


TN 535 WIND TURBINE

GENERAL DESCRIPTION

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1 INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This document provides a General Description of the TN 535 WEC.

The document is organized as follows:

- Chapter 1 (the present chapter) describes the purpose of the document and its application domain;
- Chapter 2 describes limitations of the TN 535 WEC;
- Chapter 3 provides a short technical description of the TN 535 WEC;
- Chapter 4 describes the operation of the TN 535 WEC.

1.2 APPLICATION DOMAIN

This document is applicable to TN 535 WEC designed, manufactured by Tozzi Nord.

1.3 REFERENCE DOCUMENTS

TITLE	CODE	RELEASE
[Ref. 1] Wind turbines – Part 2: Design requirements for small wind turbines	IEC 61400-2	Second edition, 2006-07
[Ref. 2] Electrical apparatus for explosive atmospheres / Areas and zones	IEV426-03-02	-
[Ref. 3] TN 535 User Manual	TN535-1_MU_en	01
[Ref. 4] Electrical diagram of TN 535 WT : control & power cabinet	60002-1	-
[Ref. 5] Electrical diagram of TN 535 WT: nacelle cabinet	60010-1	-
[Ref. 6] Electrical diagram of TN 535 WT : nacelle wiring diagram	60021-1	-
[Ref. 7] TN 535 Lightning Protection	TN11-48	A

Table 1 - Reference documents.

1.4 LIST OF ABBREVIATIONS AND DEFINITIONS

Abbreviation	Definition
WT	W ind T urbine
WEC	W ind E nergy C onverter
HW	H ard W are
SW	S oft W are
PLC	P rogrammable L ogic C ontroller
IEC	International E lectrotechnical C ommission
IEV	International E lectrotechnical V ocabulary
DLC	D esign L oad C ase

Table 2 - List of abbreviations and definitions.

2 LIMITATIONS

This chapter describes the limitations to use the TN 535 WEC.

2.1 ENVIRONMENTAL CONDITIONS

TN535 is designed to withstand standard SWT-Class IV, as defined in section 6 of CEI/IEC 61400-2 [Ref. 1]; all environmental conditions for which TN535 is designed are summarized in the table below.

Wind conditions:			
	SWT Class	IV	
Reference wind speed V_{ref} (10 min average, hub height, recurrence time 50 years)	30.0	[m/s]	
Annual average wind speed V_{ave}	6.0	[m/s]	
turbulence intensity level at 15m/s I_{15}	0.18	[-]	
dimensionless slope parameter α (to be used for the calculation of standard deviation turbulence as a function of V_{hub} and I_{15})	2.0	[-]	
expected extreme wind speed V_{e50} (3 sec average, hub height, recurrence time 50 years)	42.0	[m/s]	
expected extreme wind speed V_{e1} (averaged over 3 s, recurrence time 1 years)	31.5	[m/s]	
design wind speed	8.4	[m/s]	
Other Environmental conditions:			
Normal temperature range	-10<T<40	[°C]	
Relative humidity of the air	<95%	[-]	
Air density ρ	1.225	[kg/m³]	
Solar radiation	1000	[W/m²]	
Lightening protection system electric scheme described in: [Ref. 4], [Ref. 5], [Ref.6]			
Atmospheric content equivalent to that of a non-polluted inland atmosphere (see IEC 60721-2-1);			
Earthquake model: TN535 standard towers and foundations are verified according to "Decreto Ministeriale 14.01.2008, Testo Unitario - Norme Tecniche per le Costruzioni" (NTC08), seismic class-II			
Electrical network conditions:			
Normal supply voltage and range	400±10%	[V]	
Normal supply frequency and range	50±3%	[Hz]	

Table 3 Summary of environmental conditions for which TN535 is designed

For sites with environmental conditions outside of the design conditions, TN cannot be held responsible for any defects, including but not limited to damages and/or loss of energy yield.

2.1.1 Cold climate

Standard machine is rated and tested for temperature range included between -10°C and +40°C. At maximum temperature, is possible an automatic and temporary power derating, according with cycle of the power and other environmental condition (like insulation or wind). Moving over or below these limit not represent risk of injuries.

The product can be equipped for extended temperature range with several options: heater and or insulation, additional ventilation, different greases. According to customer need and site characteristic right configuration is implemented.

2.1.2 Wind farm influence

Loading of wind turbines is calculated for a single wind turbine.

In general Tozzi Nord recommend that wind turbines are placed in distances of at least 5 rotor diameters.

2.1.3 Complex terrain

Loading of wind turbines is calculated for a non-complex terrain.

Standard machine is rated for 1000m above sea level. For use over this altitude customer has to contact TN for quantify losses in performance and eventually application limit.

2.2 PROPER USE

The machine can be used in all the conditions specifically described in the User Manual of the product [Ref. 3], section A.5.

3 TECHNICAL DESCRIPTION

The Tozzi Nord TN 535 is a wind energy converter with a three-bladed rotor, active pitch control and variable speed operation with a rated power of 9.9 kW. With its rotor diameter of 13.2 m and tower height of 15 or 18 or 24 m the TN 535 efficiently makes use of the prevailing wind conditions at its respective operating sites to generate electrical energy.



Figure 1 - Tozzi Nord TN 535 wind turbines.

The main focus for development and design of all Tozzi Nord products is the idea to optimize the energy production even at low wind speed and minimizing the loads.

Power control with variable speed allows the TN 535 to operate with optimum efficiency in the entire operation field and avoid undesirable power spikes. Therefore guaranteeing good energy yield and high quality power fed to the grid.

The active pitch control reduces the loads on the structure especially at high wind speeds.

Please refers to Appendix A for further details concerning the TN 535 WEC.

3.1 TN 535 ARCHITECTURE

The TN 535 is a 3 bladed, pitch controlled wind turbine. It is designed for full variable speed, using full power inverters for the grid connection. The rotor runs upwind.

3.2 ELECTRICAL SYSTEM OVERVIEW

Please refers to the schematics in Appendix B.

3.3 ROTOR

The rotor has three blades, made out of glass reinforced epoxy resin. The blades are directly fixed to the blade bearings which allow pitching of the blades. The TN 535 has a collective pitch, driven by an electrical linear drive or in redundancy by a mechanical system.

3.4 POWER TRANSMISSION

The torque, produced by the rotor, is transmitted directly to the big wheel of the belt drive, without load the main shaft with any torsion.

The belt gear has a transmission ratio of 1:11.4 and transmit the power to a PMSG (Permanent Magnet Generator) with a nominal speed of 750 rpm .

The belt drive train adopted in the TN 535 is key point of the proposed WT. In fact, with respect to other WT fitted with traditional gearbox train one have:

- Greater efficiency due to minor losses especially partial load.
- Minor maintenance costs (for example oil changes are no longer necessary).
- High temperature range without change in the efficiency.
- Noiseless.
- Acts as a safety friction coupling in case of the generator short circuit.

3.5 GENERATOR

The TN 535 WT adopts a PMSG with a nominal speed of 750 rpm driven by the turbine rotor by means of the belt drive train. The generator provides its rated power already at a rotor speed of 66 rpm. The copper windings are fitted with an isolation class F for 155 °C.

3.6 YAW SYSTEM

The Yaw system is built up by the three elements yaw bearing, yaw brake and yaw drive.

The yaw bearing is built up as a sliding bearing. This has different advantages:

- Maintenance free.
- Higher friction than a roller bearing which supports the yaw brakes.

The yaw brake is built up with two brakes loaded by compression springs. The brakes are constantly acting, means, they brake also when the machine is yawing.

The yaw drive is an asynchronous three-phase motor 400 Vac with a flanged reduction gear. The gear is greased for live time, means it is maintenance free. The torque of the motor is transmitted by a chain drive to the yaw bearing. The max torque of the drive is higher than the friction torque of the brakes and the yaw bearing

3.6.1 Cinematism

The yaw bearing is mounted directly to the top of the tower using a geared ring and a slewing ring bearing. Two adjustment drives ("yaw drives") turn the nacelle out of the wind with the geared ring. The weight of the nacelle is also transferred via this yaw bearing into the tower. The main carrier is attached directly to the yaw bearing.

3.6.2 Cable unwinding

The sensors for the cable twist are switches connected to the yaw ring. Changes in the nacelle position are converted to electric signals for the control system.

3.7 TOWER

The TN 535 is sold with a 16-sides polygonal tubular steel tower, built in two sections. It is available in heights of 14.6m, 17.6m e 23.6m.

3.8 PITCH SYSTEM

The TN 535 is equipped with a collective pitch system controlled by the PLC. The pitch drive consists of a linear drive, run by a brushless DC motor. It is feed through the 28 VDC BUS of the machine. In case of grid failure the DC BUS has a backup battery. The high speed of the pitch drive allows the blade angle to be quickly and precisely adjusted according to the prevailing wind conditions.

Actual TN535 setup consider an optimum root-pitch of +13.3°, a waiting root-pitch of 36.3° and a parking root-pitch of 87.4°.

	Optimum	Waiting	Parking	
Nominal-pitch →	2.0	25.0	76.1	[deg]
Tip-pitch →	0.5	23.5	74.6	[deg]
root-pitch at r=1500mm (reference for this document) →	13.3	36.3	87.4	[deg]

Table 4 Definition of important pitch angles.

3.9 CONTROL SYSTEM

The TN 535 control system is based on an industrial PLC which constantly monitors the sensors of the various components as well as e.g. the data of wind direction and wind speed and in return adapts the operation of the TN 535 accordingly.

This is done by optimizing the rotor speed, the blade angle, the yaw position of the nacelle and the power output of the generator accordingly.

During operation, all relevant sensors are constantly monitored in order to initiate the appropriate measures (e.g. parking or emergency stop) in case an irregularity occur.

3.9.1 Yaw control

The wind vane at hub height continuously detects the wind direction. If the average deviation of the nacelle direction compared to the measured wind direction is greater than a certain quantity, the nacelle is repositioned by means of the yaw motor. Yaw motion is monitored by counting the rotations of the yaw motor and by checking the yaw time for plausibility.

3.9.2 Pitch control

When the maximum rotor speed limit is reached, the blade angles are changed accordingly to keep it constant. To achieve this, the appropriate blade angle is selected by evaluating the speed and acceleration measurements.

3.10 SAFETY SYSTEM

The safety system of the TN 535 is designed to keep the wind turbine under safe condition in all cases mentioned in the norm IEC 61400-2 [Ref. 1]. To control the machine and guaranty its safety, the values are monitored continuously by the PLC.

Appendix C shows the load case according to IEC 61400-2 [Ref. 1] coming up by the different faults.

There are three types of sensors or status monitored:

- Safety relevant sensors.
- Status signals from switches and inverters.
- Not safety relevant sensors.

3.10.1 Safety relevant sensors and measurements

The safety relevant sensors are continuously checked for reliable values. These sensors stop the machine in a normal braking procedure by pitching the blades into braking position whenever the value is out of the threshold or not reliable.

- Rotor speed sensors 1, checked continuously by comparing with rotor sensor 2.
- Rotor speed sensors 2, checked continuously by comparing with rotor sensor 1.
- Vibration sensor, checked continuously for unreliable values cause by short circuit or broken cable.
- Voltage level of 28 VDC checked continuously.
- Battery voltage level, checked monthly and after each start up out of the braking position.
- Battery capacity, checked monthly and after each start up out of the braking position.
- Belt slipping, checked continuously by comparing rotor speed and generator speed.
- Yaw sensor 1, checked when passing the maker, right sequence with yaw sensor 2.
- Yaw sensor 2, checked when passing the maker, right sequence with yaw sensor 1.
- Yaw time, checked by a timer.
- Sensor pitch drive braking position, checked when moving to braking position by a timer.
- Sensor pitch drive waiting position, checked when moving to waiting position by a timer.
- Sensor pitch drive working position, checked when moving to working position by a timer.

3.10.2 Status signals

If a status signal is missing or the value is wrong, the machine is stopped in a normal braking procedure by pitching the blades into braking position.

- Inverter status, checked continuously.
- Status of 28 VDC grid supply switch, checked continuously.
- Status of 28 VDC sensors switch, checked continuously.
- Grid failure, checked continuously.
- Grid monitoring interface, checked continuously.
- Yaw motor protection, checked continuously.

3.10.3 Not safety relevant sensors

Not safety relevant sensors cause a warnings.

Hereafter a list of not relevant sensors:

- Wind vane broken or iced, checked continuously
- Generator temperature, checked continuously for unreliable values cause by short circuit or broken cable.

3.11 THE BRAKE SYSTEM

The TN 535 brakes always aerodynamically by collective pitching the three blades. There are two independent actuator systems working on the pitch mechanism of the three blades. The main actuator is electrically driven, the emergency actuator is a completely independent mechanical system.

3.11.1 Electrical Brake System

The electrical system uses an electrical linear actuator working on all three blades by a mechanical system. The electric power is coming from the 28 VDC BUS, feed by a power supply, feed from the grid. A backup battery is always kept charged and its capacity is tested monthly by the controller.

3.11.2 Mechanical Brake System

The mechanical emergency system is triggered by centrifugal force when the electrical system is not working anymore and the machine goes into an rotor over speed. The energy to move the pitch system is coming from the rotating rotor. The system is designed to have ten times the power of the electrical system. The high power of the emergency system gives the assurance, that it is able pitch the blades into the braking position, even then the electrical actuator was not able any more. The emergency system has to be rested by hand, means a skilled person has to climb the nacelle.

3.12 PROTECTION OF THE ELECTRICAL POWER LINE

The electric power line is mainly protected by the control logic of the static converter against following faults:

- Generator short circuit to ground
- Generator short circuit phase to phase
- Short circuit in the cables between generator and inverter
- Inverter faults
- Grid failure

3.13 LIGHTENING PROTECTION

Please refers to TN 535 Lightening Protection document [Ref. 7] .

4 OPERATING THE TN 535 WEC

This paragraph describes the main operating conditions of the TN 535 WEC. For a more detailed information, please refers to the User Manual [Ref. 3].

4.1 CONTROL LEVELS OF THE TN 535

4.1.1 Level 1, access for the user

The user, usually the customer of the machine, is the person who has read and understood the instructions of use expressed in the User Manual Wind turbine model TN535 [Ref 3]. He has access to the first level. On this level is an OPERATION MODE SELECTOR SWITCH and the MAIN SWITCH.

The OPERATION MODE SELECTOR SWITCH has three positions:

1. *OFF* The WEC is completely off, it does not pitch nor yaw.
2. *Standby* The WEC is off, it does not pitch but still align to the wind.
3. *Auto* The WEC is in automatic operation, normal position of the switch. The behaviour of the WEC is described in next paragraphs.

Any time, the switch is moved out of the position *Auto*, the turbine goes into braking position by pitching the blades.

Furthermore the MAIN SWITCH cuts off the electricity coming from the grid to the WEC and the opposite's way.

4.1.2 Level 2, access for the skilled people only

This level is used only for service and outstands from the purpose of the present document.

4.2 NORMAL OPERATING OF THE TN 535

The figure below shows the operating range of the TN 535. The controller keeps the machine always inside the allowed envelope. All start up and brake down procedures are performed automatically.

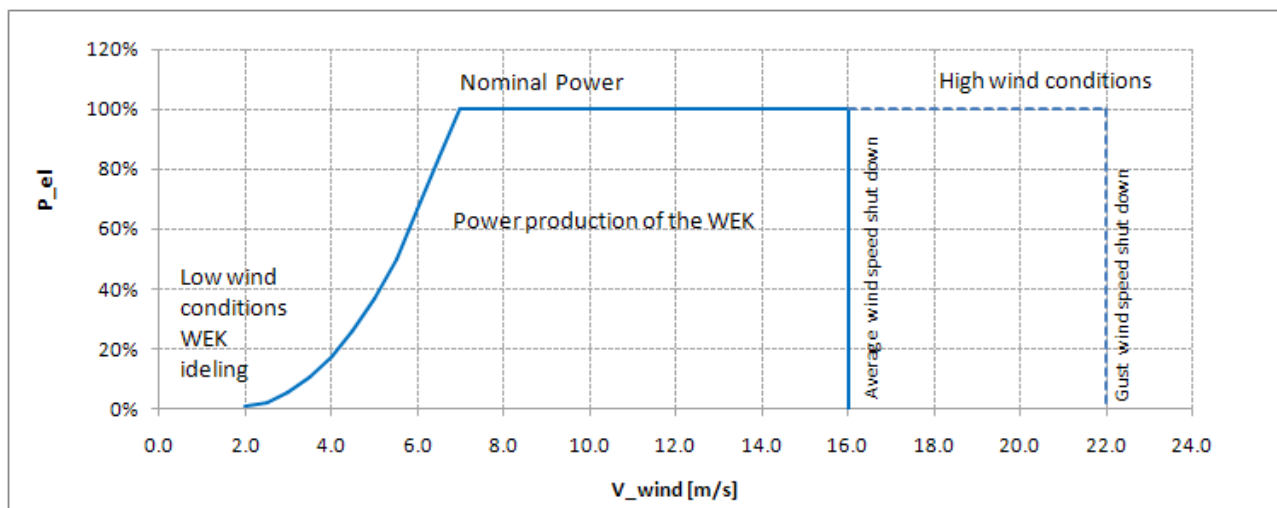


Figure 2 - Operating range of the TN 535.

4.2.1 Idling at Low Wind Conditions

If the wind is not strong enough for energy production, the turbine switches into the status *waiting*, pitching the blades to an angle of approximately 36.3° and switch off the inverters. The rotor is then idling with about 2.5 ^{rpm}/m/s over m/s of wind speed. The yaw system is aligning the nacelle to the wind whenever necessary.

4.2.2 Start up

If the average rotary speed in the waiting position exceeds during 100 seconds 11 rpm, or if the present rotary speed in the waiting position exceeds 20 rpm, the turbine switches from status *waiting* to the status *start up*. The status *start up* has the following sequences:

- Start up the inverters.
- Accelerated the rotor speed along a ramp up to 20 rpm by pitching the blades.
- Wait at 20 rpm for the acknowledgment of the inverters.
- If the ok of the inverters does not arrive within 10 s, the machine goes into and inverter fault condition and tries after 2 minutes again. This is done 5 times before a fault condition is signalled to the maintainer.
- If the ok of the inverters arrives within 10 s, the status is switched to *power production*, the inverters are activated and the rotor speed is accelerated along a ramp by pitching the blades to the optimal pitch position of 2°.

4.2.3 Power Production

There are two different situations in the power production of the turbine:

- Below rated wind speed.
- Above rated wind speed.

Below the rated wind speed, the machine is working in the optimal pitch angle. The rotor speed is controlled by the generator torque to let the blades work in the point of maximum efficiency, means the rotor speed is almost linear to the wind speed. The power production grows more or less with the 3rd power of the wind speed.

Above the nominal wind speed, the turbine controls the rotor speed by pitching the blades, try to keep the nominal rotor speed. Because the turbine is connected by an inverter to the grid, the system is “soft” and the rotor speed can vary a little bit around the nominal rotor speed. In the last, the power is all the time at nominal power.

4.2.4 Yawing

The TN 535 has an active yaw system. A wind vane measures the relative wind direction according to the WEC and an special algorithm controls the yaw drive in a way, that it does not move to often but keeps the WEC aligned to the prevalent wind direction.

In case of a broken wind vane or one of its cables, the PLC doesn't yaw anymore and gives out the warning “*wind vane broken*”.

In case of blowing wind and the signal of the wind vane is not changing for a certain period, the PLC doesn't yaw anymore and gives out the warning “*wind vane not moving*”.

4.2.5 Normal Shut Down because of Low Wind

When, in the status *Power*, the rotary speed drops below 25 rpm in the average over 30 seconds or when it drops below 8 rpm, the system returns to the status *waiting* by pitching the blades to 36.3°.

4.2.6 High Wind Conditions

In the event of wind speeds over 16 m/s (average over **480 sec**), or maximum gusts over 22 m/s, the turbine stops down by pitching the blades to the parking position (87.4° pitch angle). The PLC decides when the wind has fallen sufficiently for a return to the production state.

4.2.7 Shut down because of a fault condition

Most of the faults causes a normal shut down of the machine, means, the rotor is stopped by pitching the blades into the parking position of about 87.4°. In this position, the machine is idling with about 0.6 ^{rpm}/m/s. The yaw is still aligning the nacelle to the wind whenever necessary.

4.2.8 Manual Stop

The TN 535 can be stopped manually by switching the OPERATION MODE SELECTOR SWITCH out of the position *Auto*. The turbine goes into parking position by pitching the blades.

4.2.9 Emergency in operation

If any anomalous condition is detected the machine can be switched off through the OPERATION MODE SELECTOR SWITCH.

In case of fire the machine should also be switched be switched off from the external main through the MAIN SWITCH.

4.2.10 Emergency in service

During service operation all the actuator and the voltage in nacelle can be switched off pressing one of the EMERGENCY BUTTON (one in nacelle and one inside the control cabinet).

APPENDIX-A: TN535 SPECIFICATIONS

Turbine Architecture:

Type:	Upwind rotor with active pitch control and active yaw control
Direction of rotation:	Clockwise, seen from upwind
Number of blades:	3
Rotor diameter:	13.2 m
Hub height:	15 -18 -24m
Nominal electric power:	9,9 kW
Power regulation:	Active pitch (pitch to feather)
Cut-in wind speed	2.5 m/s
Cut-out wind speed	16 m/s
Nominal output at	6.7 m/s
Rotor diameter	13.2 m
Swept area:	136.7 m ²

Rotor

Type	LWTB535
Blade length	6.344 m
Material	GFRP
Lightening protection	Optional
Hub:	Rigid (no tilt)

Drive train

Transmission	belt drive
Main bearing:	Single-row ball bearing
High speed shaft rotational speed	225-750 rpm
Low speed shaft rotational speed	20-66 rpm
Grid feed:	ABB ACS M1

Generator

Nominal power	11.0 kVA
Type	Permanent Magnets Synchronous Generator 8 poles
Protection	IP54
Insulation class	F

Yaw System

Yaw Type Active yaw control,
1 driver, 2 beaks (always braking)

Yaw Rate 3.35 deg/s

Controller

Type PLC
Remote monitoring Tozzi Nord SCADA / Real Time Viewer
UPS Backup by means fo lead acid batteries (2X12V)

Breaking System

Aerodynamic brake Collective pitch

Redundant aerodynamic brake Passive centrifugal system that bring blades to barking
position

Rotor lock Metal pin inserted for maintenance

Tower

tower height 14.6m-17.6 m - 23.6 m
tower type polygonal steel tower, 16 sides, 2 sections
Design wind class IV

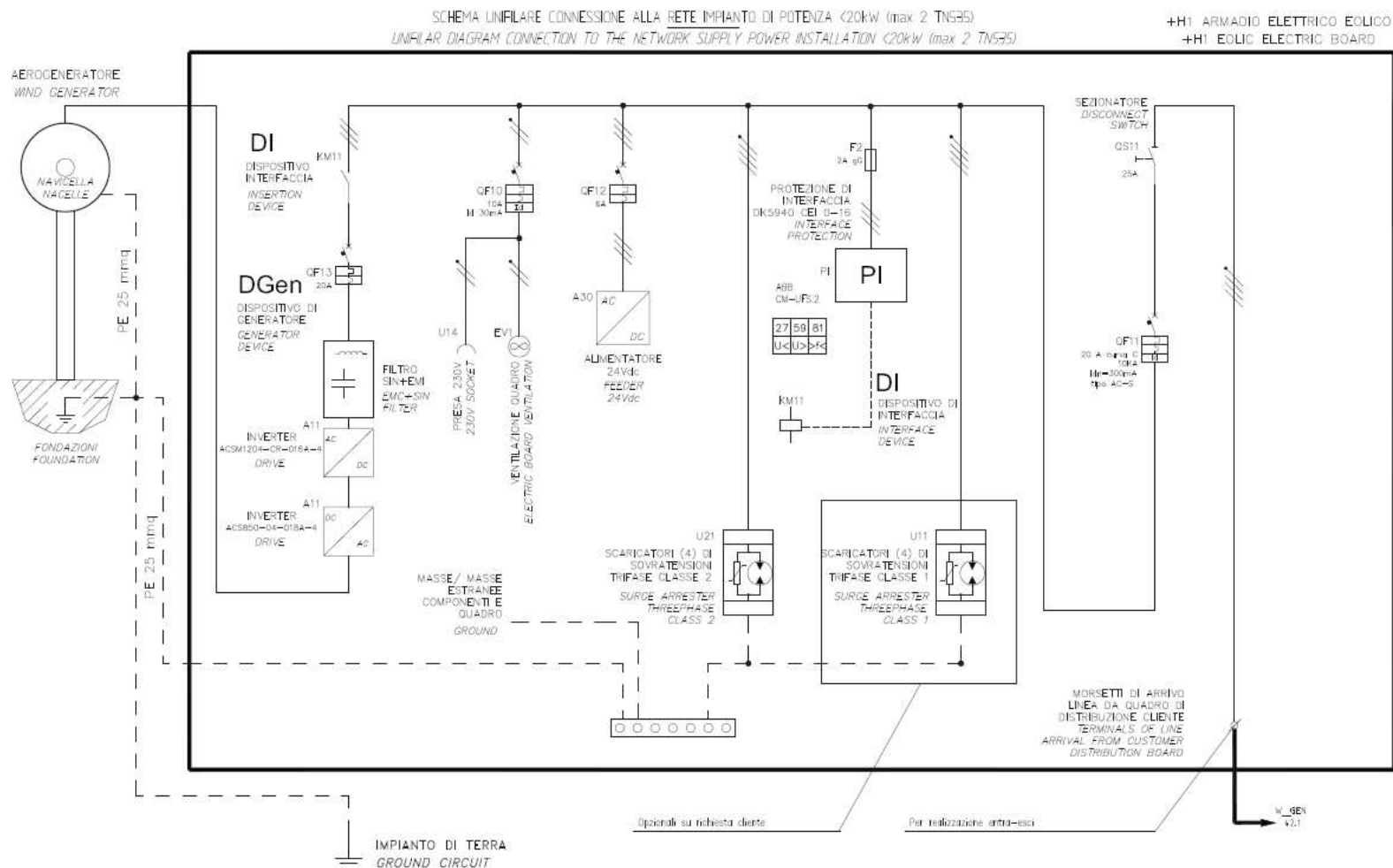
Weights

Nacelle, excluding rotor and hub 783 kg
rotor, including hub 332 kg
Tower 1300kg (14.6m)-1750kg (17.6m)-3350kg (23.6m)

Noise emissions

Max Lwa@10m/s 87.1dB

APPENDIX B: TN535 UNIFILAR SCHEMATIC



APPENDIX C: DESIGN LOAD CASE ACCORDING TO IEC 61400-2 COMING UP BY THE DIFFERENT FAULTS

Class	Component	Load case	Reaction of PLC	Effect of the fault
Sensor problem	Rotor speed sensor 1 broken	3.1	Normal shut down	
	Rotor speed sensor 2 broken	3.1	Normal shut down	
	Yaw sensor 1 broken	3.1	Normal shut down	
	Yaw sensor 2 broken	3.1	Normal shut down	
	Pitch drive sensor 1 broken	-	Remain in parking	negligible
	Pitch drive sensor 2 broken	3.1	Shut down from waiting to parking	
	Pitch drive sensor 3 broken	3.1	Normal shut down	
	Acceleration sensor broken	3.1	Normal shut down	
	Wind speed broken	-		negligible
	Wind vane broken	-	PLC give a warning	negligible
Internal faults	Generator short circuit	3.1	Normal shut down	High vibration of generator support during braking down can happen, when asymmetric short circuit, below 10 rpm avoided by short circuit over all 3 phases
	Inverter fault in operation	3.1	Normal shut down	
	Inverter fault during start up	3.1	Shut down from waiting to parking	Small loads
	Grid loss	3.1	Normal shut down	
	PLC broken	2.x	Mechanical over speed	
	Azimuth motor broken	3.1	Normal shut down	
	Chain broken	3.1	Normal shut down	running misaligned
	Pitch drive broken	2.x	Mechanical over speed	
Normal operation	Brake down	3.1	Shut down from working to waiting	Small loads
	High wind speed shut down	3.1	Normal shut down	
	Battery test	3.1	Shut down from waiting to parking	Small loads
	Manuel shut down	3.1	Normal shut down	