ELECTRIC VEHICLES AND POWER ELECTRONICS

RESEARCH TOPICS

- Wireless power transfer systems for recharging of electrical vehicles
- Power systems for electric vehicles

WIRELESS POWER TRANSFER SYSTEMS

Keywords: Inductive coupling; resonant compensation networks; high frequency inverters

Wireless power transfer (WPT) systems based on the inductive coupling have been studied. The analysis of the general working principles of the WPT led to the design and realization of a small-scale prototype that allowed testing experimentally the findings about the characteristics of different compensation topologies. Pairs of coils with both the receiver and the transmitter coils having the same size have been initially considered and then pairs of coils with the receiving coils longer than the transmitting one have been proposed. A technique devoted to the modeling of the WPT systems on the basis of the envelopes of the involved signals has been developed.

POWER SYSTEMS FOR ELECTRIC VEHICLES

Keywords:V2G technology, supercapacitors; fuel cells

The conventional battery chargers have been analyzed from the point of view of the V2G technology in order to assess their capabilities in performing ancillary services, such as the exchange of reactive power, in favor of the grid. An electric hybrid supply system has been developed where supercapacitors work in synergy with the battery to deliver or absorb the power peaks that are generated during accelerations and decelerations of the vehicle. A hydrogen-based supply system for light electric vehicles has been studied. It uses metal hydride technology to store hydrogen and a fuel cell to generate the electrical energy that powers the drive train.

References

[1] R.K. Jha, G. Buja, M. Bertoluzzo, S.Giacomuzzi, and K.N. Mude, "Performance Comparison of the One-Element Resonant EV Wireless Battery Chargers," EEE Transactions on Industry Applications, vol. 54, n° 3, pp. 2471-2482, 2018.

[2] G. Buja, M. Bertoluzzo, and H. K. Dashora, "Lumped Track Layout Design for Dynamic Wireless Charging of Electric Vehicles,"IEEE Transactions on Industrial Electronics, vol. 63, n° 100, pp. 6631-6640, 2016.

[3] G. Buja, M. Bertoluzzo, and H. K. Dashora, "Design of DWC System Track with Unequal DD Coil Set," IEEE Transactions on Transportation Electrification, vol. 3, n°2, pp. 380-391, 2017.

[4] G. Buja, M. Bertoluzzo, and , and C. Fontana, "Reactive Power Compensation Capabilities of V2G-Enabled Electric Vehicles," IEEE Transactions on Power Electronics, vol. 32, n° 12, pp. 9447-9459, 2017.

MACHINE DESIGN

RESEARCH TOPICS

- Axial flux PM (AFPM) machines for high speed applications
- Small single-phase PM motors
- Design of synchronous reluctance (SynR) machines
- Losses reduction in high-speed permanent magnet machines
- Induction Motor Analysis for Efficiency Improvement and Variable-Speed Performance Prediction

AXIAL FLUX PERMANENT MAGNET MACHINES FOR HIGH SPEED APPLICATIONS

Keywords: Flywheels; Magnetic gears; Magnetic losses; Road vehicle power systems

An AF magnetic gear is proposed for the contact-less recharging of a flywheel system, supplying heavy-duty electric buses. Its design is optimized by suitable simplified finite element analyses, which are also adopted to evaluate the core losses for a full recharge operation. A small-rated AF generator is studied, suitable to supply automotive auxiliary loads. An electromagnetic model is then set up to define the optimal supply circuit parameters, considering output power, efficiency and attractive force.

SMALL SINGLE-PHASE PM MOTORS

Keywords: Design optimization; Electromagnetic modeling; Permanent magnet motors

A novel configuration is presented, integrating an auxiliary PM on the stator side. By means of a nonlinear mathematical model, the improved dynamic performances are assessed with respect to a conventional motor for a pump application. The more evident enhancements have concerned the starting condition, the reduction of the torque and speed ripple as well as of the steady state losses.

DESIGN OF SYNCHRONOUS RELUCTANCE (SYNR) MACHINES

Keywords: Rotor geometry optimization; High speed motors; Automotive; Power limit curves

The SynR motor has been deeply studied using sophisticated analytical models coupled with the Finite Element Analysis, and very precise analytical models have been developed also for high-speed SynR motor design. Because of the complexity of SynR motors, the Pareto Multiobjective Optimization Design has been adopted. This strategy allows the best compromise between average torque and torque pulsation to be achieved. The Optimization Design is connected not only with the electromagnetic analysis but also with the mechanical verification. In this way the best design for Flux-Barrier high speed Reluctance Motor can be obtained. The Optimization Design challenge is to get the best combination of barrier angles, tangential and radial ribs for the best electromagnetic and mechanical performance at high speed.

LOSSES REDUCTION IN HIGH-SPEED PERMANENT MAGNET MACHINES

Keywords: High speed motors; Permanent Magnets; Rotor losses

In high speed systems the recent trend is to couple the electric machine directly to the mechanical shaft, in order to avoid the gear-box use. Additional rotor losses in the magnets due to harmonic currents are strongly affected by the stator winding configuration. Optimal winding arrangements have been studied and implemented in large high-speed SPM generator for Organic Rankin Cycles (ORC).

INDUCTION MOTOR ANALYSIS FOR EFFICIENCY IMPROVEMENT AND VARIABLE-SPEED PERFORMANCE PREDICTION

Keywords: Motor Efficiency; Variable speed drive; Performance prediction

The induction motor analysis, using finite element method, is closely connected to the machine analytical model in the rotor flux reference frame. In this way the motor on-load behaviour can be simulated according to the Rotor Field Oriented Control strategy. This method is particularly suitable for variable speed Induction Motor performance prediction. Further, zero-frequency on-load simulations are linked with Time-Harmonic finite-element analyses in order to properly analyze Squirrel Cage Motors behavior in high-speed flux weakening operations.

References

[5] M. Andriollo, F. Graziottin, and A. Tortella, “Design of an Axial-type Magnetic Gear for the Contact-less Recharging,” IEEE Trans. on Industry Applications, Vol.: 53, Issue: 4, July-Aug. 2017.

[6] C. Babetto, G. Bacco, and N. Bianchi, "*Synchronous reluctance machine optimization for high speed applications*", IEEE Transactions on Energy Conversion, pp. 1-1, 2018.

[7] C. Babetto, G. Bacco, and N. Bianchi, "Design methodology for high-speed synchronous reluctance machines", IET Electric Power Appl., May 2018, DOI: 10.1049/iet-epa.2017.0872.

[8] H. Mahmoud, G. Bacco, M. Degano, N. Bianchi and C. Gerada, "Synchronous Reluctance Motor Iron losses: Considering Machine Non-Linearity at MTPA, FW, and MTPV Operating Conditions", in IEEE Transactions on Energy Conversion, 2018.

[9] G. Bacco, N. Bianchi and H. Mahmoud, "A Nonlinear Analytical Model for the Rapid Prediction of the Torque of Synchronous Reluctance Machines," in IEEE Transactions on Energy Conversion, 2018.

[10] Y. Wang and N. Bianchi, "*Analysis of Self-Excited PM-Assisted Reluctance Generators*," in IEEE Transactions on Energy Conversion, vol. 33, no. 2, pp. 877-885, June 2018.

[11] Y. Wang and N. Bianchi, "*Investigation of Self-Excited Synchronous Reluctance Generators*," in IEEE Transactions on Industry Applications, vol. 54, no. 2, pp. 1360-1369, March-April 2018.

ELECTRIC DRIVES

RESEARCH TOPICS

- Artificial intelligence-based techniques applied to electric drives
- Low/zero speed and medium/high speed sensorless control
- Model-based and Model-free Predictive Control
- Diagnostics – fault diagnosis techniques for induction motors

ARTIFICIAL INTELLIGENCE-BASED TECHNIQUES

Keywords: Artificial neural networks (ANNs); magnetic flux linkages; permanent magnet (PM) motors; reluctance motors

The availability of accurate mathematical models that describe anisotropic motors is essential to the design of any model-based advanced control. The relationship between currents and flux linkages can be obtained through innovative radial basis function neural networks. These special drive-oriented neural networks take as inputs the motor voltages and currents, returning as output the motor flux linkages, inclusive of any nonlinearity and cross-coupling effect. The simple structure of the neural network fits for implementation on standard drives.

LOW/ZERO SPEED AND MEDIUM/HIGH SPEED SENSORLESS CONTROL

Keywords: HF voltage injection; Moving Horizon Estimators; Sensitivity analysis; Fundamental frequency observers

Research on the topic is aimed to achieve full speed range sensorless synchronous motor drives. Both injection and fundamental frequency techniques are studied and applied. Low/zero speed estimation of rotor position is obtained by pulsating or rotating voltage injection. Self-sensing capability of IPM and Reluctance Synchronous Motors have been deeply investigated and design criteria of the estimator have been found to cancel estimation errors and even failures. A Moving Horizon Estimator is proposed for the medium/high speed operation. The approach exhibits accuracy and robustness comparable to those of the Extended Kalman Filter with reduced computation burden and convergence pitfalls. To avoid the problems related to signal injection, fundamental-frequency observers are used, based on either the extended electromotive force or active flux concepts. Through an analytical sensitivity analysis, the influence of model uncertainty on the observed position was evaluated. The resulting functions and graphic plots are useful to draw interesting considerations about the motor selection and the control design of the sensorless drive.

MODEL-BASED AND MODEL-FREE PREDICTIVE CONTROL

Keywords: Predictive Control; AC Motor Drives; Self-learning algorithms

Model-based Predictive Control has been widely investigated and implemented in the Laboratory in the last decade. This kind of control is able to predict the future drive behaviour (relying on the drive model) and uses this capability to select, step-by-step, the best control action. An alternative effective solution is the Model-free Predictive Control has been recently developed by the Laboratory to overcome the drawbacks of the model inadequacies. Such an approach incorporates self-learning features: the current variations relative to a given voltage vector are stored in a LUT. The current prediction is then obtained by accessing the LUT in the position related to the considered voltage vector. Criteria for updating the LUT is the core action of the new control algorithm, proved by experimental tests.

FAULT DIAGNOSIS TECHNIQUES FOR INDUCTION MOTORS

Keywords: condition monitoring; multilayer perceptrons; neural networks; signal processing

A fault diagnosis and classification scheme has been developed for induction motors by using stator current signature analysis together with neural networks and dimensionality reduction techniques. The adopted strategy utilizes 3-phase stator current sensors and calculates appropriate features using non-parametric (harmonic retrieval using prominence measure) and a statistical approach. The proposed scheme is validated experimentally on stator inter-turn fault (SITF) and/or broken rotor bar fault (BRBF).

References

[12] F. Toso; D. Da Ru; P. Alotto; S. Bolognani, "*A Moving Horizon Estimator for the Speed and Rotor Position of a Sensorless PMSM Drive*", IEEE Transactions on Power Electronics, 2018.

[13] L. Ortombina, F. Tinazzi and M. Zigliotto, "Magnetic Modeling of Synchronous Reluctance and Internal Permanent Magnet Motors Using Radial Basis Function Networks," in *IEEE Trans. on Ind. Electr.*, vol. 65, no. 2, pp. 1140-1148, Feb. 2018.

[14] S. Bolognani, L. Ortombina, F. Tinazzi and M. Zigliotto, "Model sensitivity of fundamental-frequency-based position estimators for sensorless pm and reluctance synchronous motor drives," in *IEEE Transactions on Industrial Electronics*, vol. 65, no. 1, pp. 77-85, Jan. 2018.

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