

## GENERAL INFORMATION

Course information	
<b>Name</b>	Decision support models in the electric power industry
<b>Code</b>	MOD
<b>Degree</b>	Master in the Electric Power Industry (MEPI)
<b>Year</b>	1 <sup>st</sup>
<b>Semester</b>	1 <sup>st</sup> (Fall)
<b>ECTS credits</b>	6 ECTS
<b>Type</b>	Compulsory
<b>Department</b>	Electrical Engineering
<b>Area</b>	Power Systems
<b>Coordinator</b>	Javier García González, Andrés Ramos Galán

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## DETAILED INFORMATION

<b>Contextualization of the course</b>
<b>Contribution to the professional profile of the degree</b>
The overall objective of this course is that students understand the importance of decision support models in the electric power industry, and to know their theoretical foundations and scope, both from the perspective of utilities, operators and regulators.
<b>Prerequisites</b>
Students willing to take this course should be familiar with optimization techniques.

## CONTENTS

<b>Contents</b>
<b>Theory (Laboratory sessions marked in red)</b>
<b>Chapter 1. Introduction</b>
1.1. Electricity characteristics 1.2. Hierarchy of planning models. Planning functions in a centralized and in a deregulated framework
<b>Chapter 2. Short-term generation planning</b>
2.1. Unit commitment and economic dispatch 2.2. Chronological demand and time representation 2.3. Conventional generation: thermal, storage hydro and pumped storage hydro 2.4. Mathematical formulation 2.5. Use of a prototype model, input data and analysis of the results 2.6. Practical session
<b>Chapter 3. Medium-term generation planning</b>
3.1. Monotonic demand and time representation 3.2. Dual variables: system marginal cost and water value 3.3. Use of a prototype model, input data and analysis of the results 3.4. Practical session
<b>Chapter 4. Network constrained economic dispatch</b>
4.1. Active and reactive load flow equations 4.2. Direct current load flow 4.3. Network losses 4.4. Mathematical formulation 4.5. Use of a prototype model, input data and analysis of the results 4.6. Practical session
<b>Chapter 5. Impact of renewable energy sources in the short-term generation planning</b>
5.1. Uncertainty modeling. Operation reserves 5.2. Stochastic unit commitment 5.3. Use of a prototype model, input data and analysis of the results 5.4. Practical session
<b>Chapter 6. Medium-term stochastic hydrothermal scheduling</b>
6.1. Hydro scheduling 6.2. Hydroelectric system modeling. Cascaded hydro reservoirs 6.3. Uncertainty modeling of stochastic hydro inflows. Scenario tree generation 6.4. Stochastic optimization formulation

- 6.5. Use of a prototype model, input data and analysis of the results
- 6.6. Practical session

**Chapter 7. Generation reliability**

- 7.1. Deterministic and stochastic reliability measures
- 7.2. State table. Monte Carlo simulation
- 7.3. Probabilistic production cost model
- 7.4. Use of a prototype model, input data and analysis of the results
- 7.5. Practical session

**Chapter 8. Introduction to electricity markets**

- 8.1. Fundamental and quantitative approaches. Classification of electricity market models
- 8.2. Nash equilibrium. Market-clearing procedures

**Chapter 9. Short-term operation. The perspective of a utility and a decentralized agent (micro-grid)**

- 9.1. Residual demand
- 9.2. Self-unit commitment model
- 9.3. Bidding on the day-ahead market
- 9.4. Uncertainty modeling of competitors
- 9.5. Optimal scheduling of a micro-grid (practical session)

**Chapter 10. Medium-term market equilibrium model**

- 10.1. NLP optimality conditions
- 10.2. Cournot conjecture. Conjectural variation. Hydrothermal Cournot model
- 10.3. Use of a prototype model, input data and analysis of the results

**Chapter 11. Long-term generation expansion planning**

- 11.1. Modeling techniques
- 11.2. Centralized models
- 11.3. Competitive equilibrium models
- 11.4. System dynamics models

**Chapter 12. Long-term transmission expansion planning**

- 12.1. Centralized models
- 12.2. Equilibrium models
- 12.3. Use of a prototype model, input data and analysis of the results
- 12.4. Practical session

**Chapter 13. Long-term distribution expansion planning**

- 13.1. Planning and operation of electricity smart distribution grids
- 13.2. Reference model

**Chapter 14. Time series analysis and forecasting**

- 14.1. Time series analysis
- 14.2. Demand forecasting. Electricity price forecasting
- 14.3. Renewable generation forecasting
- 14.4. Practical session

**Chapter 15. Risk management in electricity markets**

- 15.1. Basics of risk management
- 15.2. Market risk management
- 15.3. Models for measuring and managing market risk
- 15.4. Example

## Competences and Learning Outcomes

### Competences

#### General Competences / Basic Competences

CB1. To have acquired and demonstrated advanced knowledge in a context of scientific and technological research (or in a highly specialized area), detailed and informed understanding of the theoretical and practical aspects in one or more fields of study, and the related work methodology

#### Specific Competences

CE3. Understanding the importance of decision support models in the area of power systems, and why it is necessary to develop planning and operation decisions according to a temporal and functional hierarchy.

CE4. Explain the functions of the various models used in the planning and operation of power systems in a market environment, and know what optimization/simulation techniques are more suited for each case.

### Learning outcomes

By the end of the course students should be able to:

- LO1. Understand the importance of models to aid decision making in the planning of power systems.
- LO2. Understand why it is necessary to coordinate planning and operating decisions according to a temporal hierarchy (short, medium and long term)
- LO3. Explain the functions of the different models in both a centrally planned and in liberalized electricity markets.
- LO4. Understand how to apply optimization and simulation techniques, and to identify which is the most appropriate solution for each case.
- LO5. Understand the mathematical formulation of the models presented in the course, so that students can apply this knowledge to possible future needs in their professional career.
- LO6. Being able to specify, design and code modifications to the models presented in the course.
- LO7. Interpret the results obtained by the prototypes used in the practical sessions.
- LO8. Develop critical analysis to adequately assess decision support tools as users.

## TEACHING METHODOLOGY

<b>General methodological aspects</b>	
<p>The best way of gaining a full understanding of decision support models is to complement the theoretical concepts presented in the classroom with practical sessions, and to schedule a set of out-of-class activities in order to reinforce the learning process of the students.</p>	
<b>In-class activities</b>	<b>Competences</b>
<ul style="list-style-type: none"> <li>▪ <b>Lectures (40 hours):</b> Presentation of the theoretical concepts by the instructors with proven experience in developing decision support tools for the power sector. These lectures will include dynamic presentations, case studies, and the participation and interaction with students.</li> </ul>	CB1, CE3, CE4.
<ul style="list-style-type: none"> <li>▪ <b>Practical sessions (20 hours):</b> Under the instructor's supervision, students, will apply the concepts and techniques covered in the lectures to real problems and will become familiar with the software tools developed for this course. These sessions will take place in the computer room after Topic 2 (Short-term generation planning), Topic 3 (Medium-term generation planning), Topic 4 (Network constrained economic dispatch), Topic 5 (Medium-term stochastic hydrothermal scheduling), and Topic 15 (Time series analysis and forecasting).</li> </ul>	CB1, CE3, CE4
<ul style="list-style-type: none"> <li>▪ <b>Tutoring (up to 5 hours)</b> for groups or individual students will be organized upon request.</li> </ul>	CB1, CE3, CE4
<b>Out-of-class activities</b>	<b>Competences</b>
<ul style="list-style-type: none"> <li>▪ <b>Personal study of the material (55 hours):</b> This is an individual activity by the students, in which they will read, analyze and question the readings provided as background material, and that will be discussed with other students and lecturers in the classroom.</li> </ul>	CB1, CE3, CE4
<ul style="list-style-type: none"> <li>▪ <b>Individual term papers or team assignments (60 hours):</b> Learning activities that will be carried out individually or by pairs, outside of the classroom.</li> </ul>	CB1, CE3, CE4.

## ASSESSMENT AND GRADING CRITERIA

Assessment activities	Grading criteria	Weight
Exams	<ul style="list-style-type: none"> <li>Understanding of the theoretical concepts.</li> <li>Application of these concepts to problem-solving.</li> </ul>	70%
Reports	<ul style="list-style-type: none"> <li>Application of theoretical concepts to real problem-solving.</li> <li>Ability to use the provided decision support models.</li> <li>Interpretation and critical analysis of numerical results.</li> <li>Written communication skills.</li> </ul>	30%

## GRADING AND COURSE RULES

The student has two periods of final evaluation during one academic year. The first one (regular assessment) will be carried out at the end of course (end of the semester). In case that this was not passed obtaining 5 or more points, the student has another opportunity of final evaluation (Retake) at the end of the academic year. The dates of evaluation periods will be announced in the web page.

Grading
Regular assessment
<ul style="list-style-type: none"> <li><b>Theory</b> will account for 70%, of which:               <ul style="list-style-type: none"> <li>Mid-term exam: 35%</li> <li>Final exam: 35%</li> </ul> </li> </ul> <p>Each theory exam is a combination of two parts: Part 1 (short questions to elaborate) and Part 2 (multi-option test). The grades of each one of these parts (average considering the mid-term and final exam) must be greater or equal to 3 out of 10 points in order to be weighted in the compilation of the theory grade. If not the minimum of both parts will be the final grade.</p> <ul style="list-style-type: none"> <li><b>Assignment reports</b> will account for the remaining 30%. There are 4 assignments plus one optional that the students must do by pairs or individually following the instructions of the professor. The topics covered are Short-term generation planning, Medium-term generation planning, Generation Reliability, Generation Expansion, Risk management in electricity markets, and Time Series.</li> </ul> <p>In order to pass the course, the grade of the Theory part must be greater or equal to 5 out of 10 points and the marks of both the mid-term and the final exams must be at least 3 out of 10 points. Otherwise, the final grade will be the lower of the two marks.</p>
Retake
<ul style="list-style-type: none"> <li><b>Theory, 70%:</b> <ul style="list-style-type: none"> <li>A single retake final exam (combination of short questions and a multi-option test), with the same minimum grade requirements as in the regular assessment.</li> </ul> </li> <li><b>Practical assessment</b> will account for 30%, of which:               <ul style="list-style-type: none"> <li><b>Assignment reports</b> marks will be preserved, 15%.</li> <li><b>Term paper, 15%.</b> Each student will develop individually a decision support model of a particular topic and will apply it to a small case study. The model development and the analysis carried out with it will be reported in a short term paper.</li> </ul> </li> </ul>

In order to pass the course, the weighted average grade in the retake has to be greater or equal than 5. However, next requirements about the partial grades apply: the mark of the final exam must be greater or equal to 4 out of 10 points and the mark of the term paper must be at least 5 out of 10 points. Otherwise, the final grade will be the lower of the two marks.

### Course rules

- Class attendance is mandatory according to Article 93 of the General Regulations (Reglamento General) of Comillas Pontifical University and Article 6 of the Academic Rules (Normas Académicas) of the ICAI School of Engineering. Not complying with this requirement may have the following consequences:
  - Students who fail to attend more than 15% of the lectures may be denied the right to take the final exam during the regular assessment period.
  - Regarding laboratory, absence to more than 15% of the sessions can result in losing the right to take the final exam of the regular assessment period and the retake. Missed sessions must be made up for credit.

Students who commit an irregularity in any graded activity will receive a mark of zero in the activity and disciplinary procedure will follow (cf. Article 168 of the General Regulations (Reglamento General) of Comillas Pontifical University).

## WORK PLAN AND SCHEDULE<sup>1</sup>

In and out-of-class activities	Date/Periodicity	Deadline
Mid-term exam	Week 7-9	
Final exam	Week 15	
Lab sessions	Weeks 2,3,4,5,6,7, 11,12, and 13	
Review and self-study of the concepts covered in the lectures	After each lesson	–
Lab preparation	Before every session	–
Assignment report writing		Between one and three weeks after the publication of the assignments (5)
Term paper		Only for retakes
Final exam preparation	January	–

STUDENT WORK-TIME SUMMARY		
IN-CLASS HOURS		
Lectures	Lab sessions	
40	20	
OUT-OF-CLASS HOURS		
Self-study	Assignment reports and readings	Tuition
55	60	5
ECTS credits:		6 (180 hours)

<sup>1</sup> A detailed work plan of the subject can be found in the course summary sheet (see following page). Nevertheless, this schedule is tentative and may vary to accommodate the rhythm of the class.

## BIBLIOGLOPHY

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### Complementary bibliography

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Week	IN-CLASS ACTIVITIES			OUT-OFF-CLASS ACTIVITIES			Learning outcomes	
	h/w	Lectures & in-class participation	Assessment	h/w	Self-study	LAB preparation and reporting		Other activities
1	4	Intro. to Decision support models (2h) Unit commitment (2h)		7	Review the slides and class notes (4h)		Reading (press) (1h) Discussions (2 h)	LO1, LO2, LO6
2	4	Unit commitment and hourly scheduling (lab) (2h) Midterm generation planning (KKT) (2h)		7	Review the slides and class notes (4h)	Review LAB slides (0.5 h)	Install GAMS, prototype UC and run basic cases (1.5h), discussions with partner (1)	LO3, LO4, LO6, LO7
3	4	Midterm generation planning (lab) (2h) Transmission constrained economic dispatch (2h)		8	Review and self-study (3 h)	Review LAB slides and prepare Assignment 1 (3.5 h)	Install prototype Midterm and run basic cases (1.5 h)	LO3, LO4, LO5, LO7
4	4	Transmission constrained economic dispatch (lab) (2h) Impact of intermittent generation: Stochastic Unit Commitment (2h)		8	Review and self-study (3 h)	Review LAB slides and prepare Assignment 2 (3.5 h)	Install prototype DC-OPF and run basic cases (1.5 h)	LO6, LO7
5	4	Stochastic Unit Commitment (lab) (2h) Midterm stochastic hydrothermal coordination (2h)		8	Review and self-study (3 h)		Team work assignments 1 & 2 (5 h)	LO3, LO4, LO5, LO7
6	4	Midterm stochastic hydrothermal coordination (lab) (2h) Generation reliability (2h)	Deadline Assignment 1	8	Review and self-study with the focus on the mid-term exam (4 h)	Finish Assignment 1 (3.5 h)	Install prototype Stoch. Hydro-Thermal Coord. and run basic cases (0.5 h)	LO6, LO7
7	4	Generation reliability (lab) (2h) Exam Part 1 (2h)	Mid-term exam	8	Review and self-study with the focus on the mid-term exam (3 h)	Finish Assignment 2 (2 h)	Team work assign. 3 (2h) + tuition (1 h)	LO7, LO8
8	4	Models for liberalized power systems Short term models in a market environment Self UC: price maker-price taker (2h)	Deadline Assignment 2	8	Review and self-study (3h)	Finish Assignment 2 (2 h)	Team work assignments 3 (2 h) + tuition (1 h)	LO3, LO4
9	4	MCP and Midterm models: market equilibrium (2h) Midterm models: market equilibrium (2h)		7	Review and self-study (3h)	Assignment 3 (4 h)		LO3, LO4, LO5
10	4	Generation expansion (2h) Generation expansion (lab) (2h)	Deadline Assignments 3	8	Review and self-study (3h)	Finish Assignment 3 (4 h)	Tuition (1 h)	LO3, LO4, LO5
11	4	Transmission expansion model (2h) Transmission expansion model (Lab) (2h)		8	Review and self-study (4 h)		Install prototype Trans. Expansion and run basic cases (4 h)	LO3, LO4, LO5, LO7
12	4	Reference Model for Distribution networks (2h) Time series models for forecasting (lab) (2h)		8	Review and self-study (3 h)	LAB Preparation (1 h)	Develop assignment 4 (4 h)	LO3, LO4, LO7
13	4	Time series models for forecasting (lab) (2h) Correction and discussion homeworks (2h)		9	Review the slides and class notes (4 h)	Lab preparation (0.5 h) Report Assignment 4 (3.5h)	Review of corrections to identify errors (1 h)	LO7, LO8
14	4	Models for risk management (2h) Models for risk management (lab) (2h)	Deadline Assignments 4	9	Review and self-study (4h)	Report Assignment 5 (4h)	Review of corrections to identify errors (1 h)	LO3, LO4
15	4	Correction and discussion homeworks (2h) Final conclusions + Exam (2h)	Deadline Assignments 5 Final Exam	9	Review and self-study (7h)		Tuition (2h)	LO6, LO8