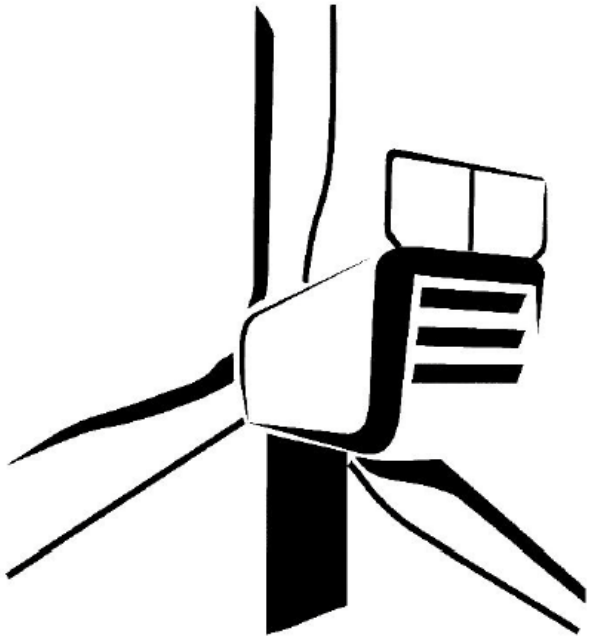


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Validity

Turbine generation	Product series	Product
Delta	Delta4000	N133/4.X

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1. Structure

The Nordex N133/4.8 wind turbine is a speed-variable wind turbine with a rotor diameter of 133.2 m and a nominal power between 4000 and 4800 kW. The wind turbine has been designed for class S as per IEC 61400-1 and is offered in the variants for 50 Hz and 60 Hz.

A Nordex N133/4.8 wind turbine consists of the following main components:

- Rotor, with rotor hub, three rotor blades and pitch system.
- Nacelle with rotor shaft and bearing, gear, generator, Yaw system, medium voltage transformer and converter.
- Tubular steel tower or hybrid tower with medium-voltage switchgear.

1.1 Tower

The wind turbine N133/4.8 can be erected on a steel tower or on a hybrid tower. The steel tower is cylindrical and consists of several sections. This tower is bolted to the anchor cage embedded in the foundation. The bottom part of the hybrid tower consists of a concrete tower and the top part of a tubular steel tower with three sections.

A climbing assistance, e. g a service lift or a climb assist, the vertical ladder with fall protection system as well as resting and working platforms inside the tower allow for a weather-protected ascent to the nacelle.

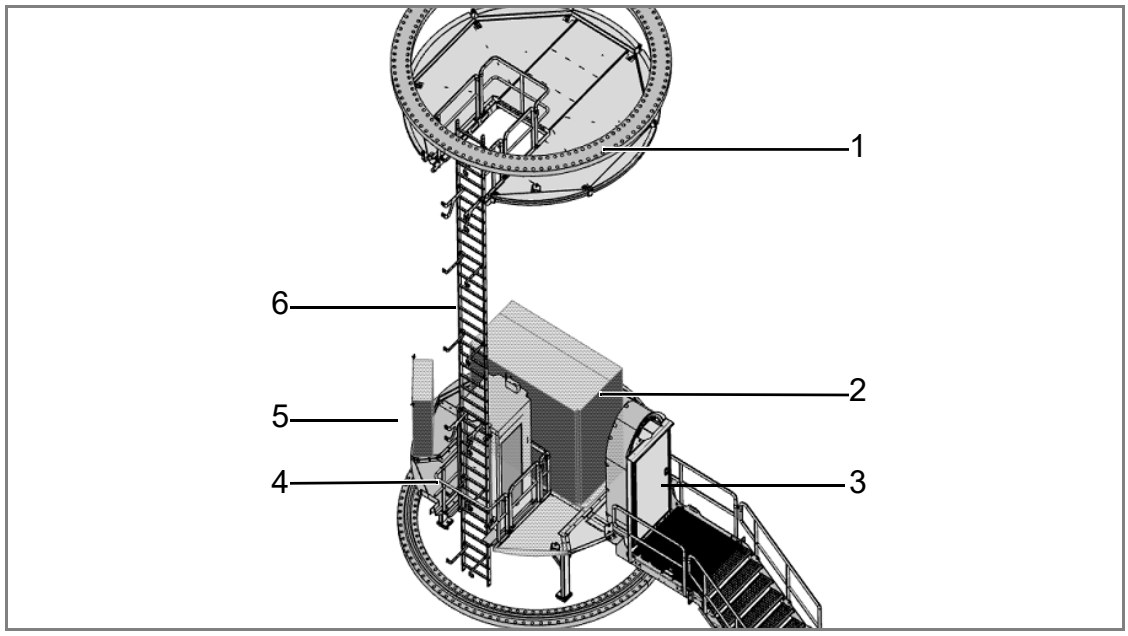


Fig. 1: Overview of installations in the bottom section of the steel tube tower with a vertical ladder (in case of a climb assist different image)

1 Flange platform
2 MV switchgear
3 Tower access
4 Tower service lift
5 Control cabinet
6 Ladder path

The foundation structure of all towers depends on the soil conditions at the intended location.

1.2 Rotor

The rotor consists of the rotor hub with three slewing bearings, the pitch system for blade adjustment and three rotor blades.

The **rotor hub** consists of a base element with support system and spinner. The base element consists of a stiff cast structure, on which the pitch bearings and the rotor blades are assembled. The rotor hub is covered with the spinner which enables the direct access from the nacelle into the rotor hub.

The **rotor blades** are made from high quality fiber glass- and carbon-fiber reinforced plastic. The rotor blade is tested statically and dynamically in accordance with the guidelines IEC 61400-23 and DNVGL-ST-0376 (2015).

The **pitch system** serves to adjust the pitch angle of the rotor blades set by the control system. For each individual rotor blade the pitch system comprises an electromechanical drive with rotary current motor, planetary gear and drive pinion, as well as a control unit with frequency converter and emergency power supply. Power supply and signal transfer are realized through a slip ring in the nacelle.

1.3 Nacelle

The nacelle contains essential mechanical and electric components of the wind turbine.

The **rotor shaft** transmits the rotary motion of the rotor to the gearbox and is mounted in the **rotor bearing** in the nacelle. A rotor lock is integrated in the rotor bearing housing, with which the rotor can be reliably locked in place mechanically. With the mechanical **rotor brake** the rotor is locked during maintenance work. For this, a sufficient oil pressure is generated by the hydraulic pump.
The **gearbox** increases the rotor speed until it reaches the speed required for the generator. The bearings and gearings are continuously lubricated with oil. A combination filter element with coarse, fine and ultrafine filter retains solid particles. The control system monitors the contamination of the filter element. The gear oil used for lubrication also cools the gearbox. The temperatures of the gearbox bearings and the oil are continuously monitored. If the optimum operating temperature is not yet reached, a thermal bypass directs the gear oil directly back to the gearbox. Only when the gear oil temperature reaches a predetermined value is the transmission oil cooled by an oil / water cooler, which is located directly on the gearbox. As a result, the gear oil temperature is kept in a narrow temperature range during operation.
The **coupling** acts as force-transmitting connection between the gearbox and the generator.
The **generator** is a 6-pole doubly-fed induction machine. The generator has a built-on air-water heat exchanger and is connected to the cooling circuit.
The **converter** connects the electrical grid to the generator which means the generator can be operated with variable rotational speeds.
The **transformer** converts the low voltage of the generator-converter system into medium voltage of the wind farm grid. The transformer is cooled by the connection to the cooling circuit.
In the **switch cabinet**, all electrical components required for the control and supply of the turbine are located.The cooling water is re-cooled by a **passive cooler** on the nacelle roof.
The **yaw drives** optimally rotate the nacelle into the wind. The yaw drives are located on the machine frame in the nacelle. A yaw drive consists of an electric motor, multi-stage planetary gear, and a drive pinion. The drive pinions mesh with the external gearing of the yaw bearing. In the aligned position the nacelle is held with the yaw drives.

All nacelle assemblies are protected against wind and weather conditions by means of a **nacelle housing**.

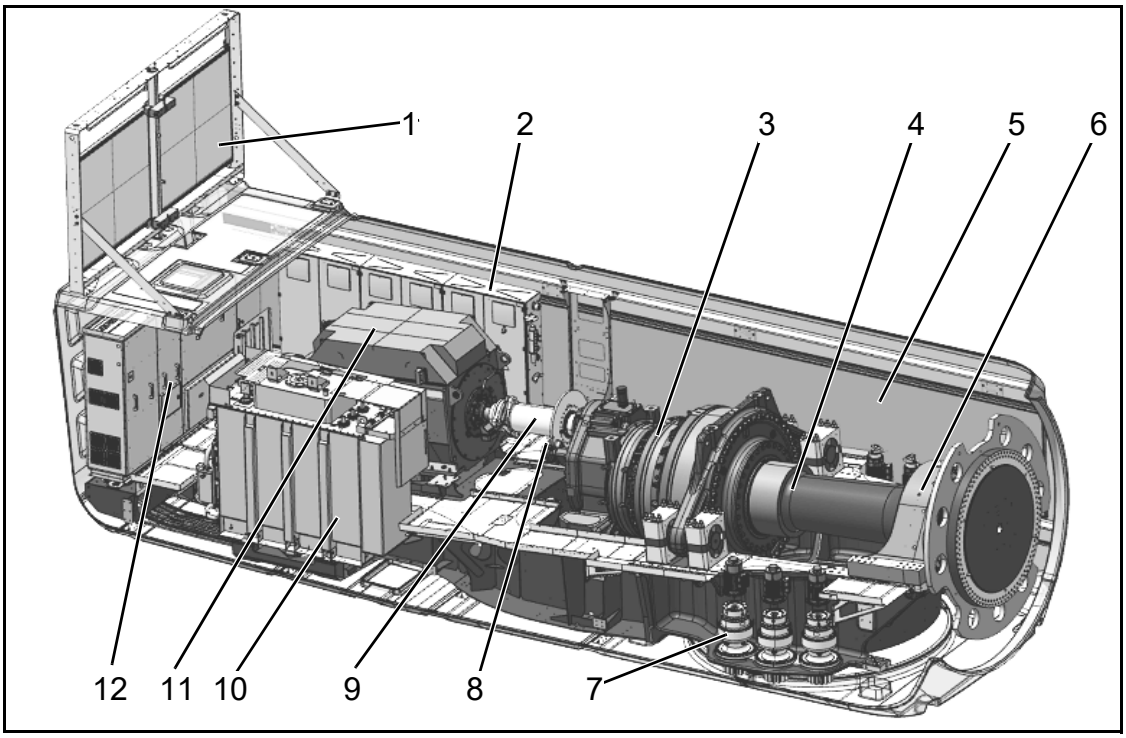


Abb. 2: Schematic diagram of the nacelle

1 Passive cooler
2 Switch cabinet
3 Gearbox
4 Rotor shaft
5 Nacelle housing
6 Rotor bearing
7 Yaw drives
8 Rotor brake
9 Coupling
10 Transformer
11 Generator
12 Converter

1.4 Auxiliary systems

1.4.1 Automatic lubrication system

Generator bearing, gearing of the pitch bearings, rotor bearing and gearing of the yaw bearing are each equipped with an **automatic lubrication system**.

1.4.2 Heaters

Gearbox, generator, cooling circuit and all relevant switch cabinets are equipped with **heaters**.

1.4.3 E-chain hoist and crossbeam

An electric **chain hoist** is installed in the nacelle which is used for lifting tools, components and other work materials from the ground into the nacelle.

A crossbeam including a sliding trolley is prepared for the use of a manual chain hoist to move the materials within the nacelle.

1.4.4 Cooling system

Gearbox, generator, converter and transformer are cooled via a coupled air/water heat exchanger. A pump conveys the mixture through the heat exchanger.
At startup the lightly heated gear oil is directly fed back into the gearbox via a thermal bypass and only directed into the plate-type heat exchanger after reaching operating temperature.

Heat exchange takes place via two passive coolers on the nacelle roof.

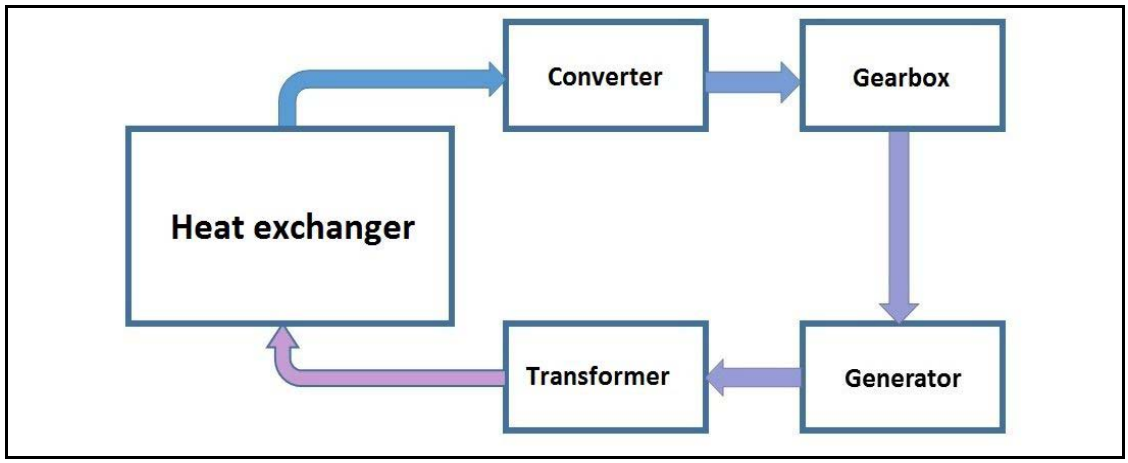


Fig. 3: Diagram of the cooling of major components in the nacelle

2. Control and electrical system

The WT operates automatically. A programmable logic controller (PLC) continuously monitors the operating parameters using various sensors, compares the actual values with the corresponding setpoints and issues the required control signals to the WT components. The operating parameters are specified by Nordex and are adapted to the individual location. The controller is located in a control cabinet in the tower base.

When there is no wind the WT remains in idle mode. Only various auxiliary systems are operational or activated as required: e.g., heaters, gear lubrication or PLC, which monitors the data from the wind measuring system. All other systems are switched off and do not use any energy. The rotor idles. When the cut-in wind speed is reached, the WT changes to the "ready for operation" condition. Now all systems are tested, the nacelle turns into the wind and the rotor blades turn into the wind. When a certain speed is reached, the generator is connected to the grid and the WT produces electrical energy.

At low wind speeds the WT operates at part load. The rotor blade remain turned into wind to the maximum extent. The power produced by the WT depends on the wind speed.

When the nominal wind speed is reached, the WT switches over to the nominal load range. If the wind speed continues to increase, the speed control changes the rotor blade angle so that the rotor speed and thus the power output of the WT remain constant.

The yaw system ensures that the nacelle is always optimally aligned to the wind. To this end two separate wind measuring systems on the nacelle measure the wind direction. Only one wind measuring system is used for the control system, while the second system monitors the first and takes over in case the first system fails. If the wind direction measured deviates too much from the nacelle alignment, the nacelle is yawed into the wind.

The wind energy absorbed from the rotor is converted into electrical energy using a doubly-fed induction machine with slip ring rotor. Its stator is connected directly, and the rotor via a specially controlled frequency converter, to the MV transformer which connects the turbine to the grid. Only part of the power needs to be routed via the converter, permitting low electrical system losses.

2.1 Safety systems

Nordex wind turbines are equipped with technical equipment and devices that protect people and systems and ensure permanent operation. The entire turbine is designed in accordance with the Machinery Directive 2006/42/EC and certified as per IEC 61400.

Safety-relevant parameters in the system control are monitored continuously. Here, the sensor data of the safe sensors are transmitted via a safe bus system to the safe controller for evaluation. If specified parameters are exceeded, the system is stopped via safe actuators and set to a safe state.

Depending on the cut-out cause, different brake programs are triggered. In event of external causes, such as excessive wind speeds or below operating temperatures, the wind turbine is gently braked by means of rotor blade adjustment.

Other safety functions are used to stop drives safely for maintenance work.

2.2 Lightning/overvoltage protection, electromagnetic compatibility (EMC)

The lightning/surge protection of the wind turbine is based on the EMC-compliant lightning protection zone concept, which comprises the implementation of internal and external lightning/surge protection measures under consideration of the standard IEC 61400-24. The wind turbine is designed according to lightning protection class I.

The wind turbine with the electrical equipment, consumers, the measurement, control, protection, information and telecommunication technology meets the EMC requirements according to IEC 61400-1.

2.3 Medium-voltage system

The medium voltage components are used to connect a WT to the wind farm medium-voltage grid or the local grid operator. The tower base contains the **MV switchgear**. It consists of a transformer field with circuit breakers and at least one ring cable field as default and up to three ring cable fields as an option (dependent on the wind farm configuration). The transformer panel consists of a vacuum circuit breaker and the disconnector with ground switch. The ring cable panel consist of a switch disconnector with a ground switch. The entire MV switchgear is assembled on a support/adapter frame.

Further characteristics of the MV switchgear:

- Routine tests of each switchgear in compliance with IEC 62271-200
- Type tested, SF6 insulation
- Internal switchgear for self-contained electrical systems (min. IP2X)
- SF-6 tank: metal-clad, metal-enclosed (min. IP65), independent of environmental influences
- Switch positions shown "On - Off - Grounded"
- Test terminal strip for secondary test
- Low-maintenance in accordance with class E2 (IEC 62271-100)

In case of technical availability Nordex can as an alternative to traditional SF6 insulated switchgear also supply SF6-free switchgear. This option is to be agreed upon with Nordex in advance.

The system protection of the MV switchgear is achieved by the following items:

- Improved personal safety and system protection in case of arcing by type testing in compliance with IEC 62271-200.
- Protection device supplied with converter current and stabilized for inrush current as DMT protection relay (independent maximum current protection).
- Actuating openings for switchgear are interlocked to preclude operation of more than one simultaneously, and can be locked as an option.
- Corrosion protection of the switchgear cells through hot-dip galvanization and painted surfaces.
- Pressure relief by pressure absorber duct in case of arcing. Alternatively, for the USA, an arc suppressor can be installed in the tank and in the cable connection compartment.

Transformer and **converter** are located in the nacelle. The transformer has been specified in accordance with IEC 60076-16.

The steel components at the transformer are dimensioned for corrosion protection class C3 (H).

Additional protection measures:

- Grounded tank (Ester transformer)
- Overtemperature protection with temperature sensor and relay
- Hermetic protection (leakage) and overpressure protection for ester transformer

2.4 Low-voltage grid types

The **690 V low voltage grid** is the primary wind turbine low voltage energy system. It is insulated from the ground as an IT grid and three phase AC network. The elements of the electrical operating and measuring devices of this network are grounded directly or via separate protective equipotential bonding cables. A central insulation monitor has been installed as another protective measure for personal and turbine safety in the 690-V-IT system.

The **400 V / 230 V low voltage grid** is the auxiliary wind turbine low voltage system. It has its neutral point grounded directly in the supplying grid transformers as a TN system and three-phase system. The equipment grounding conductor PE and the neutral conductor are available separately. The bodies of electrical equipment and consumers, including the additional protective equipotential bonding, are connected directly, through protective earthing conductor connections, straight to the neutral points of the supply grid transformers.

2.5 Auxiliary power of the wind turbine

The auxiliary low voltage required by the wind turbine in stand-by mode and feed-in mode is requested by the following consumers:

- System control including main converter control
- 400 V/230 V auxiliary power of the main converter
- 230 V AC UPS supply including 24 V DC supply
- Yaw system
- Pitch system
- Auxiliary drives such as pumps, fans and lubrication units
- Heating and lighting
- Auxiliary systems such as service lift, obstacle lights

Long-term measurements show that the average annual base load of the low-voltage auxiliary power plant in WT feed-in operation is approx. 15 kW in the average 10 min mean value and the maximum 10-min average value can reach up to 25 kW/32 kVA. These values are already included in the power curves. For locations with an average annual wind speed of 6.5 m/s approx. 10 MWh auxiliary consumption arise, however, this value is greatly dependent on location.

Auxiliary consumption is defines as the energy consumption of the WT from the grid for a period during which the WT does not supply current to the grid.

3. Options

Various options are available upon request as additional equipment for Nordex wind turbines.

The option of optional equipment must be coordinated with Nordex in advance.

4. Technical data

4.1 Technical design

Technical design	
Survival temperature	-40 °C to +50 °C
Operating temperature range	Normal Climate Version: -20 °C to +40 °C*
	Cold Climate Version: -30 °C to +40 °C*
Stop	Default: -20 °C, restart at -18 °C
	Cold Climate Version: -30 °C, restart at -28 °C
Max. height above MSL	2000 m*
Certificate	in accordance with IEC 61400-1
Type	3-blade rotor with horizontal axis Up-wind turbine
Output control	Active single blade adjustment
Nominal power	variable 4800 kW*
Nominal power starting at wind speeds of (at air density of 1.225 kg/m^3)	Approx. 13.5 m/s
Operating speed range of the rotor	6.5 min^{-1} to 13.0 min^{-1}
Nominal speed	approx. 11.4 min^{-1}
Cut-in wind speed	3 m/s
Cut-out wind speed	28 m/s**
Cut-back-in wind speed	22.0 m/s**
Calculated service life	≥ 20 years

* Nominal output is achieved depending on the power factor and the installation altitude up to defined temperature ranges.

** Depending on the project, the cut-out wind speed can be decreased to safeguard the structural stability.

Power adjustment depending on reactive power, temperature and altitudes ≤ 1000 m above MSL

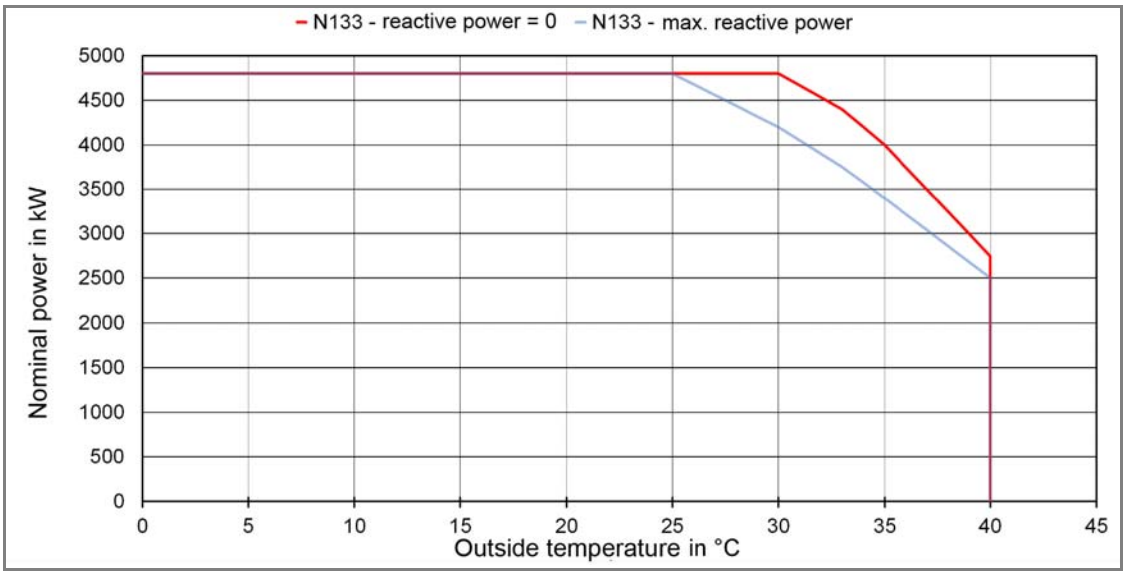


Fig. 4: Power adjustment for Nordex N133 wind turbines

4.2 Towers

Towers	TS78-00	TS83	TS90-00*	TS100-00
Hub height**	78.0 m	82.5 m	90.0 m	102.0 m
Tower type**	Tubular steel tower			
Wind class	DIBt S IEC S	DIBt S IEC S	IEC S	DIBt S IEC S
Number of tower sections	3	3	3	4
Surface finish	Color system coating (color code: RAL 7035 light grey)			

Towers	TS110	TS125-02	TS135*	TCS164
Hub height**	110.0 m	125.4 m	135.0 m	164.0 m
Tower type**				
Wind class	DIBt S IEC S	DIBt S IEC S	IEC S	DIBt S IEC S
Number of tower sections	4	6	5	3 steel sections 1 concrete part
Surface finish	Color system coating (color code: RAL 7035 light grey)			Steel section: Color system coating Concrete part: Fair-faced concrete

* Project-specific tower.

** Includes foundation height above ground level.

4.3 Rotor and rotor blades

Rotor	
Rotor diameter	133.2 m
Swept area	13935 m^2
Nominal power/area	344.5 W/m^2
Rotor shaft inclination angle	5 °
Blade cone angle	3.5 °

Rotor blade	
Material	Fiber glass and carbon fiber reinforced plastic
Total length	64.40 m

Rotor hub	
Material of the rotor hub body	Casting
Material spinner	Glass-fiber reinforced plastic

4.4 Nacelle

Nacelle	
Support structure	Welded steel structure
Cladding	Glass-fiber reinforced plastic
Machine frame	Casting
Generator frame	Welded steel construction

4.4.1 Rotor shaft

Rotor shaft / rotor bearing	
Type	Forged hollow shaft
Material	42CrMo4 or 34CrNiMo6
Bearing type	Spherical roller bearing
Lubrication	Regularly using lubricating grease

4.4.2 Brake and gearbox

Mechanical brake	
Type	Actively actuated disk brake
Location	On the high-speed shaft
Number of brake calipers	1
Brake pad material	Organic pad material

Gearbox	
Type	Multi-stage planetary gear + spur gear stage
Gear ratio	50 Hz: i = 107.6 60 Hz: i = 129.1
Lubrication	Forced-feed lubrication
Oil quantity including cooling circuit	Max. 650 l
Oil type	VG 320
Max. oil temperature	Approx. 77 °C
Oil change	Change, if required

4.4.3 E-chain hoist and crossbeam

E-chain hoist and lifting beam	
Electrical chain hoist max load	Min. 850 kg
Crossbeam max load	Sliding trolley to accommodate a manual chain hoist 1000 kg

4.5 Electrical system

Electrical system	
Nominal power P_{nG}	Up to 4800 kW*
Nominal voltage	3 x AC 690 V ± 10 % (specific to grid code)
Nominal current during full reactive current feed-in I_{nG} at S_{nG}	4571 A
Nominal apparent power S_{nG} at P_{nG}	5463 kVA
Power factor at P_{nG}	1.00 as default setting 0.8785 underexcited (inductive) up to 0.8785 overexcited (capacitive) possible
Frequency	50 and 60 Hz

* All data are maximum values. The values may deviate depending on the rated voltage, rated apparent power and WT active power.

4.5.1 Transformer

Transformer*	50 Hz	60 Hz
Total weight	Approx. 8 t	
Insulation medium	Ester	
Rated voltage OV, U_r	690 V	
Maximum rated voltage OS, dependent on MV grid, U_r	20 kV / 30 kV / 34 kV	
Taps, overvoltage side	20 kV and 30 kV: + 4 x 2.5 % 34 kV: + 4 x 0.5 kV	
Grid voltage OS	20; 20.5 kV; 21 kV; 21.5 kV; 22 kV / 30; 30.75; 31.5; 32.25; 33 kV / 34; 34.5; 35; 35.5; 36 kV	
Rated frequency, f_r	50 Hz	60 Hz
Vector group	Dy5	
Installation altitude (above MSL)	Up to 2000 m	
Rated apparent power, S_r	5350 kVA	
Impedance voltage, U_z	8 to 9 % ± 10 % tolerance	
Minimum peak efficiency index, η, (EU) 2019/1783, 548/2014	99.554 %	–
Inrush current	≤ 5.5 x I_N (peak value)	
Power loss** No-load losses Short circuit losses	ECO VERSION (EU) 2019/1783, 548/2014 Minimum peak efficiency index PEI=99.554 % approx. 2400 W approx. 58000 W	approx. 4000 W approx. 60000 W
	NON-ECO VERSION approx. 4000 W approx. 60000 W	

* The values are, if not specified otherwise, maximum values. The values may deviate depending on the rated voltage, rated apparent power and WT active power.

** Guide values.

4.5.2 Medium-voltage switchgear

Medium-voltage switchgear	
Rated voltage (depending on MV network)	24; 36; 38 or 40.5 kV
Rated current	50 Hz: 630 A 60 Hz: 600 A
Rated short-circuit duration	1 s
Rated short circuit current	24 kV: 16 kA (20 kA optional) 36/40.5 kV: 20 kA (25 kA optional)
Minimum/maximum ambient temperature during operation	Normal Climate Version: -25 °C to +40 °C
	Cold Climate Version: -30 °C to +40 °C
Connection type	External cone type C according to EN 50181 For USA: External cone type E according to IEEE 386
Circuit breaker	
Number of switching cycles with rated current	E2
Number of switching cycles with short-circuit breaking current	E2
Number of mechanical switching cycles	M1
Switching of capacitive currents	Min. C1 - low
Switch disconnector	
Number of switching cycles with rated current	E3
Number of switching cycles with short-circuit breaking current	E3
Number of mechanical switching cycles	M1
Disconnector	
Number of mechanical switching cycles	M0
Ground switch	
Switching number with rated short-circuit inrush current	E2
Number of mechanical switching cycles	≥ 1000

4.5.3 Generator

Generator	
Type	6-pole doubly-fed induction machine
Degree of protection	IP 54 (slip ring box IP 23)
Nominal voltage	690 V
Frequency	50 and 60 Hz
Speed range	50 Hz: 692 to 1400 min^{-1} 60 Hz: 892 to 1680 min^{-1}
Poles	6
Weight	Approx. 12.5 t

4.6 Cooling system

Gearbox cooling and filtration	
Gearbox	
Type	1st cooling circuit: Oil circuit with oil/water heat exchanger and thermal bypass 2nd cooling circuit: Water/air combined with generator, main converter and transformer
Filters	Coarse filter 50 µm / fine filter 10 µm / ultrafine filter < 5 µm
Flow rate	Stage 1: Approx. 100 l/min / Stage 2: Approx. 200 l/min
Generator	
Type	Water circuit with water/air heat exchanger and thermal bypass
Coolant	Water/glycol-based coolant
Flow rate	Approx. 160 l/min
Converter	
Type	Water circuit with water/air heat exchanger and thermal bypass
Coolant	Water/glycol-based coolant
Flow rate	Approx. 160 l/min
Transformer	
Coolant	Water/glycol-based coolant
1st cooling circuit	Ester circuit with ester/water heat exchanger
2nd cooling circuit	Water/air combined with generator, converter and gearbox

4.7 Pitch system

Pitch system	
Pitch bearing	Double-row four-point contact bearing
Gearing/raceway lubrication	Regular lubrication with grease
Drive	Electric motors incl. spring-loaded brake and multi-stage planetary gear
Emergency power supply	Batteries

4.8 Yaw system

Yaw system	
Yaw bearing	Double-row four-point contact bearing
Gearing/raceway lubrication	Regular lubrication with grease
Drive	Electric motors incl. spring-loaded brake and four-stage planetary gear
Number of drives	4-6
Yaw speed	Approx. 0.5 °/s

4.9 Corrosion protection

Corrosion protection*	Inside	Outside
Nacelle	C3	C4
Hub	C3	C4
Tower	C3	C4
Steel sections Concrete components	Color system coating Fair-faced concrete	Color system coating Fair-faced concrete

* Categories of corrosion protection according to ISO 12944-2.

4.10 Automation systems

Automation system	
Field bus system	Profinet
Safe fieldbus system	Profisafe via Profinet
Turbine control	Profinet system control
Safety control	Integrated safety control

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