

COURSE GUIDE

2025/26

Faculty

345 - Faculty of Engineering - Bilbao

Cycle

Degree

INTER401 - Máster in Integration of Renewable Energy Sources Into The Elec

Year

COURSE

502150 - Impact of Distributed Generation on the Electric Power System

Credits, ECTS: 3

COURSE DESCRIPTION

The integration of renewable energy in the electricity system is being carried out at two levels: large generation plants connected to the transmission network and medium and small generation plants connected to the distribution network. In both cases, generation is dispersed in a wide geographical area, so they share many characteristics in terms of their technical, economic and social impact on the system.

At the distribution network level, distributed generation is a mix of generation, demand management and storage resources, of small power, connected close to the end-customer. This type of generation is being driven in recent years by the massive connection of wind and photovoltaic facilities, along with other traditional solutions such as diesel groups. Renewable and distributed generation is connected to high, medium and low voltage networks, which raises problems of integration in the electrical system at all its voltage levels. These impacts are both technical, as well as economic and regulatory, and much of them are caused because the current power systems have not been conceived for a massive integration of this type of distributed resources. The increase in renewable electric generation involves increasing distributed generation based on renewable resources, which implies solving the current problems of integration in the electricity system.

The main objective of the course is to provide students with the knowledge and the ability to analyze the impacts caused by the integration of renewable generation in the power system. A supplementary objective is to provide student with the ability to use modern simulation tools to evaluate the performance of electric power systems with high penetration of renewable energy

The subject "Integration of renewable energy into the electricity system" is a joint subject of the "Master en Integración de las Energías Renovables en el Sistema Eléctrico" and the "Master in Offshore Renewable Energy". The subject tries to complete the vision on the renewable generation systems, taught together with the subjects "Solar Generation", "Wind Generation" and "Other sources of electrical generation and storage. Microgrids" by analyzing their interaction with the electrical system to which they are connected. Specifically, the present subject focuses on evaluating the impacts caused by the connection of these generation resources in the distribution networks and in the power system.

The subject "Integration of renewable energy into the electricity system" belongs to the second semester of the master's degree, since it is necessary that students have completed, or have prior knowledge of the contents of, the subjects "Electric power systems", "Power System Analysis", "Fundamentals of modeling and simulation in electrical engineering", "Power System Planning". These subjects are necessary to have a good base on the components of the electrical system, its operation, the techniques of analysis and the methods and tools for modeling and simulation of power systems. At the same time, basic knowledge of the different renewable generation technologies is required, studied in the subjects "Solar generation", "Wind generation", "Other sources of electrical generation and storage. Microgrids".

COMPETENCIES/LEARNING RESULTS FOR THE SUBJECT

COMPETENCIAS DE LA ASIGNATURA

- To explain and to demonstrate knowledge and understanding of the main technical and economic impacts of distributed renewable generation, as well as the solutions proposed to limit them
- To explain and to demonstrate knowledge and understanding of the regulatory framework for distributed renewable generation and its relation to the technical, economic and social issues
- To have knowledge and to become skilled with simulation tools to analyze the impacts of distributed renewable generation in the electrical system
- To acquire new skills, organize information and make effective reports
- To use communication skills in various formats: group discussion, debate and exhibition

RESULTADOS DE APRENDIZAJE DE LA ASIGNATURA

- To analyze the technical impact of the connection of renewable energy to electricity systems, understanding the affection to the electricity signal in terms of voltage and frequency variations.
- To master the use of simulation software to analyze local and system wide impacts caused by the connection of renewable energy generators.
- To evaluate the impact of the regulatory framework on the connection of renewable energy generators to the grid, analyzing the requirements and proposing a plan to test and validate the requirements
- To communicate the results of a network connection study in a report analyzing the results of different studies performed with a simulation software

Theoretical and Practical Contents

- Lesson 1: Introduction to renewable distributed generation and system impacts
- General introduction to the renewable and distributed generation and its technical, economic and social impacts in the

electricity system

- Lesson 2: Network topologies with distributed and renewable generation

Description of the different network topologies where distributed and renewable generation can be connected. Basic design, operation and protection principles

- Lesson 3: Types of generators and system studies

Description of the types of generators used in distributed renewable generation, their modeling and use in system studies

- Lesson 4: Technical Impact: Voltage control

Study of the technical impact of distributed and renewable generation focusing the study on voltage control

- Lesson 5: Technical Impact: Stability

Study of the technical impact of distributed and renewable generation focusing the study on system stability

- Lesson 6: Technical Impact: Power quality

Study of the technical impact of distributed and renewable generation focusing the study on power quality

- Lesson 7: Technical impact: Protection

Study of protection practice for distributed and renewable generators and their impact on the network protection system, both transmission and distribution

- Lesson 8: Regulatory framework. Grid Codes

Analysis of the regulatory framework of renewable generation in the European and Spanish systems. Grid codes

- Lesson 9: Economic impact

Economic impact analysis of distributed renewable generation in the planning and operation of the electric energy system.

Integration of distributed renewable generation in the electricity market

- Lesson 10: Integration of distributed renewable generation into the electricity system

Current status, challenges and prospects. Case Studies

METODOLOGIA (ACTIVIDADES FORMATIVAS)

Actividad Formativa	Hours	Porcentaje presencialidad
Classroom/Seminar/Workshop	6	100 %
Working with it equipment	8	100 %
Reading and practical analysis	9	0 %
Expositive classes	16	100 %
Groupwork	16	0 %
Systematised study	20	0 %

TYPES OF TEACHING

Types of teaching	M	S	GA	GL	GO	GCL	TA	TI	GCA
Hours of face-to-face teaching	16	2	4		8				
Horas de Actividad No Presencial del Alumno/a	20	25							

Legend: M: Lecture-based S: Seminar GA: Applied classroom-based groups
GL: Applied laboratory-based groups GO: Applied computer-based groups GCL: Applied clinical-based groups
TA: Workshop TI: Industrial workshop GCA: Applied fieldwork groups

Evaluation tools and percentages of final mark

Denominación	Ponderación mínima	Ponderación máxima
Attendance and participation	0 %	20 %
Drawing up reports and presentations	0 %	40 %
Written examination	50 %	100 %

ORDINARY EXAMINATION PERIOD: GUIDELINES AND OPTING OUT

CONTINUOUS EVALUATION:

The final grade in the case of the continuous assessment system will be composed of:

- Attendance and active participation in classes: 10%
- Group work: 40%
- Final exam: 50%

To pass the subject it will be necessary to obtain 4 points out of 10 in the final exam. If this requirement is not met, the final grade will be the weighted average of each part, unless it exceeds 5, in which case the final grade will be 4.5.

To renounce to the continuous evaluation, students must request it in writing to the subject's teaching staff, before week 10 after the beginning of the teaching of said subject. The rejection of the continuous evaluation implies the application of the final evaluation system.

FINAL EVALUATION:

In the final evaluation system, the final grade will be composed of:

- Individual work: 35%
- Final exam: 65%

To pass the subject it will be necessary to obtain 4 points out of 10 in the final exam. If this requirement is not met, the final grade will be the weighted average of each part, unless it exceeds 5, in which case the final grade will be 4.5.

To renounce the call, students must request in writing to the academic committee of the master, at least one week before the official date of the final exam established for the call.

EXTRAORDINARY EXAMINATION PERIOD: GUIDELINES AND OPTING OUT

FINAL EVALUATION:

In the final evaluation system, the final grade will be composed of:

- Individual work: 35%
- Final exam: 65%

To pass the subject it will be necessary to obtain 4 points out of 10 in the final exam. If this requirement is not met, the final grade will be the weighted average of each part, unless it exceeds 5, in which case the final grade will be 4.5.

To renounce the call, students must request in writing to the academic committee of the master, at least one week before the official date of the final exam established for the call.

MANDATORY MATERIALS

All the material for the subject is in the eGela platform

BIBLIOGRAPHY

Basic bibliography

- [1] Jenkins N., Allan R., Crossley P., Kirschen D., Strbac G., Embedded generation. IEE Power and Energy Series 31. London, 2000.
- [2] Jenkins N., Ekanayake J.B., Strbac G., Distributed generation. IET Renewable Energy Series 1. London 2010.
- [3] Keyhani A., Marwali M.N., Dai M., Integration of green and renewable energy in electric power systems. Wiley. Hoboken 2010.
- [4] Bollen M.H.J., Hassan F., Integration of distributed generation in the power system. IEEE Press Series on Power Engineering. Wiley. Hoboken 2011.

Detailed bibliography

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- [2] Resource Dynamics Corporation (2003). Application guide for distributed generation interconnection: 2003 update. The NRECA guide to IEEE 1547.
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- [4] Lacroix B., Calvas R., Los esquemas de las conexiones a tierra en el mundo y su evolución. Cuaderno Técnico Nº 173. Schneider Electric. Barcelona 2000.
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- [7] Microgrids Task A1, Digital models for micro sources. February 2004.
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- [9] WECC Modeling and Validation Workgroup, WECC Wind Power Plant Dynamic Modeling Guide. November 2010.
- [10] WECC Modeling and Validation Workgroup, WECC Guide for Representation of Photovoltaic Systems in Large-Scale Lod Flow Simulations.
- [11] WECC Modeling and Validation Workgroup, Generic Solar Photovoltaic System Dynamic Simulation Model Specification. September 2012.
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- [13] Chung I.L., Liu W., Cartes D.A., Collins E.G., Moon S.I., Control methods of inverter-interfaced distributed generators in a microgrid system, IEEE Trans. on Industry Applications, Vol 46, No 3, May/June 2010.
- [14] CIGRE WG B5.34, The impact of renewable energy sources and distributed generation on substation protection and automation . August 2010
- [15] IEEE Power System Relay Comittee WG D3, Impact of distributed resources on distribution relay protection . August

2004.

Journals

- [1] Renewable and sustainable energy reviwes
- [2] Energy
- [3] IEEE Transactions on Smart Grids
- [4] IEEE Transactions on Power Systems
- [5] IEEE Transactions on Power Delivery
- [6] Electric Power systems Research

Web sites of interest

- [1] www.ieee.org
- [2] www.cigre.org
- [3] www.nrel.gov