Integration of renewables into the grid

Academic Year: (2020 / 2021) **Review date: 16-12-2020**

Department assigned to the subject: Electrical Engineering Department

Coordinating teacher: RODRIGUEZ AMENEDO, JOSE LUIS

Type: Compulsory ECTS Credits : 6.0

Year : 1 Semester : 2

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Students who study this subject must have previous knowledge of electrical systems, electrical machines and control theory

OBJECTIVES

Students who pass the course will be able to:
CB6 Possess and understand knowledge that provides a basis or opportunity to be original in the development and / or application of ideas, often in a research context
CB7 That students know how to apply the acquired knowledge and their ability to solve problems in new or little-known environments within broader (or multidisciplinary) contexts related to their area of ¿¿study
CB8 That students are capable of integrating knowledge and facing the complexity of formulating judgments based on information that, being incomplete or limited, includes reflections on social and ethical responsibilities linked to the application of their knowledge and judgments
CB9 That students know how to communicate their conclusions and the knowledge and ultimate reasons that support them to specialized and non-specialized audiences in a clear and unambiguous way
CB10 That students possess the learning skills that allow them to continue studying in a way that will be largely self-directed or autonomous.
-Students who pass the subject will be able to:
- Acquire adequate knowledge of Electrical Engineering and areas that have application here.
- To know the technical requirements and the international regulation of connection of the plants of renewable generation in the electrical systems.
- Evaluate the impact of renewable generation on the technical operation of the electrical system and know its real contribution to voltage and frequency control.
- To assimilate the operating principle and the state-of-the-art technology of wind turbines, photovoltaic solar panels and thermoelectric solar plants in relation to their associated electrical systems.
- Know the electronic devices used in flexible AC systems (FACTS) used in the joint operation with renewable sources.
- Analyze the behavior of renewable generation plants in the electrical system in the event of severe disturbances (short circuits, voltage gaps) and their contribution to the stability of the system.
- Know the general criteria and the design of protection systems for renewable energy plants.
- Know the state of the art and modern control techniques to incorporate renewable generation into weak and isolated electrical systems.
- Know how the operation of electrical networks with renewable energies is carried out.
- To know the peculiarities of the electrical systems associated to the marine wind farms.
- Knowledge of the requirements for the integration of renewable energies in the electricity grid and in the electricity markets. (CE10)
- Ability to design the integration of renewable energies in electricity networks and markets. (CE11)
- Supervision of the network integration of renewable energy plants.

DESCRIPTION OF CONTENTS: PROGRAMME

1.- Introduction to the integration of renewable energies in electrical systems
Grid-connected Voltage Source Converters. Operation and control
- Description of the subject
- Topologies
- Modulation techniques
- Operating principles
- Phase-locked loop
- Vector control

- Operating limits

2.- Electrical installations of renewable energy plants
- Low-voltage electrical installations
- Grounding and protection against indirect contacts
- Protection against overloads and over-voltages
- Transformation centre
- Medium voltage network
- Electric substation

3.- Control of variable speed electrical generators
- Vector control of asynchronous generators. Doubly fed asynchronous generators
- Vector control of synchronous generators. Permanent magnets synchronous generators

4.- Grid Codes. International guidelines and requiremets
- Requiremets for generators. ENTSO-E
- REE Operational procedure P.O.12.2

5.- Voltage control
- Fundamentals
- Methods and devices
- Compensation of transmission lines
- Passive compensation elements
- Active compensation elements. SVS
- STATCOM

6.- Fault ride trough capability
- Voltage dips. Definition and classification
- Test devices. Voltage dips generators
- Procedure for verification, validation and testing of voltage dips
- Response of synchronous generators
- Response of fixed speed wind turbines
- Response of variable speed wind turbines
- Solar inverter response
- Voltage dips compensation devices

7.- Frequency control
- Speed regulation of synchronous generators
- Frequency-power regulation
- Participation of renewable generation in frequency stability

8.- Virtual Synchronous Machines
- Inertia emulation
- Grid-forming operation and control of VSC
- Energy managment systems

9.- Grid integration studies I.
- Load flow calculations
- Accessibility of the renewable generation
- Short circuit power
- Case study with PSS/E program

10. Grid Integration studies II.
- Stability in electrical power systems
- Studies of transitory stability. Eligibility criteria
- Case study with PSS/E program

11.- Grid integration studies III.
- Small signal studies
- Models of renewable power plants for grid integration
- Case study with PSS/E program

12. Electrical protections
- Introduction and basic concepts
- Short circuit currents
- Behavior of wind turbine technology in short circuits

- Protection systems
- Impact produced by the penetration of power electronic equipments

13. HVDC transmission systems
- Comparison of HVAC and HVDC transmission systems. Pros and cons
- HVDC-LCC
- HVDC-VSC
- HVDC connection links in the Spanish power system.

14. Offshore wind farms
- AC and DC topologies
- Components and systems

LEARNING ACTIVITIES AND METHODOLOGY

The teaching method will be lectures and presentation of papers by students classes.
The master classes will be taught by professors from the Carlos III University and renowned specialists in the topics covered.
The presentation of work by students consists of a public exhibition proposed by the tutor at the beginning of the subject matter.

ASSESSMENT SYSTEM

The evaluation criteria will be continuous and their weighting will be as follows:
- 1 Supervised work (50%/ final grade)
- Attendance to theory class (15% of the final grade)
- Final Test (35% of the final grade)

If the student does not exceed the minimum note in continuous assessment, he must be submitted to a final extraordinary examination

Extraordinary examination will consist of a public presentation of a topic related with course programme, as well as a written test

% end-of-term-examination:	35
% of continuous assessment (assigments, laboratory, practicals…):	65

BASIC BIBLIOGRAPHY

- N. Jenkins, R. Allan, P. Crossley, D. Kirschen, G. Strbac Embedded Generation, The Institution of Electrical Engineering, 2000
- T. Ackermann (Ed.) Wind Power in Power Systems, Wiley, 2005

ADDITIONAL BIBLIOGRAPHY

- A.J. Wood, B.F. Wollenberg, G.B. Sheblé Power Generation, Operation and Control, Wiley, 2014
- D.S. Kirschen, G. Strbac Fundamentals of Power System Economics, Wiley, 2004
- D.S. kirschen, G. Strbac Fundamentals of Power System Economics, Wiley, 2004
- I.J. Pérez-Arriaga (Ed.) Regulation of the Power Sector, Springer, 2013
- S. Stoft Power System Economics. Designing markets for Electricity, Wiley, 2002