1EL2000 – Electrical Energy

Instructors: Martin Hennebel
Department: DÉPARTEMENT SYSTÈMES D'ÉNERGIE ÉLECTRIQUE
Language of instruction: ANGLAIS, FRANCAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35,00

Description

Electrical energy is indispensable to the functioning and development of society all across the globe. Over 100 years of continuous progress has allowed its integration into new sectors (ground, maritime, and aerial transport, onboard systems, renewable energy, spatial). Presently, environmental and sustainable development objectives have motivated further progress in the technology at different power levels. This course on electrical energy aims to provide students with the fundamentals and methods used for the analysis of systems using electricity as an energy vector. The course associates knowledge of physics and magnetic materials for the characterization of the elements which constitute electrical energy systems. To start with, the course touches on major actors and global issues associated with the use of electrical energy for the functioning of society, with an emphasis on the pertinence of different scientific disciplines. Next, the course presents the principal concepts and tools needed for the analysis of electrical systems along with examples for their application. The course focuses on the importance of understanding magnetic coupling in electrical systems using the laws of electromagnetism. The behavior of the associated magnetic materials and their analysis is then applied to establish models for the systems in order to better understand their performance at different levels of excitation or frequency. The representation of typical magnetic circuits is then used to give students better understanding of how the physics associated with elements of the systems may be used to develop a system model. The natural application of the principals learned by students in the first parts of the course is the study of transformers and inductively coupled systems. Afterward, the conversion of electrical into mechanical energy will be formalized using the principal of virtual work based on magnetic energy associated to magnetic coenergy for the formulation of forces and torques produced by motors and generators. An application of electrical to mechanical energy conversion, the direct current machine, will then be presented in order to provide students with the basis for understanding the principals of motorization or electrical generation at variable speed.

Quarter number
SG1 and SG3

Prerequisites (in terms of CS courses)
None

Syllabus
Introduction to electrical power engineering
Omnipresence of electrical engineering : production, transport, conversion, utilization and control of electrical energy. Multi-physical and economic aspects.

Transport and consumption of electrical energy
Single phase and three phase systems, definition and calculation of electrical power. Equipment sizing and power factor.

Physics associated with electrical power engineering
Electromagnetism applied to electrical power engineering. Magnetic materials, creation and channeling of magnetic fields, permanent magnets. Modeling methods, magnetic circuits, reluctance and electromotive force. Taking into account power losses associated with magnetic circuits.

Principals of magnetic coupling
Notions of magnetic flux and leakage flux. Partial and total leakage inductance. Modeling of magnetic coupling.

Single and three phase transformers
Function and structure ; ideal transformer ; modelling of a real transformer, transformer operation at 50 Hz and influence of variable frequency; construction of magnetic circuit, insulation and conductors.

Electro-mechanical conversion
Link between electrical, magnetic, and mechanical energy. Systems with moving parts ; calculation of forces and torques; resistive torque.

Direct Current machine
Principal and structure/construction. Fundamental equations. Excitation modes. Problems associated with operation. Principles of control with variable speed. DC brushless motor.

Class components (lecture, labs, etc.)
Lectures (CM), tutorials (TD) and pratical works (TP). Tutorials ant pratical works are hold simutaneaously due to the limited capacity of the laboratory.

CM (9h) // TD1 & TP1 (6h) // CM (3h) // TD2 & TP2 (6h) // CM (3h) // TD3 & TP3 (6h)

Grading

The evaluation will be done by a written examination of 2h. The pratical works will be taken into account in the final grade of the module for 20%. Absence at a pratical work session will give the mark 0/20 to the TP.

Course support, bibliography

Text provided by the teaching group.
Electrical Machines, Drives and Power Systems (Theodore Wildi, Prentice-Hall Intl)

Resources

• Teaching staff : Martin Hennebel - Michael Kirkpatrick - Romaric Landfried – Mohamed Bensetti
• Maximum enrollment : 25
• Software, number of licenses required:
• Equipment-specific classrooms (specify the department and room capacity): Electrical Energy System departmentq teaching laboratory for practical work.
Occurrence 1.1 is taught in English, occurrences 1.2, 1.3 and 1.4 are taught in French.

Learning outcomes covered on the course

At the end of this course, the student will be able to:

- Modelling electrical devices and equipment based on magnetic coupling

    - Make the choice of an adapted model of behaviour (integral form of Maxwell's equations, equivalent diagram of type circuit ...)
    - Identify the parameters of this model using experimental data and / or geometric and physical properties
    - Validate the quality of the model

- Predefining an AC power transmission system (three-phase) with its main elements

- Analyse and evaluate a motorisation based on AC or DC actuators

    - Analyse the electrical, magnetic and mechanical behaviour of the actuator
    - Compare to nominal behaviour
    - Evaluate the performances and criticise the results obtained

Description of the skills acquired at the end of the course

This course validates milestone 1 of skills C1 and C2 :

The course, and in particular the practical work sessions allow to develop the C1 competence, i.e. the analysis, the modeling and resolution, as well as the design of complex systems. These skills apply to the three-phase power systems, magnetic systems (transformers, magnets) and electromechanical actuation systems (actuators, motors).

This course develops an in-depth competence in the field of electrical power systems engineering, which corresponds to milestone 1 of competence C2.