Renewable Energy Grid Integration and Distributed Generation Specialization

EUREC European Master in Renewable Energy

Module Handbook

Instituto Universitario de Investigación Mixto
CIRCE
Universidad Zaragoza

Contents:

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INTRODUCTION TO ELECTRIC POWER SYSTEMS AND POWER ELECTRONICS

INTRODUCTION TO ELECTRIC POWER SYSTEMS AND POWER ELECTRONICS (3 ECTS)	
1.A. Introduction to Electric Power System Operation	
- Electric grid introduction - Supply guarantee and power quality - Stability - Electric circuit analysis - Effects of renewable energy into the grid - Boundaries of the actual grid configuration - Consumption models and patterns. Demand Side Management	
1.B. Introduction to Power Electronics	
- Basic concepts on power electronics: power semiconductors, switching, converters and application examples	
Learning outcomes	
By the end of this module, students should be able to manage theoretical aspects related to power distribution, stability and quality. The student will: • Become familiar with the basic theory and practical knowledge about the electric energy. • Get basic knowledge on supply guarantee and power quality topics. • Get basic knowledge on stability issues. • Know the main effects of the introduction of Renewable Energies into the electric grid. • Become familiar with power electronics concepts **Knowledge and understanding.** Graduates will be able to demonstrate and in-depth knowledge of Power Systems operations and Distributed Generation integration in existing grids. **Transferable skills.** Graduates will be able to work effectively as a professional and as team member in the resolution of technical problems. Also, graduates will demonstrate their abilities to communicate effectively in multinational groups.	
Module Coordinator	María Paz Comech Moreno

Lecturers	María Paz Comech Moreno María Teresa Villén Martínez Samuel Borroy Vicente Laura Giménez de Urtasún Andrés Honrubia Escribano Jesús Muñoz-Cruzado Alba	
Language	English	
ECTS credits	3	
Teaching format / class hours	20h 6 h 0 h 2 h	Lecture Laboratory Excursion Others...(Test, Oral presentation, Tutorials)
Contact hours	28	
Workload	77	
Assessment methods	Exam	
Literature	• “Power System Analysis” by John J. Grainger, William D. Stevenson.1995, McGraw-Hill Inc. • “Power System Analysis and design” by J. Duncan Glover, Mulukutla S. Sarma, and Thomas Overbye. 2008, Cengage Learning. • “Electrical Machines, Drives and Power System” by Theodore Wildi.2002, Prentice-Hall. • “Guide to Electrical Power Distribution Systems” by A.J. Pansini. 2005, The Fairmont Press Inc. • “Tecnología eléctrica” by M.Paz Comech, M. Garcia-Gracia. • "Análisis de circuitos eléctricos I” by A.A. Bayod; J.L. Bernal; J.A. Dominguez; M.A. García García; A. Llombart; J.M. Yusta. Colección Textos Docentes, vol. 58. Prensas Universitarias de Zaragoza.	

DISTRIBUTED ENERGY RESOURCES (6.1 ECTS)
2.A. Basic aspects of Distributed Generation
- Challenges and technology trends for the grid integration of renewable power generation - Challenges concerning power system operation due to high RE integration/international studies - Marine and offshore technologies & markets - Wind power prediction techniques
2.B. Introduction to integrated renewable energy sizing

- Introduction to integrated renewable energy sizing and optimization
  - Photovoltaic systems and solar resources
  - Backup systems
  - PV- battery offgrid systems sizing
  - Hybrid systems simulation and optimization

2.D. Hydrogen Technologies and Power Storage Systems
- State of the art on Hydrogen Technologies - State of the art on Power storage systems - Batteries, Ultra capacitors based energy storage systems and Flywheel
Visits: - Hydraulic central visit - CECOEL (REE Control Centre) and CECRE (Renewable Energy Control Center) visit - Wind farm and substation visit - PV facilities visit - Hydrogen applications and Walqa visit
Learning outcomes

By the end of this subject, students should be able to display a clear understanding of the state of the art of RE power generation technologies, the theoretical aspects of storage technologies and the impact of electric vehicles in the electric grid.
The student will get a suitable knowledge about the following topics:

- Distributed Generation main concepts
- New generation technologies
- Optimization of hybrid systems based on renewable energies
- Wind power generation
- Biomass power
- Hydraulic Power
- Storage
- Electric vehicle regarding grid integration

Engineering analysis.
Graduates will be able to demonstrate a clear understanding of the state of the art of RE power generation technologies and related aspects as storage or impact in the electric grid.

Transferable skills.
Graduates will be able to work effectively as a professional and as team member in the resolution of technical problems. Also, graduates will demonstrate their abilities to communicate effectively in multinational groups.

Module Coordinator	Rodolfo Dufo López	
Lecturers	Rodolfo Dufo López Agustín Diaz García Gustavo Quiñonez Varela Ismael Aso Aguarto Roberto Veguillas Pérez Ana Patricia Talayero Navales Paula Junto Madero Juan Peiró Juan José Abellán Pérez Ana Rodriguez Aparicio María Teresa Villén Martinez	
Language	English	
ECTS credits	6.1	
Teaching format / class hours	25h 12 h 18 h 4 h	Lecture Laboratory Visits Others...(Test, Oral presentation, Tutorials)
Contact hours	59	
Workload	155	

Assessment methods	Exam Developed topic presentation
Literature	• “Energy Storage for Power Systems” by A. Ter-Gazarian. IEE Energy, No 6. • “Integration of Alternative Sources of Energy” by Felix A. Farret and M. Godoy Simoes. 2006, John Wiley and Sons. • “Distributed Generation” by Ann-Marie Borbely, Jan F. Kreider. 2001, CRC Press.

CONTROL TECHNIQUES AND RENEWABLE ENERGY INTEGRATION SYSTEMS (5.5 ECTS)
3.A. AC/DC Drives Control
- Introduction to basic analysis and operation techniques on power electronic systems. - Basic commutation cell - Functional analysis of power converters main topologies - Power conversion schemes between electric machines and the grid - Power systems control using power converters - High power electronic converters. Tendencies, topologies and basic functional principles - Multilevel converter with 3 stages - Electronic conversion systems application to renewable energy generation systems. Basic schemes and functional advantages. Wind Power and Photovoltaic Power applications.
3.B. Technological aspects of power electronic systems connection to the grid
- PLL - Sampling effect, commutation frequency, etc… Modulation types - Dimensioning LC filters - Harmonic cancellation by modulation
3.C. Active Network Devices, Control and FACTS Technology
- Theory and operation principle of FACTS - Implementation and FACTS technologies (Series / Shunt compensation) - Talk from “Wind to Power System” (Carlos III University)
Possible visit to tri-generation central
Learning outcomes

By the end of this subject, students should be able to manage the theoretical and practical aspects related to Power electronics, with an emphasis in the analysis of the operation of specific devices used to integrate RE.

At the completion of this module, the student will:

- Become familiar with the AC/DC Drives control systems (multilevel converters, PWM, etc…)
- Get basic knowledge on the technological aspects of power electronic systems connection
- Get knowledge about reactive power compensation
- Be introduced to FACTS Technology

Engineering analysis.
Graduates will be able to formulate and solve engineering problems related to the control of power systems connected to the grid. Also, will be able to design and optimise Micro Grids.

Investigations.
Graduates will be able to evaluate the requirements to implement Micro Grids.

Transferable skills.
Graduates will be able to work effectively as a professional and as team member in the resolution of technical problems related to integration of RE in electric grids. Also, graduates will demonstrate their abilities to communicate effectively in multinational groups.

Module Coordinator	Jesús Sergio Artal Sevil	
Lecturers	Jesús Sergio Artal Sevil Carmen Longás Oriol Gomis Jesús Muñoz-Cruzado Alba Eduardo Martínez Carrasco	
Language	English	
ECTS credits	5.5	
Teaching format / class hours	32 h 12 h 0 h 7 h	Lecture Laboratory Excursion Others...(Test, Oral presentation, Tutorials)
Contact hours	51	
Workload	145	

Assessment methods	Exam Subject's work Developed topic presentation
Literature	• "Understanding FACTS: Concepts and Technology of Flexible AC. Transmission Systems" Wiley, by N.G. Hingorani; L. Gyugyi. 1999, John Wiley and Sons. • "FACTS, Modelling and Simulation in Power Networks" by E. Acha; C.R. Fuerte-Esquivel; H. Ambriz-Perez; C. Angeles-Camacho. 2004, John Wiley and Sons. • "Power Electronics, Converters, Applications and Design" by N. Mohan; T.M. Undeland; W.P. Robbins. 1995, John Wiley and Sons. • "Power Electronics Handbook" Muhammad H. Rashid. 2001, Academic Press. • "Grid Converters for Photovoltaic and Wind Power Systems" Remus Teodorescu, Marco Liserre, Pedro Rodriguez. 2011, IEEE- Wiley and Sons Publications.

DISTRIBUTED ENERGY RESOURCES IMPACTO ON ELECTRIC POWER SYSTEMS (6 ECTS)
4.A. Electric Systems Modelling

- Modelling and simulation of electric systems introduction. Simulation grid studies and used tools. Per Unit system.
- Electric system modelling for permanent regime studies
  - Steady state simulation studies. Load flow
  - Sequence grids, three phase short-circuit
- Transient regime electric systems modelling and simulation

4.B. Power Supply Quality

- Background and problems of the lack of electric supply quality
  - Frequency variations
  - Slow voltage variations
  - Flicker voltage fluctuations
  - Voltage gaps and brief voltage cuts
  - Voltage boosts
  - Harmonic distortion
  - Voltage unbalances

4.C. Optimization and Grid Planning
- Introduction to classical optimization: Linear programming, nonlinear programming and powerflow approach - Modern Methods of optimization: Ant colony optimization, genetic algorithm, particle swarm optimization…
Learning outcomes

By the end of this subject, students should be able to acquire relevant data to evaluate grid power quality, to model permanent and dynamic transient regimes of electric grid elements and to plan and optimise grid design.

Specifically, the student will:

- Be able to perform different studies (Permanent, dynamic or transitional regimes) to undertake in electric grids to ensure correct planning and operation.
- Get basic knowledge on grid modelling (static and dynamic)
- Be able to perform stability studies.
- Get know different aspects about power supply quality.
- Be able to perform an optimal sizing of renewable energies installations.

Engineering analysis.
Graduates will be able to formulate and solve engineering problems related to Power Supply Quality.

Investigations.
Graduates will be able to acquire relevant data to evaluate grid power quality.

Engineering design.
Graduates will be able to model permanent and dynamic transient regimes of electric grid elements. Also to plan and optimise grid design.

Transferable skills.
Graduates will be able to work effectively as a professional and as team member in the resolution of technical problems related to integration of RE in electric grids. Also, graduates will demonstrate their abilities to communicate effectively in multinational groups.

Module Coordinator	Mª Paz Comech Moreno	
Lecturers	Mª Paz Comech Moreno Sergio Martínez Villanueva Itziar Quintana Hontoria Juan José Pérez Aragües José Luis Dominguez García Ana Morales Martínez Carmen Longás Viejo José Manuel Fresno de Marcos Marta Abad López Agustín Díaz García Jorge Bruna Romero Alezeia González García	
Language	English	
ECTS credits	6	
Teaching format / class hours	28 h 17 h 0 h 4 h	Lecture Laboratory Excursion Others...(Test, Oral presentation, Tutorials)

Contact hours	49
Workload	133
Assessment methods	Exam Subject's work Developed topic presentation
Literature	• "Power System Analysis" by John J. Grainger, William D. Stevenson.1995, McGraw-Hill Inc. • "Power Systems Modelling and Fault Analysis: Theory and Practice" by N.D. Tleis. 2008, Elsevier Ltd.

SMART GRID SOLUTIONS (6.1 ECTS)
5.A. Intelligent Network Programming
- Smart Grids form the point of view of network operator (Demand management, electric vehicle, storage - Operation and network planning with quality criteria in distribution systems
5.B. Protections
- Introduction to protections in electric power system - Overcurrent, Distance and Differential protection - Protection coordination - Impact of distributed generation in power system protection
5.C. SMART GRIDS
- Communications in Smart Grids - IEC 61850 - Supply guarantee automatisms - Control devices. IEDs - Measurement and control communications (PLC, wireless…)
2.G. Electric Vehicles
- EV interests. Random generation forecast corrections - EV needs according to users and grid exigencies - Dimension and security according to EV needs - Batteries and chargers - Standard UNE 61851. EV conductive system
3.E. Micro-Grids
- Resources evaluation and needs - Dimensioning integration systems - Optimizing integration systems - Integration systems control - Cases of study: multi-generation buildings
Learning outcomes

By the end of this subject, students should be able to program and protect smart-grids. Also, the student will get a suitable knowledge on:

- Smart grid concept and development
- Protection system in electrical power systems
- Telecommunication infrastructure in smart grids
- Electric Vehicle
- Microgrids

Engineering design.
Graduates will be able to design engineering solutions to the challenge of programming smart-grids. They will be able to do the complex task of coordinating protective devices for RE, integrate mini and micro generation in distribution grids or plan and optimise primary-secondary distribution systems.

Transferable skills.
Graduates will be able to work effectively as a professional and as team member in the resolution of technical problems related to integration of RE in electric grids. Also, graduates will demonstrate their abilities to communicate effectively in multinational groups.

Module Coordinator	Samuel Borroy Vicente	
Lecturers	Samuel Borroy Vicente Marta Abad López Asier Moltó Llovet Cristina Corchero García Jesús Torres Tenor Marciej Goraj Hans Bludszuweit	
Language	English	
ECTS credits	4.5	
Teaching format / class hours	36 h 10 h 2 h 8 h	Lecture Laboratory Visits Others...(Test, Oral presentation, Tutorials)
Contact hours	56	
Workload	158	
Assessment methods	Exam Subject's work Developed topic presentation	

Literature	• "Power Systems Protection, Power Quality, Substation Automation" 1994, IDC TechBooks. • "IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems" 2001, IEEE Inc. • "Protective Relaying of Power Systems Using Mathematical Morphology" by Q.H. Wu; Z. Lu; T.Y. Ji. 2009, Springer Inc. • "The Art and Science of Protective Relaying" by C.R. Mason. GE Inc. • "Telecommunication—Handbooks, manuals, etc" by P.I. Morreale, K. Terplan. 2000, CRC Press.

ENERGETIC MARKETS (4 ECTS)

6.A. Electric Market

- The electric sector: structures and models
- Cost Benefit analysis of investments in RES
- Electricity markets
- Grid Tariff for distributed generation
- New activities regulation proposals

Learning outcomes

By the end of this subject, students should be able to display a clear understanding of the different laws and economic regulations ruling distributed generation in liberalised electric markets. Also, to identify boundaries and opportunities in those markets. At the completion of this module, the student will:

- Become familiar with the basic rules of electric markets
- Get know the standards for RE
- Know the smart grid installations from the economical point of view

Engineering practice.
Graduates will possess a comprehensive understanding of the structure and regulations of local and international electric markets. The economics of distributed generation systems. The state of the art in standards and regulations ruling distributed generation in liberalised electric markets.

Transferable skills.
Graduates will be able to work effectively as a professional and team member in the resolution of technical problems related to integration of RE in electric grids. Also, graduates will demonstrate their abilities to communicate effectively with the engineering community in national and international contexts.

Transferable skills.
Graduates will be able to work effectively as a professional and as team member in the resolution of technical problems related to integration of RE in electric grids. Also, graduates will demonstrate their abilities to communicate effectively in multinational groups. Demonstrate awareness of the legal issues and responsibilities of the engineering practice.

Module Coordinator	José Mª Yusta Loyo
Lecturers	Alezeia Gonzalez García Miguel Marco Fontdevila Miguel Cañas Carretón Gregorio Fernandez Aznar
Language	English
ECTS credits	4

Teaching format / class hours	30 h 0 h 0 h 8 h	Lecture Laboratory Excursion Others...(Test, Oral presentation, Tutorials)
Contact hours	38	
Workload	102	
Assessment methods	Exam Developed topic presentation	
Literature	• "The Power to Choose: Demand Response in Liberalised Electricity Markets" 2003, OECD/IEA.	