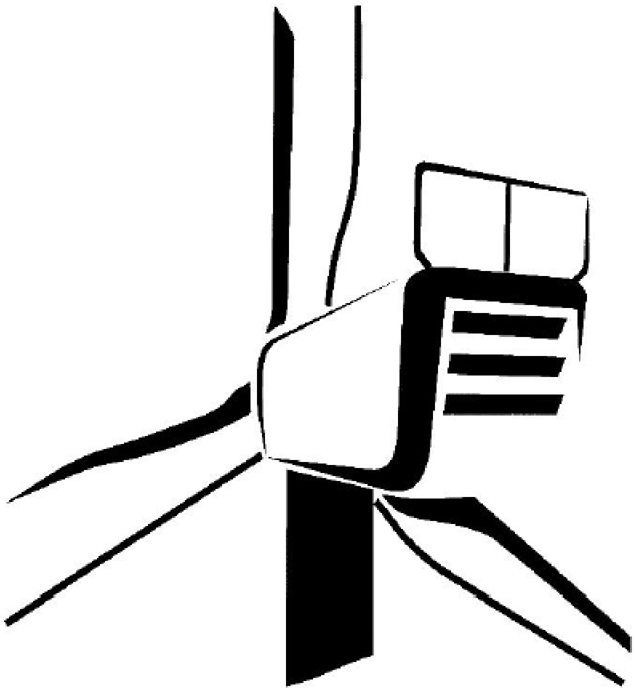
TECHNICAL DESCRIPTION

N155/4.5



Rev.	Date	Revision Description
A	2019-03-26	First edition
B	2019-05-30	Standard and extended configurations defined
C	2019-11-22	Technical data values updated
D	2019-12-19	Technical data values updated. New variants added
E		

Done	*Reviewed*	*Approved*
SCI	JGS	MNP
19-12-2019	19-12-2019	19-12-2019

1. STRUCTURE

The Nordex N155/4.5 wind turbine (WT) is a speed-variable wind turbine with a rotor diameter of 155 m and a nominal power of 4500 kW. The wind turbine is designed for class S in accordance with IEC 61400-1 and is available in 50 Hz and 60 Hz variants.

A Nordex N155/4.5 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 steel or concrete tower or hybrid tower with MV switchgear

1.1. Tower

A N155/4.5 class wind turbine can be erected on a tubular steel tower, on a tubular concrete 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. Corrosion protection is guaranteed by a coating system of the surface according to ISO 12944.

The concrete tower is a structure with prefabricated concrete elements called keystones. The union of the tower to the ground is made by inserting the steel bars of the lower section keystones into the sheaths embedded in the foundation. Then, the sheaths are filled with high resistance mortar to form a union with the foundation. The entire tower is also post-tensioned from the top of the tower to 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.

A service lift, the vertical ladder with fall protection system as well as resting and working platforms inside the tower (depends on the model) allow for a weather-protected ascent to the nacelle.

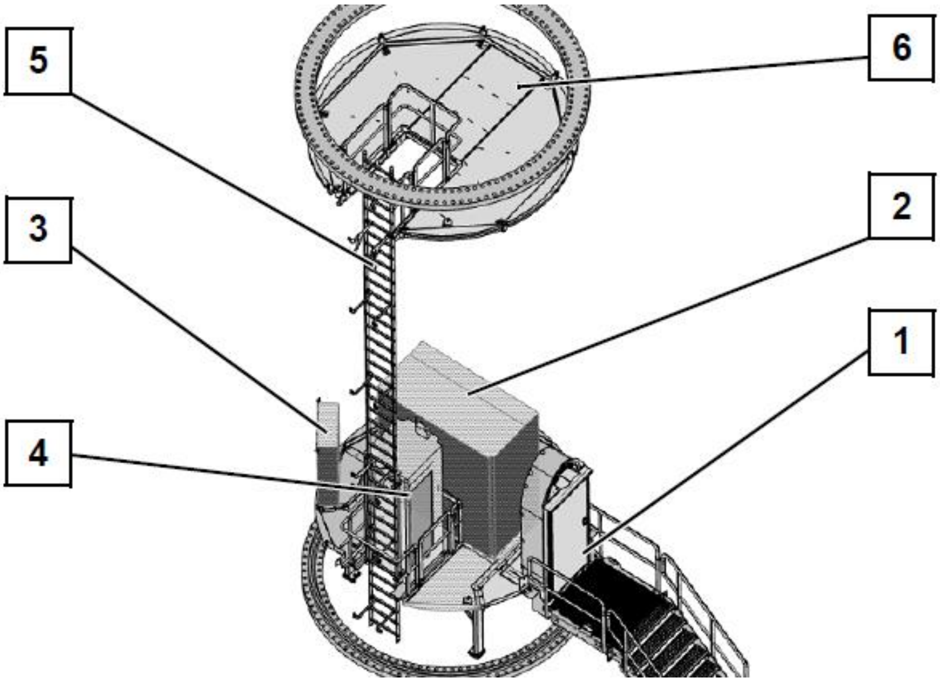


Fig. 1 Overview of the bottom section in a tubular steel tower, tower plates not shown

1) Tower access	*4) Tower service lift*
2) MV switchgear	*5) Ladder path*
3) Control cabinet	*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 manufactured in epoxy-reinforced fiberglass, with a smooth superficial coating intended to protect them from UV radiation and to keep their colour. Each blade comprises two joined sections, supported by beams and internal ribs. The rotor blade is tested statically and dynamically in accordance with the guidelines IEC 61400-1 and IEC 61400-23.

The **pitch system** serves to adjust the pitch angle of the rotor blades set by the control system. The pitch system comprises independent hydraulic cylinders for pitch angle setting for each individual rotor blade. These cylinders are fixed to the hub, and their rod ends are mounted onto the pitch plates which are connected to the inner ring of the blade bearings, provoking their rotation when the cylinders push or pull. Each blade has a nitrogen accumulator located in the hub, where there is sufficient permanent supply of pressurized oil to ensure the blade can enter the feather position, even in the case of insufficient power supply from the hydraulic unit (system pressure drop).

1.3. Nacelle

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

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 torque-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.

There are two configuration with different electrical capabilities: **standard and extended configuration**. The extended option has a nacelle refrigeration kit system and an upgraded cooling system. The electrical capabilities of both options are described in the DG200861.

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.

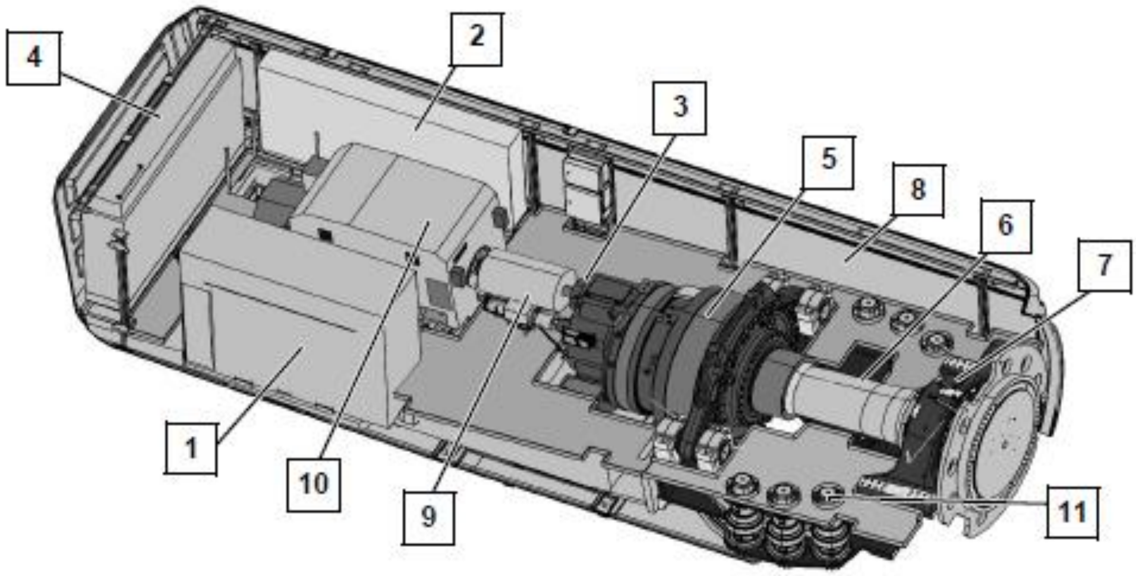


Fig. 2 Schematic diagram of the nacelle

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

2. MEDIUM-VOLTAGE SWITCHGEAR

The medium voltage components are used to connect a WT to the medium voltage grid in the wind farm or the grid of 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 consists 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.

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

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 cut-in wind speed is reached, the wind turbine will change to the mode 'Ready for operation'. 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 blades 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 a wind measuring system on the nacelle measure the wind direction. If the measured wind direction deviates too greatly from the alignment of the nacelle, 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 case of external causes, such as excessive wind speeds or if the operating temperature is not met, the wind turbine is softly 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 **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 grid are grounded directly or via separate protective equipotential bonding cables. As a further protection measure for personal and turbine protection in the 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 at the supplying grid transformers as TN netwosystem and three-phase system. The equipment grounding conductor PE and the neutral conductor are available separately. The bodies of the electrical equipment and consumers are connected directly and straight to the neutral points of the supplying grid transformers via equipment grounding conductors, including the protective equipotential bonding. The 400 V/230 V low voltage grid is the auxiliary low voltage system of the wind turbine.

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.

4. TECHNICAL DATA

DESIGN	
Survival temperature range	NCV: -20 °C to +50 °C CCV: -40ºC to +50ºC
Operating temperature range	*TC120N & TCS164N NCV:* -10 °C to +40 °C[1) 2)] *TS108-XX & TS105-XX NCV:* -20 °C to +40 °C[1) 2)] *TS108-XX CCV:* -30 °C to +40 °C[1) 2)]
Stop	*TC120N & TCS164N NCV:* -10.5 °C, restart at -9.5°C *TS108-XX & TS105-XX NCV:* -20.5 °C, restart at -19.5°C *TS108-XX CCV:* -30.5 °C, restart at -29.5°C
Max. height above MSL	1000 m[1) 2)]
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	4500 kW[1) 2)]
Nominal power starting at wind speeds of (at air density of 1.225 kg/m^3)	Approx. 10.5 m/s
Operating speed range of the rotor	6 rpm – 10.58 rpm
Cut-in wind speed	3 m/s
Cut-out wind speed ($\mathbf{V_{out,10min}}$)	25m/s [3)]
Cut-back-in wind speed ($\mathbf{V_{restart,10min}}$)	See DG200855
Calculated service life	At least 20 years

1) *Nominal power is achieved up to defined temperature ranges depending on the power factor*

2) *Nominal power is achieved up to defined temperature ranges depending on the configuration: standard or extended option (see DG200861)*

3) *Depending on the project, the cut-out wind speed can be decreased*

TOWERS	TS105-XX	TS108-XX	TC120N	TCS164N
Hub height	105 m	108 m	120 m	164 m
Wind class	IEC S	IEC S	IEC S	IEC S
Number of tower sections	4	5	6	2 steel sections 5 concrete sections

ROTOR	
Rotor diameter	155 m
Swept area	18869.2 m^2
Nominal power/area	238.48 W/m^2
Rotor shaft inclination angle	5°
Blade cone angle	5º

ROTOR BLADE	
Material	Epoxy-reinforced fiberglass
Total length	76 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 = 113.48 60 Hz: i = 136.17
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	
Nominal power P_{nG}	4500* 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}	4071 A
Nominal apparent power S_{nG} at P_{nG}	4865 kVA
Power factor at P_{nG}	1.00 as default setting 0.925 underexcited (inductive) up to 0.925 overexcited (capacitive) possible
Frequency	50 and 60 Hz

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

STEP-UP TRANSFORMER*	
Total weight	Max. 9 t
Insulation medium	Ester transformer
Rated voltage OV, U_r	0.69 kV
Maximum rated voltage OV, dependent on MV grid, U_r	20-30-34 kV
Taps, overvoltage side	+ 4 x 2.5 % / + 4 x 2.5 % / + 4 x 0.5kV
Grid voltage OV	20 kV; 20.5 kV; 21 kV; 21.5 kV; 22 kV; 30 kV; 30.75 kV; 31.5 kV; 32.25 kV; 33 kV / 34 kV; 34.5 kV; 35 kV; 35,5 kV; 36 kV
Rated frequency, f_r	50/60 Hz
Vector group	Dy5
Installation altitude (above MSL)	Up to 1000m
Rated apparent power, S_r	5350 kVA
Impedance voltage, u_z	8 to 9 % ± 10 % tolerance
Minimum Peak Efficiency Index, η	99.490 %
Activation current	< 5.5 x I_N (peak value)
Power loss[1)] Idle losses Short circuit losses	 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 (dependent on MV grid)	24 or 36 kV or 40.5kV
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 kV: 20 kA (25 kA optional)
Minimum/maximum ambient temperature during operation	-25 °C to +40 °C
Connection type	External cone type C acc. to EN 50181
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
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	690 VAC
Frequency	50 and 60 Hz
Speed range	50 Hz: 730 to 1390 rpm 60 Hz: 876 to 1668 rpm
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
Filter	Coarse filter 50 µrn / fine filter 10 µrn / ultrafine filter <5µm
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 2nd cooling circuit	Ester circuit with ester/water heat exchanger Water/air combined with generator, converter and gearbox

PITCH SYSTEM	
Pitch bearing	Double-row four-point contact bearing
Raceway lubrication	Grease Regular lubrication with grease (optional)
Drive	Individual hydraulic cylinder for each blade fixed to the hub and with rod end mounted onto the pitch plates, which are connected to the inner ring (mobile part) of the blade bearing.
Emergency power supply	Individual nitrogen accumulator on hub for each blade

YAW SYSTEM	
Yaw bearing	Double-row four-point contact bearing
Gearing lubrication	Grease Regular lubrication with grease (optional[1)])
Drive	Electric motors incl. spring-loaded brake and four-stage planetary gear
Number of drives	6
Yaw speed	Approx. 0.5 °/s

1) To be confirmed