Assignment #1:
This assignment deals with applying the BEM algorithm to learn the basic operation of a variable speed pitch regulated wind turbine. The DTU 10 MW virtual experimental wind turbine is used, since all aerodynamic and structural data are publicly available and most details can be found in the report “Description of the DTU 10 MW Reference Wind Turbine”, DTU Wind Energy Report-I-0092.

Overall data for the DTU 10 MW WT:
Rotor radius R= 89.17 m
Number of blades 3
Rated power 10000 kW
Cut in wind speed 4 m/s
Cut out wind speed 25 m/s
Air density ρ=1.225 kg/m^3

The blade is described with following table:

r [m]	c [m]	β [deg]	t/c [%]
2,80	5,38	14,50	100,00
11,00	5,45	14,43	86,05
16,87	5,87	12,55	61,10
22,96	6,18	8,89	43,04
32,31	6,02	6,38	32,42
41,57	5,42	4,67	27,81
50,41	4,70	2,89	25,32
58,53	4,00	1,21	24,26
65,75	3,40	-0,13	24,10
71,97	2,91	-1,11	24,10
77,19	2,54	-1,86	24,10
78,71	2,43	-2,08	24,10
80,14	2,33	-2,28	24,10
82,71	2,13	-2,64	24,10
84,93	1,90	-2,95	24,10
86,83	1,63	-3,18	24,10
88,45	1,18	-3,36	24,10
89,17	0,60	-3,43	24,10

The airfoils used are the FFA-W3-xxx, where the last three digits indicate the profile thickness. When estimating the lift and drag coefficients one must interpolate in both angle of attack and thickness.

Tip: **Avoid placing the last blade element too close to the tip since this will cause numerical problems. However, when integrating the loads to determine the thrust and torque an element should be placed at the tip and the loads put 0 N/m.**

Q#1 Using following recommended Glauert correction determine the highest obtainable power coefficient, $C_{p,\,opt}(\lambda_{opt},\, \theta_{p,\,opt})$, and the corresponding values of the tip speed ratio and pitch angle, λ_{opt} and θ_{opt}.

$$C_T = \begin{cases} 4aF(1-a) & a \le 0.33 \\ 4aF(1-\frac{1}{4}(5-3a)a) & a > 0.33 \end{cases}$$

Tip: The optimum pitch lies between -2 and 5 degrees and the optimum tip speed ratio between 5 and 10.

Q#2 Imagine that the tip speed is limited to 90 m/s corresponding to ω_{max}=1.01 rad/s. What would be the maximum wind where the turbine can run at its maximum efficiency $C_{p,\,opt}(\lambda_{opt},\, \theta_{p,\,opt})$ and what would be the power. Plot $\omega(V_o)$.

Q#3 To limit the power at high wind speeds the blades are pitched towards either lower or higher angles of attack. Below rated power the pitch is assumed constant at $\theta_{p,opt}$. Compute and plot the necessary pitch setting as a function of wind speed, $\theta_p(V_o)$, to limit the power at 10 MW, both when you pitch to higher and lower angles of attack. Plot and comment as function of the wind speed the power and thrust as function of wind speed, $P(V_o)$, $T(V_o)$ and their corresponding non-dimensional coefficients $C_p(V_o)$ and $C_T(V_o)$.

Q#4 Compute the flapwise and edgewise bending moments at r=2.8m, at Vo=(4, 8, 11, 18 and 25)m/s, again both when you increase and decrease the angle of attack.

Q#5 Compute the annual energy production for the pitch regulated wind turbine erected at a site with following Weibull parameters, A=9 m/s and k=1.9. How much energy is lost if the wind turbine is stopped at V_o=20 m/s instead of 25 m/s.

Document your work and comment the results in a signed report of maximum 7 pages, including figures. There is no need to repeat all theory and equations in your report, since you are allowed to refer to the course material. Clearly state how you solved the problem and very importantly comment on the results. Please, also make sure that the fonts and captions of your figures and tables are large enough to be clearly read.
It is also required to upload in a separate file the Matlab scripts.

All groups larger than one person (max. 3 persons/group) must attach to the report as an extra page a small progress report signed by all members of how the group worked together and the work load for each member MUST explicitly be stated as a percentage. You cannot pass the course unless this is done.