Diagnostic systems for electrical machines and drives

Course code: 064187
Degree course: Ingegneria Elettrica
Disciplinary field of science: ING-IND/32
University credits: CFU 3
Lecturer: Lucia Frosini
Course website: http://www.unipv.it/dmae/

Course entry requirements

The students of this course are required to possess or acquire adequate initial training on the functional and construction aspects of the induction and synchronous rotating electrical machines.

Specific course objectives

The course aims to provide students with the knowledge of the main types of fault that can occur in synchronous and induction rotating electrical machines (powered by the mains or by a power converter, at low and at high voltage), the diagnostic methods for their early detection and the techniques to reduce their probability and the magnitude of their damage. At the end of the course, students should be able to identify the appropriate diagnostic tools for identifying actual or incipient faults in the different rotating electrical machines and the techniques for the mitigation of the effects produced by these faults.

Course programme

1. Introduction.

Aim of a diagnostic system: detection, isolation and identification of the fault. Relationship among the diagnostics and the concepts of protection, maintenance, condition monitoring. Reactive, preventive, predictive and proactive maintenance. Reliability, availability, probability density of fault, failure rate, criteria for the classification of the faults.

2. Types of fault in electrical machines and drives and methods for their detection.

Types of fault: in the stator (windings and core), in the bearings, in the rotor, static and dynamic irregularities of the air-gap, others. Electrical methods: measurement of voltage, current, power, magnetic flux (at the air-gap and leakage), shaft voltage, bearing current, partial discharge. Mechanical methods: measurement of vibration, acoustic noise, force, torque, speed. Other methods: chemical measurements, temperature, etc. Signal analysis in the time and frequency domain.

3. Vibrations in electrical machines and drives.

Vibration measurement as diagnostic tool. Longitudinal, flexional (Jeffcott rotor) and torsional vibrations. Natural and forced vibrations. Electromagnetic forces: Maxwell tensor, Lorentz forces. Static and dynamic eccentricity. Vibrations in the end-windings. Practical examples.

4. Bearing faults.

Rolling and friction bearings. Possible damages in the bearing faults and their causes. Methods to detect bearing faults: vibration and stator current analysis. Practical examples.

5. Faults in the stator windings.

Thermal, electrical, environmental and mechanical stresses which can determine the failure of the windings insulation.

Low voltage stator windings: construction characteristics and possible faults. Diagnostic methods to detect faults in windings powered by the mains or by inverter: stator current and leakage flux analysis. Additional stresses in electrical drives due to the reflected wave phenomenon.
High voltage stator windings: construction characteristics, ground insulation failure. Off-line diagnostic methods: insulation resistance, polarization index, tan-delta or insulation power factor, AC and DC hi-pot test. Partial discharge (PD) measurement: positive or negative polarity of the PD, comparison of the effectiveness of the PD method with respect to the other diagnostic methods, PD detection by measurement of the electric pulses, interpretation of the experimental measurements, PD as direct cause or as symptom, effect of the load and the temperature on the PD.

6. Shaft voltages and currents
Shaft voltages and currents in turbo-generators: causes, diagnostic methods for their monitoring and techniques to prevent faults. Shaft voltages and currents in low voltage electrical drives, induced by the inverter supply: causes and techniques for their mitigation.

7. Rotor faults.
Rotor short circuits in the generators and methods for their detection: measurement of the air-gap flux, recurrent surge oscillation, dynamic impedance. Broken rotor bars in induction motors and their detection by stator current, vibration and leakage flux analysis. Inter-bar current phenomenon.

Course structure and teaching
The course is organized by means of frontal lessons, featured through PowerPoint presentations, which allow to show many images of electrical machines (healthy and faulty) and diagnostic systems, useful for reaching the course objectives. The lessons include some analyses of specific applications of diagnostic methods, with experimental results presented with graphs. The training activities are completed by a seminar held by technical personnel, with a remarkable industrial competence.
Lectures (hours/year in lecture theatre): 24.

Suggested reading materials
The presentations in PowerPoint, prepared and used by the teacher during the course, are available for the students in PDF format via KIRO website. This documentation is sufficiently detailed to form the reference text of the course.
For further details, the following texts can be consulted:
- Peter Tavner, Li Ran, Jim Penman and Howard Sedding: *Condition Monitoring of Rotating Electrical Machines*, 2nd Edition, IET, 2008.
- Stone G., Boulter E.A., Culbert I., Dhirani H.: *Electrical Insulation for Rotating Machines: Design, Evaluation, Aging, Testing, and Repair*, Wiley-IEEE Press, 2004.
- Geoff Klempner, Isidor Kerszenbaum: *Handbook of Large Turbo-Generators. Operation and Maintenance*, Wiley-IEEE Press, 2008.

Testing and exams
The exam consists of an individual oral test to assess the skills acquired in relation to the content of the course. The test focuses on at least three distinct topics handled during the course. The final evaluation is based on the degree of understanding of the topics presented and the ability to integrate the knowledge gained during the course.