FLORIDA ATLANTIC UNIVERSITY™

Graduate Programs—NEW COURSE PROPOSAL[1]

UGPC APPROVAL ______
UFS APPROVAL ______
SCNS SUBMITTAL ______
CONFIRMED ______
BANNER POSTED ______
CATALOG ______

DEPARTMENT: Department of Ocean and Mechanical Engineering

COLLEGE: ENGINEERING AND COMPUTER SCIENCE

RECOMMENDED COURSE IDENTIFICATION:

PREFIX EML **COURSE NUMBER** 6456 **LAB CODE** (L or C) N/A

(*TO OBTAIN A COURSE NUMBER, CONTACT* MJENNING@FAU.EDU)

COMPLETE COURSE TITLE:

Wind Turbine Systems

EFFECTIVE DATE

(first term course will be offered)

FALL 2017

CREDITS[2]: 3

TEXTBOOK INFORMATION:
Wind Energy Explained, Theory, Design and Application, J. F. Manwell, J. G. McGowan and A. L. Rogers, John Wiley, 2e, 2009.

GRADING (*SELECT ONLY ONE GRADING OPTION*): **REGULAR** YES **SATISFACTORY/UNSATISFACTORY** ______

COURSE DESCRIPTION, NO MORE THAN THREE LINES:

This course thoroughly reviews wind turbine systems and practical means of harnessing green energy. The coverage includes: wind turbine technology, power rating and efficiency, blade-hub-nacelle-tower system, wind data analysis, turbulence and rotational sampling, rotor aerodynamics, control systems, economics and environmental aspects.

PREREQUISITES *:	COREQUISITES*:	REGISTRATION CONTROLS (MAJOR, COLLEGE, LEVEL)*:
Graduate Standing or UG w/ Dynamics, Fluid Mechanics & Computer Application I or equivalent	NONE	MAJOR

* *PREREQUISITES, COREQUISITES AND REGISTRATION CONTROLS WILL BE ENFORCED FOR ALL COURSE SECTIONS.*

MINIMUM QUALIFICATIONS NEEDED TO TEACH THIS COURSE:

Faculty contact, email and complete phone number:

Dr. Gopal Gaonkar, PE, Professor

Office Address:
Engineering West (EG-36), Room 103

Telephone Number: (561)297-3417
Email Address: gaonkar@fau.edu

Please consult and list departments that might be affected by the new course and attach comments.[3]

This course doesn't not affect any other department.

Approved by:	*Date:*	1. **Syllabus** must be attached; see guidelines for requirements: www.fau.edu/provost/files/course syllabus.2011.pdf
Department Chair: [signature]	1/6/15	
College Curriculum Chair: [signature]	9/16/16	
College Dean: [signature]		2. Review **Provost Memorandum: Definition of a Credit Hour** www.fau.edu/provost/files/Definition_Credit_Hour_Memo_2012.pdf
UGPC Chair:		
Graduate College Dean:		
UFS President:		3. **Consent** from affected departments (attach if necessary)
Provost:		

Email this form and syllabus to UGPC@fau.edu **one week before** the University Graduate Programs Committee meeting so that materials may be viewed on the UGPC website prior to the meeting.

1. Course title/number, number of credit hours	
EML 6456 Wind Turbine Systems	**3 Credit Hours**

2. Course prerequisites, co-requisites, and where the course fits in the program of study

Prerequisite: Graduate Standing or UG w/ Dynamics, Fluid Mechanics & Computer Application I or equivalent

3. Course logistics

Class hours: TBA

For students in online sections, homeworks, projects and term papers are administered through Blackboard and tests are administered through the Division of Engineering Student Services office. The course contains about eight HWs and two projects as well as two tests and one term paper. The course does not have laboratory experiments. This is a classroom lecture course; it has no design content.

4. Instructor(s) contact information

Name: Office Address: Office Hours: Telephone Number: Email Address:	Dr. Gopal Gaonkar Engineering West (EG-36), Room 103 M, W, Fr : 4:00-6:00 pm, (561)297-3417 gaonkar@fau.edu

5. TA contact information

Name: Office Address: Office Hours: Telephone Number: Email Address:	TBA

6. Course description

A comprehensive introduction to wind turbine systems and practical means of extracting green energy. The course begins with a historical perspective and taxonomy such as horizontal axis and vertical axis wind turbines and the basic parameters such as power rating and efficiency, describes the structural components ranging from blade and hub to nacelle and tower. This is followed by a treatment of wind data analysis and turbulence, rotor aerodynamics, rotor and hub and tower dynamics, and wind turbine control, as well as economics and environmental aspects.

7. Course objectives/student learning outcomes/program outcomes	
Course objectives:	The course is designed to introduce the students to the behavior of wind turbine systems subjected to deterministic and stochastic wind loading. They will also evaluate economics of wind energy systems and their environmental aspects and impacts.
Student learning outcomes & relationship to ABET a-k objectives:	1. The students will be able to analyze and compute the deterministic and stochastic wind loading on wind turbine systems. 2. The students will be able to develop physical understanding of how wind turbine systems respond to wind loading and control inputs. 3. The students will be able to judge the economics and environmental aspects of wind energy systems.
8. Course evaluation method	
Homeworks & Projects Midterm Exam Term Paper Final Exam	**25%** **25%** **25%** **25%**

9. Course grading scale:

Above 90% = A- to A; Between 80% and 90% = B- to B+; Between 70% and 79% = C- to C+; Between 60% and 69% = D- to D+; Below 60% = F (+ Grade will be given if the score is at the higher end. For example, a score from 74 to 76 will be given C grade, a score from 70 to 73 will be given C-, and from 77 to 79 will be C+).

10. Policy on makeup tests, late work, and incompletes:

Late Submission will be accepted only if there is a valid reason (medical, family emergency etc.) that prevented the student from doing HWs, projects and a term paper and from taking the tests. Similarly, an incomplete grade will be considered if the student has compelling reasons for not being able to complete the course requirements. An "I" will not be given to a student failing the course.

11. Special course requirements:

N/A

12. Classroom etiquette policy

University policy requires that in order to enhance and maintain a productive atmosphere for education, personal communication devices, such as cellular phones and laptops, are to be disabled in class sessions.

13. Disability policy statement

In compliance with the Americans with Disabilities Act (ADA), students who require special accommodations due to a disability to properly execute coursework must register with the Student Accessibility Services (SAS) located in Boca Raton campus, SU 133 (561) 297-3880 and follow all SAS procedures.

14. Honor code policy

Students at Florida Atlantic University are expected to maintain the highest ethical standards. Academic dishonesty is considered a serious breach of these ethical standards, because it interferes with the university mission to provide a high quality education in which no student enjoys unfair advantage over any other. Academic dishonesty is also destructive of the university community, which is grounded in a system of mutual trust and which places high value on personal integrity and individual responsibility. Harsh penalties are associated with academic dishonesty. See University Regulation 4.001 at www.fau.edu/regulations/chapter4/4.001_Code_of_Academic_Integrity.pdf

15. Required texts/reading

1. Lecture notes;
2. Wind Energy Explained, Theory, Design and Application, J. F. Manwell, J. G. McGowan and A. L. Rogers, John Wiley, 2e, 2009.

16. Supplementary/recommended readings

1. Characteristics of the Wind, Walter Frost and Carl Aspliden, Chapter 8, Wind Turbine Technology, ASME Press, Second Edition, pp. 371-443, 2009.
2. Principles of Sustainable Energy Systems, Chapters 1 and 3, Frank Kreith, CRC Press, Second Edition, 2014, pp. 1-80 and 135-195.

17. Course topical outline, including dates for exams/quizzes, papers, completion of reading

Course Topics:

Week 1: Introduction and Requisites
Wind energy and the world of sustainable energy systems, key sustainability considerations, renewable energy systems, historical perspective and re-emergence of wind energy, modern (horizontal-axis) wind turbine, other wind turbine concepts, wind mills and wind turbines, technological underpinnings of modern wind turbines, power output prediction (cut-in speed, cut-out speed, rated wind speed and power curve), dimensions and units of energy measurement, gamma functions & elements of probability and statistics. (This course primarily addresses Horizontal Axis Wind Turbines (HAWT)).

Week 2: Wind Characteristics and Resources
The atmospheric boundary layer (ABL), mechanics of wind motion, variations in time, estimation of potential wind resource, stability of ABL, introduction to turbulence (mean flow and intensity), wind speed probability density functions, autocorrelation and power spectral density functions, wind variation with height and power law.

Week 3: Wind Data Analysis and Resource Estimation
Available wind power, general aspects of wind turbine energy production, direct use of data, statistical analysis of wind data, Rayleigh and Weibull distributions, extreme wind speeds and Gamma distribution, method of bins for wind data distribution and power prediction.

Week 4: Energy Production Estimates from Statistical Technique
Capacity factor, power coefficient and tip speed ratio, average wind turbine power, idealized turbine power production using Rayleigh and Weibull distributions, Betz factor.

Week 5: Wind Turbine Aerodynamics
General overview, momentum (actuator-disk) theory and Betz limit, thrust coefficient, Betz turbine and its operating parameters, axial induction factor, momentum theory with axial rotation, turbine airfoils, angle of attack, lift force, drag force and pitching moment, Reynolds number, circulation, momentum and blade-element theory, blade geometry for a horizontal axis wind turbine and tip loss factor.

Week 6: Unsteady and Non-linear Aerodynamics Effects
Static and dynamic stall, Dynamic stall models: Laishnon-Beddoes, and ONERA dynamic stall models, the method of acceleration potential and Pitt-Peters dynamic inflow modeling.

Week 7: Turbulence Loading on Wind Turbines
Nature of turbulence, concept of mean flow and intensity, homogeneous isotropic turbulence (HIT), frozen turbulence hypothesis, rotational sampling and turbulence seen by a hub element and a blade element, experimental validation of HIT with frozen turbulence hypothesis and rotational sampling, von Karman and Kaimal spectra, length scales, von Karman-Howarth equation, cross-spectra and coherence functions.

Week 8: Wind Turbine Dynamics
Type of Wind turbine loads: Steady (static and rotating), cyclic, transient and stochastic, resonance-induced loads, gyroscopic loads, coordinate systems, blade flapping equations of motion, multiblade coordinates, blade and hub loads, tower loads, tower vibration and flap-lag equations of motion.

Week 9: Fatigue in Wind Turbines
Fatigue assessment, fatigue life characterization, (S-N Curve), alternating stresses with non-zero mean, Goodman diagram, modeling fatigue damage: cumulative damage (Palmgren-Miner rule), random load cycles and rainflow cycle counting method.

Week 10: Wind Turbine Control
Type of control systems, overview of wind turbine control systems, controlling processes in wind turbines, wind turbine sensors and actuators, wind turbine controllers, aerodynamic turbine control, yaw orientation control, stall regulated and active pitch-regulated turbines, control issues specific to wind turbines, elements of open-loop and closed-loop response to disturbances.

Week 11: Wind Turbine Siting
Introduction to onshore and offshore wind farms, general overview of wind turbine siting, related issues: economics, topography, legal aspects, permits, foundation and ground resistance, environment, public acceptance, safety and grid-connection. Wind farm infrastructures, roads, control and monitoring and data-collection systems, downwind and crosswind spacing, array losses, frequency distribution of wind directions, wake modeling, elements of wake turbulence, wind farm power curves, and power smoothing.

Week 12: Wind Turbine Design and Testing
Design procedures, previous experience, Selection of topology, preliminary load estimation, performance prediction, estimate costs and cost of energy, refine design, rotor power control, upwind and downwind positions, free or active yaw control, constant or variable rotor speed, tip speed ratio and solidity, hub design, number of blades, generator speed, design constants, wind turbine standards, technical specifications and certifications.

Week 13: Wind Energy System Economics
Life time, present cost, future cost, learning curves to predict capital costs, market value of wind energy, simple payback period analysis, life cycle costing methods, time value of money and present worth factor, life cycle costing analysis, levelized cost of energy, wind energy market considerations, incentivize to wind energy development.

Week 14: Environmental Aspects and Impacts
Avian/Bat interaction, and case studies, visual impacts, visual impact mitigation design strategies for US sites, noise and sound fundamentals, noise mechanism of wind turbines, mechanical noise, noise prediction for simple and multiple wind turbines, noise propagation, noise reduction methods for wind turbines, electromagnetic interference effects, other environmental considerations such as blade throw and fire hazards, impact on flora and fauna and mitigation measures

- Approximately **8 HWs and two projects** are based on topics from each of **chapters 1-4 and 6-12** of the text book; they will be assigned weekly/bi-weekly on Blackboard after the coverage of the respective topics in class.

- The students are allowed to use the hard-copy of their textbooks and NCEES approved calculators in the examinations.

Dates of exams, home works, projects and term paper:

Midterm Exam:	TBA
Homeworks and Projects:	TBA
Term paper:	TBA
Final Exam	Follow university final examination calendar.