GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Control and Automation in Wind Energy Systems , PG_00066994		
Field of study	Smart Renewable Energy Engineering		
Date of commencement of studies	October 2025	Academic year of realisation of subject	2026/2027
Education level	second-cycle studies	Subject group	Specialty subject group Subject group related to scientific research in the field of study
Mode of study	Full-time studies	Mode of delivery	at the university
Year of study	2	Language of instruction	English
Semester of study	4	ECTS credits	3.0
Learning profile	general academic profile	Assessment form	assessment
Conducting unit	Division of Automation and Marine Energy -> Institute of Naval Architecture -> Faculty of Mechanical Engineering and Ship Technology -> Wydziały Politechniki Gdańskiej		
Name and surname of lecturer (lecturers)	Subject supervisor	dr inż. Mohammad Ghaemi	
	Teachers		

Lesson types and methods of instruction

Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
Number of study hours	15.0	15.0	15.0	0.0	0.0	45
E-learning hours included: 0.0						

Learning activity and number of study hours

Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
Number of study hours	45	7.0	23.0	75

Subject objectives

This course aims to provide students with an advanced understanding of control and automation principles in modern wind energy systems, covering mechanical, hydraulic, and electrical components, as well as integrated management at the farm level. Students will learn how to design, analyze, and implement reliable and efficient control solutions, applying cutting-edge methods to real-world wind power applications

Learning outcomes

Course outcome	Subject outcome	Method of verification
[K7_W02] knows and understands the challenges of effectively integrating decentralized renewable energy generation into the power grid, including energy storage issues, and is particularly familiar with technologies used in wind power	Knows and understands the technologies used in wind energy and the key interactions within automation and control systems in onshore and offshore wind power plants, particularly the relationships between the turbine, generator, control loops, and environmental conditions.	[SW1] Assessment of factual knowledge
[K7_K101] acknowledges the importance of knowledge related to the field of study in solving cognitive and practical problems, critically assessing the information obtained	Can recognise the importance of knowledge in automation and control in wind power plants for solving technical and engineering problems, and critically analyses information related to control algorithms, dynamic modelling, and integration of wind turbine system components.	[SK2] Assessment of progress of work
[K7_U02] is capable of creating and analyzing digital models of renewable energy systems, including wind power systems, and utilizes digital tools for project analysis, evaluation, supervision, and optimization	Can create and analyse digital models of wind turbines and their control systems, using simulation and digital tools to evaluate performance, monitor operation, and optimise automation systems in wind power plants.	[SU5] Assessment of ability to present the results of task
[K7_W101] is able to make an in-depth identification of key objects and phenomena related to the field of study, as well as theories that describe them and applicable analytical and design methods	Identifies the key components of wind energy systems, such as turbines, generators, and control systems, and the relevant theories and applicable methods for their modelling, analysis, and design of automation systems.	[SW1] Assessment of factual knowledge

Subject contents	1. Introduction and Course Framework • Overview of grading and formal details • Purpose of wind turbine control (objectives, scope) • Key definitions and abbreviations 2. Fundamentals of Wind Turbines - Modelling and Dynamics of the Wind Turbine • Aerodynamics overview: Betz limit, power coefficient, torque coefficient • Wind characteristics: average wind speed, turbulence intensity, normal vs. extreme wind conditions • Kinematics and kinetics of the WT (forces, moments, energy flow) • Wind as a stochastic process: spectral density, turbulence modeling • Multimass (e.g., twomass) transmission models for mechanical drive trains • Influence of waves (for offshore/floating WTs) 3. Generators and Power Electronics • Comparison of synchronous vs. asynchronous (induction) generators • Control Systems for Generators in Wind Power Plants • Fixedspeed vs. variablespeed operation • Typical converter topologies: doublyfed induction generator (DFIG), fullscale converters, rotor resistance control • State Variable Estimation Methods in Wind Power Plants • Efficiency considerations and IEC turbine classes • Meeting grid requirements (voltage/frequency support) 4. Core Control Methods and Strategies • Passive vs. active methods (stall regulation, pitch control, yaw control) • Maximum Power Point Tracking (MPPT) at partial load • Power and rotationalspeed regulation (examples for asynchronous/synchronous setups) • Power limitation/curtailment at higher wind speeds • Loadreduction strategies (fatigue, towervibration damping) 5. Detailed Control System Structures and Approaches • Block diagrams of typical WT regulators • Pitch system control loops (bladeangle control) • Yaw control (orientation to the wind) • Generatorside controls (speed, torque, power factor, reactive power) • Examples of supervisory and subordinate regulators (e.g., speed, power, pitch) • Adaptive control (online parameter estimation, reference models) • Robust (H) control strategies for parameter uncertainties • LinearQuadratic (LQR/LQG) methods • Integration with floating windturbine platforms (additional degrees of freedom) 6. Monitoring, Safety, and Integration • Safety systems, emergency shutdown, UPS for critical components • Condition Monitoring Systems (CMS): detecting wear or faults, adjusting operation • SCADA systems and remote monitoring control aspects • Communication tools and protocols (Modbus, OPC, Ethernet, MQTT, etc.), integration with broader power/industrial networks • Data acquisition, alarm handling, event logging • Cybersecurity of control systems 7. Additional and Practical Notes • Balancing efficiency, reliability, and structural loads • Future directions: floating WTs, advanced control algorithms, deeper integration with energy systems, hybrid systems, • Economic aspects, market review -------------- **Excercises & Tutorials:** • Simulation Modeling of a Wind Power Plant: 1. Modeling, simulation and Analysis of Wind Turbine and its Control Systems 2. Analysis of Dynamic Properties and Natural Vibrations 3. Implementation and Testing of Generator State Variable Estimation Systems 4. Multiscalar Control of Asynchronous Generators 5. Field-Oriented Control (FOC) in Asynchronous and Synchronous Generators -------------- **Laboratory:** 1. Measurement of Wind Turbine and Fan Characteristics 2. Implementation of an MPPT Control System in a Microprocessor Controller 3. Testing of Multiscalar Control System for an Asynchronous Generator 4. Testing of Field-Oriented Control System for an Asynchronous Generator 5. Testing of Control System for a Synchronous Generator 6. Experimental Analysis of Wind Energy Resources 7. Implementation and Testing of a State Variable Observer for a Generator 8. Implementation of PID Controller Structures in a Generator Control System

<table>
<tr><td>Prerequisites
and co-requisites</td><td colspan="2">• Fundamentals of automation (at the undergraduate/engineering level, e.g. in the field of Power Engineering)
• Fundamentals of electrical engineering and electronics (at the undergraduate/engineering level, e.g. in the field of Power Engineering)</td></tr>
<tr><td>Assessment methods
and criteria</td><td colspan="2">

Subject passing criteria	Passing threshold	Percentage of the final grade
Lab. report (Laboratory)	50.0%	33.0%
Test (Exercises)	50.0%	33.0%
Test (Lecture)	50.0%	34.0%

</td></tr>
<tr><td rowspan="3">Recommended reading</td><td>Basic literature</td><td>1. Bianchi F. D., De Battista H., Mantz R. J., Wind turbine control systems - principles, modelling and gain scheduling design, ISBN-10: 1-84628-492-9, Springer-Verlag London Limited, 2007.
2. Krzemiński Z.: Digital Control of Asynchronous Machines, Gdańsk, PG Publishing House, 2003.</td></tr>
<tr><td>Supplementary literature</td><td>1. Orłowska-Kowalska T.: Sensorless Drive Systems with Asynchronous Machines, Wrocław University of Technology Publishing House, 2005.
2. Kołodziejek P. Transient States of the Multiscalar Controlled Double Fed Induction Generator in the Wind Farm, IEEE International Conference on Machine Learning and Applications, Honolua, USA 2011</td></tr>
<tr><td>eResources addresses</td><td></td></tr>
<tr><td>Example issues/
example questions/
tasks being completed</td><td colspan="2">1. What are the primary control objectives in modern wind turbine systems?
2. Define and explain the importance of the Betz limit in wind turbine aerodynamics.
3. How does turbulence intensity influence wind turbine control strategies?
4. Explain the difference between normal and extreme wind conditions and how each affects turbine operation.
5. Describe the kinematics and energy flow in a horizontal-axis wind turbine.
6. What is the role of a two-mass model in wind turbine drivetrain analysis?
7. How are wind characteristics modeled as a stochastic process in control design?
8. What impact do ocean waves have on the dynamics of offshore or floating wind turbines?
9. Compare the advantages and limitations of synchronous and asynchronous generators in wind energy applications.
10. Describe the function of power electronic converters in variable-speed wind turbine systems.
11. What are the main differences between DFIG and full-scale converter topologies?
12. Explain how state variable estimation is used in generator control.
13. What challenges arise when meeting grid requirements such as voltage and frequency regulation?
14. Distinguish between passive and active power regulation methods in wind turbines.
15. Describe how Maximum Power Point Tracking (MPPT) is achieved in partial-load conditions.
16. How does a wind turbine regulate rotational speed and output power at high wind speeds?
17. What are the main load-reduction strategies in modern turbine control systems?
18. Sketch and explain the block diagram of a typical pitch control loop.
19. How does yaw control contribute to optimizing turbine performance?
20. Explain the principle of field-oriented control (FOC) in asynchronous generator regulation.
21. Describe the function of a supervisory controller in a wind turbine control hierarchy.
22. What are the advantages of using adaptive control techniques in wind turbine systems?
23. How can robust control (e.g., H control) be applied to deal with parameter uncertainties?
24. What role do LQR or LQG methods play in optimizing turbine performance?
25. How do control strategies differ when applied to floating wind turbines with additional degrees of freedom?
26. Describe the architecture of a wind turbines safety and emergency shutdown system.
27. What is the role of a Condition Monitoring System (CMS) in maintaining turbine reliability?
28. How do SCADA systems contribute to remote wind farm control and optimization?
29. Which communication protocols are commonly used in wind turbine control networks, and why is cybersecurity essential?
30. Describe the implementation process of an MPPT algorithm in a microprocessor-based control system during laboratory testing.</td></tr>
<tr><td>Work placement</td><td colspan="2">Not applicable</td></tr>
</table>