Wind Energy

Academic Year: (2021 / 2022) **Review date: 11-02-2022**

Department assigned to the subject: Electrical Engineering Department

Coordinating teacher: SANTOS MARTIN, DAVID

Type: Compulsory ECTS Credits : 6.0

Year : 3 Semester : 2

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

All first and second year subjects. Among them, Electrical Power Engineering Fundamentals is of utmost importance. Furthermore, it is desirable to have followed "Electric Power Generation" in the first term of the third year.

OBJECTIVES

Students who successfully complete this course will be able:

- to summarize the history of modern wind turbines justifying the current technology development. Moreover, students should employ the exact components terminology for the most common applications including, large onshore and offshore schemes as well as small wind turbines.

- to compute the basic wind measurement statistics and understand the resource assessment process.

- to understand and use the fundamental physics equations that allow to convert wind energy into mechanical and electrical energy.

- to describe all wind turbines types and justify their main characteristics. Moreover, students should understand the main mathematical models for the most relevant types, with special emphasis on the different control strategies.

- to identify the main wind turbine manufacturers, as well as to properly analyse and compare their technical specifications.

- to understand the main impact from high penetration levels of wind energy, and the main aspects of the grid codes developed to mitigate them.

- to understand results from dedicated software packages that model wind turbines for economic assessment or power systems analysis.

- develop the capacity to work in a team and promote creative team interaction to encourage contribution from all members so as to deliver specific engineering projects and assignments

- to understand the United Nations Sustainable Development Goals (SDG), and in particular SDG 7, which ensures access to affordable, reliable, sustainable and modern energy for all. Meeting this goal means investing in clean energy sources (solar, wind or thermal) and produce improvements in technologies to have clean energy in all developing countries, always from a sustainable approach to the environment.

DESCRIPTION OF CONTENTS: PROGRAMME

1- Introduction
- History of the wind energy development
- Wind energy statitistics
- Current manufacturers and WT models
- Wind power myths

2- Aerodynamics of Wind Turbines
- Wind Speed
- Impact of Friction and Height on Wind Speed

- Air Density
- WT Blades
- Angle of Attack
- Relative Wind Speed
- Pitch Angle
- Coefficient of Performance
- Tip-Speed Ratio
- Blade Power
- Separation of WTs

3- Wind Statistics
- Average Variance and Standard Deviation
- Cumulative Distribution Function
- Probability Density Function
- Weibull Distribution Function
- Rayleigh Distribution Function
- Dependency and Repeatability
- Cross-Correlation

4- Overview of Wind Turbines
- Classification of Wind Turbines
- Alignment of Rotating Axis
- Types of Generators
- Speed of Rotation
- Power Conversion
- Control Actions
- Types of Wind Turbines
- Type 1 Wind Turbine
- Type 2 Wind Turbine
- Type 3 Wind Turbine
- Type 4 Wind Turbine

5- Wind turbine components
- Aerodynamic
- Mechanical
- Generators
- Power electronics

6- Type 1 Wind Turbine System
- Equivalent Circuit for the Squirrel-Cage Induction Generator
- Power Flow
- Electric Torque
- Maximum Power
- Maximum Torque
- Assessment of Type 1 System
- Control and Protection of Type 1 System
- Reactive Power of Type 1 System
- Inrush Current
- Turbine Stability

7- Type 2 Wind Turbine System
- Equivalent Circuit of Type 2 Generator
- Real Power
- Electric Torque
- Assessment of Type 2 System
- Control and Protection of Type 2 System
- Inrush Current
- Turbine Stability

8- Type 3 Wind Turbine System
- Equivalent Circuit
- Simplified Model
- Power Flow
- Apparent Power Flow through rotor side converter
- Apparent Power Flow through stator side converter
- Speed Control
- Protection of Type 3 Systems

- Electrical Protection
- Electromechanical Protection

9- Type 4 Wind Turbine
- Full Converter
- Power Flow
- Real Power Control
- Reactive Power Control
- Protection
- Chopper System
- Dynamic Resistance

10- Grid Integration
- System stability
- Low-Voltage Ride-Through Compliance Techniques
- Variability of the Wind Power Production
- Uncertainty of Wind Speed
- Variability of Wind Power Output
- Wind turbine reactive power control

11- Economics of Wind Energy

LEARNING ACTIVITIES AND METHODOLOGY

The learning methodology consists of:

- lectures covering the most important topics defined in the course program.

- solving problems proposed in quizzes.

- simple problem solving sessions focused on practical situations.

There will be 3 laboratory sessions and will be solved with the use of specific software packages.

ASSESSMENT SYSTEM

ORDINARY CALL (C1): CONTINUOUS EVALUATION (E1) and FINAL EXAM (E2):

- (E1) Continuous evaluation (45% of the total)

- Two exams will compute 45% of the continuous evaluation.
It will consist in solving numerical problems and theory related questions.

- (E2) Final exam (55% of the total grade)
It will consist in solving numerical problems and theory related questions covering the whole content of the course.

C1=0.45*E1+0.55*E2

Note: to be eligeble to pass by the ordinary call (C1) it is mandatory to attend to all the laboratory sessions and have followed at least 10 problem sessions, solving all the problems by the end of the lecture. Furthermore, E2 has to be greater or equal to 3.0/10.

EXTRAORDINARY CALL (C2)

- 100 % of the total record will come from a final exam (E3) that will consist in solving numerical problems and theory related questions covering the whole content of the course.

C2=E3

Note: to be eligible to pass by the extraordinary call (C2) it is mandatory to attend to all the laboratory sessions.

% end-of-term-examination: 55

% of continuous assessment (assigments, laboratory, practicals…): 45

BASIC BIBLIOGRAPHY

- Alois Schaffarczyk (Editor) Understanding Wind Power Technology: Theory, Deployment and Optimisation, Wiley, 2014
- By Mohamed A. El-Sharkawi Wind Energy: An Introduction, CRC Press, 2015
- Gonzalo Abad, Jesus Lopez, Miguel Rodriguez, Luis Marroyo, Grzegorz Iwanski Doubly Fed Induction Machine: Modeling and Control for Wind Energy Generation, Wiley-IEEE Press, 2011
- James F. Manwell, Jon G. McGowan, Anthony L. Rogers Wind Energy Explained: Theory, Design and Application, 2nd Edition, Wiley, 2009
- Olimpo Anaya-Lara, Nick Jenkins, Janaka Ekanayake, Phill Cartwright, Michael Hughes Wind Energy Generation: Modelling and Control, Wiley, 2009
- Thomas Ackermann (Editor) Wind Power in Power Systems, 2nd Edition, Wiley, 2012

ADDITIONAL BIBLIOGRAPHY

- Bin Wu, Yongqiang Lang, Navid Zargari, Samir Kouro Power Conversion and Control of Wind Energy Systems, Wiley, 2011
- Paul A. Lynn Onshore and Offshore Wind Energy An Introduction, Wiley, 2012
- R. Nolan Clark Small Wind - Planning and Building Successful Installations, Elsevier, 2013
- Siegfried Heier Grid Integration of Wind Energy: Onshore and Offshore Conversion Systems, 3rd Edition, Wiley, 2014
- Tony Burton, Nick Jenkins, David Sharpe, Ervin Bossanyi Wind Energy Handbook, 2nd Edition, Wiley, 2011

BASIC ELECTRONIC RESOURCES

- United Nations . Sustainable Development Goals (SDG): https://www.un.org/sustainabledevelopment/