COMILLAS UNIVERSIDAD PONTIFICIA
ICAI ICADE CIHS

Syllabus
2023 - 2024

GENERAL INFORMATION

Data of the subject	
Subject name	Electric power systems
Subject code	MEPI-512
Mainprogram	Máster Universitario en Sector Eléctrico / the Electric Power Industry por la Universidad Pontificia Comillas
Involved programs	Master in the Electric Power Industry [First year]
Level	Postgrado Oficial Master
Quarter	Semestral
Credits	6,0 ECTS
Type	Obligatoria
Department	Department of Electrical Engineering
Coordinator	Luis Rouco Rodríguez
Schedule	Lunes y miércoles de 19 a 21 horas
Office hours	Por cita

Teacher Information	
Teacher	
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Teacher	
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Teacher	
Name	Luis Díez Maroto
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Teacher	
Name	Luis Rouco Rodríguez
Department	Department of Electrical Engineering

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Name	Michel Luis Rivier Abbad
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DESCRIPTION OF THE SUBJECT

Contextualization of the subject

Prerequisites

Linear algebra and calculus.

Course contents

Contents

Part I: Introduction to Power Systems

Chapter 1. Physical and Functional Structure of Electric Power Systems

1. Demand
2. Generation
3. Transmission and Distribution
4. Market Operation and System Operation
5. Retailing

Chapter 2. Functional Description of Electric Power Systems

1. Time Scales
2. Expansion Planning
3. Operation Planning
4. Operation
5. Supervision and Control
6. Protection

Chapter 3. Future Trends

1. New Transmission and Distribution Technologies
2. Integration of Renewable Energy Sources

3. Smart Grids

Chapter 4. Power System Basic Analysis Tools

1. DC Circuits Review
2. Single-phase AC Circuits Review
3. Three-phase AC Systems
4. Per unit magnitudes

Part II: Technical analysis of power systems

Chapter 5. Frequency control

1. Principles of control systems
2. Principles of frequency control
3. Primary regulation
4. Secondary and tertiary regulation

Chapter 6. Voltage control

1. Principles of voltage control
2. Voltage control of transmission lines
3. Voltage control by generator excitation
4. Voltage control by ULTC transformers

Chapter 7. Power flow

1. Models of power system components
2. Network model
3. Formulation of power flow problem
4. Solution by Newton's method
5. DC power flow
6. Contingency analysis by DC power flow
7. Optimal power flow

Laboratory session # 1. Frequency control

Load regulation. Primary regulation. Secondary regulation.

Laboratory session # 2. Voltage control

Voltage control of a synchronous generator at open circuit. Voltage control of a synchronous generator connected to an infinite grid by excitation control and by transformer tap control.

Laboratory session # 3. Power flow

AC power flow data structure and solution. Generator voltage control. Contingency analysis. Optimal power flow.

EVALUATION AND CRITERIA

Evaluation activities	Evaluation criteria	Weight
The exams are a combination of a multi-option test and problems.	The weighted grade of the exams must be greater or equal to 5.	90
There are 3 assignments that the students can be done in groups following the instructions of the professor.	Assignments will be evaluated by discussing with the professor the student reports through an interview.	10

Grading

REGULAR ASSESSMENT

The theory will account for 90% of the grade, of which:

- 1st Exam: Power system structure & functional description up to medium-term decisions (13/60)
- 2nd Exam: Functional description & DC-AC circuits & Three Phase Systems (13/60)
- 3rd Exam: Frequency control (10/60)
- 4th Exam: Voltage control (14/60)
- 5th Exam: Power flow (10/60)

The weighted grade of the exams must be greater or equal to 5.

The exams are a combination of a multi-option test and problems.

Assignment evaluation will account for the remaining 10%. There are 3 assignments that the students can be done in groups following the instructions of the professor: frequency control, voltage control, and power flow. Assignments will be evaluated by discussing with the professor the student reports through an interview.

RETAKE

A single retake final exam will account for 90% of the grade.

The grade of the exam must be greater or equal to 5.

Assignment evaluation carried out in the regular assessment will account for the remaining 10%.

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).

BIBLIOGRAPHY AND RESOURCES

Basic References

- D. Laloux & M. Rivier, "Technology and Operation of Electric Power Systems", in Regulation of the Power Sector, J.I. Pérez Arriaga, Ed. (p. 1-46), Springer, 2013.
- A. Gómez Expósito, A. J. Conejo, C. Cañizares, Electric Energy Systems: Analysis and Operation, CRC Press, 2009.

COURSE SYLLABUS 2023-2024

GENERAL INFORMATION

Course information	
Name	Electric Power Systems
Code	MEPI-512
Degree	Official Master's Degree in the Electric Power Industry (MEPI)
Year	1st
Semester	Fall
ECTS credits	6 ECTS
Type	Compulsory
Department	Electrical Engineering
Area	Power Systems
Coordinator	Luis Rouco Rodríguez

Instructor	
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DETAILED INFORMATION

Contextualization of the course

Contribution to the professional profile of the degree

The objective of the course is for the student to become knowledgeable about physical and functional structure of electric power systems and to be familiar with the methods to analyze and control electric power systems. In particular, the specific objectives are:

- To understand the physical and functional structure of electric power systems
- To be able to analyze DC, single phase and three-phase AC circuits
- To understand the main control systems (load-frequency and voltage) of electric power systems and to analyze using appropriate mathematical models the performance of these control systems
- To understand the steady-state models of electric power systems (power flow problem) and to solve power flow problems using different approaches and models

Prerequisites

Students willing to take this course should have taken courses in linear algebra and calculus

CONTENTS

Contents

Part I: Introduction to Power Systems

Chapter 1. Physical and Functional Structure of Electric Power Systems

1.1 Demand
1.2 Generation
1.3 Transmission and Distribution
1.4 Market Operation and System Operation
1.5 Retailing

Chapter 2. Functional Description of Electric Power Systems

2.1 Time Scales
2.2 Expansion Planning
2.3 Operation Planning
2.4 Operation
2.5 Supervision and Control
2.6 Protection

Chapter 3. Future Trends

3.1 New Transmission and Distribution Technologies
3.2 Integration of Renewable Energy Sources
3.3 Smart Grids

Chapter 4. Power System Basic Analysis Tools

4.1 DC Circuits Review
4.2 Single-phase AC Circuits Review
4.3 Three-phase AC Systems
4.4 Per unit magnitudes

Part II: Technical Analysis of Power Systems

Chapter 5. Frequency control

5.1 Principles of control systems
5.2 Principles of frequency control
5.3 Primary regulation
5.4 Secondary and tertiary regulation

Chapter 6. Voltage control

6.1 Principles of voltage control
6.2 Voltage control of transmission lines
6.3 Voltage control by generator excitation
6.4 Voltage control by ULTC transformers

Chapter 7. Power flow

7.1 Models of power system components
7.2 Network model
7.3 Formulation of power flow problem
7.4 Solution by Newton's method
7.5 DC power flow
7.6 Contingency analysis by DC power flow
7.7 Optimal power flow

Chapter 8. Power Flow

7.1 Models of power system components
7.2 Network model
7.3 Formulation of power flow problem
7.4 Solution by Newton's method
7.5 DC load flow
7.6 Contingency analysis by DC load flow
7.7 Optimal load flow

Laboratory

Laboratory session # 1. Frequency control

Load regulation. Primary regulation. Secondary regulation.
Computer laboratory

Laboratory session # 2. Voltage control

Voltage control of a synchronous generator at open circuit. Voltage control of a synchronous generator connected to an infinite grid by excitation control and by transformer tap control.
Electric machines laboratory

Laboratory session # 3. Power flow

AC power flow data structure and solution. Generator voltage control. Contingency analysis. Optimal power flow.
Computer laboratory

Competences and Learning Outcomes	
Competences	
General Competences / Basic Competences	
CB1.	Haber adquirido conocimientos avanzados y demostrado, en un contexto de investigación científica y tecnológica o altamente especializado, una comprensión detallada y fundamentada de los aspectos teóricos y prácticos y de la metodología de trabajo en uno o más campos de estudio.
Specific Competences	
CE1.	Tener una visión general de la estructura y funcionamiento de los sistemas de energía eléctrica, así como de cuáles son las tendencias futuras desde la perspectiva tecnológica en los sistemas de energía eléctrica.
CE2.	Conocer los modelos de los componentes del sistema de energía eléctrica (generadores, transformadores y líneas) y de las técnicas apropiadas para el análisis de los sistemas eléctricos en régimen permanente y transitorio.
Learning outcomes	
By the end of the course students should be able to:	
LO1.	Understand the importance of physical structure of electric power systems
LO2.	Understand the importance of functional structure of electric power systems
LO3.	Be able to analyze DC, single-phase and three-phase AC circuits
LO4.	Understand the mechanisms of frequency control of electric power systems and its implementation details
LO5.	Understand the mechanisms of voltage control of electric power systems and its implementation details
LO6.	Understand the rationale of power flows in electric power systems
LO7.	Run power flow simulations

TEACHING METHODOLOGY

General methodological aspects	
This course will provide the students with basic concepts and tools they will require in the following courses. To obtain a good understanding of the different concepts, it is necessary to combine theory and practice. As the students will have to assimilate a wide range of knowledge in a short period of time, their commitment will be essential as well.	
In-class activities	**Competences**
Lectures (54 hours): 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.	CB1, CE1, CE2
Laboratory sessions (6 hours): Under the instructor's supervision, students will apply the concepts and techniques covered in the lectures. The sessions will take place in a computer laboratory.	CB1
Out-of-class activities	**Competences**
Personal study of the material (100 hours): 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.	CB1, CE1, CE2
Individual term papers (20 hours): Learning activities that will be carried out individually, outside of the classroom.	CB1
Tutoring (up to 10 hours): for groups or individual students will be organized upon request.	–

ASSESSMENT AND GRADING CRITERIA

Assessment activities	Grading criteria	Weight
Exams	▪ Understanding of the theoretical concepts. ▪ Application of these concepts to problem-solving.	90%
Reports	▪ Application of theoretical concepts to real problem-solving. ▪ Interpretation and critical analysis of numerical results. ▪ Written communication skills.	10%

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 throughout the course. In case this was not passed obtaining 5 or more points, the student has another opportunity for final evaluation (Retake) at the end of the academic year. The dates of the retake evaluation period will be announced on the web page.

Grading

Regular assessment

The theory will account for 90% of the grade, of which:

- 1st Exam: Power system structure & functional description up to medium-term decisions (13/60)
- 2nd Exam: Functional description & DC-AC circuits & Three Phase Systems (13/60)
- 3rd Exam: Frequency control (10/60)
- 4th Exam: Voltage control (14/60)
- 5th Exam: Power flow (10/60)

The weighted grade of the exams must be greater or equal to 5.
The exams are a combination of a multi-option test and problems.
Assignment evaluation will account for the remaining 10%. There are 3 assignments that the students can be done in groups following the instructions of the professor: frequency control, voltage control, and power flow. Assignments will be evaluated by discussing with the professor the student reports through an interview.

Retake

A single retake final exam will account for 90% of the grade.
The grade of the exam must be greater or equal to 5.
Assignment evaluation carried out in the regular assessment will account for the remaining 10%.

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:

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- 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[1]

In and out-of-class activities	Date/Periodicity	Deadline
First exam	10/10	
Second exam	5/11	
Third exam	12/11	
Fourth exam	10/12	
Fifth exam	14/01	
Lab sessions	7/11, 3/12 and 9/01	
Review and self-study of the concepts covered in the lectures	After each lesson	–
Lab preparation	Before every session	–
Assignments		Between one and three weeks after the publication of the assignments (3)

STUDENT WORK-TIME SUMMARY			
IN-CLASS HOURS			
Lectures	Problem-solving	Laboratory sessions	Assessment
35	11	6	8
OUT-OF-CLASS HOURS			
Self-study	Problem-solving	Assignments	Tutoring
65	35	20	10
		ECTS credits:	**6 (180 hours+up to 10 hours for tutoring)**

BIBLIOGRAPHY

Basic bibliography

- D. Laloux & M. Rivier, "Technology and Operation of Electric Power Systems", in Regulation of the Power Sector, J.I. Pérez Arriaga, Ed. (p. 1-46), Springer, 2013.
- A. Gómez Expósito, A. J. Conejo, C. Cañizares, Electric Energy Systems: Analysis and Operation, CRC Press, 2009.

Complementary bibliography

- A.J. Wood & B.F. Wollenberg, *Power Generation, Operation and Control (2nd ed.).* John Wiley & Sons, 1996.
- O. I. Elgerd, *Electric Energy Systems Theory: An Introduction, 2nd ed.,* Mc Graw Hill, 1982.
- A. R. Bergen & V. Vittal, *Power System Analysis, 2nd ed.,* Prentice Hall, 2000.
- J. J. Grainger & W. D. Stevenson, *Power System Analysis*, Mc Graw Hill, 1994.

[1] 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.

- P. Kundur, *Power System Stability and Control*, Mc Graw Hill, 1994.

	IN-CLASS ACTIVITIES				OUT-OF-CLASS ACTIVITIES				LEARNING OUTCOMES
Week	h	LECTURE & PROBLEM SOLVING	LAB	ASSESMENT	h	SELF-STUDY	LAB PREPARATION AND REPORTING	OTHER ACTIVITIES	Learning Outcomes
1	2	Intro to electric power systems			4	Review and self-study			LO1
1	2	Power Systems Structure: Demand			4	Review and self-study			LO1
2	2	Power Systems Structure: Generation			4	Review and self-study			LO1
2	2	Power Systems Structure: Transmission and Distribution, Market and System Operation			4	Review and self-study			LO1
3	2	Functional description of power systems: two main organisational paradigms			4	Review and self-study			LO2
3	2	Functional description of power systems: long term decisions			4	Review and self-study			LO2
4	2	Functional description of power systems: medium term decisions			4	Review and self-study			LO2
4	1	Functional description of power systems: short term decisions			2	Review and self-study			LO2
4	1			Power System Structure & Functional description up to medium term decisions: First exam					LO1, LO2
5	1	Functional description of power systems: Future trends			2	Review and self-study			LO2
5	1	DC Circuits			2	Review, self-study and problem-solving			LO3
5	2	AC Circuits			4	Review, self-study and problem-solving			LO4
6	2	Three Phase Systems (part 1)			4	Review, self-study and problem-solving			LO4
6	2	Three Phase Systems (part 2)			4	Review, self-study and problem-solving			LO4
7	2	Frequency control: Principles of control systems			4	Review, self-study and problem-solving			LO5
7	2	Frequency control: Principles of frequency control			4	Review, self-study and problem-solving			LO5
8	2	Frequency control: Primary, secondary and tertiary regulation regulation			4	Review, self-study and problem-solving			LO5
8	1	Functional description of power systems: Future trends			2	Review and self-study			LO2
8	1			Functional Description & DC-AC circuits & Three Phase Systems: Second exam					LO2, LO3,LO4
9	2		Frequency control: Computer laboratory session		10		Review, self-study and numerical simulation	Assigment on frequency control	LO5
9	2			Frequency control: Third exam					LO5
10	2	Voltage control: Principles of voltage control			4	Review, self-study and problem-solving			LO6
10	2	Voltage control: Principles of voltage control			4	Review, self-study and problem-solving			LO6
11	2	Voltage control: Voltage control of transmission lines			4	Review, self-study and problem-solving			LO6
11	2	Voltage control: Voltage control with generators			4	Review, self-study and problem-solving			LO6
12	2	Voltage control: Voltage control with transformers			4	Review, self-study and problem-solving			LO6
12	2		Voltage control: Electric machines laboratory session		8		Review and self-study	Assigment on voltage control	LO6
13	2			Voltage control: Fourth exam					LO6
13	2	Power flow: Models			4	Review, self-study and problem-solving			LO7
14	2	Power flow: AC power flow			4	Review, self-study and problem-solving			LO7
14	2	Power flow: DC power flow and optimal power flow			4	Review, self-study and problem-solving			LO7
15	2		Power flow: Computer laboratory session		10		Review, self-study and numerical simulation	Assignment on power flow	LO7
15	2			Power flow: Fifth exam					LO7