Wind Turbines – Components and Design Basics

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Overview Part I

- Product range
- Components of a wind turbine

Overview Part II

- Load assumptions for wind turbines
- Loads and load cases
- Rocking spring stiffness

Rated power: 330 kW
Hub height: 44 – 50 m

E33

Rated power: 900 kW
Hub height: 45 m / 55 m

E44

Rated power: 800 kW
Hub height: 50 – 76 m

E48

Rated power: 800 kW
Hub height: 73 m

E53

Rated power: 2.300 kW
Hub height: 64 – 113 m

E70

Rated power: 2.000 kW
Hub height: 78 – 138 m

E82

E126

Highest power producing WEC worldwide:

Rated power:	6.000 kW
Rotor diameter:	127 m
Hub height:	135 m
Power production:	20 Mio. kWh p.a.

- Produces electricity for more than 5000 households
- 35% more yield compared to predecessor - E-112
- Two-segment rotor blade facilitates transport

-> blades

-> nacelle with generator and hub

-> tower (steel / concrete)

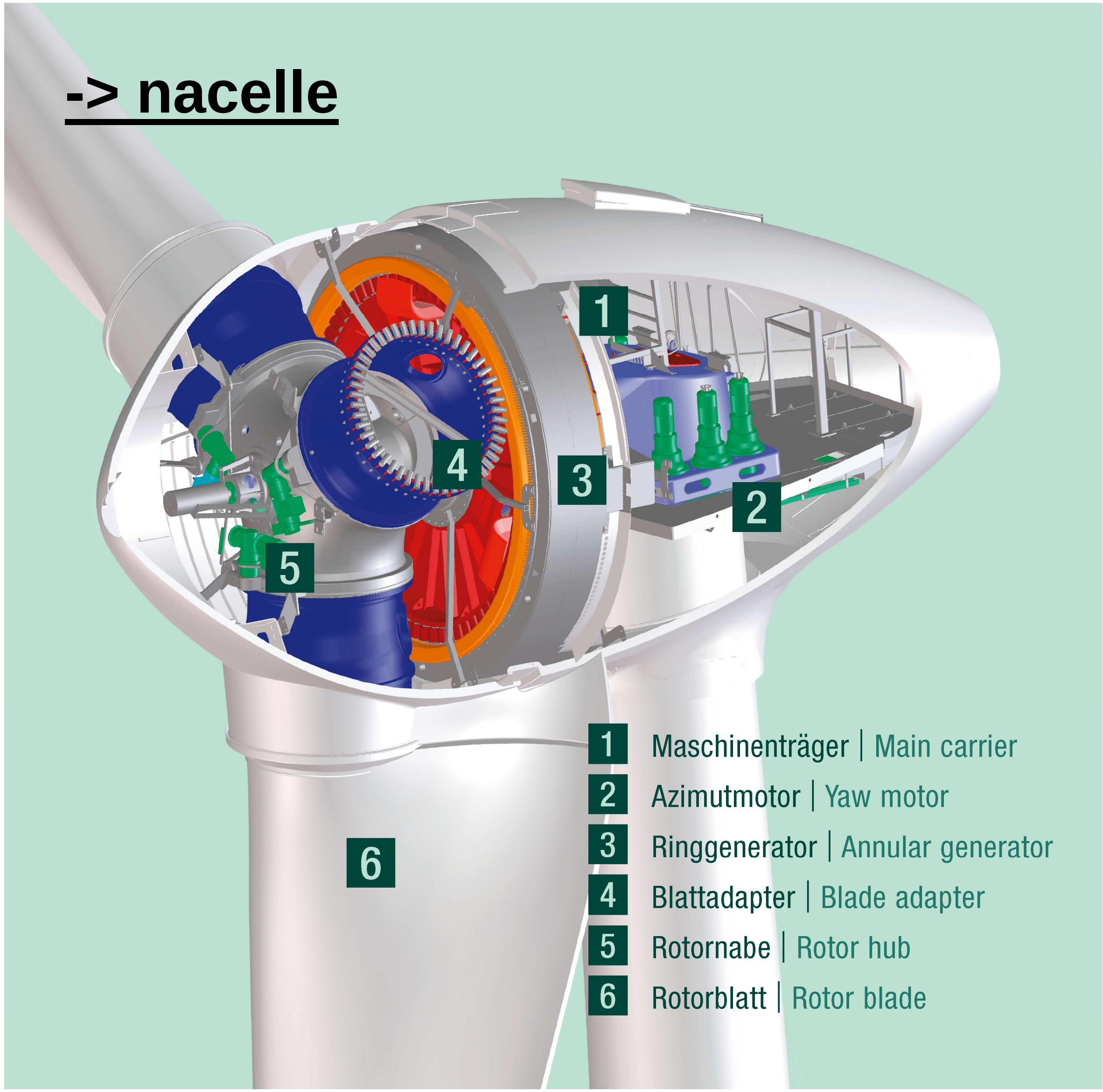
-> electrical installation and grid connection

-> foundation

-> with piles or soil improvement (if necessary)

-> blades

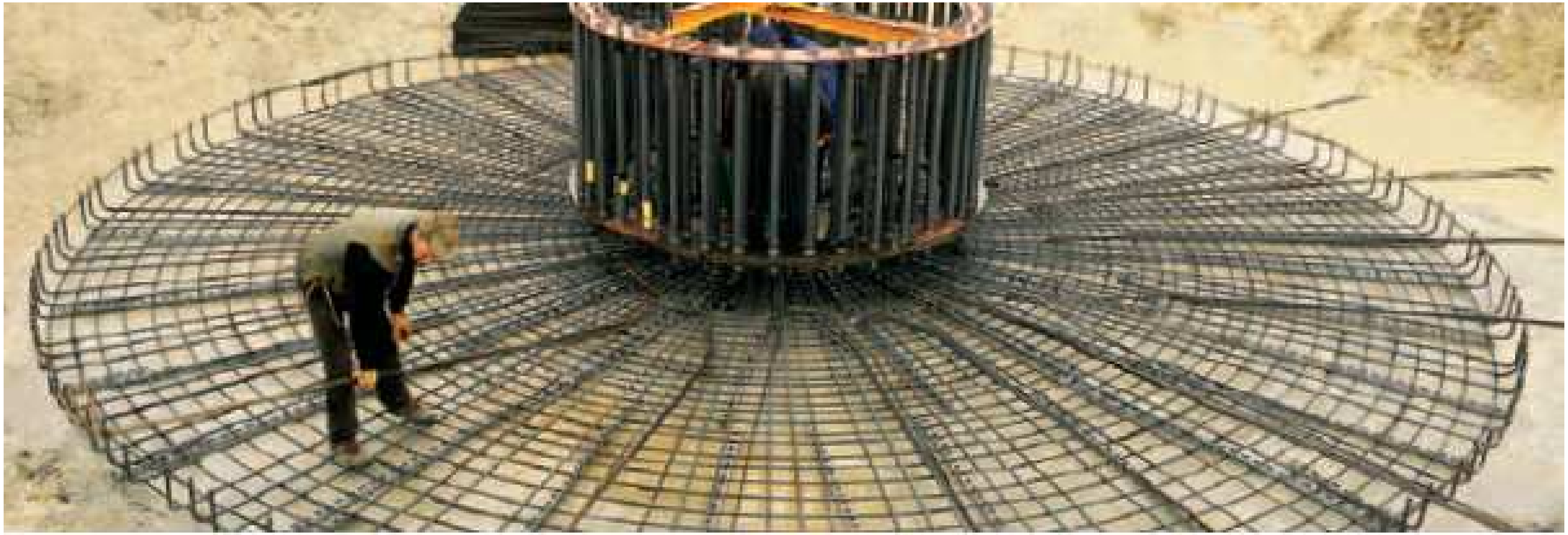
-> nacelle


1
2
3
4
5
6
1 Maschinenträger | Main carrier
2 Azimutmotor | Yaw motor
3 Ringgenerator | Annular generator
4 Blattadapter | Blade adapter
5 Rotornabe | Rotor hub
6 Rotorblatt | Rotor blade

-> steel tower

-> concrete tower

-> foundation with basket



-> foundation with section

-> foundation for concrete tower

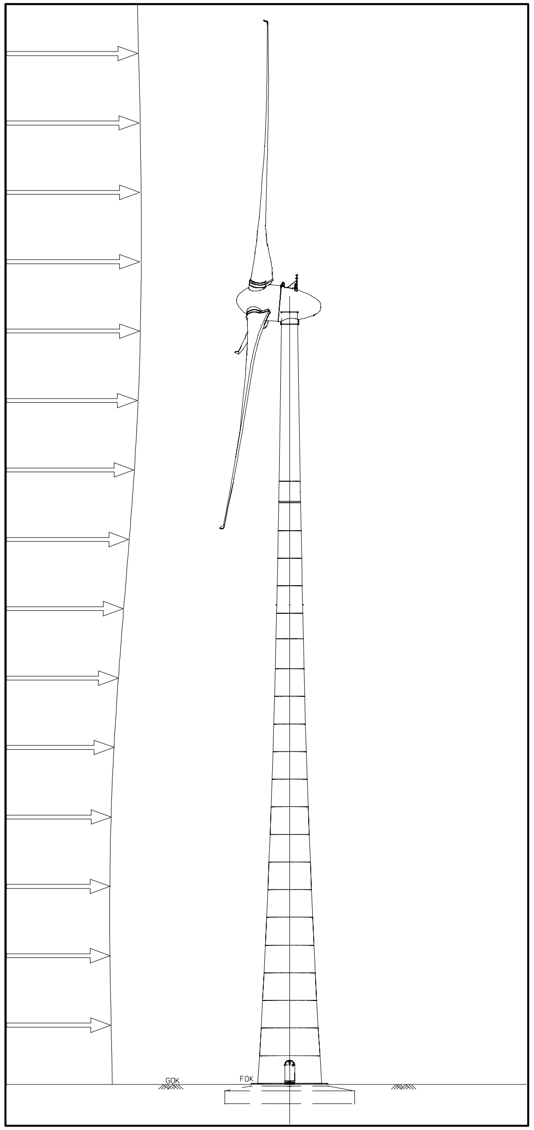
Overview
Part I

- Product range
- Components of a wind turbine

<u>Overview</u>
<u>Part II</u>

- Design situations for wind turbines
- Loads and load cases
- Rocking spring stiffness

Design situations



Environmental conditions

- Wind, Temperature, Ice, Earthquake

Operational conditions

- Normal operation and power production
- Start up, shut down, idling, standstill

Temporary conditions

- Transportation of components
- Installation and assembling
- Maintenance and repair

Design load cases

- Normal operation and normal external conditions
- Normal operation and extreme external conditions
    - extreme wind speed
    - extreme direction change
    - extreme dynamic wind shear
- Fault situations and appropriate external conditions
    - Control system fault
    - Electrical fault
    - Yaw system fault
- Transportation, installation and maintenance situations

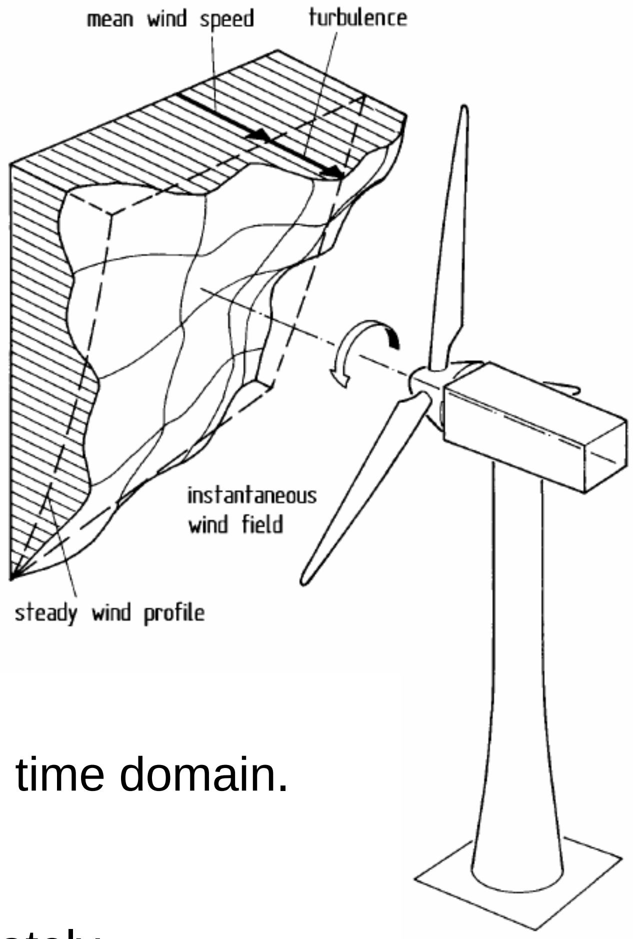
Load cases for operational and environmental conditions defined in EN 61400-1

Table 2 – Design load cases

Design situation	DLC	Wind condition*		Other conditions	Type of analysis	Partial safety factors
1) Power production	1.1	NTM	$V_{hub} = V_r$ or V_{out}		U	N
	1.2	NTM	$V_{in} < V_{hub} < V_{out}$		F	*
	1.3	ECD	$V_{hub} = V_r$		U	N
	1.4	NWP	$V_{hub} = V_r$ or V_{out}	External electrical fault	U	N
	1.5	EOG_1	$V_{hub} = V_r$ or V_{out}	Loss of electrical connection	U	N
	1.6	EOG_{50}	$V_{hub} = V_r$ or V_{out}		U	N
	1.7	EWS	$V_{hub} = V_r$ or V_{out}		U	N
	1.8	EDC_{50}	$V_{hub} = V_r$ or V_{out}		U	N
	1.9	ECG	$V_{hub} = V_r$		U	N
2) Power production plus occurrence of fault	2.1	NWP	$V_{hub} = V_r$ or V_{out}	Control system fault	U	N
	2.2	NWP	$V_{hub} = V_r$ or V_{out}	Protection system or preceding internal electrical fault	U	A
	2.3	NTM	$V_{in} < V_{hub} < V_{out}$	Control or protection	F	*

Due to the nature of wind the loads are high variable !

• mean wind, gravity loads	(steady)
• turbulence, earthquake	(stochastic)
• unbalanced mass, rotor frequency	(periodic)
• start up / shut down, gusts	(transient)



• Loads are calculated with special computation program in time domain.

• Load calculations have to determined for each type separately.

[Hau 2005]

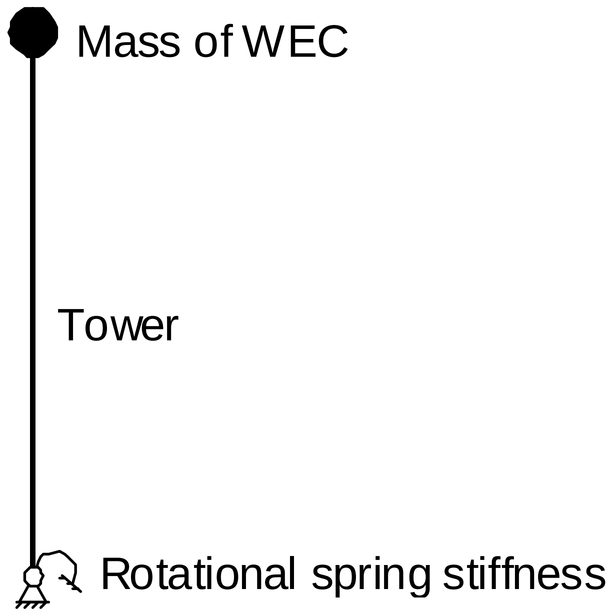
Different aspects for structural design

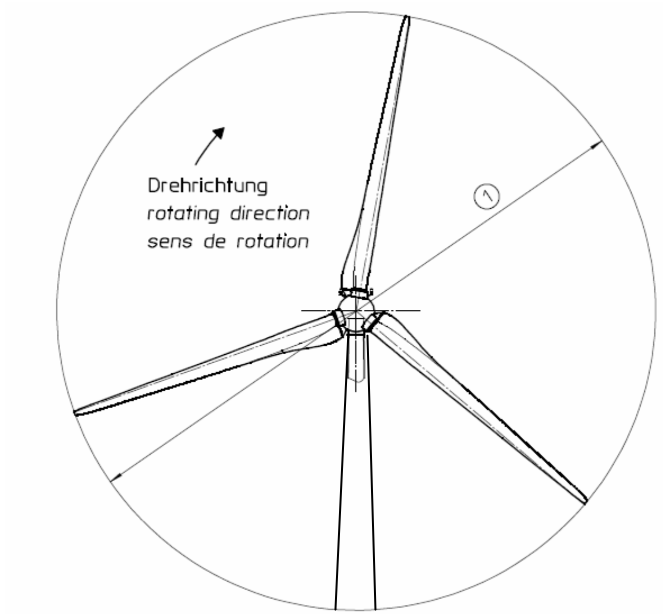
1.	Extreme Loads	(Ultimate Limit State)
2.	Fatigue Loads	(Ultimate Limit State)
3.	Stiffness of components	(ULS and SLS)
	- Vibrations	(resonance effects)
	- Deflections	(distance between blade and tower)

Vibrations - Rocking spring stiffness $k_{\phi,dyn}$

To avoid resonance we have to consider the stiffness of the components but also the soil-structure interaction. The eigenfrequency of the system *machine - tower – foundation - soil* shall not be in the range of the variable frequencies. To ensure this requirement a minimum stiffness of foundation and soil is necessary.

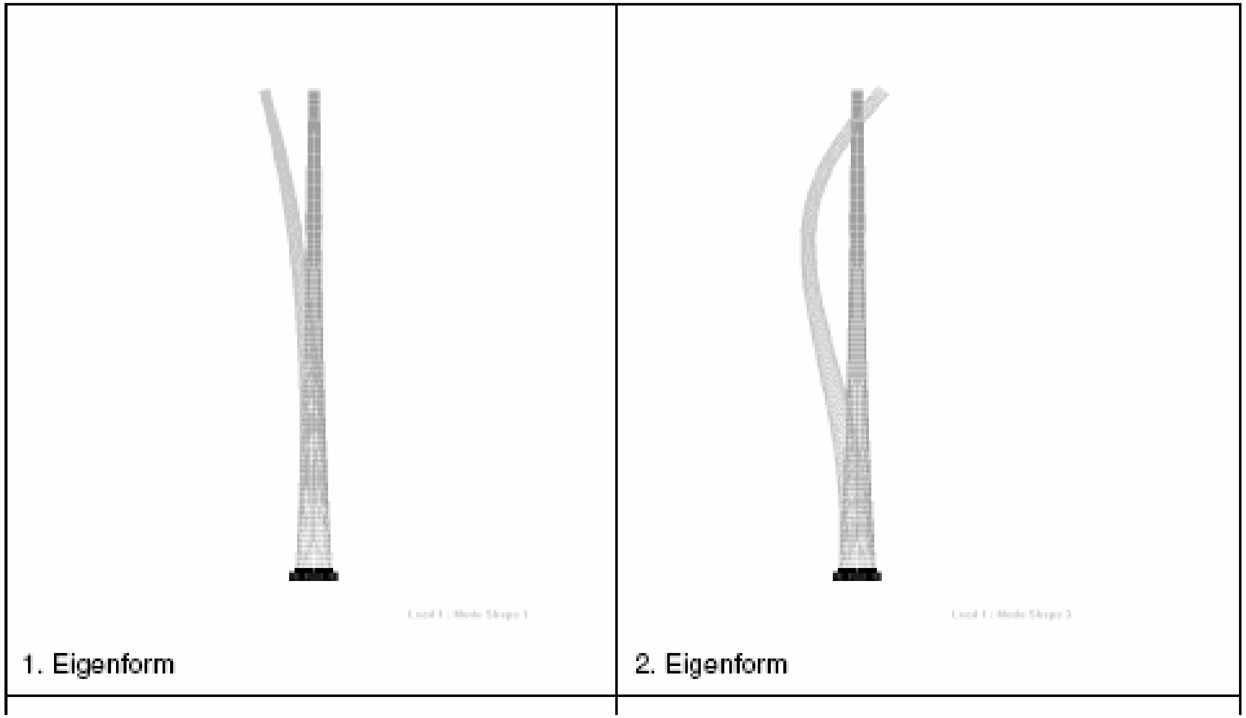
System





Important design parameter for WEC:

- Rotational frequency of rotor (1P)
- Rotational frequency of one blade (3P)
- Eigenfrequencies of the whole system (1. EF / 2. EF)



Eigenmodes of the tower structure

Merci pour votre attention