GENERAL INFORMATION

Course information	
Name	Network Business: Transmission, Distribution and Smart Grids
Code	
Degree	Master in the Electric Power System (MEPI)
Year	
Semester	2nd (Spring)
ECTS credits	6 ECTS
Type	Elective
Department	
Area	
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DETAILED INFORMATION

Contextualization of the course

Contribution to the professional profile of the degree

The process of liberalization that has took place during the last decades resulted in the introduction of competition in some activities in the electricity sector. However, network activities, considered as natural monopolies, remain under regulation. This course is focused on the fundamentals and the regulation of the two network industries: transmission and distribution of electricity. On the other hand, the increasing deployment of distributed energy resources (DER) is introducing significant changes in the planning and operation of distribution networks, which are transforming more and more rapidly to smart grids.

By the end of the course, students will understand the basic principles behind the regulation of network industries, will be able to critically understand the regulation of transmission and distribution in different countries, and will know the motivations and the current and future expectations about the transformation of distribution networks into smart grids.

Prerequisites

Students willing to take this course should be familiar with fundamentals on electric power systems. Previous experience with regulation, economics and programming languages is also desired although not required.

CONTENTS

Contents
Transmission
1. Background concepts
The transmission activity. Modeling transmission networks in power systems decision support tools. Nodal pricing: concepts, computation and properties.
2. Regulatory issues
Short term economic signals: ohmic losses and congestion management. Long term economic signals: network remuneration and tariffs. Access issues. Transmission planning.
3. Business activities
Description of the organization of a Transmission Owner. Examples of activities: Access and expansion planning decision making in the Spanish TO (REE); Large interconnection system studies of the Spanish TO (REE).
4. Interconnected power systems
Transmission network regulation within regional markets.
Distribution
1. Fundamentals on regulation
Different regulatory alternatives.
2. Quality of service and network losses
Regulation of power quality. Incentives for improving quality of service and reducing network losses.
3. International experiences
Implementation of distribution regulation in selected countries.
Smart grids
Drivers and technological development. Smart meters, automation of electricity networks. Active demand management. Distributed generation.

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

CE13 Comprender la función de la red de transporte y de la red de distribución en el suministro de electricidad, así como de su integración con el resto de las actividades eléctricas, tanto desde un punto de vista técnico como regulatorio o económico

CE14 Conocer en profundidad los principios económicos que subyacen a las alternativas de regulación para las actividades de transporte, e identificar y saber evaluar los diferentes conceptos de coste por los que las empresas distribuidoras deben ser remunerada: costes de operación y mantenimiento, amortización de infraestructuras, tasa de retorno sobre el capital invertido, gestión comercial, tributos e impuestos, etc.

CE15 Entender el impacto que la generación distribuida produce sobre las redes convencionales, y las implicaciones técnicas, económicas y regulatorias que tendrán las redes inteligentes en el futuro.

Learning outcomes

The objective of the course is for the student to become knowledgeable about the network business of electricity systems. In particular, the specific learning outcomes are:

RA1. To have acquired the advanced concepts presented in this course, both theoretical and practical, showing a detailed understanding about the regulation of network business, and about the main characteristic of network business.

RA2. To understand the chief technical and economic characteristics that make the transmission and distribution networks a natural monopoly and therefore subject to regulation, distinguishing between how to use short- and long-term economic signals.

RA3. To acquire a working knowledge of the various regulatory alternatives for decision-making with respect to transmission network investment and to understand and to be able to evaluate the various alternatives proposed to regulate transmission network access in the event of transmission constraints.

RA4. To understand the fundamentals of electric distribution business and regulation and to identify the different regulatory alternatives proposed to regulate economically the distribution business.

RA5. To understand the role of smart grids in future distribution networks and to acquire the knowledge about the different alternatives regarding smart grids in transmission and distribution networks.

TEACHING METHODOLOGY

General methodological aspects	
The teaching methodology combines both theoretical sessions (included invited speakers from the industry) and practical sessions that will enable the students to practice and deeply understand the problems faced in the regulation of network industries. The personal study and the individual/group assignment will complement this classroom training.	
In-class activities	**Competences**
▪ **Lectures** (60 hours): Presentation of the main concepts and procedures, by the instructor and professionals from the power sector. They will include dynamic presentations, case studies, and the participation and interaction with students	CB1, CE13, CE14, CE15
Out-of-class activities	**Competences**
▪ **Personal study** of the material to be discussed in the lectures (60 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, CE13, CE14, CE15
▪ **Individual/Group assignments** (60 hours): Learning activities that will be carried out individually, outside of the classroom, and that will require personal research or commentary of different materials).	CE13, CE14, CE15

ASSESSMENT AND GRADING CRITERIA

Assessment activities	Grading criteria	Weight
Transmission 1st Mid-term exam	▪ Multi-choice test and short questions to evaluate the basic understanding of the concepts	11,25%
Transmission 2nd Mid-term exam	▪ Multi-choice test and short questions to evaluate the basic understanding of the concepts	11,25%
Transmission 3rd Mid-term exam	▪ Multi-choice test and short questions to evaluate the basic understanding of the concepts	4,5%
Transmission Group assignments	▪ Application of theoretical concepts to real problem-solving ▪ Collection and critical review of information on transmission regulation ▪ Ability to use and develop specific software	18%
Distribution Mid-term exam	▪ Multi-choice test and short questions to evaluate the basic understanding of the concepts	8,25%
Distribution Final exam	▪ Multi-choice test and short questions to evaluate all topics dealt with during the course	19,25%
Group and individual case studies	▪ Application of theoretical concepts to real problem-solving ▪ Ability to use and develop specific software ▪ Capability to analyze the regulatory implications of numerical results	11%
Final group assignment	▪ Analyze a real-life regulatory context based on the theoretical concepts ▪ Collection and critical review of information on distribution regulation ▪ Ability to use and develop specific software	16.5%

GRADING AND COURSE RULES

Grading

Regular assessment

The evaluation of the students' learning will comprise two grades: one corresponding to the **transmission** lectures, and the other one corresponding to **distribution** and smart grids. **If both grades are larger than, or equal to, 4 out of 10**, the final grade shall be calculated as the weighted average of both grades, giving a weight of **45% to transmission and 55% to distribution** and smart grids. **Otherwise**, the final grade shall be computed as the **minimum between 4 out of 10 and this weighted average**. In order to pass the course, students must obtain a **final grade of at least 5 out of 10**.

The evaluation of the transmission part will be based on exams (60%) and other aspects of the assessment (40%) comprising individual assignments, group assignments, attendance and active participation in class (no more than 10% of the grade).

The evaluation of distribution and smart grids will be based on exams (50%) and other aspects of the performance assessment (50%) comprising individual assignments, group assignments, attendance and active participation in class.

Retakes

Students not passing the course according to the regular assessment criteria shall have a second chance to pass it in a second evaluation period at the end of June. This retake shall comprise an exam for each part of the course (transmission, or distribution and smart grids) where the student has not obtained a grade of at least 5 out of 10.

The grade obtained in this retake shall be the final grade of these students for the corresponding part or parts. For those parts (transmission, or distribution and smart grids) where the student has obtained at least a 5 out of 10 in the regular assessment period, students will keep this grade. Provided that the student has obtained a **final grade of at least 5 out of 10 in both parts** (transmission and distribution and smart grids), the final grade shall be calculated as the weighted average of the grades obtained by the student in each of the two parts of the course, giving a weight of **45% to transmission and 55% to distribution** and smart grids. Otherwise, the final grade shall be minimum between the grades obtained in the two parts of the course.

No student having passed the course in the first evaluation period shall be allowed to go through the assessment in the second period.

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 Academicas) 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.

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
Mid-term exam	Weeks 7, 8, 17, 19	
Final exam	Week 19	
Review and self-study of the concepts covered in the lectures	After each lesson	
Problem-solving	Occasionally	
Assessment preparation	Weeks 3, 4, 5, 10, 11	
Distribution Group Assessment Transmission Group Assessment	During the last half of the course	Week 19
Final exam preparation	June	Week 19

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

STUDENT WORK-TIME SUMMARY		
IN-CLASS HOURS		
Lectures	Problem-solving & Lab sessions	Assessment
45	10	5
OUT-OF-CLASS HOURS		
Self-study	Assignments preparation	Assignment reports writing
60	50	10
	ECTS credits:	6 (180 hours)

BIBLIOGRAPHY

Basic bibliography

Perez-Arriaga, Ignacio J., Regulation of the Power Sector. Springer. 2013

- Chapter 4: Monopoly Regulation
- Chapter 5: Electricity Distribution
- Chapter 6: Electricity Transmission
- Chapter 10: Regional Markets
- Chapter 14: Challenges in power Sector Regulation

Complementary bibliography

Texts related to competition schemes within the Electrical Sector:

- International Energy Agency (2001) Competition in electricity markets. OECD.
- Hunt, S., Shuttleworth, G. (1996) Competition and choice in electricity. Wiley.
- Hunt, S. (2002) Making competition work in electricity, Wiley Finance.
- Stoft, S. (2002) Power System Economics, Wiley-IEEE Press.

Power Systems technology and economic bases with emphasize on transmission topics:

- Schweppe, F.C., Caramanis, M.C., Tabors, R.D., Bohn, R.E. (1988) Spot pricing of electricity. Kluwer Academic Publishers.
- Wood, A.J., Wollenberg, B.F., (1984) Power generation, operation and control. John Wiley.
- Levêque, F. (editor) Transport pricing of electricity networks, Kluwer, 2003.
- Woolf, F. (2003) Global Transmission Expansion. Recipes For Success. PennWell.

Power Systems technology and economic bases with emphasize on distribution topics:

- T.A. Short. Electric Power Distribution Handbook. CRC Press, 2004
- H. Lee Willis. Power Distribution Planning Reference Book. 2nd Edition, Marcel Dekker, Inc. 2004.
- Incentive Regulation in Theory and Practice: Electricity Distribution and Transmission Networks. Paul L. Joskow, 2006
- R. Cossent. Economic regulation of Distribution System Operators and its adaptation to the penetration of Distributed Energy Resources and smart grid technologies. PhD Thesis, Comillas University. 2013.

	IN-CLASS ACTIVITIES			OUT-OF-CLASS ACTIVITIES			LEARNING OUTCOMES
Week	h/w	LECTURE & PROBLEM SOLVING	ASSESMENT	h/w	SELF-STUDY	ASSESSMENT PREPARATION AND REPORTING	Learning Outcomes
1	4	The transmission activity. Introduction to distribution networks		2	Review and self-study		RA1, RA2
2	4	Representation of the transmission network in the models of analysis and management of power systems. Operation and planning of distribution grids		4	Review and self-study		RA1, RA2
3	4	Nodal prices: concept, computation and properties. Fundamentals on regulation of distribution networks		6	Review, self-study and problem-solving	Transmission Case Study	RA2, RA4
4	4	Nodal prices: concept, computation and properties. Distribution: Network costs and regulatory tools		8	Review, self-study and problem-solving	Distribution Case Study	RA2, RA4
5	0			6	Review, self-study and problem-solving	Distribution Case Study	RA1, RA2, RA4
6	4	Short term economic signals: losses and constraints. Power quality: definitions, standards and voltage control		4	Review, self-study		RA2, RA3, RA4
7	4	Short term economic signals: losses and constraints. Distribution energy losses incentives: definitions and international experience.	Distribution Mid-term exam	4	Review and self-study		RA2, RA3, RA4
8	2	Long term economic signals: transmission remuneration and tariffs	Transmission Mid-term exam	4	Review and self-study		RA2, RA3
9	2	Distributed Energy Resources: drivers and impact on the distribution grid		4	Review and self-study		RA4, RA5
10	4	Long term economic signals: transmission remuneration and tariffs. Self-generation and tariff design		9	Review, self-study and problem-solving	Distribution Case Study	RA2, RA3, RA5
11	4	Network access and investments. Smart grids: a new paradigm for distribution networks. International experiences, network automation and smart metering		9	Review, self-study and problem-solving	Distribution Case Study	RA1, RA2, RA3, RA5
12	0			4	Review and self-study		RA2, RA3, RA4
13	4	TSO Business organization 1. DER and smart grids: Revisiting distribution regulation		4	Review and self-study		RA1, RA4, RA5
14	0			4	Review and self-study		RA1, RA4, RA5
15	4	TSO Business organization 1. Enhanced LV network observability and data analysis		5	Review and self-study		RA1, RA5
16	4	TSO Business organization 3. Operating a largely decentralized power system: business models and aggregation		10	Review, self-study and problem-solving	Distribution Group Assignment Transmission Group Assignment	RA1, RA5
17	4	The transmission network in regional markets. New roles of DSOs in Europe	Transmission Mid-term exam	10	Review, self-study and problem-solving	Distribution Group Assignment Transmission Group Assignment	RA2, RA4, RA5
18	4	The transmision network in regional markets. Smart grids and ICTs		11	Review, self-study and problem-solving	Distribution Group Assignment Transmission Group Assignment	RA2, RA5
19	4	Presentation of group assignments in distribution	Transmission Mid-term exam Distribution final exam	12	Review, self-study and problem-solving	Distribution Group Assignment Transmission Group Assignment	RA1, RA2, RA3, RA4, RA5