Wind Turbine Tower Natural Frequency and 1P/3P Check

First bending frequency of a tubular tower with a top mass and the rotor 1P and blade-passing 3P frequency bands, to classify the tower as soft-stiff or not.

Method: Cantilever with tip mass (Rayleigh) and rotor excitation bands

Input parameters

Unit system: SI

Parameter	Value	Unit
Tower height	90.000	m
Tower outer diameter (uniform equivalent)	4.0000	m
Wall thickness	25.000	mm
Young's modulus	210.00	GPa
Steel density	7,850.0	kg/m³
Top mass (nacelle and rotor)	150.00	t
Minimum rotor speed	6.0000	rpm
Maximum rotor speed	13.000	rpm
Number of blades	3.0000	

Calculated results

Parameter	Value	Unit
First tower bending frequency	0.25851	Hz
Tower mass	220.57	t
1P at minimum speed	0.10000	Hz
1P at maximum speed	0.21667	Hz
Blade passing at minimum speed	0.30000	Hz
Blade passing at maximum speed	0.65000	Hz

Notes for this case

- Cantilever with a tip mass, Rayleigh estimate f = (1/2π)√[3EI/((M + (33/140)m_t)L³)] for a uniform tube; tapered towers and foundation flexibility lower the frequency. Soft-stiff: the frequency lies between the 1P and blade-passing bands with 10 % margins.

Formula and method

$$f_1 = \frac{1}{2\pi}\sqrt{\frac{3EI}{(M + \frac{33}{140}m_t)L^3}}, \quad f_{1P} = \frac{n}{60}, \quad f_{BP} = B\frac{n}{60}$$

Variables

L	Tower height	m
D	Tower outer diameter (uniform equivalent)	m
t	Wall thickness	m
E	Young's modulus	Pa
ρ_s	Steel density	kg/m³
M	Top mass (nacelle and rotor)	kg
n_{min}	Minimum rotor speed	rad/s
n_{max}	Maximum rotor speed	rad/s

B	Number of blades	-
f_1	First tower bending frequency	1/s
m_t	Tower mass	kg
$1P_{min}$	1P at minimum speed	1/s
$1P_{max}$	1P at maximum speed	1/s
BP_{min}	Blade passing at minimum speed	1/s
BP_{max}	Blade passing at maximum speed	1/s

Method and standards

Tower frequency screening.

Assumptions and limits

- Uniform tube; fixed base; Rayleigh approximation.

References

Cantilever with tip mass (Rayleigh) and rotor excitation bands

Report details

Report reference	FCC-ACDM-XYX6 (the same inputs always give the same reference)
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Release checks	3 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/environmental/wind-power/wind-turbine-tower-frequency-1p-3p

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.