CARLETON UNIVERSITY

Department of Mechanical and Aerospace Engineering

Wind Engineering

(MECH 5206F)

Fall 2021

Instructor: Dr. A. Hemami,
Lecture sessions: Friday 14:35 – 17:25 (Remote, via Zoom or BBB meeting)
Office Hours: Friday, 17:45 - 18:50 (Remote, via Zoom or BBB meeting)

Course Objective

This course is designed to cover the theoretical and practical areas pertinent to the operation of wind turbines. After completing the course, a student is expected to have gained the knowledge to (a) be considered as a wind energy engineer and (b) be prepared to work in any company engaged in designing, manufacturing or utilization of wind turbines and the associated components or in utility companies

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Course Outline: Lectures, 3 hours/week

Session 1: **Introduction & Fundamental**

World energy needs
Importance of renewable energy
Status of wind energy in the world
Wind farms, comparison of a wind farm with a traditional power plant
Air foil, geometry and fundamental aerodynamics
Drag and lift forces on an air foil
Drag and lift coefficients

Session 2: **Wind characteristics**

Energy in the wind, actuator disk theory, Betz limit,
Wind flow variation (minutely, hourly, daily, seasonal)
Wind speed calculations, Wind atlas
Small scale and large scale use of wind energy

Session 3: **Wind turbine basic types and characteristics**

Propeller turbine: Horizontal-Axis Wind Turbine (HAWT),
Darrieus machine, Savonius Rotor: Vertical-Axis Wind Turbine (VAWT)
Variations in basic design, Capabilities of newer industrial turbines

Session 4: **Propeller turbine**

(most common turbine type)
Description of turbine components

Yaw system and blade pitch
Industrial wind turbine classes

Session 5: **Propeller turbine analysis**
Analysis of the forces on a blade
Torque and power
Torque and power coefficients
Turbine characteristic curve
Tip speed ratio (TSR) and blade pitch control

Session 6: **Example of energy yield**
Calculation of daily and yearly energy production
Power curve and how it is constructed
Array loss in wind farms
Other matters influencing the annual production

Session 7: **Fundamental of electricity and 3-phase systems**
DC and AC electricity, voltage, current and power
Power relationships in DC and AC, Active and reactive power in AC, power factor and pf correction definition
3-phase AC electricity, delta and star connection, power relationships

Session 8: **Electric Generators**
Explanation of DC and AC motors and generators
Construction differences of AC generators
Synchronous machines and induction machines
Variation of induction machines
Permanent magnet generators

Session 9: **Wind turbine control**
Protective control, Safe operation, Safe to the neighborhood
Blade pitch control effects
Performance control (speed, productivity, matching to grid)
Power quality control (flawless production)

Session 10: **Modes of operation**
Isolated application and grid connection
Voltage and frequency requirement
Fixed speed operation
Variable speed design
Direct drive turbines
Turbine type classification by wind energy industry
Examples of commercial wind turbines

Session 11: **Mechanical Design**
Variation in tower design
Analysis of loads on blade and tower

Wind turbine gearbox and loads in gearbox
Structure of turbine blades
Sources of vibration
Turbine braking

Session 12: **Wind energy economics**
Initial cost (Turbine manufacturing, transportation, installation and grid connection)
Operating cost (Running cost and maintenance)
Typical breakdown of costs
Comparison with other power plants

Session 13: **Environmental concerns**
Issues related to onshore wind farms
Issues related to offshore wind farms
Noise, shadow flicker, flashing
Effects on birds and marine animals
Effects on radio frequency communication waves

Session 14: **Wind projects assessment**
Wind forecasting for power generation
Introduction to forecasting methods
Uncertainties in power generation calculations
Uncertainty in financial assessment
P50 and P90 and application to wind energy projects risk assessment

Workload: Assignments, project, quiz and exam

Prerequisites: Dynamics, Fluid dynamics, Electric Machinery (or equivalents)

Marking Scheme:

Assignments	10% (8 assignments, electronic submission)
Midterm	20% (1 midterm remote exam, electronic submission)
Quizzes	20% (About 5 quizzes, via CUlearn)
Final exam	35% (remote exam, electronic submission)
Project	15% (Group of 2 people submitting an electronic report)

Project: Each group of 2 students takes a project which implies a complete design and/or investigation of a practical or simulated scenario on one related topic. Example topics are (But not limited to):

(1) Mechanical design of the tower or another component
(2) Design of electrical components (Transformer, generator, etc)
(3) A detailed study of a pertinent topic (design, economics, etc)
(4) A case study of a wind farm installation
(5) Characteristics of various available turbines of a particular category

Course material resources (Texts or reference books):

No particular required book is assigned for the course. Students are expected to take notes. Power points for the course notes will be available to the students through Moodle. Since the course is conducted remotely, lectures are available with prerecorded sound. A number of books are recommended as references for the course material. The lectures are not necessarily in the same sequence as any book in the references.

References: (Alphabetical)

Wind Power Plants, Fundamentals, Design, Construction and Operation
By R Gasch and J. Twele, 2002

Wind Turbines Fundamentals, Technologies, Application, Economics,
By Erich Hau, 2000, Springer

Wind Turbine Technology
By Ahmad Hemami, 2012, ISBN 1435486463, Cengage Learning

Wind Energy Engineering
By Pramid Jain, 2011, ISBN 978-0-07-171477-8, McGraw-Hill

Wind Energy Explained: Theory, Design and Application
By J. F. Manwell, J. G. McGowan, A. L. Rogers, Second edition, 2008
ISBN: 0-471-49972-2

Notes:

To pass the course one must get:
a) a passing mark
b) at least 50% from each component of the course (assignments, quizzes, midterm, final, project)

The relationship between marks and letter grades is based on the university standards
Participation in the course is necessary

Note: This year the course is remotely and through internet. You need to be sure about the sufficiency and reliability of your hardware, software and the internet accessibility for all lectures, quizzes, midterm and final exam.

“Academic Accommodation

You may need special arrangements to meet your academic obligations during the term. For an accommodation request the processes are as follows:

Pregnancy obligation: write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details see the Student Guide (http://www2.carleton.ca/equity/accommodation/academic/students/).

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Academic Accommodations for Students with Disabilities: The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 orpmc@carleton.ca for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send me your Letter of Accommodation at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, meet with me to ensure accommodation arrangements are made. Please consult the PMC website for the deadline to request accommodations for the formally-scheduled exam (if applicable).”