1 CIP 4

The following parameters are relevant for the remainder of this section:

$$\Omega_{rated} = 12.59rpm \text{ (rotor rated speed)}$$
$$D = 5m \text{ (tower diameter)}$$
$$E = 211000000000\frac{N}{m^2} \text{ (elastic modulus)}$$
$$l = 100m \text{ (hub height)}$$
$$m_{top} = 323000kg \text{ (nacelle and rotor mass)}$$
$$\rho = 7850\frac{kg}{m^2} \text{ (material density)}$$

1.1 Task a

For tower design resonances of excitation frequencies from the rotating blades must be taken into account. The Eigenfrequency of the tower can thus be obtained by adding a 10% safety margin to the rotor rated speed which represents the maximum stationary rotor speed:

$$f_0 = \Omega_{rated} \cdot 1.1 = \frac{12.59}{60}Hz \cdot 1.1 = 0.23081Hz$$

1.2 Task b

The design range of our turbine is a classical soft-stiff design which results in large wave excitation.

1.3 Task c

The wall thickness t can be computed from the following equations:

$$f_0 2\pi = \sqrt{\frac{k}{m_{top} + 0.25m_{tower}}} \tag{1}$$
$$k = \frac{3E\pi D^3 t}{l^3 8} \tag{2}$$
$$m_{tower} = \rho\pi Dtl \tag{3}$$

By substituting Equations (2) and (3) into (1) we obtain the following equality which can be fed into Matlab in order to solve for the only unknown t:

$$0 = \sqrt{\frac{3E\pi D^3 t}{l^3 8 \cdot (m_{top} + 0.25\rho\pi Dtl)}} - f_0 \cdot 2\pi$$

Extract from Matlab code used to solve for variable t:

```
t=1;
func = @(t) sqrt(3*E*pi*D^3*t/(l^3*8*(mTop+0.25*rho*pi*D+t*l)))-0.23081*2*pi;
t = fsolve(func,t);
```

The resulting value for the wall thickness is $t = 0.0239m$. The tower mass is then $m_{tower} = 295310kg = 295.31t$. The material cost for this tower would thus be of 147655 €, assuming a price of 500 €/t. Obviously a thicker tower wall leads to a higher price overall (linear increase). As depicted in Figure 1 a thicker wall leads to a higher Eigenfrequency of the tower as well. However, in this case the relationship is not a linear one due to the exponent of 0.5 in the formula. Hence, a thicker wall results in a higher Eigenfrequency but the increase is only significant for wall thicknesses up to $0.1m$. Above that the cost increase does not justify the gain in Eigenfrequency.

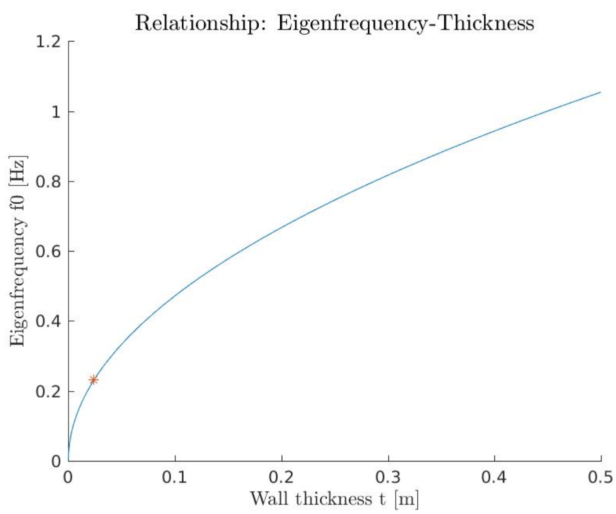

Figure 1: Effect of wall thickness on Eigenfrequencies

1.4 Task d

The Campbell diagram is depicted in Figure 2 (work in progress)

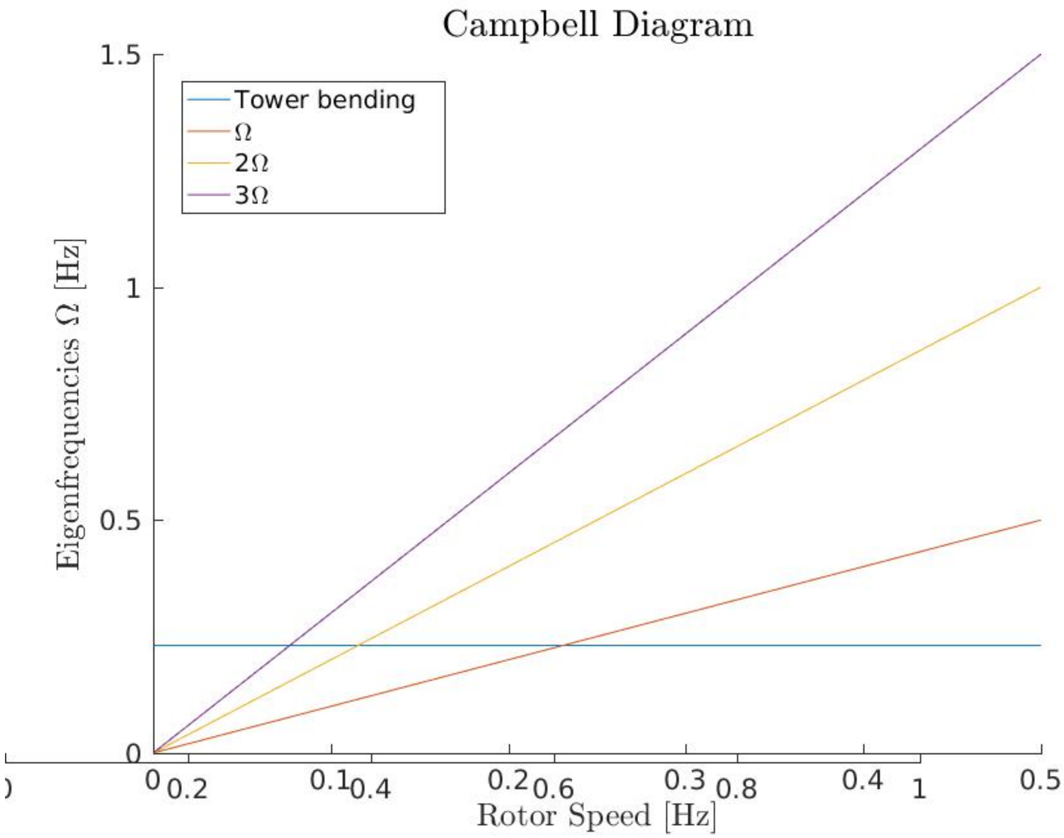

Figure 2: Campbell Diagram