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Fundamentals of wind power, rotor design, and wind park planning

COURSE DESCRIPTION

Fundamentals of Wind Power, Rotor Design, and Wind Park Planning

BACKGROUND – RELEVANCE

The accelerating global shift toward decarbonization places wind energy at the forefront of renewable power generation. With increasing demand for sustainable, scalable, and efficient energy sources, wind turbines have become a pivotal technology.
This course provides a structured path from foundational concepts in atmospheric dynamics and rotor aerodynamics to advanced wind park planning using simulation tools such as windPRO. Understanding wind behavior, rotor blade optimization, and site evaluation is essential for engineers involved in planning and implementing wind energy systems that meet performance, safety, and regulatory requirements. The course combines theoretical foundations with applied skills to prepare students for careers in wind energy engineering, rotor design, and simulation-based wind park development.

ABSTRACT

This course delivers a comprehensive overview of wind energy systems, spanning wind formation, rotor blade dynamics, and wind park layout. It begins with the physics of wind generation and power extraction, including Betz Law and the Weibull distribution. Students' progress through advanced topics in rotor blade design, aerodynamic forces, and structural mechanics using Blade Element Theory. The course culminates in practical wind park design using windPRO, incorporating wind resource analysis, noise and shadow impact simulations, and energy yield calculations. Interactive materials including video lectures, self-assessments, and simulation tasks ensure both theoretical grounding and practical competence. By the end of the course, participants will have a deep understanding of how power electronics facilitate the efficient harvesting and utilization of solar and wind energy, positioning them to contribute effectively to the advancement of sustainable energy technologies.

KEYWORDS - HASTAGS

WindEnergy, WindPower, RotorBladeDesign, BladeElementTheory, WeibullDistribution, WindAtlas, WindParkPlanning, windPRO, SimulationTools, RenewableEnergy, TurbineLayout, EnergyYield

AUTHOR

Prof. Dr. habil. Ingo Stadler

ingo.stadler@th-koeln.de

Institute of Electrical Power Engineering (IET)

Faculty of Information, Media and Electrical Engineering

AUTHOR

Mozaher Patwary, M.Sc.

mozaher.patwary@th-koeln.de

Institute of Electrical Power Engineering (IET)

Faculty of Information, Media and Electrical Engineering

FOCUS ON …	Knowledge	Application		Implementation	
CDIO		Conceive	Design	Implement	Operate
DIFFICULTY LEVEL	Basic	Intermediate		Advanced	
EQF LEVEL	6	CREDITS	3 ECT	HOURS Soft-ware	88h windPro (will be pro-vided)

LEARNING OUTCOMES

By the end of this course, students will be able to:

- Describe atmospheric circulation systems and wind resource modeling.
- Apply Betz Law and Impulse Theory to calculate theoretical wind power limits.
- Use Weibull distribution and wind profile equations for wind speed estimation.
- Understand aerodynamic principles of rotor blades and apply Blade Element Theory.
- Analyze structural and design considerations of rotor blades.
- Use windPRO to perform site assessment, simulate energy yield, and optimize turbine layout.
- Evaluate noise and shadow impacts in compliance with environmental regulations.

PRIOR KNOWLEDGE REQUIRED

1. Basic physics and fluid mechanics
2. Mathematics (algebra, calculus, statistics)
3. Fundamentals of renewable energy systems

	theoretical part/simulations/exercises	Hands on part
ORGANISER	TH Köln, Prof. Ingo Stadler, Mozaher Patwary	TH Köln, Prof. Ingo Stadler , Mozaher Patwary
ERASMUS: Blended Intensive program (BIP)	This course is one out of two alternative focal points (besides a. Power Electronics for Photovoltaic- and Wind Energy Systems) within the Blended Intensive Programme "Grid-Integration of Renewables" Titel of the BIPs: Grid-Integration of Renewables BIP-ID: 2024-1-DE01-KA131-HED-000214080-2	
WHEN	Start Sept. 29th 2025 until Feb 7th 2025 It is intended that the blended phase before the hands on part is much more intense compared to the phase afterwards.	Nov 24th-28th 2025
WHERE	Flipped classroom + offline	TH Köln Campus Deutz Laboratory for Wind Power Germany
COURSE MATERIAL	available end of September in www.Xdemia.com	available end of October in www.Xdemia.com
MAX ATTENDEES	12	12
REGISTRATION	Both following points mut be fulfilled: 1. **At the home university** applicants contact both the P4ELECS contact persons and the international office. Formulate your wish to participate in the BIP: "Grid-Integration of Renewables, BIP-ID: 2024-1-DE01-KA131-HED-000214080-2" accordingly and also request support for travel expenses. Follow the instructions of your home university. 2. Contact **Prof. C. Dick (Christian.dick@th-koeln.de) at TH Köln** and name the focus topic you would like to complete in Cologne, i.e. : a. Power Electronics for Photovoltaic- and Wind Energy Systems b. Fundamentals of Wind Power, Rotor Design, and Wind Park Planning Stay in close contact and inform Prof. Dick on any changes to plans. Please indicate if you would be ready to change the focus topic.	
EVALUATION	E-Assessment, Short report	
CONTACT PERSON	Mozaher Patwary (mozaher.patwary@th-koeln.de)	

COURSE PROGRAM			
	Calendar Week	**LOCATION**	**TOPIC**
1	**Fri 3/10/2025 1PM – 2.30PM**	online	Introduction and overview
2	W41/2025	Interactive Recorded Lecture	Introduction of Wind Power - Wind Systems, Power of Wind, Betz Impulse Theory
3	w42/2025	Interactive Recorded Lecture	Introduction of Wind Power : Weibull Distribution, Height Dependence of Wind Velocity, European Wind Atlas
4	w43/2025		self-studying and repetition (Q & A)
5	w44/2025	Interactive Recorded Lecture	Rotor : Rotor Blades, Blade Element Theory, Comparison with airplane wings, Velocities and Forces at Rotor Blades
6	w45/2025	Interactive Recorded Lecture	Rotor: Blade Design, Rotor Blade Number, Rotor Blade Construction
7	w46/2025		self-studying and repetition (Q & A)
8	Mon 24/11/25	TH Köln	Wind Park Planning – Introduction to the windPro software
9	Tue 25/11/25	TH Köln	windPro – noise emissions simulation
10	Wed 26/11/25	TH Köln	windPro – shading conditions simulation
11	Thu 27/11/25	TH Köln	windPro - Energy yield Calculation
12	Fri 8/11/25	TH Köln	E-Assessment and Short Report