2EL6140 – Electric machinery, power electronics and grids.

Instructors: Herve Gueguen
Department: CAMPUS DE RENNES
Language of instruction: ANGLAIS
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35,00
Elective Category : Engineering Sciences
Advanced level : Yes

Description

The supply of electricity to isolated sites such as islands has some specific characteristics due to the small size of their power grid. This leads to a high risk of instability and therefore the control of a microgrid, including all its electrical components, is crucial for its proper operation.

This elective proposes to study this issue from two perspectives:

- **Electrical engineering**: presentation of the key electrical components of an alternating microgrid
- **Automatic control**: implementation of control techniques on these components and introduction to the control of large-scale systems (i.e. how to go beyond the “classical” control theory which only deals with 2–3 variables).

Note: the electrical engineering program of this elective is close to the “Energy Conversion” elective offered in Paris-Saclay. The automatic control part is unique to this elective.

Quarter number
SG8

Prerequisites (in terms of CS courses)

Power systems concepts you need to know (e.g. by having taken the first-year elective “Electrical Energy (ENE)”):

- Power in AC regime: P (active), Q (reactive) and S (apparent)
- **Three-phase** electric power system: phase-to-neutral and phase-to-phase voltages

Control theory concepts you need to know (e.g. by having followed the ST5 common course on automatic control):

- Modeling a system by a transfer function
- Regulation of a linear system by a PID controller

Having taken the ST7 “Smart grids and energy challenge: energy management in isolated sites” would be a plus, but is not a prerequisite, as the topics addressed are very different:

- ST7 “Renewable energies and microgrids” course: high level modeling (energy flows), with economic optimization.
- this elective: voltage/current modeling and more detailed analysis of electrical components and their low-level regulation.

Syllabus

This elective belongs to both *electrical engineering* and *automatic control*, with extra *transversal and practical* skills on the analysis and control of systems thanks to the intensive use of a modeling and simulation software.

For the electrical part, the aim is to understand the operation and modeling of the *energy conversion components* of a microgrid:

- power electronics converters (choppers and inverters)
- AC electric machines (synchronous and asynchronous)

This knowledge is presented through lectures and exercise sessions.

For the automatic control part, the aim is to understand the *control and regulation* strategies of microgrid components, in particular the power electronics converters. In addition, this part includes an introduction to the control of large-scale systems (the microgrid with its many components).

This automatic control part is mainly conducted as hands-on sessions on computers. These sessions are an opportunity to *intensively practice* a modeling and simulation tool (Simulink/Simscape). One of the issues addressed is the choice of a level of details in the model adapted to the objective (compromise between simplicity, speed, fidelity…). This transversal skill is meant to be transposable to other engineering fields.

Note: the optimization of power flows (power dispatch) to ensure the economically optimal operation of a microgrid is not addressed. Indeed, this issue is part of the ST7 optimization project. “Smart grids and the energy challenge: energy management in isolated sites”.

Class components (lecture, labs, etc.)

Lecture sesssions aim at acquiring basic knowledge in the field of power systems. These sessions include exercises on paper.

The practical sessions are done on computers (Matlab/Simulink). Computer work can be done in pairs. The time devoted to these sessions is substantial to allow the students to become fully comfortable with the simulation tool.

Lectures: 9 hours, Tutorials: 9 hours, Laboratories: 15 hours, Evaluation (written exam): 2 hours.

Grading

The evaluation of the lecture sessions is one final written exam.

The evaluation of the computer lab sessions is done by checking the progress along the sessions and by a final synthesis report.

The weighting between the lecture part and the practical part is 50%, 50%.

Course support, bibliography

Course site on Edunao:
https://centralesupelec.edunao.com/course/view.php?id=1494

Resources

Course staff:

- Pierre Haessig: course supervisor
- Alexandros Charalampidis: computer lab sessions
- Loïc Matel: electric machines & power electronics lectures

Required software: Matlab, with Simulink and the Simscape Electrical toolbox. Academic licenses for those products are free for all CentraleSupélec students.

Learning outcomes covered on the course

At the end of the lectures, students will be able to:

- *Describe the operation* and *perform simple theoretical analyses* of the electrical machines and power electronic converters covered in the course

At the end of the practical part, students will be able to:

- *Implement* models of electronic converters in a simulator (Simulink) with a complexity adapted to the phenomena to be studied.
- *Describe* the control structure of an electronic converter and *adjust* some control loops of this structure.
- *Evaluate/analyze* the proper operation of the regulation through well-selected simulations

Description of the skills acquired at the end of the course

The learning outcomes of this course allow validating the following CentraleSupélec engineer core skills:

- C1.2 Use and develop appropriate models, select the appropriate modeling scale and relevant simplifying assumptions to tackle a problem
- C1.3 Apply problem-solving through approximation, simulation and experimentation
- C1.4 Specify, design, build and validate all or part of a complex system