Teaching materials
Guide notes 1. Wind Turbine Performance

MISCE project

Mechatronics for Improving and Standardizing Competences in Engineering

Competence: Wind Energy

Workgroup: Universidad de Castilla-La Mancha

Universitat Politècnica de València

This document corresponds to the first practice lecture for the competence ‘Wind Energy’ using the ‘Wind Turbine platform’

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1 Objective

The main objective of this lesson is to experimentally check the influence of the nacelle orientation over the energy production.

Other parameters as angle of attack will remain constant during this practice lecture.

2 Preliminaries

In wind energy systems, the orientation difference between the wind direction and the nacelle (the housing that contains the turbine's key components) is a critical factor affecting performance. For optimal energy production, the nacelle must be aligned as closely as possible with the incoming wind direction. Misalignment, known as yaw error, can significantly reduce the aerodynamic efficiency of the turbine blades, leading to lower power output. Therefore, accurate and responsive yaw control systems are essential to ensure the nacelle continuously adjusts to changes in wind direction, maximizing energy capture and improving overall system efficiency.

On the other hand, the angle of attack of a wind turbine blade is the angle between the blade's chord line and the relative wind flow—and it's absolutely vital for turbine performance. At the optimum angle of attack, lift forces are maximized while drag is minimized, enabling the turbine to convert wind energy into rotational power with high efficiency. If the angle strays too far—especially increasing beyond its critical stall angle—lift sharply drops and drag surges, significantly reducing power output and potentially stressing the structure.

Modern turbines actively control this angle via pitch (twisting) mechanisms that adjust blade orientation in real time, adapting to changing wind speeds and operating conditions. This dynamic control not only maximizes energy capture but also limits harmful loads, preventing stalling and reducing fatigue on the blades—extending their lifespan and reliability. Without precise angle-of-attack management, turbines would operate well below their aerodynamic potential, leading to lower energy yield and inefficiencies across the system.

Let's assume that φ_{wn} is the angle between the wind direction and the nacelle orientation as shown in Figure 1 and θ_a as the angle of attack of the wings as in Figure 2.

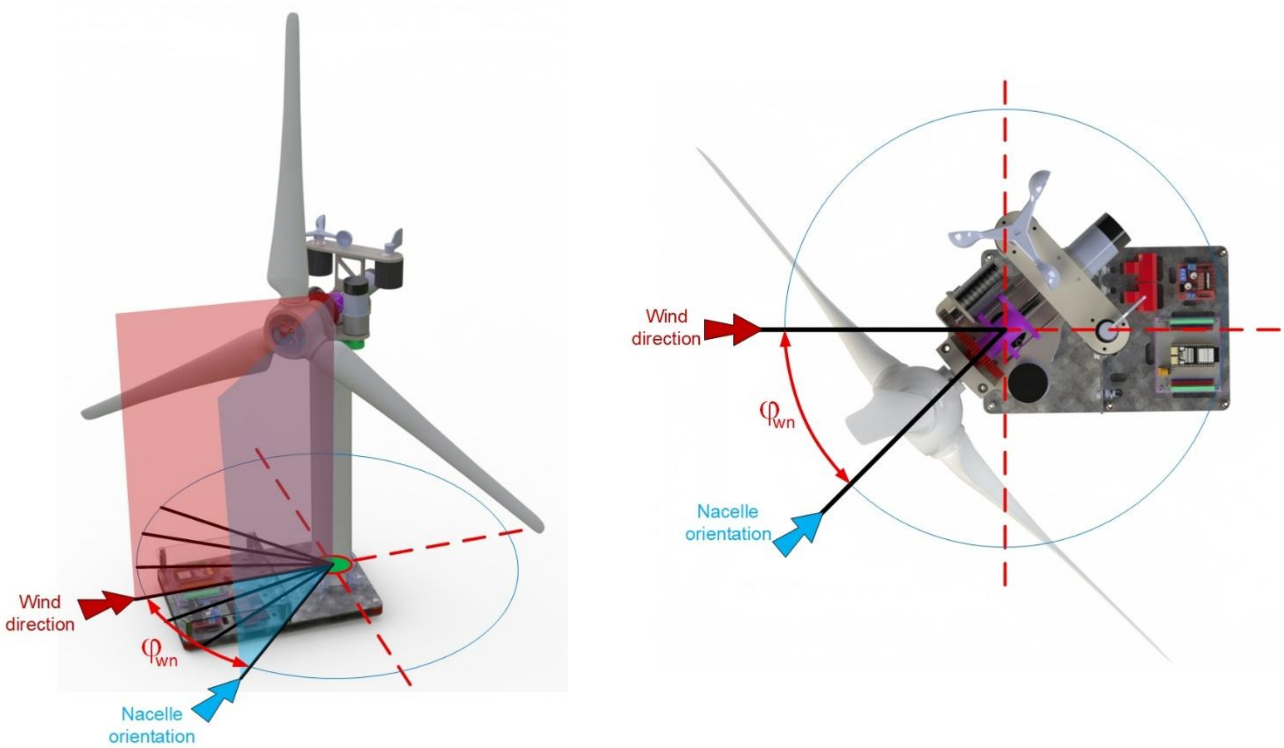

Figure 1. Nacelle orientation.

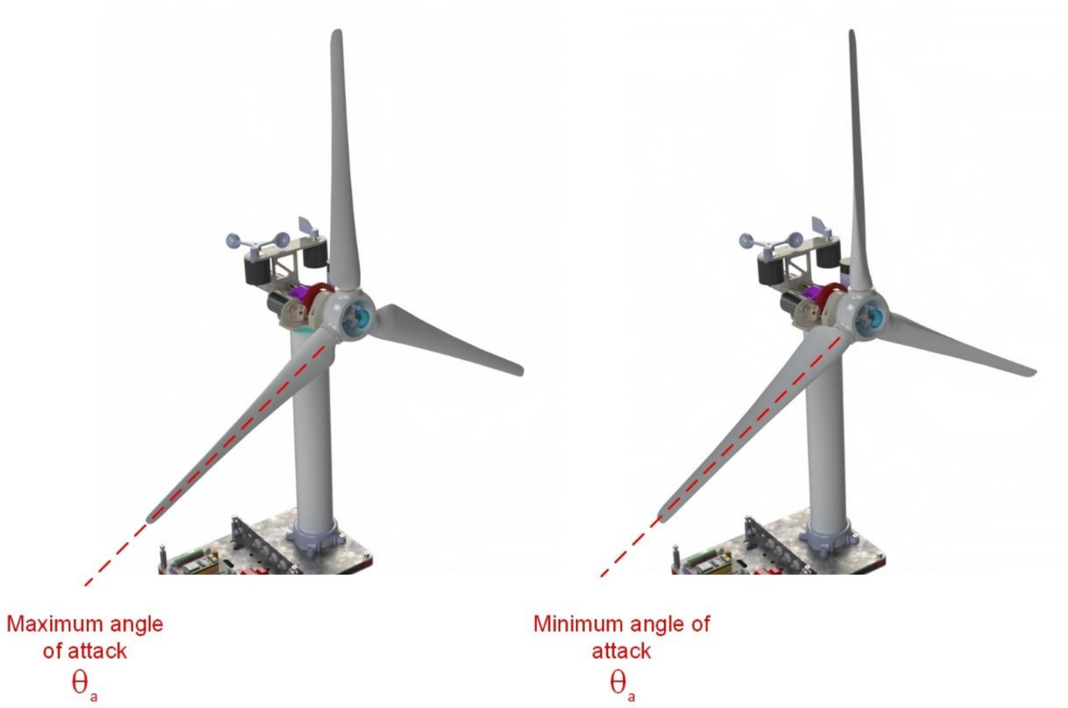

Figure 2. Wings angle of attack

The objective of this practice session is to quantify the performance in energy production of the wind turbine when the nacelle orientation and angle of attack changes under different wind speed conditions.

3 Nacelle orientation

The first experiment consists of fixing the angle of attack on its maximum value and fix the wind source at an established direction. For this given condition, fixed by the student, the nacelle orientation should be changed from [-45º, 45º] range. For each value of nacelle orientation, the energy production shall be obtained (an average value of the last n values is recommended).

The student must represent the energy production of the wind turbine when the nacelle orientation changes and to quantify the loss of performance when the wind turbine is misaligned to the wind direction.

4 Angle of attack

The second experiment consists of obtaining the energy production with regards to this angle, φ_{wn}, and different wings angle of attack, θ_a.

Fixing the value of θ_a to 0º, φ_{wn} angle must be swept from -45º to 45 in step of 5º and the steady state value of the energy production must be obtained (an average value of the last n values is recommended).

This experiment must be repeated for different values of θ_a.

As results the student shall obtain a matrix results similar to the shown in Table I.

Table I. Matrix of results for Nacelle Orientation experiment I

$\theta_a(°) \setminus \varphi_{wn}$ (°)	-45	…	0	…	45
0					
15					
30					
45					
60					
⋮					

A graphical representation of the results is strongly recommended. The student should obtain the qualitative and quantitative conclusion about the performance of the wind turbine with the nacelle orientation.

5 Wind speed

In this case, for a given value of angle of attack (maximum angle is recommended), the energy production with regards to this angle, φ_{wn}, and the wind speed shall be obtained.

Fixing the wind speed, V_w, at its lower level, φ_{wn} angle must be swept from -45º to 45 in step of 5º and the steady state value of the energy production must be obtained (an average value of the last n values is recommended).

This experiment must be repeated for different values of V_w.

As results the student shall obtain a matrix results similar to the shown in Table II.

Table II. Matrix of results for Nacelle Orientation experiment II

$V_w(m/s) \setminus \varphi_{wn}$ (°)	-45	…	0	…	45
0					
2					
4					
6					
8					
⋮					

A graphical representation of the results is strongly recommended. The student should obtain the qualitative and quantitative conclusion about the performance of the wind turbine with the variation of the wind speed.