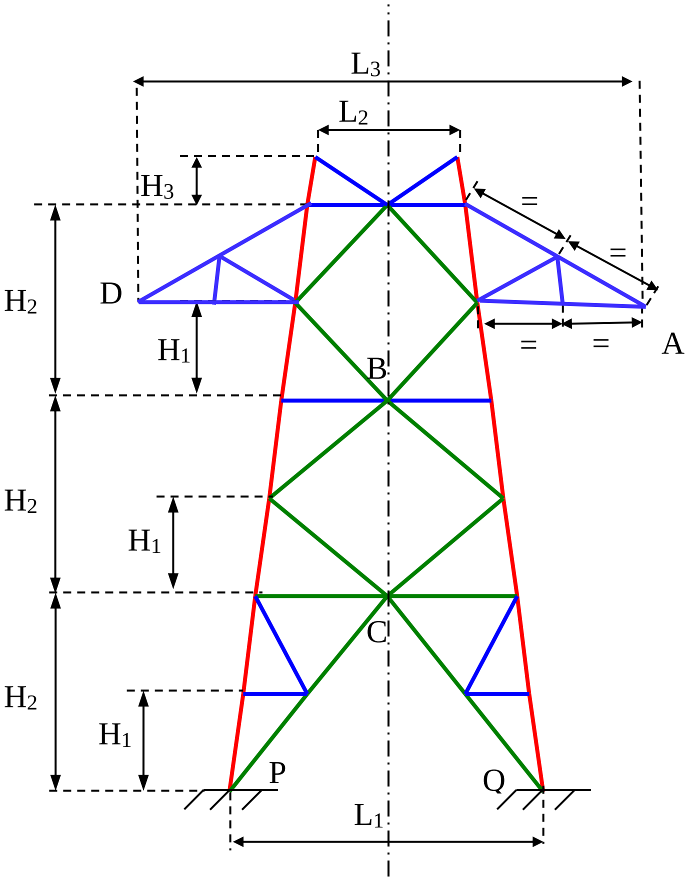
Transmission line tower



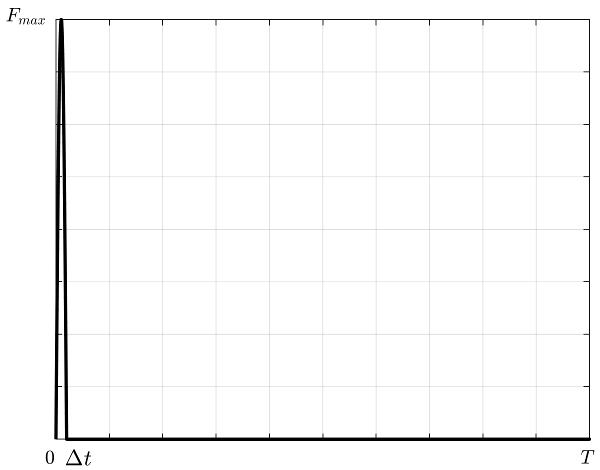
The system in figure represents a tower of a high voltage electrical line. The tower is symmetric with respect to the central vertical axis. Points P and Q are clamped to the ground; points A and D are the two extremities of the tower cross arms where the upper phase conductors are hanged through the insulator strings (both the insulator strings and the phase conductors are not represented in this model). The tower is shown in its static equilibrium position subjected to its own weight and to that of the hanged elements. The geometrical and mechanical data of the structure are reported in the table below:

Width at the tower basis [m]	L_1	48
Width on top [m]	L_2	22
Distance between the insulator strings [m]	L_3	80
Height H_1 [m]	H_1	15
Height H_2 [m]	H_2	30
Height H_3 [m]	H_3	7.5
Height H_4 [m]	H_4	15
RED beams: unit length mass [kg/m]	m_R	60
RED beams: axial stiffness EA [N]	EA_R	4e8
RED beams: bending stiffness EI [Nm^2]	EJ_R	1e8
Green beams: unit length mass [kg/m]	m_G	15
Green beams: axial stiffness EA [N]	EA_G	2e8
Green beams: bending stiffness EI [Nm^2]	EJ_G	6e7
Blue beams: unit length mass [kg/m]	m_B	20
Blue beams: axial stiffness EA [N]	EA_B	2e8
Blue beams: bending stiffness EI [Nm^2]	EJ_B	6e7
Non-dimensional damping: first mode of vibration	h_1	7e-3
Non-dimensional damping: second mode of vibration	h_2	5e-3
Non-dimensional damping: third mode of vibration	h_3	6e-3
Impulse duration [s]	Δt	0.3
Max value of the impulsive force [N]	F_{max}	4000

Structural damping is to be accounted for, according to the proportional damping assumption $[C]=\alpha[M]+\beta[K]$, with values α and β that have to be identified from the value of the non-dimensional damping of the first three modes of vibration given in the input data table.

<u>The students are asked to:</u>

1) define a FE model of the structure valid in the frequencies range 0÷5 Hz
2) compute the natural frequencies and the modes of vibration in the frequencies range 0÷ 5 Hz
3) plot the diagrams (magnitude and phase) of the following Frequency Response Functions in the frequencies range 0 ÷ 5 Hz
    1. vertical displacement of point A applying a vertical force at point A
    2. vertical displacement of point D applying a vertical force at point A
    3. vertical displacement of point A applying a vertical force at point D
    4. horizontal displacement of point A applying a horizontal force at point A
    5. horizontal displacement of point B applying a horizontal force at point A
4) study the tower response to a phase conductor failure due to an *ice galloping* event (aeroelastic instability due to the ice deposition on the conductor). Consider the impulsive force shown in the diagram below, applied at point A in vertical direction:



   The parameters of the impulse are given in the input data table; approximation of the impulsive force: half-sine function padded with zero values. We suggest to use different values of the duration T of the time history, in the range T=6 – 24 s.

   Compute:
    1. the Discrete Fourier Transform of the impulsive force in the frequency range 0-5 Hz.
    2. the time histories of the following output quantities:
        a) the vertical displacement of point A;
        b) the horizontal displacement of point A;
        c) the constraint forces at the clamp in point P.

   The detailed list of the output diagrams that are requested is given in the attached checklist.

5) Define a change in the structure suitable for reducing by at least 20% the maximum amplitude of the vertical component of the constraint force at clamp P for the same excitation condition of question 4 without increasing the mass of the system by more than 5%.