General documentation

Technical description

Wind turbine class Nordex Delta4000
N149/4.0-4.5

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This is a translation of the original German document. In case of doubt, the German text shall prevail.

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1. Structure

The Nordex N149/4.0-4.5 wind turbine (WT) is a speed-variable wind turbine with a rotor diameter of 149 m and a nominal power between 4000 and 4500 kW (project-specific up to 4800 kW) which can be adapted dependent on location. The wind turbine is designed for class S in accordance with IEC 61400-1 or wind zone S in accordance with DIBt 2012 and is available in 50 Hz and 60 Hz variants.

A Nordex N149/4.0-4.5 wind turbine consists of the following main components:

- Rotor, with rotor hub, three rotor blades and pitch system.
- Nacelle with drive train, generator, yaw system, medium voltage transformer and converter.
- Tubular tower or hybrid tower with MV switchgear.

1.1 Tower

A N149/4.0-4.5 class wind turbine can be erected on a tubular 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 two sections.

Corrosion protection is guaranteed by a coating system of the surface according to ISO 12944. A service lift, 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.

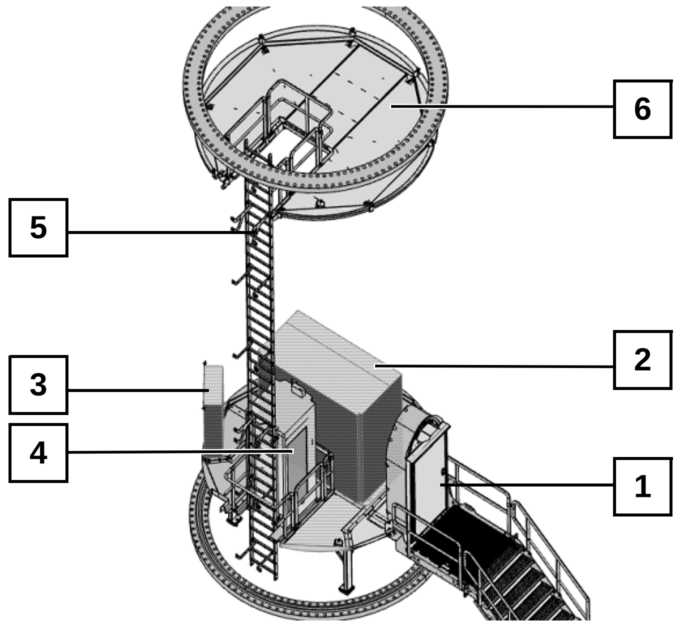

Fig. 1 Overview of the bottom section in a tubular steel tower, tower plates not shown

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

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). Optionally the blades can be equipped with serrations to optimize the noise level. The serrations consist of several serrated light-gray components made from glass fiber laminate, with a length of approx. 0.3 m to approx. 0.7 m, which are attached to the trailing edge of the rotor blades.

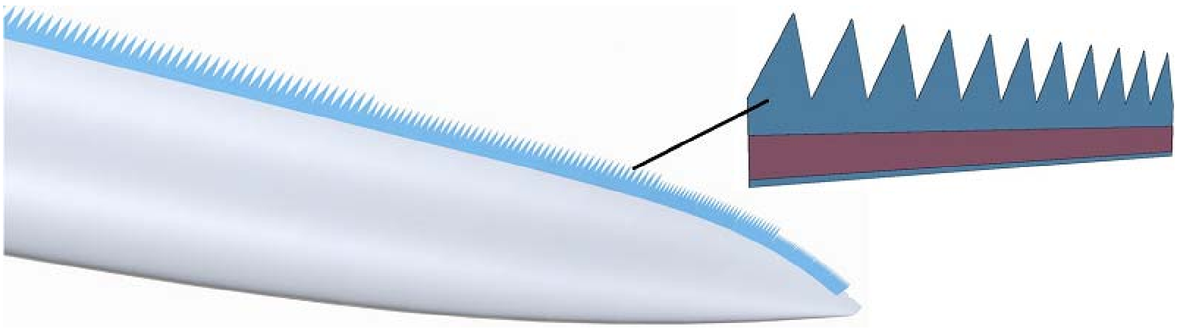

Fig. 2 Serrations on a rotor blade's trailing edge

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 3-phase 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 nacelle can be pivoted on the tower.

The **transformer** converts the generator/converter system's low voltage to the medium voltage defined by the point of supply.

In the **switch cabinet**, all electrical components required for the control and supply of the turbine are located.

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 **converter** connects the electrical grid to the generator which means the generator can be operated with variable rotational speeds.

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 2-stage pump enables the oil circulation. 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. If the operating temperature of the gear oil is exceeded it is cooled down.

The gearbox cooling is realized with an oil/water cooler that is installed directly at the gearbox. The cooling water is re-cooled together with the cooling water from the generator, converter and transformer in a passive cooler on the roof of the nacelle.

The **rotor shaft** is supported in the **rotor bearing** inside the nacelle. A rotor lock is integrated in the rotor bearing, with which the rotor can be reliably locked in place mechanically.

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

The **coupling** acts as force-transmitting connection between the gearbox and the generator.

The **generator** is a 6-pole doubly-fed induction machine. An air/water heat exchanger is mounted on the generator. The cooling water is re-cooled together with the cooling water of the other major components in a passive cooler on the roof of the nacelle.

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 teeth of the yaw bearing. In the aligned position the nacelle is locked with the yaw drives.

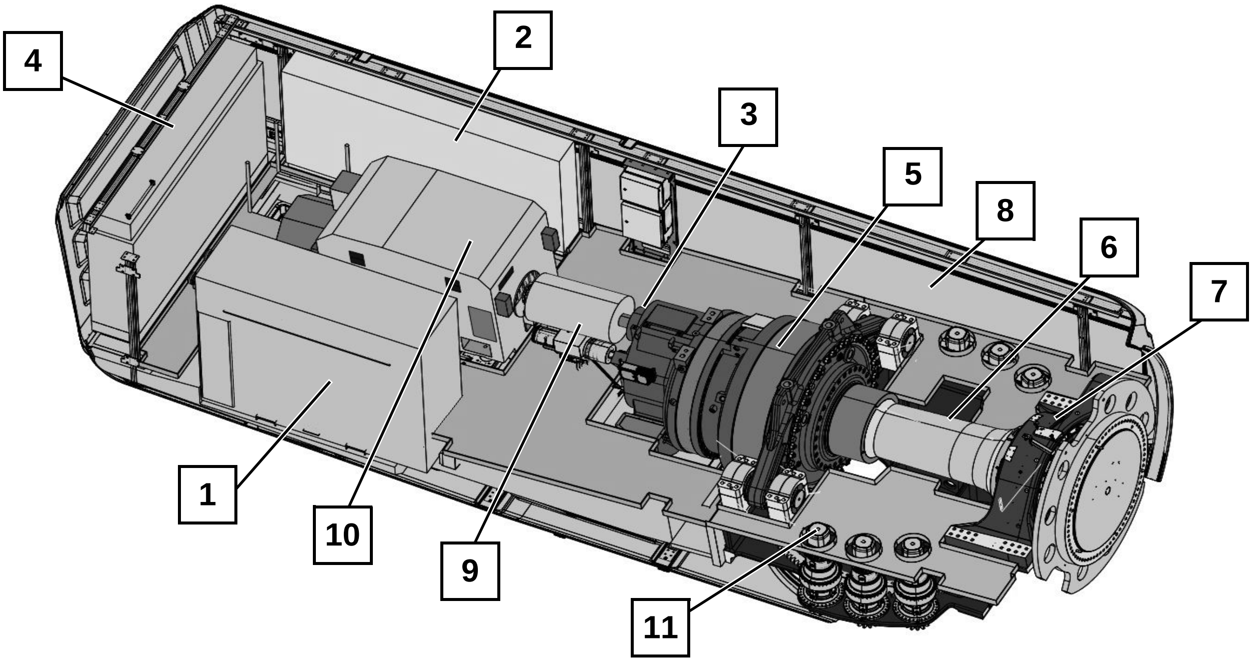

Fig. 3 Schematic diagram of the nacelle, example

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

1.4 Auxiliary systems

Generator bearing, gearing of the pitch bearings, rotor shaft and gearing of the yaw bearing are each equipped with an **automatic lubrication system**. An automatic lubrication of the raceways of the pitch bearing can be offered as an option.

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

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 second, movable **overhead crane** is used for carrying the materials within the nacelle.

Various options of additional equipment are available for the wind turbine.

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.

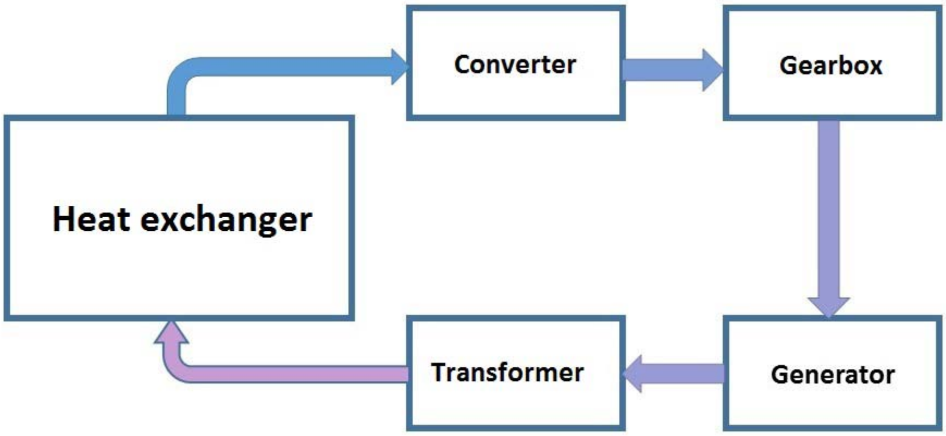

Fig. 4 Diagram of the cooling of major components in the nacelle

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

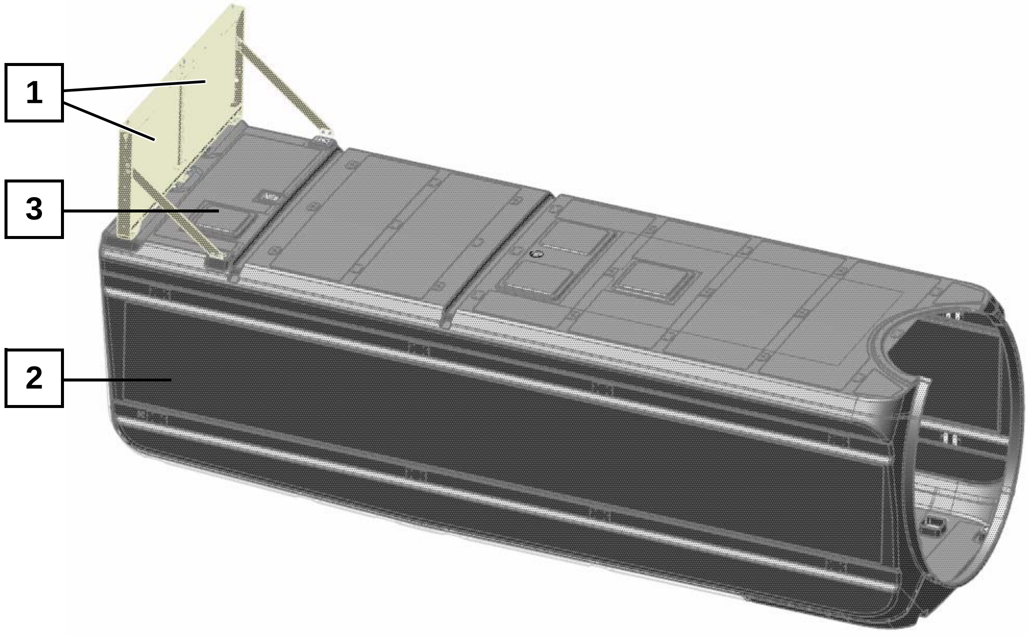

Fig. 5 Passive coolers in a frame on the roof

1	Passive cooler	2	Nacelle	3	Rear roof

2. Medium-voltage switchgear

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)
- SF6 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)

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

- Pressure relief by pressure absorber duct in case of arcing
- 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 activation current as overcurrent-time 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

Transformer and converter are located in the nacelle. The transformer has been specified in accordance with IEC 60076-16 and meets the eco-design requirements of 548/2014/EC.

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

Additional protection measures:

- Grounded housing (dry-type transformer) or grounded tank (ester transformer)
- Overtemperature protection with temperature sensor and relay
- Hermetic protection (leakage) and overpressure protection for ester transformer

3. Control and electrical system

The turbine 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.

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 optional STATCOM function has been enabled, the converter remains in operation and enables reactive power supply to the grid. 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 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.

3.1 Safety systems

Nordex wind turbines are equipped with extensive equipment and accessories to provide for personal and turbine safety and ensure continuous operation. The entire turbine is designed in accordance with the Machinery Directive 2006/42/EC and certified as per IEC 61400.

If certain parameters concerning turbine safety are exceeded, the WT will cut out immediately and is put into 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.

3.2 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 falls into lightning protection level I. All components of the internal and external lightning/surge protection are designed in accordance with lightning protection level 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, item 10.11.

3.3 Low-voltage grid types

The **660 V / 690 V low-voltage grid** as an IT grid configuration and three phase rotary current grid is insulated against ground and is the primary low voltage energy system of the wind turbine. The elements of the electrical operating and measuring devices of this network are grounded directly or via separate protective equipotential bonding cables. As a further protection measure for personal and turbine protection in the 660 V / 690 V IT grid a central insulation monitor has been installed.

The **400 V/230 V low-voltage grid** 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. The 400 V/230 V low voltage grid is the auxiliary wind turbine low voltage system.

3.4 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 base load (average active power) of the auxiliary low voltage system during WT feed-in operation mode is approx. 15 kW, based on one year. These values are already included in the power curves.

For locations with an average annual 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.

3.5 Wind turbine ratings exceeding 4500 kW

The N149/4.0-4.5 can be operated project-specifically with up to 4800 kW. For power outputs above 4500 kW, operation of an IT low-voltage grid with 690 V is required.

4. Technical data

Design	
Design temperature	Standard -20 °C to +45°C CCV -40 °C to +45 °C
Operating temperature range	-20 °C to +40 °C[1)]
Operating temperature range CCV	-30 °C to +40 °C[1)]
Stop	Standard -20 °C, restart at -18 °C CCV -30 °C, restart at -28 °C
Max. height above MSL	2000 m[1)]
Certificate	In accordance with IEC 61400-1 and DIBt 2012
Type	3-blade rotor with horizontal axis Up-wind turbine
Output control	Active single blade adjustment
Nominal power	variable 4000 - 4500 kW1)
Nominal power starting at wind speeds of (at air density of 1.225 kg/m^3)	Approx. 11.5 m/s
Operating speed range of the rotor	6.4 min^{-1} to 12.3 min^{-1}
Nominal speed	11.0 min^{-1}
Cut-in wind speed	3 m/s
Cut-out wind speed	26 m/s[2)]
Cut-back-in wind speed	25.5 m/s[2)]
Calculated service life	At least 20 years

[1)] Nominal power is achieved up to defined temperature ranges depending on the power factor. The N149/4.0-4.5 can be operated project-specifically with up to 4800 kW.
[2)] 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

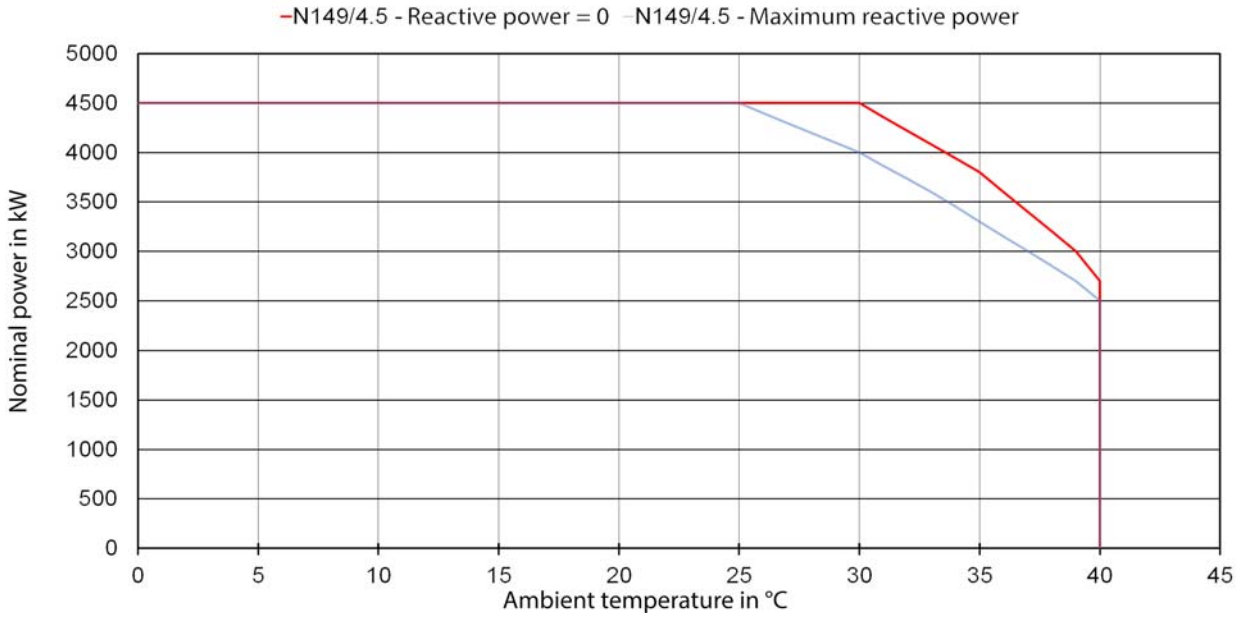

Fig. 6 *Power adjustment for Nordex N149 wind turbines with a power of up to 4500 kW*

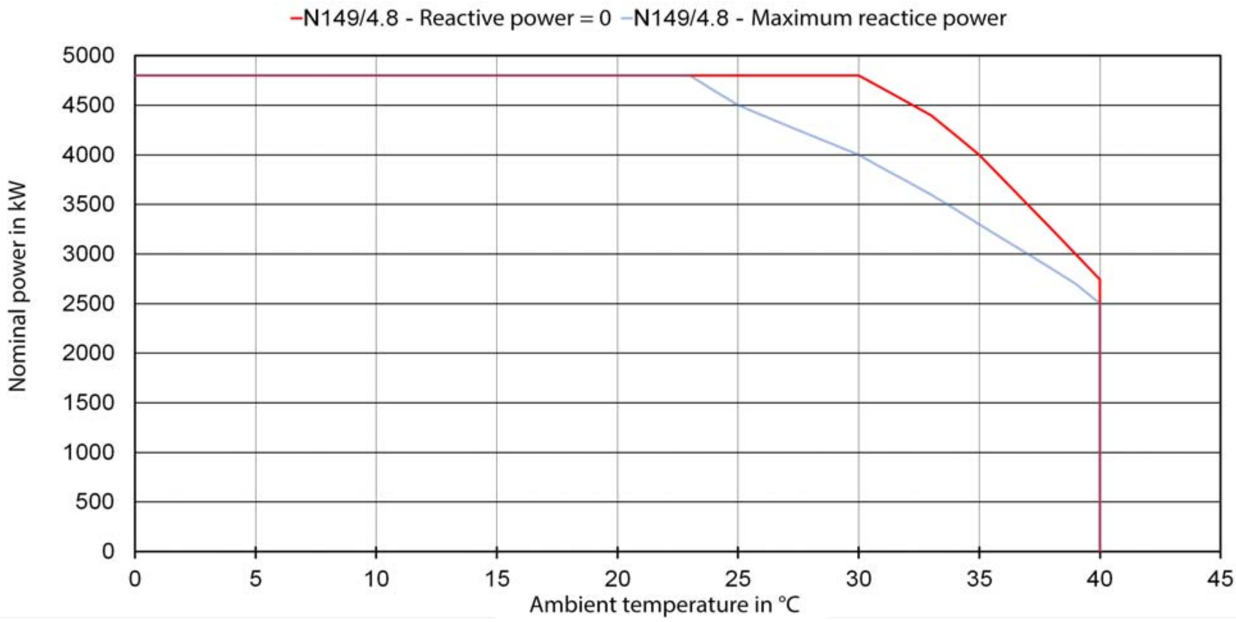

Fig. 7 *Power adjustment for Nordex N149 wind turbines with a power of up to 4800 kW*

Towers	TS105	TS108	TS125-01	TS135
Hub height	105 m	108 m	125 m	135 m
Wind class	DIBt S/ IEC S	IEC S	DIBt S/ IEC S	IEC S
Number of tower sections	4	5	6	5

Towers	TS145	TS145-01	TS155	
Hub height	145 m	145 m	155 m	
Wind class	IEC S	IEC S	IEC S	
Number of tower sections	6	5	6	

Towers	TCS164 NV05	TCS164 NV06		
Hub height	164 m	164 m		
Wind class	DIBt S/ IEC S	DIBt S/ IEC S		
Number of tower sections	2 steel sections 1 concrete part			

Rotor	
Rotor diameter	149,1 m
Swept area	17460 m2
Nominal power/area	257.7 W/m2
Rotor shaft inclination angle	5 °
Blade cone angle	3.5 °

Rotor blade	
Material	fiber glass and carbon fiber reinforced plastic
Total length	72.40 m

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

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 = 113.5 60 Hz: i = 136.2
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

Electrical installation (660 V AC) - wind turbines with a power of up to 4500 kW	
Nominal power P_{nG}	up to 4500* kW
Nominal voltage	3 x AC 660 V ± 10 % (specific to grid code)
Nominal current during full reactive current feed-in I_{nG} at S_{nG}	4503 A
Nominal apparent power S_{nG} at P_{nG}	5148 kVA
Power factor at P_{nG}	1.00 as default setting 0.869 underexcited (inductive) up to 0.885 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.

Electrical installation (690 V AC) - wind turbines with a power of up to 4800 kW	
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.

20 kV ester transformer*	660 V grid voltage	690 V grid voltage
Total weight	max. 9 t	
Rated voltage OV, U_r	0.66 kV	0.69 kV
Maximum rated voltage OV, dependent on MV grid, U_r	20 kV	
Taps, overvoltage side	+ 4 x 2.5%	
Grid voltage OV	20 kV; 20.5 kV; 21 kV; 21.5 kV; 22 kV	
Rated frequency, f_r	50 / 60 Hz	
Vector group	Dy5	
Installation altitude (above MSL)	Up to 2000 m	
Rated apparent power, S_r	5000 kVA	5350 kVA
Impedance voltage, u_z	8 to 9 % ± 10 % tolerance	
Minimum peak efficiency index, η	99.483 %	99.490 %
Activation current	≤ 5.5 x I_N (peak value)	
Verlustleistung1[1] Idle losses Short circuit losses	2800 W 57000 W	3000 W 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.

1) Guide values

20 kV resin transformer*	
Total weight	max. 9 t
Rated voltage OV, U_r	0.66 kV
Maximum rated voltage OV, dependent on MV grid, U_r	20 kV
Taps, overvoltage side	+ 4 x 2.5%
Grid voltage OV	20 kV; 20.5 kV; 21 kV; 21.5 kV; 22 kV
Rated frequency, f_r	50 / 60 Hz
Vector group	Dy5
Installation altitude (above MSL)	Up to 1000 m
Rated apparent power, S_r	5000 kVA
Impedance voltage, u_z	8 to 9 % ± 10 % tolerance
Minimum peak efficiency index, η	99.354 %
Activation current	≤ 12.5 x I_N (peak value).
Verlustleistung1) Idle losses Short circuit losses	 6000 W 42000 W

30 kV transformer*	660 V grid voltage	690 V grid voltage
Total weight	max. 9 t	
Insulation medium	Ester	
Rated voltage OV, U_r	0.66 kV	0.69 kV
Maximum rated voltage OV, dependent on MV grid, U_r	30 kV / 34 kV	
Taps, overvoltage side	+ 4 x 2.5 % / + 4 x 0.5 kV	
Grid voltage OV	30; 30.75; 31.5; 32.25; 33 kV / 34; 34.5; 35; 35.5; 36 kV	
Rated frequency, f_r	50 / 60 Hz	
Vector group	Dy5	
Installation altitude (above MSL)	Up to 2000 m	
Rated apparent power, S_r	5000 kVA	5350 kVA
Impedance voltage, u_z	8 to 9 % ± 10 % tolerance	
Minimum peak efficiency index, η	99.483 %	99.490 %
Activation current	≤ 5.5 x I_N (peak value)	
Power loss[1)] Idle losses Short circuit losses	 2800 W 57000 W	 3000 W 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.

[1)] Guide values

MV switchgear	
Rated voltage (depending on MV network)	24, 36 or 40.5 kV
Rated current	630 A (>630 A optional)
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	NCV: -25 °C to +40 °C
	CCV -30 °C to +40 °C
Connection type	External cone type C according to EN 50181
Circuit breaker	
Number of switching cycles with rated current	E2
Number of switching cycles with short-circuit breaking current	E2

MV switchgear	
Number of mechanical switching cycles	M1
Switching of capacitive currents	Min. C1 - low
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	
Number of switching cycles with rated short-circuit breaking current	E2
Number of mechanical switching cycles	≥ 1000

Generator	
Degree of protection	IP 54 (slip ring box IP 23)
Nominal voltage	660 V / 690 V
Frequency	50 and 60 Hz
Speed range	50 Hz: 730 to 1390 min^{-1} 60 Hz: 876 to 1668 min^{-1}
Poles	6
Weight	approx. 10.6 t

Gearbox cooling and filtration	
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 and converter cooling	
Type	Water circuit with water/air heat exchanger and thermal bypass
Flow rate	approx. 160 l/min
Coolant	Water/glycol-based coolant

Transformer cooling	
1st cooling circuit	Variant 1: Ester circuit with ester/water heat exchanger Variant 2: Sealed air circuit with air/water heat exchanger
2nd cooling circuit	Water/air combined with generator, converter and gearbox

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	Gel batteries

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	6
Yaw speed	Approx. 0.5 °/s

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