Course Unit	Wind Energy Systems	Field of study	Energy
Master in	Renewable Energy and Energetic Efficiency	School	School of Technology and Management
Academic Year	2023/2024	Year of study	1
Level	2-1	ECTS credits	6.0
Type	Semestral	Semester	2
Code	6793-475-1203-00-23		

Workload (hours)	Contact hours	T	TP	PL	TC	S	E	OT	O
162		30	-	30	-	-	-	-	-

T - Lectures; TP - Lectures and problem-solving; PL - Problem-solving, project or laboratory; TC - Fieldwork; S - Seminar; E - Placement; OT - Tutorial; O - Other

Name(s) of lecturer(s): Alexandra Sofia Rosa Jeronimo, Jose Fernando Lopes Barbosa, Luís Manuel Frolen Ribeiro, Orlando Manuel de Castro Ferreira Soares

Learning outcomes and competences

At the end of the course unit the learner is expected to be able to:
1. Provide methods and analysis tools for wind resources assessments.
2. Master different wind turbines designs.
3. Understand the procedure of generating electricity from mechanical energy.
4. Know the several technological solutions commonly used on wind farms to convert mechanical energy into electricity.
5. Understand the main issues related with wind farms integration on the grid as well as the corresponding conditioning, control and supervision systems.

Prerequisites

Before the course unit the learner is expected to be able to:
1. Understand the fundamentals on the field of Physics Applied to Engineering.
2. Develop applications based on programmable controlers.
3. Develop applications based on SCADA systems.

Course contents

Introduction and the wind resource. Aerodynamics of Horizontal-axis Wind Turbines. Wind-turbine performance. Design loads for horizontal-axis wind turbine. Conceptual design of Horizontal axis wind turbine. Generating electricity from mechanical energy: Technological solutions and power quality. Power conditioning and grid connection. Control and supervision of wind farms power plants.

Course contents (extended version)

1. Introduction and the wind resource:
   - Historical development.
   - Modern wind turbines.
   - Geographical variation in the wind turbine.
   - Long-term wind-speed variations.
   - Annual and seasonal variations.
   - Synoptic and diurnal variations.
   - Turbulence and extreme wind speeds.
   - Wind speed prediction and forecasting.
   - Turbulence in wakes and wind farms.
   - Turbulence in complex terrain.
2. Aerodynamics of Horizontal-axis Wind Turbines:
   - The actuator disc concept.
   - Rotor disc theory.
   - Vortex Cylinder Model of the Actuator Disc.
   - Rotor blade theory.
   - Breakdown of the momentum theory.
   - Blade geometry.
   - The effects of a discrete number of blades.
   - Aerodynamics of a wind turbine in steady yaw.
   - The method of Acceleration potential.
   - Stall delay. Unsteady flow - dynamic inflow.
3. Wind-turbine performance:
   - The performance curves.
   - Constant rotation speed operation.
   - Comparison of measured with theoretical performance.
   - Variable-speed operation.
   - Estimation of energy capture.
   - Wind-turbine field testing.
   - Wind-turbine performance measurement.
   - Analysis of test data.
   - Turbulence effects.
   - Aerodynamic performance assessment.
4. Design loads for horizontal-axis wind turbine:
   - National and International standards.
   - Basis for design loads.
   - Turbulence and wakes.
   - Extreme loads.
   - Fatigue loading.
   - Stationary blade loading; blade loads during operation, blade dynamic response.
   - Blade fatigue stresses.
   - Hub and low-speed shaft loading.
   - Nacelle loading.
   - Tower loading.
5. Conceptual design of Horizontal axis wind turbine:
   - Rotor diameter; machine rating; rotational speed.
   - Variable velocity operation, two velocities or fixed velocity.
   - Tower stiffness, safety, Nacelle access.
   - Blades; pitch controlers.
   - Rotor axis; gear shaft; generator, mechanic break.
   - Yaw rotation.
   - Tower and foundations.
6. Generating electrical energy from mechanical energy:
   - Constrains and demands on generators.
   - Induction machines directly connected to the grid.

Course contents (extended version)

- Double fed induction machines.
- Variable speed synchronous machines.
- Design aspects of both synchronous and asynchronous machines.
- Operation issues of both synchronous and asynchronous machines.
- Machines data.
- Steady state and dynamic torque.

7. Power conditioning and grid connection.
   - Technical solutions exploiting power electronic converters.
   - Functional characteristics of power converters.
   - Design of frequency converter systems.
   - Protective systems concerning power converters.
   - Power quality and its effects on the utility.
   - Generator and grid protection systems.
8. Control and supervision of wind power plants.
   - System requirements and operating modes.
   - Isolated operation of wind power plants.
   - Grid interconnected operation of wind power plants.
   - Main control concepts.
   - Controller design.
   - Management systems.
   - Monitoring and safety systems.

Recommended reading

1. “Wind Energy Handbook”, T. Burton, D. Sharpe, N. Jenkins e E. Bossanyi, John Willey & Sons, 2001
2. "Renewable Energy – Power for a Sustainable Future”, Boyle, G. Oxford University Press, 2004
3. "Grid integration of wind energy conversion systems", Siegfried Heier, John Wiley & Sons, 1998
4. "Embedded Generation", N. Jenkins, R. Allan, P. Crossley, D. Kirchen, G. Strbac, IEE Power and Energy Series, 31, London, 2000

Teaching and learning methods

This course will be based in assignments and the development of 1 project. The students will have to attend theoretical classes to get acquinted and learn the concepts and methodologies underlined in this course.

Assessment methods

1. Assessment distributed throughout the semester - (Regular, Student Worker) (Final, Supplementary, Special)
   - Case Studies - 50%
   - Intermediate Written Test - 50%
2. Wind systems integrated project - (Student Worker) (Final, Supplementary, Special)

Language of instruction

Portuguese, with additional English support for foreign students.

Electronic validation

Alexandra Sofia Rosa Jeronimo, Jose Fernando Lopes Barbosa, Luís Manuel Frolen Ribeiro, Orlando Manuel de Castro Ferreira Soares	João Eduardo Pinto Castro Ribeiro	José Luís Sousa de Magalhaes Lima	Ângela Paula Barbosa da Silva Ferreira	José Carlos Rufino Amaro
01-03-2024	01-03-2024	06-03-2024	12-03-2024	16-03-2024