOUS MACHINES

Keywords: Synchronous machines, wound rotors, MMF harmonics, Permanent Magnet, raw materials, self-excitation.

Currently PM machines represent the most common type of PM synchronous motors/generators due to their robustness and high power-density. However, the rare earth market has experienced cost increase and shortage of supplies in the past years. New machine types avoiding the use of rare earths are being investigated. The research is focused on the possibilities of Self-Excited Synchronous Machine (SESM) and Superconducting Machines. The SESM is a brushless machine in which the field excitation in the rotor is achieved by exploiting the MMF harmonics generated by a Fractional Slot concentrated winding (FSCW). A special rotor structure is therefore designed: two windings and one rectifier are located on the rotor. The excitation current is obtained by coupling one of the rotor windings to one stator MMF component and thus without using any external supply or Permanent Magnet. Finite Element Analysis and tests demonstrated the feasibility of the SESM. Two disadvantages are highlighted: its lower power density in comparison to its competitors and additional weight on the rotor. The machine is suitable to be used as a generator and in electrical vehicles, as an alternative to permanent magnet machines, and in all applications in which common machines with brushes cannot be used.

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AUTOMOTIVE INVERTER TEST BENCH SYSTEM WITH ROAD DYNAMICS

Keywords: Automotive drive test; Hardware-In-the-Loop; Electric propulsion chain emulation; Vector control; Acceleration, Braking..

The research focuses on the development of a numerically-controlled experimental bench dedicated to testing of automotive inverters and electric drives. The bench is composed by (i) a power system composed by the electric drive to be tested and the load inverter. The two inverters are in front-to-front configuration with their AC sides connected through a three-phase inductor, and (ii) a control system incorporating a NI PXI interface in which is embedded a real-time simulation HIL system. The potentialities of the developed bench are highlighted through the emulation of different automotive cycles including acceleration and braking. The HIL system implements the dynamics of the road vehicles taking into account the dominant variables affecting the propulsion power.

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PCB MOTOR WITH PASSIVE MAGNETIC BEARING (PMB)

Keywords: Genetic Algorithm, magnetic force, magnetic stiffness, magnetic levitation, passive magnetic bearing, Two dimensional Finite Element Analysis.

An Axial Flux Machine is proposed with a PCB stator winding to reduce the airgap and improve reliability and cost. Passive Magnetic Bearings (PMBs) are proposed to levitate rotational structure in a magnetic field in order to eliminate the defects of ball bearing systems like friction, speed limitation, regular maintenance and lubrication. The most important characteristics of PMB are magnetic force and magnetic stiffness. A new structure of PMB is proposed to improve functionality of PMB. New structure is optimized using Genetic Algorithm (GA) and force density is defined as an index to apply a comprehensive comparison.

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