BOLOGNA RESEARCH UNIT

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RESEARCH TOPICS

- Control of Shunt Active Filters
- Electric Drives Based on Motors with Open-End Stator Windings
- Sensorless Control of Multiphase Electric Drives
- Multiphase Wound-Rotor Induction Machine for Contactless Power Transfer
- Electric Motor/Generator for Flywheel batteries
- Detection of Rotor Magnet Demagnetization in Five-Phase and Six-Phase Surface Mounted Permanent Magnet Machines
- Comparison of Fault Tolerant Control Techniques for Quadruple Three-Phase Induction Machines Under Open-Circuit Fault
- Design and Control of Segmented Triple Three-Phase SPM Machines for Fault Tolerant Drives

CONTROL OF SHUNT ACTIVE FILTERS

Keywords: shunt active filters, resonant controllers, nonlinear control.

Shunt Active Power Filters (APFs) are used at the point of common coupling (PCC) to compensate the harmonic currents due to nonlinear loads. In recent years, the use of resonant controllers and generalized integrators has become an irreplaceable tool in APFs. The research activity focuses on the optimal exploitation of the DC-link voltage of the APF when the reduction of the high frequency harmonics is performed by a bank of resonant controllers. Some saturation algorithms for the resonant regulators used to cancel the harmonic currents have been investigated [1]. Basically, these algorithms define an independent limit for each voltage harmonics, so that the saturation of one of them does not affect the control of the remaining ones. The voltage limits are dynamically changed depending on the operating conditions, in such a way that the compensation of the most significant current harmonics is privileged.

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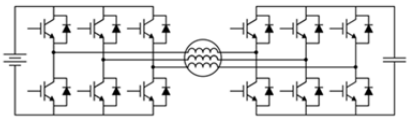
ELECTRIC DRIVES BASED ON MOTORS WITH OPEN-END STATOR WINDINGS

Keywords: open-end stator windings, high-speed drives.

The scientific community is considering new configurations of electric drives for high speed applications with a reduced content of expensive permanent magnets. The stator phases can be fed by inverters located at both sides of the stator windings, and the energy may come from a DC link and a floating bridge. The floating inverter offers a voltage boost, which can improve the motor operation and extend the speed range, and

reactive power compensation capability. The main contribution of the research is the development of a robust control system that extends the speed range of the motor by ensuring the operation at unity power factor at high speed.



Scheme based on dual inverters for open winding machines.

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SENSORLESS CONTROL OF MULTIPHASE ELECTRIC DRIVES

Keywords: sensorless speed control, speed estimation, multiphase drives.

The use of multiphase drives has been recognized as a viable approach to obtain high power ratings without increasing the stator current per phase, making it possible to use standard power switches based on a single device. The research activity faces the problem of the sensorless speed estimation of multiphase induction motors with an odd number of phases and proposes a new methodology, based on the use of third-order spatial harmonic of the magnetic field. A sensorless speed observer has been developed for induction motors. The performance of the control scheme has been experimentally verified.

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MULTIPHASE WOUND-ROTOR INDUCTION MACHINE FOR CONTACTLESS POWER TRANSFER

Keywords: multiphase induction motors, power transfer, rotating platform, automatic machines.

The use of rotary assembly platforms, such as the automated box-fill system rotary table, is widespread in automation applications. One of the problems that the designers have to face is how to transfer the power to the auxiliary actuators mounted on the rotating platform. In this research, this problem is solved by adopting a direct drive wound-rotor five-phase machine that can independently control the rotor torque and the power flow delivered to the rotor loads. The control system developed in this paper uses the fundamental component of the magnetic field to generate the torque acting on the rotating platform, and the third harmonic component of the field to transfer energy from the stator to the rotor.

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ELECTRIC MOTOR/GENERATOR FOR FLYWHEEL BATTERIES

Keywords: energy storage, ironless machines, permanent magnet machines.

Energy storage is an emerging technology that can enable the transition towards renewable-energy-based distributed generation, reducing peak power demand and the time difference between production and use. Mechanical storage can reduce impacts on environment and on raw materials exploitation. The electric motor/generator is the key item to fulfill the major challenges: high discharge duration and size/dimensions compatible with constraints of a household application. For a flywheel, self-discharge time is the most critical parameter, as it directly affects discharge duration. Self-discharge time is mainly affected by mechanical losses, core losses, and windage losses. Hence, machine design must reduce these losses. An ironless machine is a promising option, that, on the other hand, features higher reluctance of the magnetic paths, and hence, lower power density and efficiency. A prototype of ironless dual rotor PM machine for a flywheel energy storage system at household level, named MechSTOR, was designed, realized and tested.

MechSTOR prototype dual-rotor ironless radial flux permanent magnet machine.

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DETECTION OF ROTOR MAGNET DEMAGNETIZATION IN FIVE-PHASE AND SIX-PHASE SURFACE MOUNTED PERMANENT MAGNET MACHINES

Keywords: multiphase machines, permanent magnet machines, rotor magnet demagnetization, fault diagnosis, current signature analysis, voltage signature analysis, spectral analysis.

Multiphase permanent magnet machines are becoming attractive alternative for a wide range of industry applications owing to their reliability, dynamic performances, and their greater degrees of fault tolerability compared to three–phase machines. In this context, diagnosing rotor magnets degradation at incipient stage is crucial to guaranty the required efficiency of the machines. Several diagnostic techniques exploiting the greater number of degrees of freedom of a multiphase systems, have been proposed for five-phase and six-phase surface mounted permanent magnet machines. In particular, techniques based on voltage signature analysis, current signature analysis [1], third-space power signature analysis [2] and back-emf spectral analysis [3] have been studied. The results of numerical simulations, finite element analyses and experimental tests on a prototype of a six-phase surface mounted permanent magnet machine confirm the effectiveness of the proposed diagnostic techniques.

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COMPARISON OF FAULT TOLERANT CONTROL TECHNIQUES FOR QUADRUPLE THREE-PHASE INDUCTION MACHINES UNDER OPEN-CIRCUIT FAULT

Keywords: fault tolerant systems, multiphase induction machines, more electric aircraft.

Two Fault Tolerant Control (FTC) techniques for open-phase faults in a quadruple three-phase machine have been developed and compared [1]. The first one (three-phase subsystem FTC) disables the faulty inverter. In contrast, the second one (single-phase FTC) tries to exploit the remaining healthy phases of the inverter. If only the stator Joule losses are taken into account, the single-phase FTC is the best one. Conversely, if the controller cannot afford the introduction of additional regulators in terms of memory usage and calculation time, the three-phase subsystem FTC has lower requirements. Some experimental tests have been carried out on a quadruple three phase induction machine, fed by four independent inverters, developed for More Electric Aircraft (MEA) applications.

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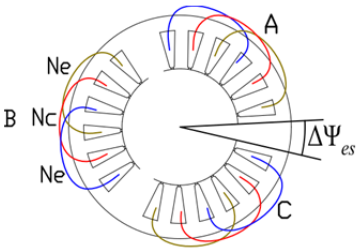
DESIGN AND CONTROL OF SEGMENTED TRIPLE THREE-PHASE SPM MACHINES FOR FAULT TOLERANT DRIVES

Keywords: brushless machines, fault tolerant systems, force control, bearingless control.

A new Triple Three-Phase Surface Permanent Magnet (TTPSPM) machine design is investigated [1]. The machine has a nine-phase winding arranged in three sectors and supplied by three different Voltage Source Inverters (VSI). A new control technique is proposed to overcome the drawbacks introduced by the stator segmentation. Then, an optimized design is proposed, and a prototype of the final design has been manufactured. The radial force control technique for the TTPSPM machine is investigated in [2]. The radial force control can be useful to compensate for a bearing fault or for a rotor eccentricity. Finite element simulations are used to validate the model and the control technique. In [3], a new advanced fault tolerant control technique, able to avoid the radial force appearance in case of open winding of one machine sector, is investigated. Finally, two different approaches to characterize the torque and radial force production in a bearingless TTPSPM machine are presented in [4]. The first method consists of modelling the motor in terms of torque and force production as a function of the stationary reference frame currents. The second method is based on the control of the magnetic field harmonics in the airgap through the current Space Vector (SV) technique. The methods are validated and compared by experimental tests on a prototype.



Segmented triple three-phase machine stator, with sectored winding configuration.

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