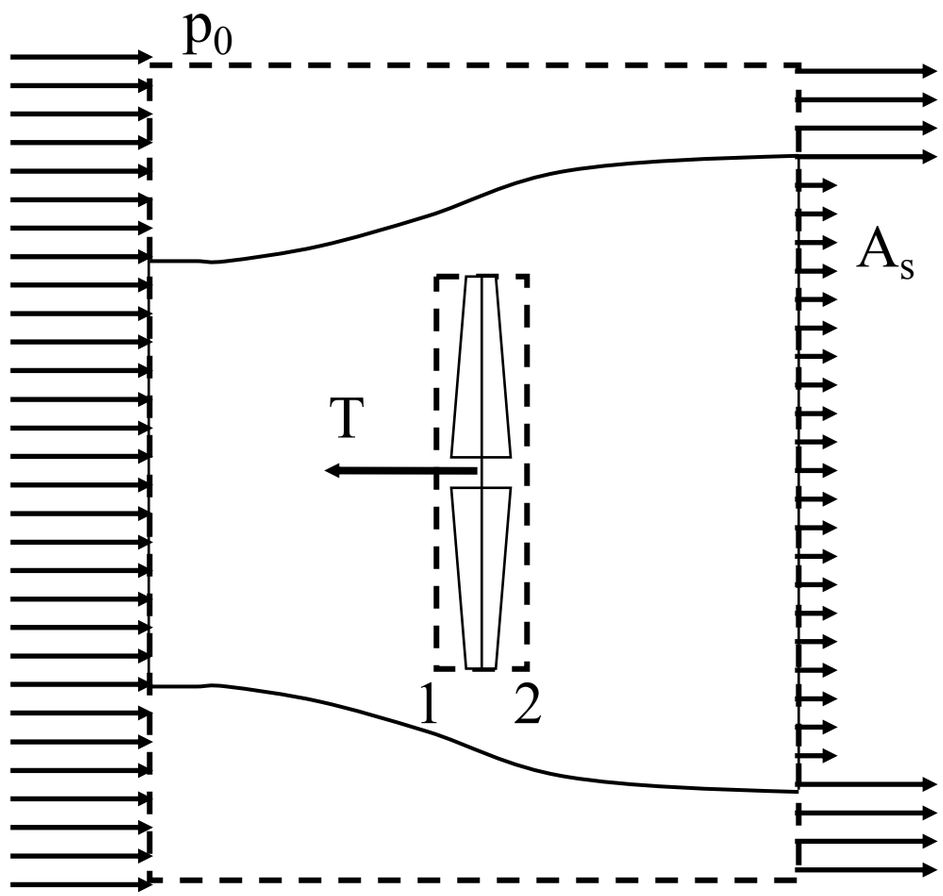
Back to the flow around the turbine : the induction factors



axial velocity	U_∞	$U_{turbine} = (1-a)U_\infty$	$U_{wake} = (1-2a)U_\infty$
tangential velocity	$W_\infty = 0$	$W_{turbine} = a'\omega r$	$W_{wake} = 2a'\omega r$

The velocity at the blades takes into account the induction factors

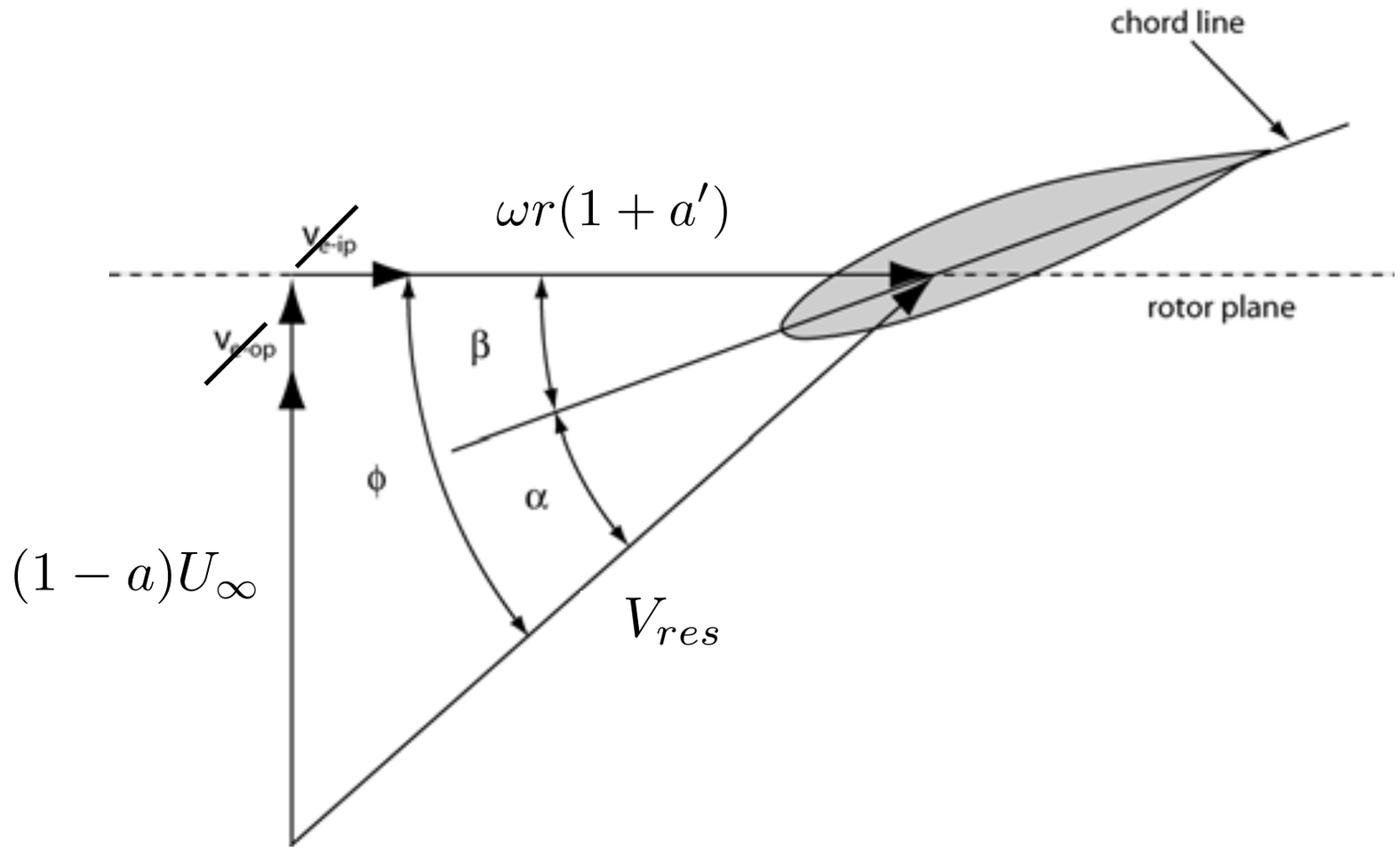


Figure 2. Local element velocities and flow angles

$$\tan\phi = \frac{U_\infty(1-a)}{\omega r(1+a')}$$

Force and torque are derived for an annular section at distance r from the axis : the BEM

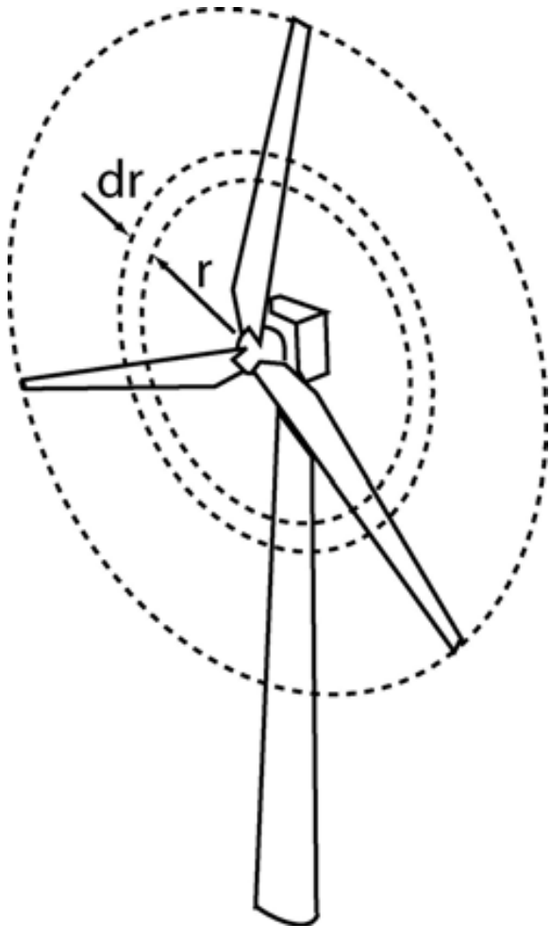


Figure 1. Annular plane used in blade element momentum theory

Contribution to the force and the torque based on the force on the airfoil

$$dT = B\,\frac{1}{2}\rho V_{res}^2 (C_l \cos\phi + C_d \sin\phi) c\, dr$$

$$dQ = B\,\frac{1}{2}\rho V_{res}^2 (C_l \sin\phi - C_d \cos\phi) c\, r dr$$

Contribution to the force and the torque based on the momentum balance

$$dT = 2\pi r dr \rho U_\infty (1-a)(U_\infty - U_{wake})$$

$$dQ = 2\pi r dr \rho U_\infty (1-a) 2a' \omega r\, r$$

$$dT = 4\pi r \rho U_\infty^2 (1-a) a dr$$

$$dQ = 4\pi r^3 \rho U_\infty (1-a) a' \omega dr$$

Torque and Thrust are obtained after integration on the rotor disk

The NREL 15MW virtual turbine

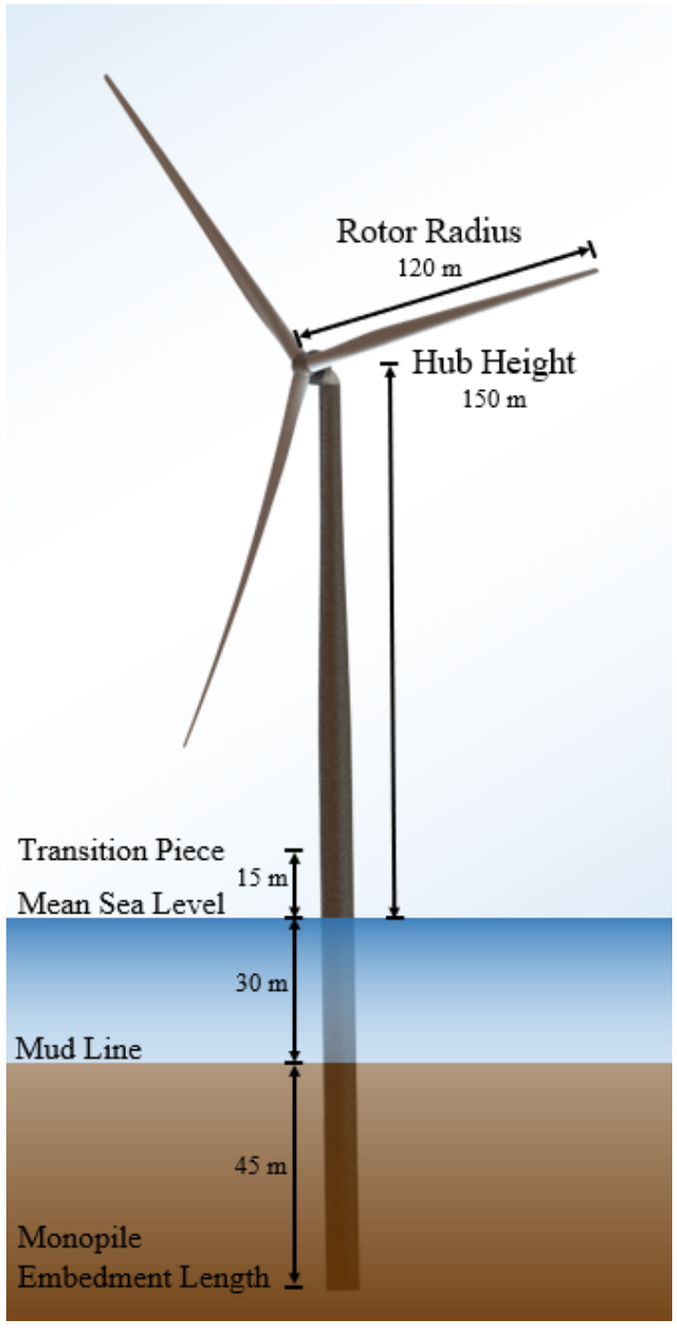


Figure 1-1. The IEA Wind 15-MW reference wind turbine

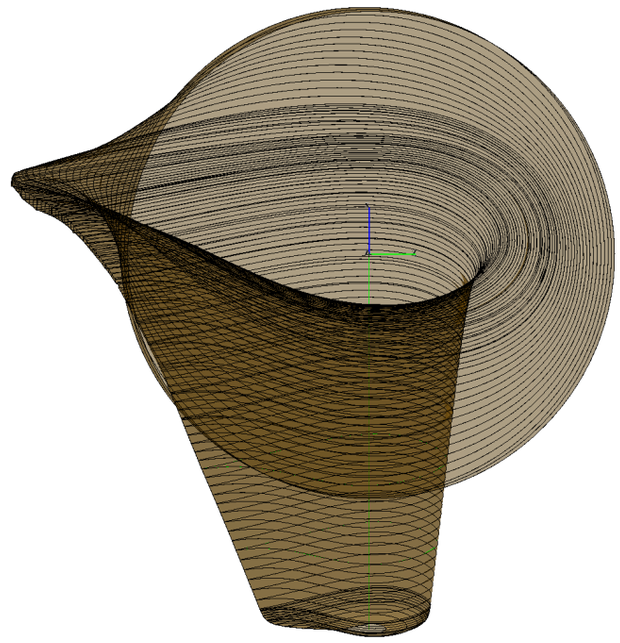
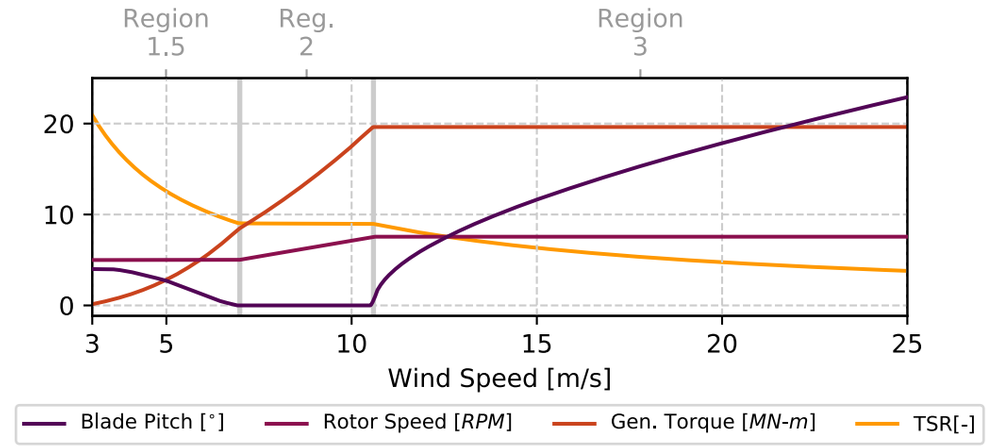
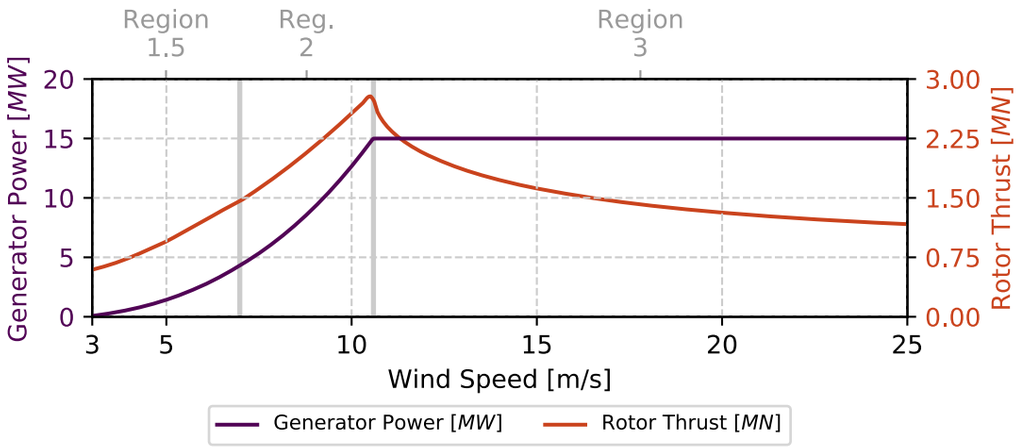


Figure 2-5. Lofted blade shape

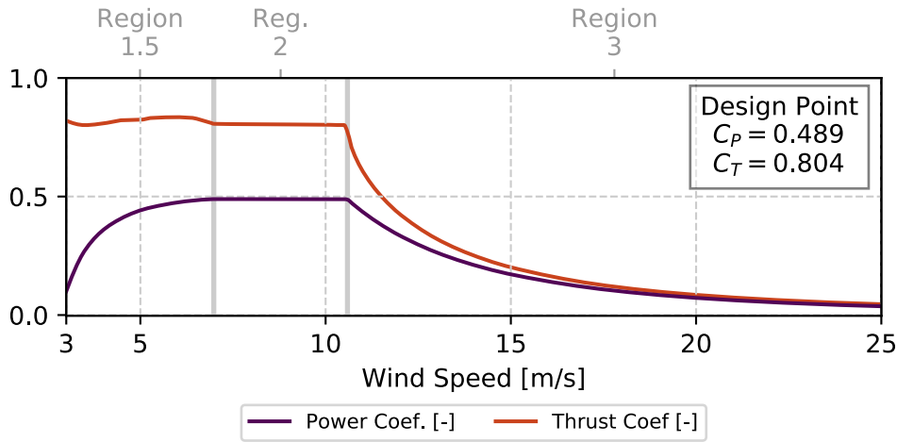
RPM and pitch of the 15MW turbine



(a) Controller regulation trajectory



(b) Power and thrust curve



(c) Aerodynamic performance coefficients

Your tasks related to the mechanical aspects

1) Read the reference documents available on moodle

Definition of the IEA Wind 15-Megawatt Offshore Reference Wind Turbine

=> the whole document

AeroDyn theory manual => only the sections on the BEM

2) Understand the algorithm of the BEM

- test the given code (written in python)
- explain with your own words the algorithm (it can be in the form of a pseudo-code)

3) Apply the BEM to estimate the torque and power of the 15MW turbine at selected wind speeds. Look at the induction factors obtained

4) Compare the calculated values with the actual torque/power curves and comment on the hypotheses, simplifications, etc.

5) From the wind data available on moodle, derive the annual energy production and the load factor