1 CIP 1

In CIP 1 we were asked to estimate the main parameters of our wind turbine model. In addition we also calculated the airfoil aerodynamics properties and defined the geometry of our blade. The following table shows the side specific conditions and the limitations for the design process of the wind turbine.

Name	unit	value
Airfoil profile set number	-	4
Design wind regime	-	Rayleigh
Target wind regime	-	High
Weibull A-factor (local)	m/s	9
Weibull k-factor (local)	-	2
Rated electrical power	kW	3500
Number of blades	-	3
Cut-in wind speed	m/s	3.5
Cut-out wind speed	m/s	25
Max. tip speed	m/s	82
Max. hub height – reference (*)	m	100
Max. blade length - reference (*)	m	60
Blade root length	m	5
Transmission	-	90

Figure 1: Design parameters

1.1 Total conversion efficiency

The total conversion efficiency is used to calculate the amount of energy which can be extracted from the wind flow. Therefore it contains all loses due to mechanical and electrical conversions as the corresponding c_p reference value. The c_p variable describes the maximum amount of energy which can be theoretical extracted from the wind. Taking all these losses into account we have the following equation for the total conversion efficiency:

$$\text{total conversion efficiency} = c_p * \nu_{el} * nu_{mech} = 0.4705 \tag{1}$$

1.2 Wind Power for nominal electrical power

The rated electrical power of the wind turbine is 3.500 kW. With the total conversion efficiency we computed in the last section we are now able to estimate how much wind power is needed to obtain nominal electrical power.

$$\text{total wind power} = \frac{\text{nominal power}}{\text{total conversion efficency}} = \frac{3500kW}{0.4705} = 7439.26kW \tag{2}$$

1.3 Rated wind speed

At rated wind speed the turbine is able to extract nominal wind speed. The following equation is used to calculate the power output of the wind turbine. It should be noted that resulting value had to be rounded up.

$$P_{rated} = 0.5 \cdot c_{total} \cdot \rho \cdot \pi \cdot R^2 \cdot V_{rated}^3 \tag{3}$$

where:
P_{rated} = rated electrical power
c_{total} = total conversion efficiency
ρ = density
R = reference max. blade length
V_{rated} = rated wind speed
This equation can be solved for V_{rated}:

$$V_{rated} = \sqrt[3]{\frac{2 \cdot P_{rated}}{\rho \cdot c_{total} \cdot R^2 \cdot \pi}} = 11m/s \tag{4}$$

1.4 Rotor radius

To calculate the rotor radius we used equation (3). Instead of solving for V_{rated} we solved for the blade radius.

$$R = \sqrt{\frac{2 \cdot P_{rated}}{c_{total} \cdot \rho \cdot \pi \cdot V_{rated}^3}} = 54m \tag{5}$$

With a hub diameter of 2.5 meters we end up with a blade length of 52.75 m.

1.5 Rotor area and specific rating

The rotor area is simply the area which is covered by the rotating blades. That leaves us with:

$$A_{area} = \pi * R^2 = 9161m^2 \tag{6}$$

Next we were asked to calculate the specific rating which is defined as:

$$rating = \frac{\text{electrical power}}{area} \tag{7}$$

We receive 382.06 W/m^2 as specific rating.

1.6 Rotor rated speed & design tip speed ratio

The design tip speed ratio is the ratio between maximum tip speed and rated wind speed of the turbine. The maximum tip speed for the wind turbine is $82m/s$ and the calculated rated wind speed is $11m/s$. That leads to a design tip speed ratio λ_d of **7.45**.
Next the we calculated the rotor rated speed. The rotor rated speed in rotations per minute (rpm) is given by:

$$n = \frac{60s/min \cdot \text{ max. tip speed}}{2 \cdot \pi \cdot R} = 14.5rpm \tag{8}$$