Wpd Altilia S.r.l.

Corso d'Italia n. 83 - 00198 ROMA

PROGETTO DEFINITIVO PER LA REALIZZAZIONE DI UN PARCO EOLICO CON POTENZA DI 72,00 MW RICADENTE NEL TERRITORIO DEL COMUNE DI ALTAMURA (BA) IN LOCALITA' "LAMA DI NEBBIA"

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Azienda con Sistema di Gestione Certificato
UNI EN ISO 9001:2015
UNI EN ISO 14001:2015
UNI ISO 45001:2018

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DANILO
18.05.2022
12:29:18
GMT+01:00

ELABORATO	TITOLO	COMMESSA	TIPOLOGIA
C19	**SPECIFICHE TECNICHE AEROGENERATORE DI PROGETTO ED OPERE ACCESSORIE**	**20123**	**D**
		CODICE ELABORATO	
		DC20123D-C19	
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		DC20123D-C19.doc	**124 + copertina**

REV	DATA	MODIFICA	Elaborato	Controllato	Approvato
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SG 6.0-170
Developer Package

SIEMENS Gamesa
RENEWABLE ENERGY

Developer Package SG 6.0-170

Application of the Developer Package
The Developer Package serves the purpose of informing customers about the latest planned product development from Siemens Gamesa Renewable Energy (SGRE). By sharing information about coming developments, SGRE can ensure that customers are provided with necessary information to make decisions.

Furthermore, the Developer Package can assist in guiding prospective customers with the indicated technical footprint of the SG 6.0-170 in cases where financial institutes, governing bodies, or permitting entities require product specific information in their decision processes.

All technical data contained in the Developer Package is subject to change owing to ongoing technical developments. Information contained within the Developer Package may not be treated separately or out of the context of the Developer Package.

The information contained in the Developer Package may not be used as legally binding documentation and cannot be used in contracts between SGRE and any other parties. This Developer Package contains preliminary technical data on SGRE turbines currently under development and can be used in an indicative capacity only.

All technical data is subject to change according to the technical development of the wind turbine.

SGRE and its affiliates reserve the right to change the below specifications without prior notice.

Developer Package
SG 6.0-170

Table of content

Introduction

The SG 6.0-170 is a new wind turbine of the next generation Siemens Gamesa Onshore Geared product series, which builds on the Siemens Gamesa design and operational experience in the wind energy market.

With a new 83m blade, a 6.0 MW generator and an extensive tower portfolio including hub heights such as 100m, 115m, 135m and 165m, the SG 6.0-170 aims at becoming a new benchmark in the market for efficiency and profitability.

This Developer Package describes the turbine technical specifications and provides preliminary information for the main components and subsystems.

For further information, please contact your regional SGRE Sales Manager.

Technical Description

Rotor-Nacelle
The rotor is a three-bladed construction, mounted upwind of the tower. The power output is controlled by pitch and torque demand regulation. The rotor speed is variable and is designed to maximize the power output while maintaining loads and noise level.

The nacelle has been designed for safe access to all service points during scheduled service. In addition the nacelle has been designed for safe presence of service technicians in the nacelle during Service Test Runs with the wind turbine in full operation. This allows a high quality service of the wind turbine and provides optimum troubleshooting conditions.

Blades
The SG 6.0-170 blade is made up of fiberglass infusion & carbon pultruded-molded components. The blade structure uses aerodynamic shells containing embedded spar-caps, bonded to two main epoxy-fiberglass-balsa/foam-core shear webs. The SG 6.0-170 blade uses a blade design based on SGRE proprietary airfoils.

Rotor Hub
The rotor hub is cast in nodular cast iron and is fitted to the drive train low speed shaft with a flange connection. The hub is sufficiently large to provide room for service technicians during maintenance of blade roots and pitch bearings from inside the structure.

Drive train
The drive train is a 4-points suspension concept: main shaft with two main bearings and the gearbox with two torque arms assembled to the main frame.
The gearbox is in cantilever position; the gearbox planet carrier is assembled to the main shaft by means of a flange bolted joint and supports the gearbox.

Main Shaft
The low speed main shaft is forged and transfers the torque of the rotor to the gearbox and the bending moments to the bedframe via the main bearings and main bearing housings.

Main Bearings
The low speed shaft of the wind turbine is supported by two spherical roller bearings. The bearings are grease lubricated.

Gearbox
The gearbox is 3 stages high speed type (2 planetary + 1 parallel).

Generator
The generator is a doubly-fed asynchronous three phase generator with a wound rotor, connected to a frequency PWM converter. Generator stator and rotor are both made of stacked magnetic laminations and formed windings. Generator is cooled by air.

Mechanical Brake
The mechanical brake is fitted to the high speed side of the gearbox.

Yaw System
A cast bed frame connects the drive train to the tower. The yaw bearing is an externally geared ring with a friction bearing. A series of electric planetary gear motors drives the yawing.

Nacelle Cover
The weather screen and housing around the machinery in the nacelle is made of fiberglass-reinforced laminated panels.

Tower
The wind turbine is as standard mounted on a tapered tubular steel tower. Other tower technologies are available for higher hub heights. The tower has internal ascent and direct access to the yaw system and nacelle. It is equipped with platforms and internal electric lighting.

Controller
The wind turbine controller is a microprocessor-based industrial controller. The controller is complete with switchgear and protection devices and is self-diagnosing.

Converter
Connected directly with the Rotor, the Frequency Converter is a back to back 4Q conversion system with 2 VSC in a common DC-link. The Frequency Converter allows generator operation at variable speed and voltage, while supplying power at constant frequency and voltage to the MV transformer.

SCADA
The wind turbine provides connection to the SGRE SCADA system. This system offers remote control and a variety of status views and useful reports from a standard internet web browser. The status views present information including electrical and mechanical data, operation and fault status, meteorological data and grid station data.

Turbine Condition Monitoring
In addition to the SGRE SCADA system, the wind turbine can be equipped with the unique SGRE condition monitoring setup. This system monitors the vibration level of the main components and compares the actual vibration spectra with a set of established reference spectra. Review of results, detailed analysis and reprogramming can all be carried out using a standard web browser.

Operation Systems
The wind turbine operates automatically. It is self-starting when the aerodynamic torque reaches a certain value. Below rated wind speed, th wind turbine controller fixes the pitch and torque references for operating in the optimum aerodynamic point (maximum production) taking into account the generator capability. Once rated wind speed is surpassed, the pitch position demand is adjusted to keep a stable power production equal to the nominal value.

High wind derated mode (HWRT) is a default functionality. When active the power production is limited once the wind speed exceeds a threshold value defined by design, until cut-out wind speed is reached and the wind turbine stops producing power.

If the average wind speed exceeds the maximum operational limit, the wind turbine is shut down by pitching of the blades. When the average wind speed drops back below the restart average wind speed, the systems reset automatically.

Technical Specifications

Rotor
Type ....3-bladed, horizontal axis
Position ....Upwind
Diameter..........................170 m
Swept area ....22,698 m²
Power regulation ....Pitch & torque regulation with variable speed
Rotor tilt...........................6 degrees

Blade
Type ....Self-supporting
Blade length ....83 m
Max chord ....4.5 m
Aerodynamic profile ....Siemens Gamesa proprietary airfoils
Material ....GRE (Glassfiber Reinforced Epoxy) – CRP (Carbon Reinforced Plastic)
Surface gloss ....Semi-gloss, < 30 / ISO2813
Surface color .... Light grey, RAL 7035 or White, RAL 9018

Aerodynamic Brake
Type ....Full span pitching
Activation.........................Active, hydraulic

Load-Supporting Parts
Hub.................................Nodular cast iron
Main shaft........................Forged steel
Nacelle bed frame .... Nodular cast iron

Mechanical Brake
Type ....Hydraulic disc brake
Position ....Gearbox rear end

Nacelle Cover
Type ....Totally enclosed
Surface gloss ....Semi-gloss, <30 / ISO2813
Color................................Light Grey, RAL 7035 or White, RAL 9018

Generator
Type............................... Asynchronous, DFIG

Grid Terminals (LV)
Baseline nominal power . 6.0 MW
Voltage .... 690 V
Frequency....................... 50 Hz or 60 Hz

Yaw System
Type............................... Active
Yaw bearing................... Externally geared
Yaw drive........................ Electric gear motors
Yaw brake....................... Active friction brake

Controller
Type .... Siemens Integrated Control System (SICS)
SCADA system .... SGRE SCADA System

Tower
Type .... Tubular steel / Hybrid

Hub height .... 100m to 165 m, site-specific

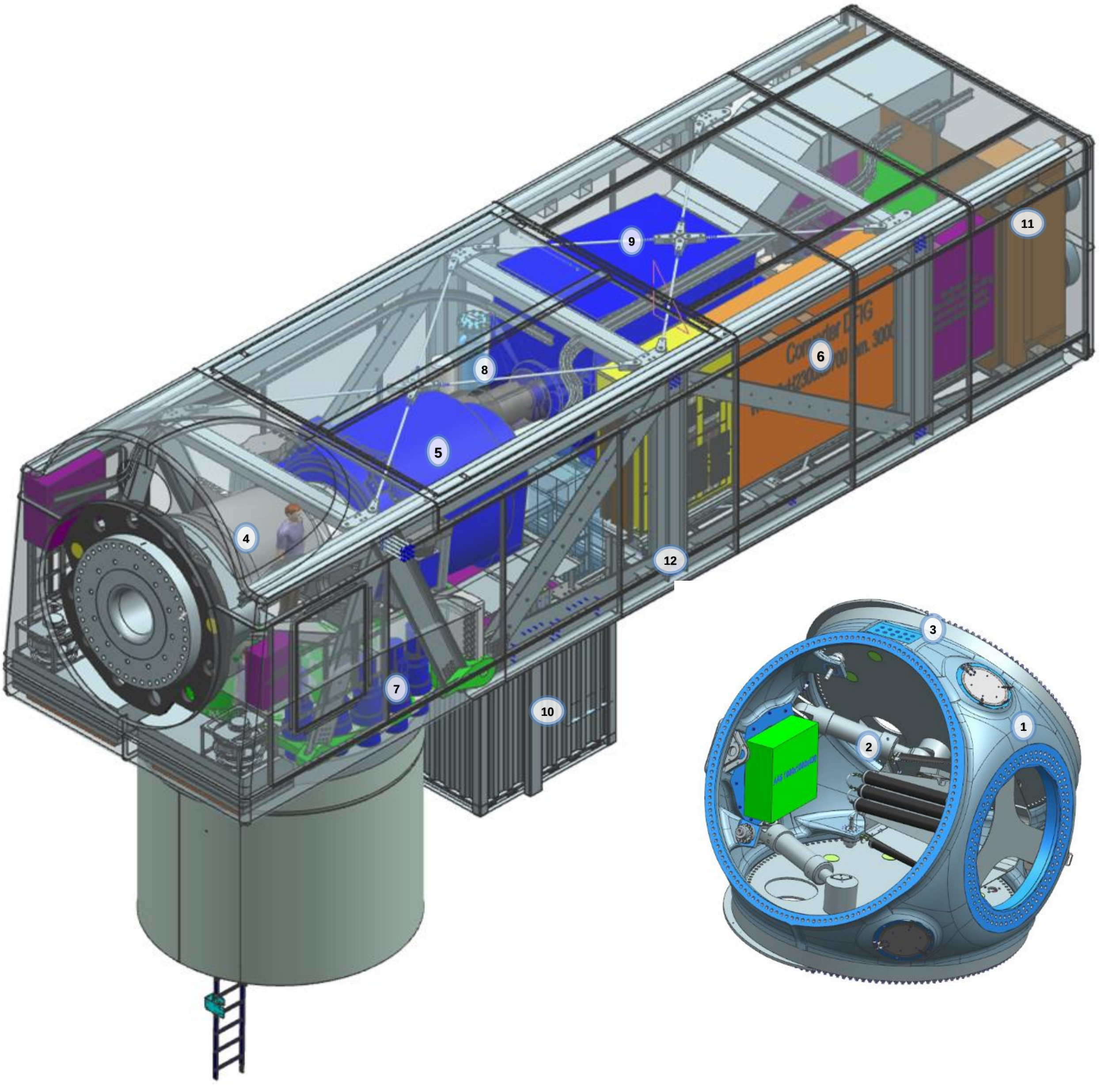
Corrosion protection ...... Painted
Surface gloss .... Semi-gloss, <30 / ISO-2813
Color .... Light grey, RAL 7035 or White, RAL 9018

Operational Data
Cut-in wind speed .... 3 m/s
Rated wind speed .... 10.0 m/s (steady wind without turbulence, as defined by IEC61400-1)
Cut-out wind speed .... 25 m/s
Restart wind speed......... 22 m/s

Weight
Modular approach........... All modules weight lower than 80 t for transport

Nacelle Arrangement

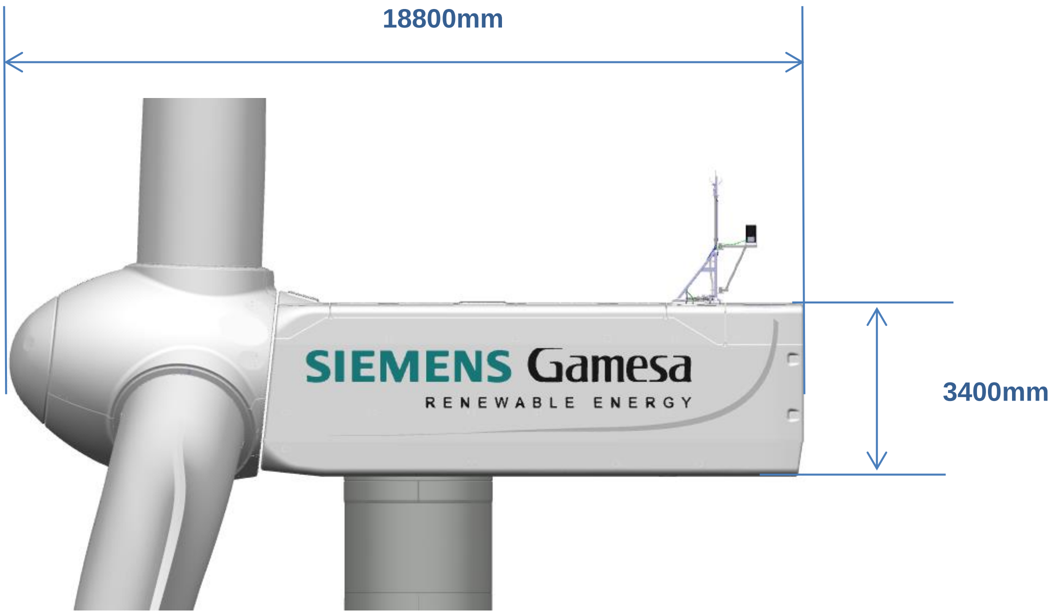
The design and layout of the nacelle are preliminary and may be subject to changes during the development of the product.

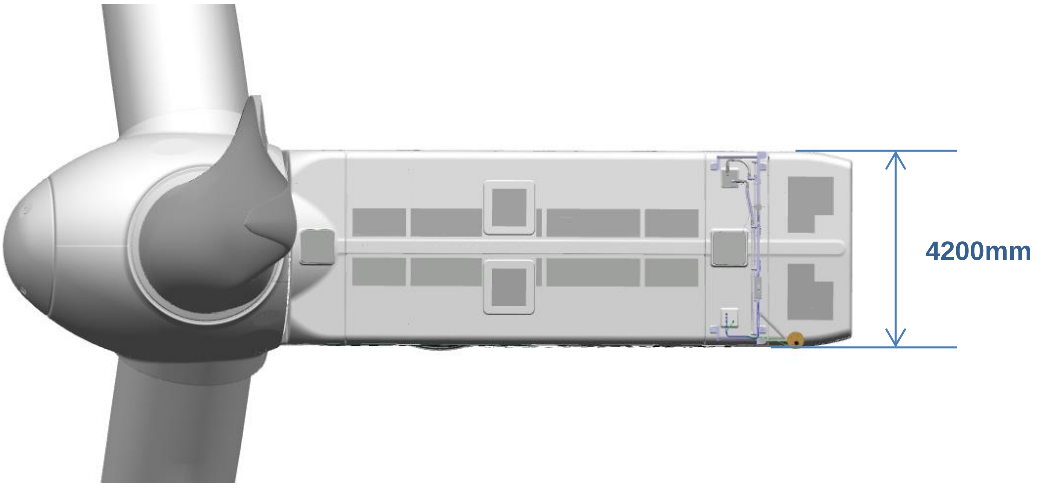


1	Hub	**7**	Yaw system
2	Pitch system	**8**	High speed shaft
3	Blade bearings	**9**	Generator
4	Low speed shaft	**10**	Transformer
5	Gearbox	**11**	Cooling system
6	Electrical cabinets	**12**	Rear Structure

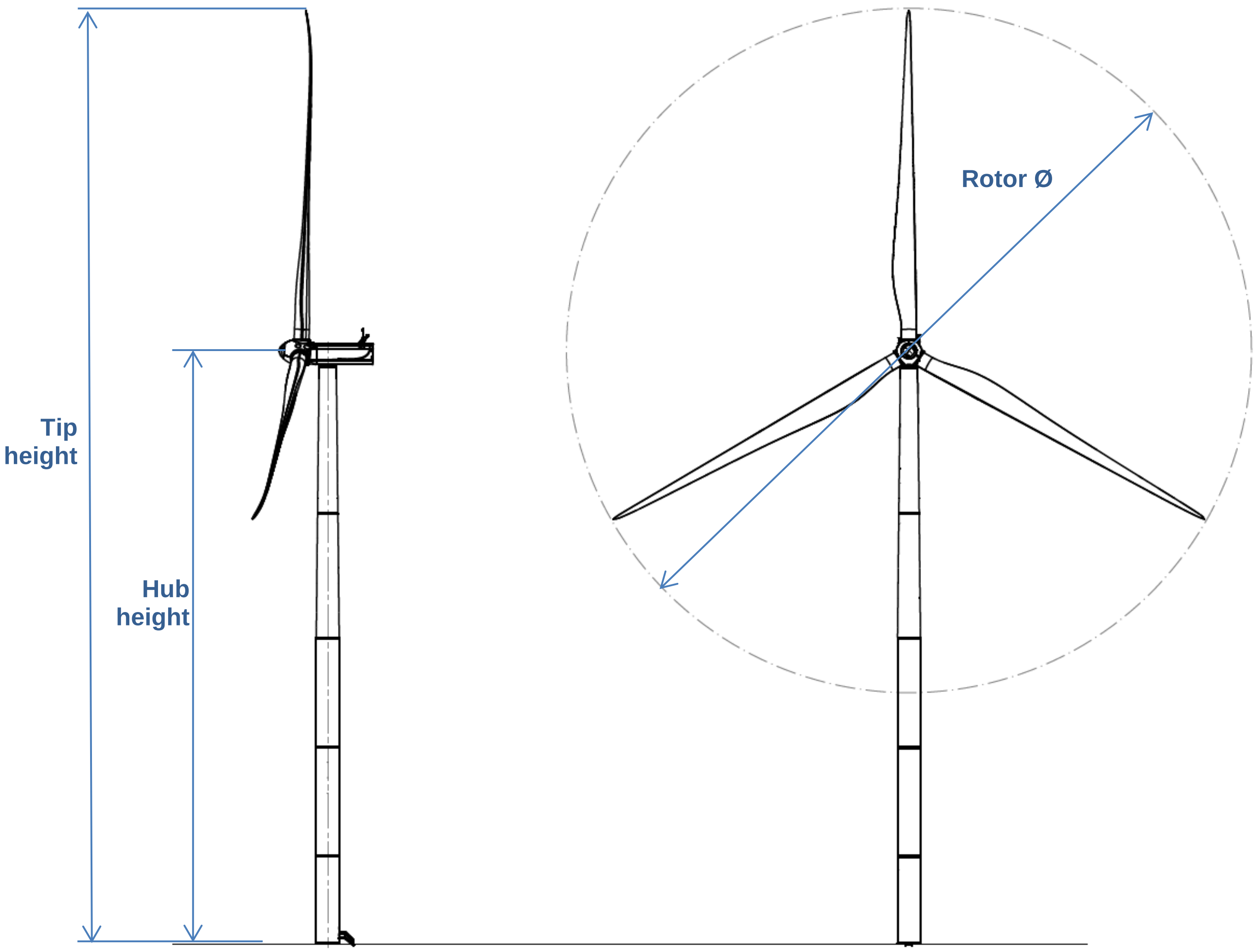
Nacelle Dimensions

The design and dimensions of the nacelle are preliminary and may be subject to changes during the development phases of the product.



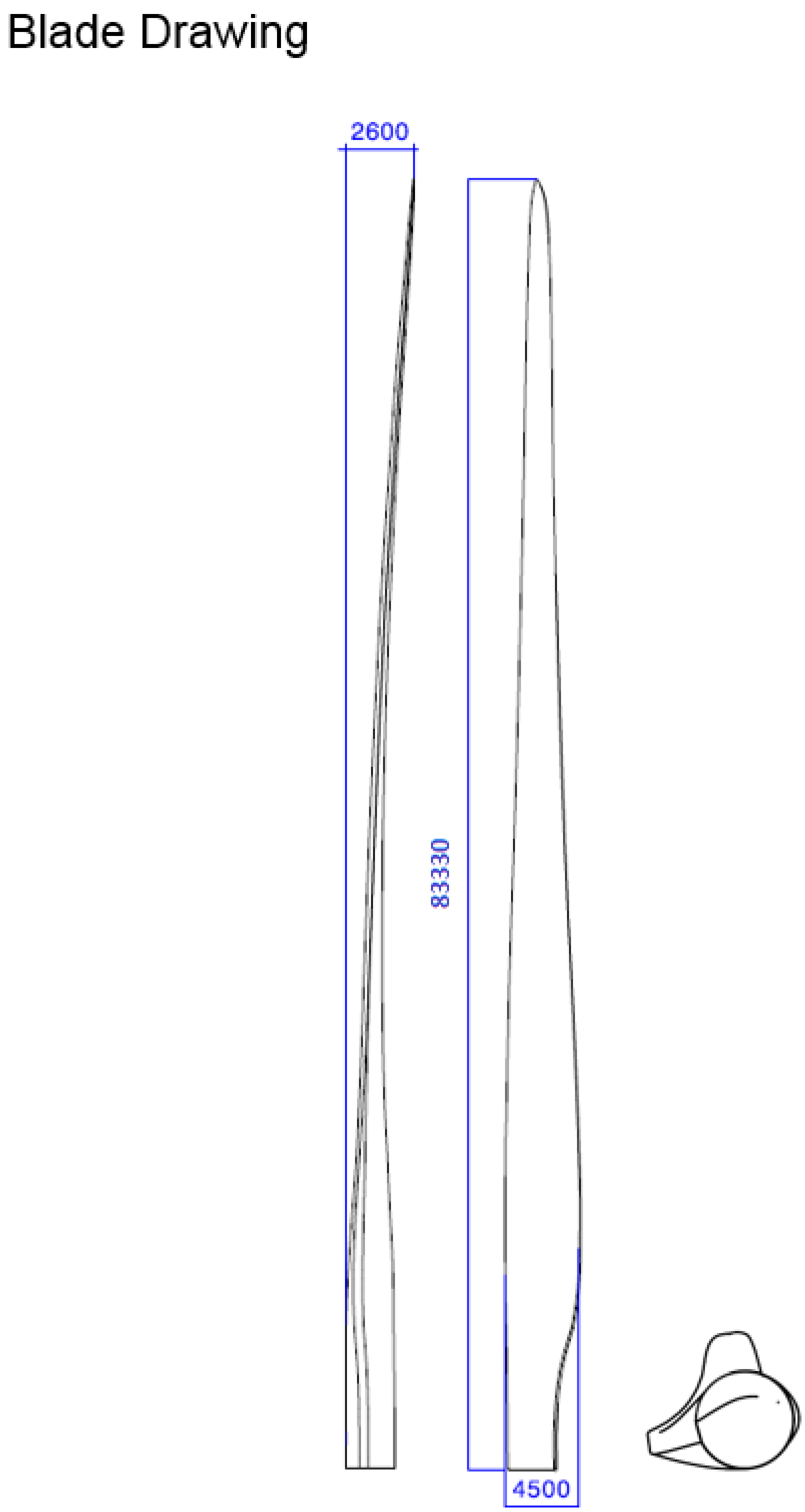


Elevation Drawing



Tip height	185m, 200m, 220m, 250m, site specific
Hub height	100m, 115m, 135m,165m, site specific
Rotor diameter	170m

Blade Drawing



Dimensions in millimeters.

Design Climatic Conditions

The design climatic conditions are the boundary conditions at which the turbine can be applied without supplementary design review. Applications of the wind turbine in more severe conditions may be possible, depending upon the overall circumstances. A project site-specific review requires the completion by the Client of the "Project Climatic Conditions" form.

Subject	ID	Issue	Unit	Value
Wind, operation	1.1	Wind definitions	-	IEC 61400-1[1]
	1.2	IEC class	-	IIIA
	1.3	Mean air density, ρ	kg/m^3	1.225
	1.4	Mean wind speed, V_{ave}	m/s	7.5
	1.5	Weibull scale parameter, A	m/s	8.46
	1.6	Weibull shape parameter, k	-	2
	1.7	Wind shear exponent, α	-	0.20
	1.8	Reference turbulence intensity at 15 m/s, I_{ref}	-	0.16
	1.9	Standard deviation of wind direction	Deg	8
	1.10	Maximum flow inclination	Deg	8
	1.11	Minimum turbine spacing, in rows	D	3
	1.12	Minimum turbine spacing, between rows	D	5
	1.13	Design lifetime	Years	20
Wind, extreme	2.1	Wind definitions		IEC 61400-1
	2.2	Air density, ρ	kg/m^3	1.225
	2.3	Reference wind speed average over 10 min at hub height, V_{ref}	m/s	37.5
	2.4	Maximum 3 s gust in hub height, V_{e50}	m/s	52.5
	2.5	Maximum hub height power law index, α	-	0.11
	2.6	Storm turbulence	-	0.11
Temperature	3.1	Temperature definitions	-	IEC 61400-1
	3.2	Minimum temperature at 2 m, stand-still, $T_{min, s}$	Deg.C	-30
	3.3	Minimum temperature at 2 m, operation, $T_{min, o}$	Deg.C	-20
	3.4	Maximum temperature at 2 m, nominal operation, $T_{max, o}$	Deg.C	35
	3.5	Maximum temperature at 2 m, stand-still, $T_{max, s}$	Deg.C	50
Corrosion	4.1	Atmospheric-corrosivity category definitions	-	ISO 12944-2
	4.2	Internal nacelle environment (corrosivity category)	-	C3H
	4.3	Exterior environment (corrosivity category)	-	C3H
Lightning	5.1	Lightning definitions	-	IEC61400-24:2010
	5.2	Lightning protection level (LPL)	-	LPL 1
Dust	6.1	Dust definitions	-	IEC 60721-3-4:1995
	6.2	Working environmental conditions	mg/m^3	Average Dust Concentration (95% time) → 0.05 mg/m3
	6.3	Concentration of particles	mg/m^3	Peak Dust Concentration (95% time) → 0.5 mg/m3
Hail	7.1	Maximum hail diameter	mm	20
	7.2	Maximum hail falling speed	m/s	20
Ice	8.1	Ice definitions	-	-
	8.2	Ice conditions	Days/yr	7
Solar radiation	9.1	Solar radiation definitions	-	IEC 61400-1
	9.2	Solar radiation intensity	W/m^2	1000

[1] All mentioning of IEC 61400-1 refers to IEC 61400-1:2018 Ed4.

Subject	ID	Issue	Unit	Value
Humidity	10.1	Humidity definition	-	IEC 61400-1
	10.2	Relative humidity	%	Up to 95
Obstacles	11.1	If the height of obstacles within 500m of any turbine location height exceeds 1/3 of (H – D/2) where H is the hub height and D is the rotor diameter then restrictions may apply. Please contact Siemens Gamesa Renewable Energy for information on the maximum allowable obstacle height with respect to the site and the turbine type.		

Standard Power Curve, Standard power operational mode

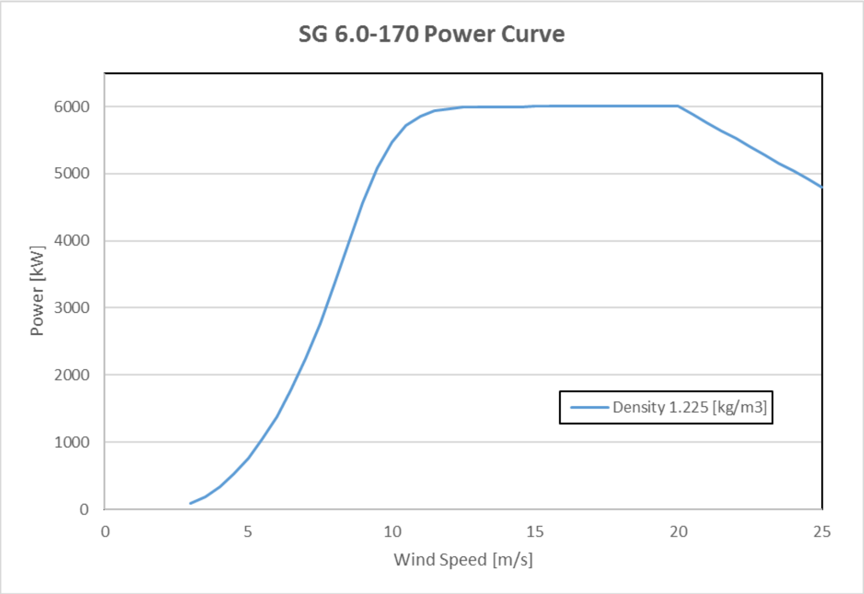
Air density 1.225 kg/m3
Validity range:

Wind Shear (10min average)	≤ 0.3
Turbulence intensity TI [%] for bin i	$5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$
Terrain	Not complex according to IEC 61400-12-1
Upflow β [º]	-2º ≤ β ≤ +2º
Grid frequency [Hz]	± 0.5 Hz

Other considerations: Clean rotor blades, undisturbed air flow, turbine operated within nominal limits according to the Electrical Specification.

Next table shows the electrical power [kW] as a function of the wind speed [m/s] horizontal referred to the hub height, averaged in ten minutes, for air density = 1.225 kg/m^3. The power curve does not include losses in the transformer and high voltage cables. The power curve is for the standard version of the turbine.

SG 6.0-170	
Wind Speed [m/s]	**Power [kW]**
3.0	94
3.5	184
4.0	334
4.5	528
5.0	764
5.5	1047
6.0	1383
6.5	1779
7.0	2238
7.5	2763
8.0	3348
8.5	3969
9.0	4570
9.5	5083
10.0	5464
10.5	5712
11.0	5855
11.5	5931
12.0	5969
12.5	5986
13.0	5994
13.5	5997
14.0	5999
14.5	5999
15.0	6000
15.5	6000



16.0	6000
16.5	6000
17.0	6000
17.5	6000
18.0	6000
18.5	6000
19.0	6000
19.5	6000
20.0	6000
20.5	5880
21.0	5760
21.5	5640
22.0	5520
22.5	5400
23.0	5280
23.5	5160
24.0	5040
24.5	4920
25.0	4800

The annual energy production data for different annual mean wind speeds in hub height are calculated from the above power curve assuming a Weibull wind speed distribution, 100 percent availability, and no reductions due to array losses, grid losses, or other external factors affecting the production.

AEP [MWh]		**Annual Average Wind Speed [m/s] at Hub Height**										
		5.0	***5.5***	***6.0***	***6.5***	***7.0***	***7.5***	***8.0***	***8.5***	***9.0***	***9.5***	***10.0***
Weibull K	***1.5***	12476	14794	16999	19055	20938	22635	24140	25455	26585	27539	28327
	2.0	11449	14237	17000	19660	22169	24498	26630	28555	30269	31771	33062
	2.5	10362	13381	16500	19590	22555	25334	27893	30219	32312	34178	35823

Annual Production [MWh] SG 6.0-170 wind turbine for the standard version, as a function of the annual mean wind speed at hub height, and for different Weibull parameters. Air density 1.225 kg/m^3

Standard Ct Curve, Standard power operational mode

Air density 1.225 kg/m³
Validity range:

Wind Shear (10min average)	≤ 0.3
Turbulence intensity TI [%] for bin i	$5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$
Terrain	Not complex according to IEC 61400-12-1
Upflow β [º]	-2º ≤ β ≤ +2º
Grid frequency [Hz]	± 0.5 Hz

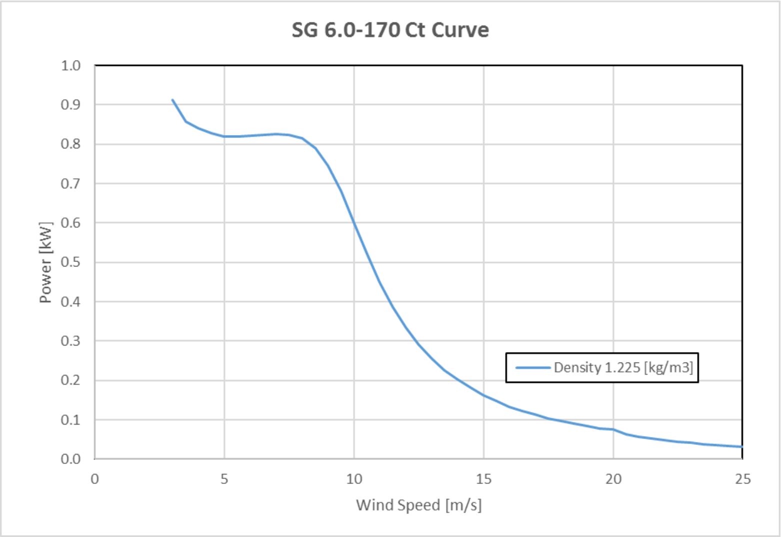
Other considerations: Clean rotor blades, undisturbed air flow, turbine operated within nominal limits according to the Electrical Specification.

The thrust coefficient Ct is used for the calculation of the wind speed deficit in the wake of a wind turbine.

Ct is defined by the following expression:
Ct = F / (0.5*ad*w^2*A)

where
F = Rotor force [N]
ad = Air density [kg/m³]
w = Wind speed [m/s]
A = Swept area of rotor [m²]

SG 6.0-170	
Wind Speed [m/s]	**C_T [-]**
3.0	0.913
3.5	0.857
4.0	0.840
4.5	0.827
5.0	0.820
5.5	0.819
6.0	0.821
6.5	0.824
7.0	0.825
7.5	0.824
8.0	0.815
8.5	0.791
9.0	0.745
9.5	0.680
10.0	0.602
10.5	0.522
11.0	0.449
11.5	0.386
12.0	0.334
12.5	0.291
13.0	0.256
13.5	0.226



14.0	0.202
14.5	0.181
15.0	0.163
15.5	0.147
16.0	0.134
16.5	0.123
17.0	0.113
17.5	0.104
18.0	0.097
18.5	0.090
19.0	0.084
19.5	0.079
20.0	0.075
20.5	0.063
21.0	0.058
21.5	0.053
22.0	0.049
22.5	0.045
23.0	0.042
23.5	0.039
24.0	0.036
24.5	0.033
25.0	0.031

Power Curve, Air density, Standard power operational mode

Air density 1.225 kg/m³
Validity range:

Wind Shear (10min average)	≤ 0.3
Turbulence intensity TI [%] for bin i	$5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$
Terrain	Not complex according to IEC 61400-12-1
Upflow β [°]	-2° ≤ β ≤ +2°
Grid frequency [Hz]	± 0.5 Hz

Other considerations: Clean rotor blades, undisturbed air flow, turbine operated within nominal limits according to the Electrical Specification.

Next table shows the electrical power [kW] as a function of the wind speed [m/s] horizontal referred to the hub height, averaged in ten minutes, for different air densities [kg/m³]. The power curve does not include losses in the transformer and high voltage cables. The power curve is for the standard version of the turbine.

P [kW]	***Air Density [kg/m3]***								
Wind Speed [m/s]	**1.225**	**1.06**	**1.09**	**1.12**	**1.15**	**1.18**	**1.21**	**1.24**	**1.27**
3.0	94	79	82	85	87	90	93	96	99
3.5	184	150	156	162	169	175	181	187	194
4.0	334	277	287	298	308	318	329	339	350
4.5	528	444	459	475	490	505	520	536	551
5.0	764	649	670	691	712	732	753	774	795
5.5	1047	894	922	949	977	1005	1033	1060	1088
6.0	1383	1185	1221	1257	1293	1329	1365	1401	1437
6.5	1779	1529	1574	1620	1665	1711	1756	1802	1847
7.0	2238	1927	1984	2040	2097	2153	2210	2266	2322
7.5	2763	2383	2452	2521	2590	2659	2728	2797	2866
8.0	3348	2892	2976	3059	3142	3225	3307	3389	3471
8.5	3969	3442	3540	3637	3734	3829	3923	4015	4105
9.0	4570	4001	4112	4220	4325	4426	4523	4616	4704
9.5	5083	4533	4648	4757	4859	4954	5042	5122	5197
10.0	5464	4995	5103	5200	5287	5365	5433	5493	5547
10.5	5712	5359	5449	5525	5589	5645	5691	5730	5764
11.0	5855	5619	5685	5737	5780	5815	5843	5866	5885
11.5	5931	5787	5831	5863	5889	5909	5924	5937	5947
12.0	5969	5888	5913	5932	5946	5957	5965	5971	5976
12.5	5986	5943	5958	5968	5975	5980	5984	5987	5990
13.0	5994	5972	5980	5985	5989	5991	5993	5994	5996
13.5	5997	5987	5991	5993	5995	5996	5997	5998	5998
14.0	5999	5994	5996	5997	5998	5998	5999	5999	5999

14.5	5999	5997	5998	5999	5999	5999	5999	6000	6000
15.0	6000	5999	5999	5999	6000	6000	6000	6000	6000
15.5	6000	5999	6000	6000	6000	6000	6000	6000	6000
16.0	6000	6000	6000	6000	6000	6000	6000	6000	6000
16.5	6000	6000	6000	6000	6000	6000	6000	6000	6000
17.0	6000	6000	6000	6000	6000	6000	6000	6000	6000
17.5	6000	6000	6000	6000	6000	6000	6000	6000	6000
18.0	6000	6000	6000	6000	6000	6000	6000	6000	6000
18.5	6000	6000	6000	6000	6000	6000	6000	6000	6000
19.0	6000	6000	6000	6000	6000	6000	6000	6000	6000
19.5	6000	6000	6000	6000	6000	6000	6000	6000	6000
20.0	6000	6000	6000	6000	6000	6000	6000	6000	6000
20.5	5880	5880	5880	5880	5880	5880	5880	5880	5880
21.0	5760	5760	5760	5760	5760	5760	5760	5760	5760
21.5	5640	5640	5640	5640	5640	5640	5640	5640	5640
22.0	5520	5520	5520	5520	5520	5520	5520	5520	5520
22.5	5400	5400	5400	5400	5400	5400	5400	5400	5400
23.0	5280	5280	5280	5280	5280	5280	5280	5280	5280
23.5	5160	5160	5160	5160	5160	5160	5160	5160	5160
24.0	5040	5040	5040	5040	5040	5040	5040	5040	5040
24.5	4920	4920	4920	4920	4920	4920	4920	4920	4920
25.0	4800	4800	4800	4800	4800	4800	4800	4800	4800

The annual energy production data for different annual mean wind speeds in hub height are calculated from the above power curve assuming a Rayleigh wind speed distribution, 100 percent availability, and no reductions due to array losses, grid losses, or other external factors affecting the production.

AEP [MWh] @ k=2		**Annual Average Wind Speed [m/s] at Hub Height**										
		5.0	***5.5***	***6.0***	***6.5***	***7.0***	***7.5***	***8.0***	***8.5***	***9.0***	***9.5***	***10.0***
Density [kg/m3]	***1.06***	10108	12709	15336	17910	20375	22693	24839	26799	28561	30120	31473
	1.09	10364	13005	15663	18257	20734	23057	25203	27158	28913	30461	31803
	1.12	10614	13293	15977	18590	21077	23403	25548	27497	29243	30781	32111
	1.15	10859	13572	16281	18910	21405	23733	25875	27818	29555	31083	32401
	1.18	11099	13843	16575	19218	21719	24049	26187	28123	29851	31369	32676
	1.21	11333	14107	16860	19515	22022	24351	26484	28413	30132	31640	32936
	1.225	11449	14237	17000	19660	22169	24498	26630	28555	30269	31771	33062
	1.24	11563	14365	17136	19802	22313	24641	26770	28692	30402	31899	33184
	1.27	11789	14617	17406	20081	22596	24922	27046	28960	30660	32147	33421

Annual Production [MWh] SG 6.0-170 wind turbine for the standard version, as a function of the annual mean wind speed at hub height and for different air densities considering a Rayleigh wind speed distribution.

Ct Curve, Air Density, Standard power operational mode

Air density 1.225 kg/m³
Validity range:

Wind Shear (10min average)	≤ 0.3
Turbulence intensity TI [%] for bin i	$5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$
Terrain	Not complex according to IEC 61400-12-1
Upflow β [º]	-2º ≤ β ≤ +2º
Grid frequency [Hz]	± 0.5 Hz

Other considerations: Clean rotor blades, undisturbed air flow, turbine operated within nominal limits according to the Electrical Specification.

The calculated Ct curve data are valid for air densities as stated below, clean rotor blades, substantially horizontal, undisturbed air flow, normal turbulence intensity and normal wind shear.

C_T [-]	***Air Density [kg/m3]***								
Wind Speed [m/s]	**1.225**	**1.06**	**1.09**	**1.12**	**1.15**	**1.18**	**1.21**	**1.24**	**1.27**
3.0	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913
3.5	0.857	0.857	0.857	0.857	0.857	0.857	0.857	0.857	0.857
4.0	0.840	0.840	0.840	0.840	0.840	0.840	0.840	0.840	0.840
4.5	0.827	0.827	0.827	0.827	0.827	0.827	0.827	0.827	0.828
5.0	0.820	0.817	0.818	0.818	0.819	0.819	0.819	0.820	0.820
5.5	0.819	0.816	0.817	0.817	0.818	0.818	0.819	0.819	0.820
6.0	0.821	0.819	0.820	0.820	0.821	0.821	0.821	0.822	0.822
6.5	0.824	0.822	0.823	0.823	0.823	0.824	0.824	0.824	0.824
7.0	0.825	0.824	0.824	0.825	0.825	0.825	0.825	0.825	0.826
7.5	0.824	0.823	0.823	0.823	0.824	0.824	0.824	0.824	0.824
8.0	0.815	0.815	0.815	0.815	0.815	0.815	0.815	0.815	0.814
8.5	0.791	0.793	0.793	0.793	0.793	0.792	0.791	0.790	0.788
9.0	0.745	0.756	0.755	0.754	0.752	0.750	0.747	0.743	0.739
9.5	0.680	0.703	0.701	0.698	0.694	0.689	0.683	0.676	0.668
10.0	0.602	0.640	0.636	0.631	0.624	0.616	0.606	0.596	0.586
10.5	0.522	0.573	0.566	0.558	0.548	0.538	0.528	0.516	0.505
11.0	0.449	0.506	0.497	0.487	0.476	0.466	0.454	0.443	0.433
11.5	0.386	0.443	0.433	0.423	0.412	0.402	0.391	0.381	0.371
12.0	0.334	0.387	0.377	0.367	0.357	0.348	0.339	0.330	0.321
12.5	0.291	0.339	0.329	0.320	0.311	0.303	0.295	0.287	0.280
13.0	0.256	0.298	0.289	0.281	0.273	0.266	0.259	0.252	0.246
13.5	0.226	0.263	0.256	0.249	0.242	0.235	0.229	0.223	0.218
14.0	0.202	0.234	0.227	0.221	0.215	0.209	0.204	0.199	0.194
14.5	0.181	0.209	0.203	0.198	0.193	0.188	0.183	0.178	0.174

15.0	0.163	0.188	0.183	0.178	0.173	0.169	0.165	0.161	0.157
15.5	0.147	0.170	0.165	0.161	0.157	0.153	0.149	0.146	0.142
16.0	0.134	0.154	0.150	0.146	0.142	0.139	0.136	0.132	0.129
16.5	0.123	0.141	0.137	0.134	0.130	0.127	0.124	0.121	0.118
17.0	0.113	0.129	0.126	0.123	0.120	0.117	0.114	0.111	0.109
17.5	0.104	0.119	0.116	0.113	0.110	0.108	0.105	0.103	0.101
18.0	0.097	0.111	0.108	0.105	0.102	0.100	0.098	0.095	0.093
18.5	0.090	0.103	0.100	0.098	0.095	0.093	0.091	0.089	0.087
19.0	0.084	0.097	0.094	0.092	0.089	0.087	0.085	0.083	0.082
19.5	0.079	0.091	0.088	0.086	0.084	0.082	0.080	0.078	0.077
20.0	0.075	0.085	0.083	0.081	0.079	0.077	0.076	0.074	0.072
20.5	0.063	0.072	0.070	0.069	0.067	0.066	0.064	0.063	0.062
21.0	0.058	0.066	0.064	0.063	0.061	0.060	0.059	0.058	0.056
21.5	0.053	0.061	0.059	0.058	0.056	0.055	0.054	0.053	0.052
22.0	0.049	0.056	0.054	0.053	0.052	0.051	0.050	0.049	0.048
22.5	0.045	0.051	0.050	0.049	0.048	0.047	0.046	0.045	0.044
23.0	0.042	0.047	0.046	0.045	0.044	0.043	0.042	0.042	0.041
23.5	0.039	0.044	0.043	0.042	0.041	0.040	0.039	0.038	0.038
24.0	0.036	0.040	0.040	0.039	0.038	0.037	0.036	0.036	0.035
24.5	0.033	0.037	0.037	0.036	0.035	0.034	0.034	0.033	0.032
25.0	0.031	0.035	0.034	0.033	0.033	0.032	0.031	0.031	0.030

Standard Acoustic Emission

Noise Level (LW): Values reported correspond to the average estimated Sound Power Level emitted by the WTG at hub height, called LW in TS IEC-61400-14. LW values are expressed in dB(A). To obtain LWd value, as defined in IEC-61400-14, it must be applied a 2 dB increase to LW.

dB(A): LW is expressed in decibels applying the "A" filter as required by IEC.

Noise generated at standard power operation mode LW is **105.0 dB(A).** Noise values for different wind speed at hub height are presented in the following table:

SG 6.0-170	
Wind Speed [m/s]	**LW [dB(A)]**
3,0	92,2
3,5	92,2
4,0	92,2
4,5	92,2
5,0	92,5
5,5	95,0
6,0	97,2
6,5	99,2
7,0	101,0
7,5	102,7
8,0	104,2
8,5	105,0
9,0	105,0
9,5	105,0
10,0	105,0
10,5	105,0
11,0	105,0
11,5	105,0
12,0	105,0
12,5	105,0
13,0	105,0
Up to cut-out	105.0

Noise values included in the present document correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade.

Noise Reduction System (NRS) operational modes

The Noise Reduction System NRS is an optional module available with the basic SCADA configuration and it therefore requires the presence of a SGRE SCADA system to work.

The purpose of this system is to limit the noise emitted by any of the functioning turbines and thereby comply with local regulations regarding noise emissions. This allows wind farms to be located close to urban areas, limiting the environmental impact that they imply.

Noise control is achieved through reducing the active power and rotational speed of the wind turbine. This reduction is dependent on the wind speed:

The task of the Noise Reduction System is to control the noise settings of each turbine to the most appropriate level at all times, in order to keep the noise emissions within the limits allowed.

In order to do this, the SCADA control has to consider the wind speed of each turbine, its direction, and a configured schedule/calendar.

There are 4 low noise modes available, besides the full operation one. Noise levels corresponding to each mode are the following:

Mode:	M1	M2	M4	M6	M9
Noise Level [dB(A)]	105.0	104.0	102.0	100.0	97.0

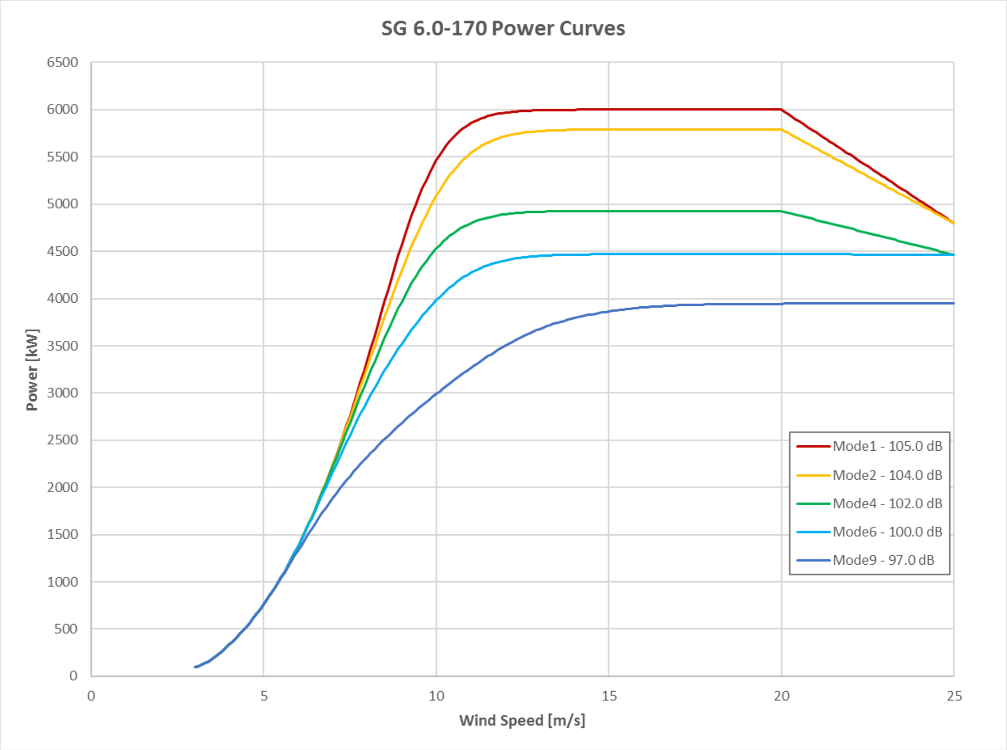
Noise values included in the present document correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade.

Depending on the type of tower selected, some of the low noise modes defined above may not be compatible. Low noise modes compatibility vs tower designs will be analyzed upon request.

Next table presents the power production as a function of the horizontal wind speed measured at hub height for different noise reduction mode settings.

P [kW]	***Application and Low Noise Operation Mode***			
Wind Speed [m/s]	**M2 104.0 dB(A)**	**M4 102.0 dB(A)**	**M6 100.0 dB(A)**	**M9 97.0 dB(A)**
3.0	94	94	94	94
3.5	184	184	184	184
4.0	334	334	334	334
4.5	528	528	528	528
5.0	764	764	764	763
5.5	1047	1047	1046	1038
6.0	1383	1383	1381	1335
6.5	1779	1776	1762	1625
7.0	2235	2219	2164	1889
7.5	2742	2686	2556	2122
8.0	3276	3148	2917	2327
8.5	3803	3582	3238	2512
9.0	4296	3968	3523	2683
9.5	4731	4288	3771	2841
10.0	5088	4530	3982	2991
10.5	5355	4696	4149	3132
11.0	5538	4799	4272	3265
11.5	5653	4860	4355	3389
12.0	5719	4893	4406	3501
12.5	5755	4910	4436	3598
13.0	5774	4919	4452	3678
13.5	5783	4923	4461	3743
14.0	5787	4926	4465	3793
14.5	5789	4927	4467	3833
15.0	5790	4927	4468	3864
15.5	5791	4927	4469	3888
16.0	5791	4927	4469	3906
16.5	5791	4927	4469	3919
17.0	5791	4927	4469	3928
17.5	5791	4927	4469	3934
18.0	5791	4927	4469	3938
18.5	5791	4927	4469	3941
19.0	5791	4927	4469	3942
19.5	5791	4927	4469	3943
20.0	5791	4927	4469	3944
20.5	5692	4881	4468	3946
21.0	5593	4835	4468	3946

21.5	5494	4788	4467	3946
22.0	5395	4742	4467	3946
22.5	5296	4696	4466	3946
23.0	5196	4649	4466	3946
23.5	5097	4603	4465	3946
24.0	4998	4557	4465	3946
24.5	4899	4510	4464	3946
25.0	4800	4464	4464	3946



Next table presents the Ct as a function of the horizontal wind speed measured at hub height for different noise reduction mode settings. The calculated Ct curve data are valid for clean rotor blades, substantially horizontal, undisturbed air flow, normal turbulence intensity and normal wind shear.

C_T [-]	***Application and Low Noise Operation Mode***			
Wind Speed [m/s]	**M2 104.0 dB(A)**	**M4 102.0 dB(A)**	**M6 100.0 dB(A)**	**M9 97.0 dB(A)**
3.0	0.914	0.914	0.914	0.913
3.5	0.857	0.857	0.857	0.857
4.0	0.839	0.839	0.839	0.839
4.5	0.826	0.826	0.826	0.826
5.0	0.819	0.819	0.819	0.814
5.5	0.819	0.819	0.818	0.793
6.0	0.821	0.821	0.815	0.744
6.5	0.823	0.818	0.795	0.672
7.0	0.820	0.800	0.750	0.593
7.5	0.803	0.759	0.687	0.518
8.0	0.765	0.701	0.617	0.452
8.5	0.711	0.637	0.548	0.396
9.0	0.649	0.573	0.486	0.349
9.5	0.586	0.510	0.432	0.310
10.0	0.524	0.451	0.383	0.276

10.5	0.464	0.395	0.339	0.248
11.0	0.409	0.345	0.300	0.223
11.5	0.358	0.301	0.265	0.201
12.0	0.314	0.264	0.234	0.182
12.5	0.277	0.232	0.207	0.166
13.0	0.244	0.205	0.184	0.150
13.5	0.217	0.183	0.164	0.137
14.0	0.194	0.163	0.147	0.124
14.5	0.174	0.147	0.133	0.113
15.0	0.157	0.133	0.120	0.103
15.5	0.142	0.120	0.109	0.094
16.0	0.129	0.110	0.099	0.087
16.5	0.118	0.100	0.091	0.080
17.0	0.108	0.092	0.084	0.074
17.5	0.100	0.085	0.077	0.068
18.0	0.093	0.079	0.072	0.064
18.5	0.087	0.074	0.067	0.059
19.0	0.081	0.069	0.063	0.056
19.5	0.076	0.065	0.059	0.052
20.0	0.072	0.062	0.056	0.049
20.5	0.061	0.053	0.049	0.043
21.0	0.056	0.049	0.046	0.041
21.5	0.052	0.046	0.043	0.038
22.0	0.048	0.043	0.040	0.036
22.5	0.045	0.040	0.038	0.034
23.0	0.041	0.037	0.036	0.032
23.5	0.038	0.035	0.034	0.030
24.0	0.036	0.033	0.032	0.029
24.5	0.033	0.031	0.031	0.027
25.0	0.031	0.029	0.029	0.026

The table below contains the noise levels as a function of the horizontal wind speed measured at hub height for different noise reduction mode settings.

Noise values included in the present document correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade.

Noise [dB(A)]	***Application and Low Noise Operation Mode***			
Wind Speed [m/s]	**M2 104.0 dB(A)**	**M4 102.0 dB(A)**	**M6 100.0 dB(A)**	**M9 97.0 dB(A)**
3.0	92.2	92.2	92.2	92.2
3.5	92.2	92.2	92.2	92.2
4.0	92.2	92.2	92.2	92.2
4.5	92.2	92.2	92.2	92.2
5.0	92.5	92.5	92.5	92.5
5.5	95.0	95.0	95.0	95.0
6.0	97.2	97.2	97.2	97.0
6.5	99.2	99.2	99.2	97.0
7.0	101.0	101.0	100.0	97.0
7.5	102.7	102.0	100.0	97.0
8.0	104.0	102.0	100.0	97.0
8.5	104.0	102.0	100.0	97.0
9.0	104.0	102.0	100.0	97.0
9.5	104.0	102.0	100.0	97.0
10.0	104.0	102.0	100.0	97.0
10.5	104.0	102.0	100.0	97.0
11.0	104.0	102.0	100.0	97.0
11.5	104.0	102.0	100.0	97.0
12.0	104.0	102.0	100.0	97.0
12.5	104.0	102.0	100.0	97.0
13.0	104.0	102.0	100.0	97.0
Up to cut-out	104.0	102.0	100.0	97.0

Electrical Specifications

Nominal output and grid conditions

Nominal power	6000 kW
Nominal voltage	690 V
Power factor correction	Frequency converter control
Power factor range...........	0.9 capacitive to 0.9 inductive at nominal balanced voltage

Generator

Type	DFIG Asynchronous
Maximum power...............	6150 kW
Nominal speed	1120 rpm-6p (50Hz) 1344 rpm-6p (60Hz)

Generator Protection

Insulation class	Stator F/H Rotor F/H
Winding temperatures	6 Pt 100 sensors
Bearing temperatures........	3 Pt 100
Slip Rings	1 Pt 100
Grounding brush…....... …	On side no coupling

Generator Cooling

Cooling system	Direct cooling
Internal ventilation	Air
Control parameter	Winding, Bearings temperature

Frequency Converter

Operation	4Q B2B Partial Load
Switching	PWM
Switching freq., rotor and grid side	2.5 kHz
Cooling.............................	Liquid/Air

Main Circuit Protection

Short circuit protection	Circuit breaker
Surge arrester	varistors

Peak Power Levels

10 min average	Limited to nominal

Grid Requirements

Nominal grid frequency......	50 or 60 Hz
Minimum voltage...............	85 % of nominal
Maximum voltage..............	113 % of nominal
Minimum frequency	94 % of nominal
Maximum frequency	106 % of nominal
Maximum voltage imbalance (negative sequence of component voltage).	≤5 %
Max short circuit level at controller's grid Terminals (690 V)	TBD kA

Power Consumption from Grid (approximately)

At stand-by,No yawing......	10 kW
At stand-by, yawing	41 kW

Controller back-up

UPS Controller system	Online UPS, Li battery
Back-up time.....................	1 min
Back-up time Scada……...	24 h

Transformer Requirements

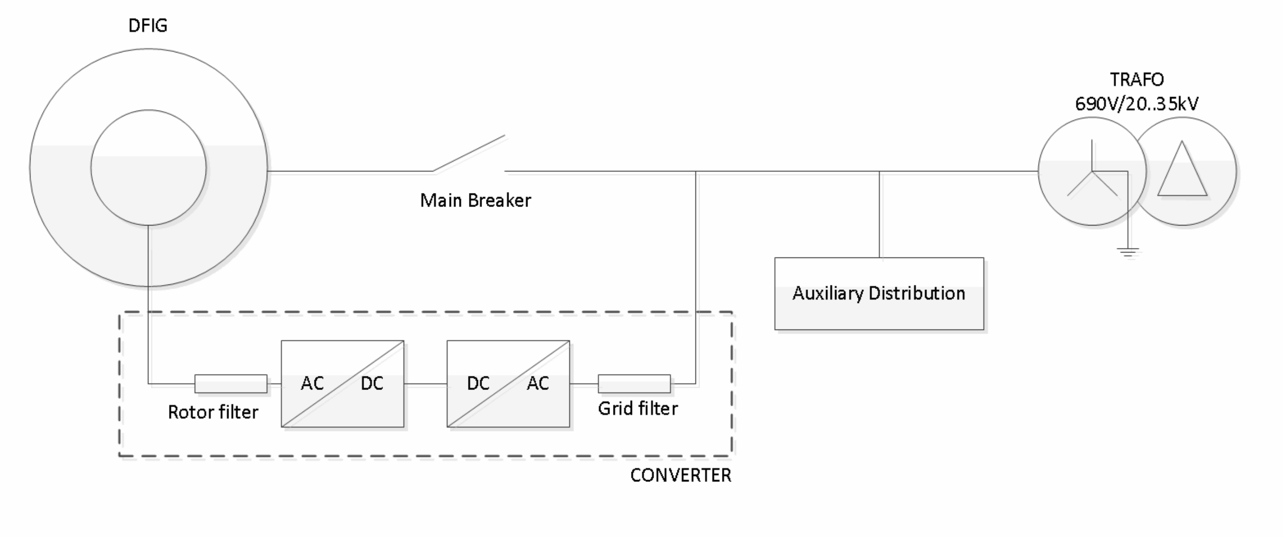
Transformer impedance requirement.......................	8.0 % -9.5%
Secondary voltage	690 V
Vector group	Dyn 11 or Dyn 1 (star point earthed)

Earthing Requirements

Earthing system	Acc. to IEC62305-3 ED 1.0:2006
Foundation reinforcement..	Must be connected to earth electrodes
Foundation terminals	Acc. to SGRE Standard
HV connection	HV cable shield shall be connected to earthing system

All data are subject to tolerances in accordance with IEC.

Simplified Single Line Diagram



Transformer Specifications ECO 30 kV*

Transformer

Type	Liquid type
Nominal power	6500 kVA @nominal voltage +13/-10 %
Nominal voltage	30/0.69 kV
Frequency	50/60 Hz
Transformer impedance	8.0% - 10.0%
Loss (P_0 /$P_{n120°C}$)	ECO Design Directive
Vector group	Dyn11
Offload tap changer	+/- 2.5% / +/- 5 %
Standard	IEC 60076 ECO Design Directive

Transformer Cooling

Cooling system..................	Water cooled
Control parameter..............	Top liquid temperature

Transformer Monitoring

Liquid temperature	PT100 sensor

Transformer Earthing

Star point	The star point of the transformer must be connected to earth

All data are subject to tolerances in accordance with IEC.
***Example for an ECO 30 kV transformer. For other Medium Voltage transformers, consult with SGRE**

Transformer Specifications 34.5 kV*

Transformer

Type	Liquid type
Nominal power	6500 kVA @nominal voltage +13/-10 %
Nominal voltage	34.5/0.69 kV
Frequency	50/60 Hz
Transformer impedance	8.0% - 10.0%
Loss (P_0 /$P_{n120°C}$)	ECO Design Directive
Vector group	Dyn1/ Dyn11
Offload tap changer	+/- 2.5% / +/- 5 %
Standard............................	IEC 60076 ECO Design Directive

Transformer Cooling

Cooling system.............	Water cooled
Control parameter..............	Top liquid temperature

Transformer Monitoring

Liquid temperature	PT100 sensor

Transformer Earthing

Star point	The star point of the transformer must be connected to earth

All data are subject to tolerances in accordance with IEC.
***Example for an ECO 34.5 kV transformer. For other Medium Voltage transformers, consult with SGRE**

Switchgear Specifications

The installation of a switchgear is an option available upon request.

Switchgear Specification (33 kV)

Technical Data for Switchgear

Switchgear

Rated voltage	33 kV
Operating voltage	30 - 36 kV
Rated current	630 A
Short time withstand current	20 kA/1s
Peak withstand current	50 kA
Power frequency withstand voltage	70 kV
Lightning withstand voltage	170 kV
Insulating medium	SF_6
Switching medium	vacuum
Consist of	1, 2 or 3 panels
Grid cable feeder	Load break switch or direct cable riser
Circuit breaker feeder	Circuit breaker
Degree of protection, vessel	IPX8
Degree of protection, front cover	IP2XD
Degree of protection, LV Comp.	IP2XD
Internal arc classification IAC:	A FLR 20 kA 1s
Pressure relief	Down
Standard	IEC 62271
Temperature range	-30°C to +40°C

Grid Cable feeder

Rated current , cubicle	630 A
Rated current , load breaker	630 A
Short time withstand current	20 kA/1s
Short circuit making current	50 kA/1s
Three position switch	Closed, open, earthed
Switch mechanism	Spring operated
Control	Local
Voltage detection system	Capacitive

Circuit breaker feeder

Rated current , Cubicle	630 A
Rated current , circuit breaker	630 A
Short time withstand current	20 kA/1s
Short circuit making current	50 kA/1s
Short circuit breaking current	20 kA/1s
Switch mechanism	Spring operated
Tripping mechanism	Stored energy
Motor voltage	Under request
Control	Local
Coil for external trip	230 V AC
Voltage detection system	Capacitive

Protection

Functions	50/51 50N/51N
Power supply	Dual (Self & Aux. powered)
Current transformer	300/1A; Cl. 5P20

Interface- MV Cables

Grid cable feeder	630A bushings type C M16 Max 3 feeder cables
Cable entry	From bottom
Cable clamp size (cable outer diameter)	up to 48mm
Circuit breaker feeder	630 A bushings type C M16
Cable entry	From bottom

Interface to turbine control

Breaker status	1 NO + 1 NC contacts
Insulation supervision	Under request

All data are subject to tolerances in accordance with IEC.
Example for a 33 kV Switchgear. For other Medium Voltage variants or different grounding systems, contact SGRE.

Preliminary Foundation Loads

Detailed information about foundation loads will be available upon request.

Tower Dimensions

SG 6.0-170 is offered with a an extensive tower portfolio ranging from 100m-165m, including the 135m and 165m catalogue towers. All the towers are designed in compliance with local logistics requirements.

Information about other tower heights will be available upon request.

Foundation Design

Detailed information about foundation loads will be available upon request

Preliminary Grid Performance Specification, 50 Hz

General

This document describes the grid performance of the SG 6.0-170, 50 Hz wind turbine. Siemens Gamesa Renewable Energy (SGRE) will provide wind turbine technical data for the developer to use in the design of the wind power plant and the evaluation of requirements compliance. The developer will be responsible for the evaluation and ensuring that the requirements are met for the wind power plant.

The capabilities described in this document are based on the assumption that the electrical network is designed to be compatible with operation of the wind turbine. SGRE will provide a document with guidance to perform an assessment of the network's compatibility.

Fault Ride Through (FRT) Capability

The wind turbine is capable of operating when voltage transient events occur on the interconnecting transmission system above and below the standard voltage lower limits and time slot according to **Figure 1.** Lower voltage limits for SG 6.0-170, 50 Hz wind turbine in the range of 0-1000 seconds. The nominal voltage is 690 V (i.e. 1 p.u.)..

This performance assumes that the installed amount of wind turbines is in the right proportion to the strength of the grid, which means that the short circuit ratio (Sk/Sn) and the X/R ratio of the grid at the wind turbine transformer terminals must be adequate.

Evaluation of the wind turbine's fault ride through capability in a specific system must be based on simulation studies using the specific network model and a dynamic wind turbine model provided by SGRE in PSS/E. This model is a reduced order model, suitable for balanced simulations with time steps between 4-10 ms.

The standard voltage limits for the SG 6.0-170, 50 Hz wind turbine are presented in **Figure 1**. Lower voltage limits for SG 6.0-170, 50 Hz wind turbine in the range of 0-1000 seconds. The nominal voltage is 690 V (i.e. 1 p.u.)..

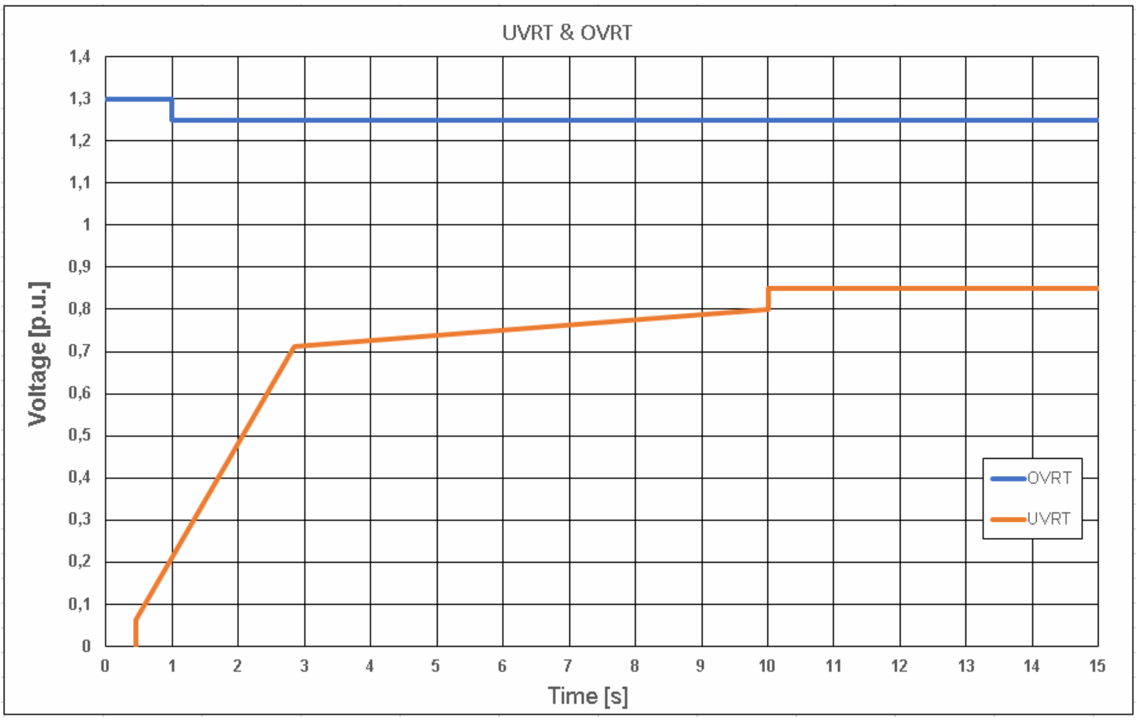


Figure 1. Lower voltage limits for SG 6.0-170, 50 Hz wind turbine in the range of 0-1000 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).

Power Factor (Reactive Power) Capability
The wind turbine is able to operate in a wide power factor range at the low voltage side of the wind turbine transformer. See the Reactive Power capability chapter for more details. The control mode for the wind turbine is with reactive power set-points.

Supervisory Control and Data Acquisition (SCADA) Capability
The SGRE SCADA system has the capability to transmit and receive instructions from the transmission system provider for system reliability purposes depending on the configuration of the SCADA system. The project specific SCADA requirements must be specified in detail for design purposes.

Frequency Capability
The wind turbine is able to operate in the frequency range between 47 Hz and 53 Hz.

Voltage Capability
The voltage operation range for the wind turbine is between 85% and 113% of nominal voltage at the low voltage side of the wind turbine transformer. The voltage can be up to 130% for 60ms. The wind turbine's target voltage shall stay between 95% and 105% in order to support the best possible performance by staying within the operation limits.

Flicker and Harmonics
Flicker and Harmonics values will be provided in the power quality measurement report extract in accordance with IEC 61400-21 Edition 2.

Reactive Power -Voltage Control
The power plant controller can operate in four different modes:

- Q Control – In this mode reactive power is controlled at the point of interconnection, according to a reactive power reference
- V Control – Voltage is directly controlled at the point of interconnection, according to a voltage reference
- V-Q static – Voltage is controlled at the point of interconnection, by means of a pre-defined voltage – reactive power characteristic
- Power factor (cosphi) control – Power factor is controlled at the point of interconnection, according to a power factor reference

The SCADA system receives feedback/measured values from the Point Of Interconnection depending on the control mode it is operating. The wind power plant controller then compares the measured values against the target levels and calculates the reactive power reference. Finally, reactive power references are distributed to each individual wind turbine. The wind turbine's controller responds to the latest reference from the SCADA system and will generate the required reactive power accordingly from the wind turbine.

Frequency Control
The frequency control is managed by the SCADA system together with the wind turbine controller. The wind power plant frequency control is carried out by the SCADA system which distributes active power set-points to each individual wind turbine, to the controllers. The wind turbine controller responds to the latest reference from the SCADA system and will maintain this active power locally.

All data are subject to tolerances in accordance with IEC.

Preliminary Grid Performance Specification, 60 Hz

General
This document describes the grid performance of the SG 6.0-170, 60 Hz wind turbine. Siemens Gamesa Renewable Energy (SGRE) will provide wind turbine technical data for the developer to use in the design of the wind power plant and the evaluation of requirements compliance. The developer will be responsible for the evaluation and ensuring that the requirements are met for the wind power plant.

The capabilities described in this document are based on the assumption that the electrical network is designed to be compatible with operation of the wind turbine. SGRE will provide a document with guidance to perform an assessment of the network's compatibility.

Fault Ride Through (FRT) Capability
The wind turbine is capable of operating when voltage transient events occur on the interconnecting transmission system above and below the standard voltage lower limits and time slot according to **Figure 2.** Lower voltage limits for SG 6.0-170, 60 Hz wind turbine in the range of 0-1000 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).

This performance assumes that the installed amount of wind turbines is in the right proportion to the strength of the grid, which means that the short circuit ratio (Sk/Sn) and the X/R ratio of the grid at the wind turbine transformer terminals must be adequate.

Evaluation of the wind turbine's fault ride through capability in a specific system must be based on simulation studies using the specific network model and a dynamic wind turbine model provided by SGRE in PSS/E. This model is a reduced order model, suitable for balanced simulations with time steps between 4-10 ms.

The standard voltage limits for the SG 6.0-170, 60 Hz wind turbine are presented in **Figure 2.** Lower voltage limits for SG 6.0-170, 60 Hz wind turbine in the range of 0-1000 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).

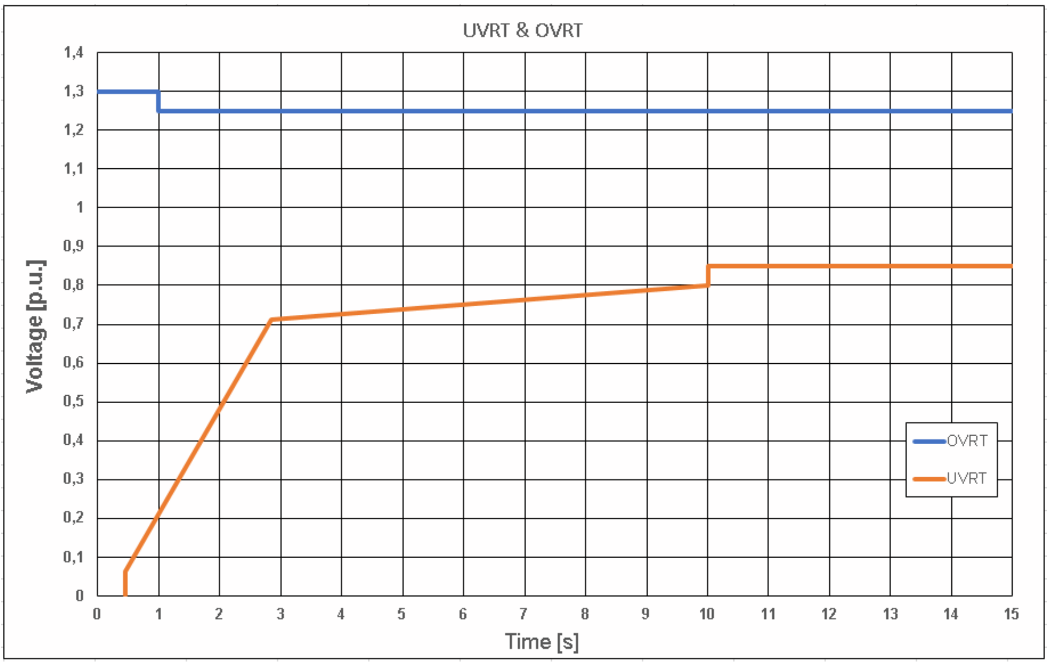


Figure 2. Lower voltage limits for SG 6.0-170, 60 Hz wind turbine in the range of 0-1000 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).

Power Factor (Reactive Power) Capability
The wind turbine is able to operate in a wide power factor range at the low voltage side of the wind turbine transformer. See the Reactive Power capability chapter for more details. The control mode for the wind turbine is with reactive power set-points

Supervisory Control and Data Acquisition (SCADA) Capability
The SGRE SCADA system has the capability to transmit and receive instructions from the transmission system provider for system reliability purposes depending on the configuration of the SCADA system. The project specific SCADA requirements must be specified in detail for design purposes.

Frequency Capability
The wind turbine is able to operate in the frequency range between 56.4 Hz and 63.6 Hz.

Voltage Capability
The voltage operation range for the wind turbine is between 85% and 113% of nominal voltage at the low voltage side of the wind turbine transformer. The voltage can be up to 130% for 60ms. The wind turbine's target voltage shall stay between 95% and 105% in order to support the best possible performance by staying within the operation limits

Flicker and Harmonics
Flicker and Harmonics values will be provided in the power quality measurement report extract in accordance with IEC 61400-21 Edition 2.

Reactive Power -Voltage Control
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- Q Control – In this mode reactive power is controlled at the point of interconnection, according to a reactive power reference
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The SCADA system receives feedback/measured values from the Point Of Interconnection depending on the control mode it is operating. The wind power plant controller then compares the measured values against the target levels and calculates the reactive power reference. Finally, reactive power references are distributed to each individual wind turbine. The wind turbine's controller responds to the latest reference from the SCADA system and will generate the required reactive power accordingly from the wind turbine.

Frequency Control
The frequency control is managed by the SCADA system together with the wind turbine controller. The wind power plant frequency control is carried out by the SCADA system which distributes active power set-points to each individual wind turbine, to the controllers. The wind turbine controller responds to the latest reference from the SCADA system and will maintain this active power locally.

All data are subject to tolerances in accordance with IEC.

Reactive Power Capability, 50 Hz

General
This document describes the reactive power capability of SG 6.0-170, 50 Hz wind turbines during active power production. SG 6.0-170 wind turbines are equipped with a B2B Partial load frequency converter which allows the wind turbine to operate in a wide power factor range.

Reactive Power Capability Curves

The reactive power capability for the wind turbine at the LV side of the wind turbine transformer will be presented in the following Figures.

Figure 3. Reactive power capability curves, 50 Hz wind turbine, at LV side of wind turbine transformer. shows the reactive power capability on the LV side of the wind turbine depending on the generated power at LV terminals.

Figure 4. Reactive power capability at no wind (QwP0) includes reactive power capability at no wind (QwP0).

The SCADA can send voltage references to the wind turbine in the range of 0.92 p.u. to 1.08 p.u. The wind power plant should be designed to maintain the wind turbine voltage references between 0.95 p.u. and 1.05 p.u. during steady state operation.

The tables and figures assume that the phase voltages are balanced, and that the grid operational frequency and component values are nominal. Unbalanced voltages will decrease the reactive power capability. Component tolerances were not considered in determining curve parameters. Instead, the curves and data are subject to an overall tolerance of ± 5 % of the rated power.

The reactive power capability presented in this document is the net capability and accounts for the contribution from the wind turbine auxiliary system, the reactor and the filter.

The reactive power capability described is valid while operating the wind turbine within the limits specified in the Design Climatic Conditions.

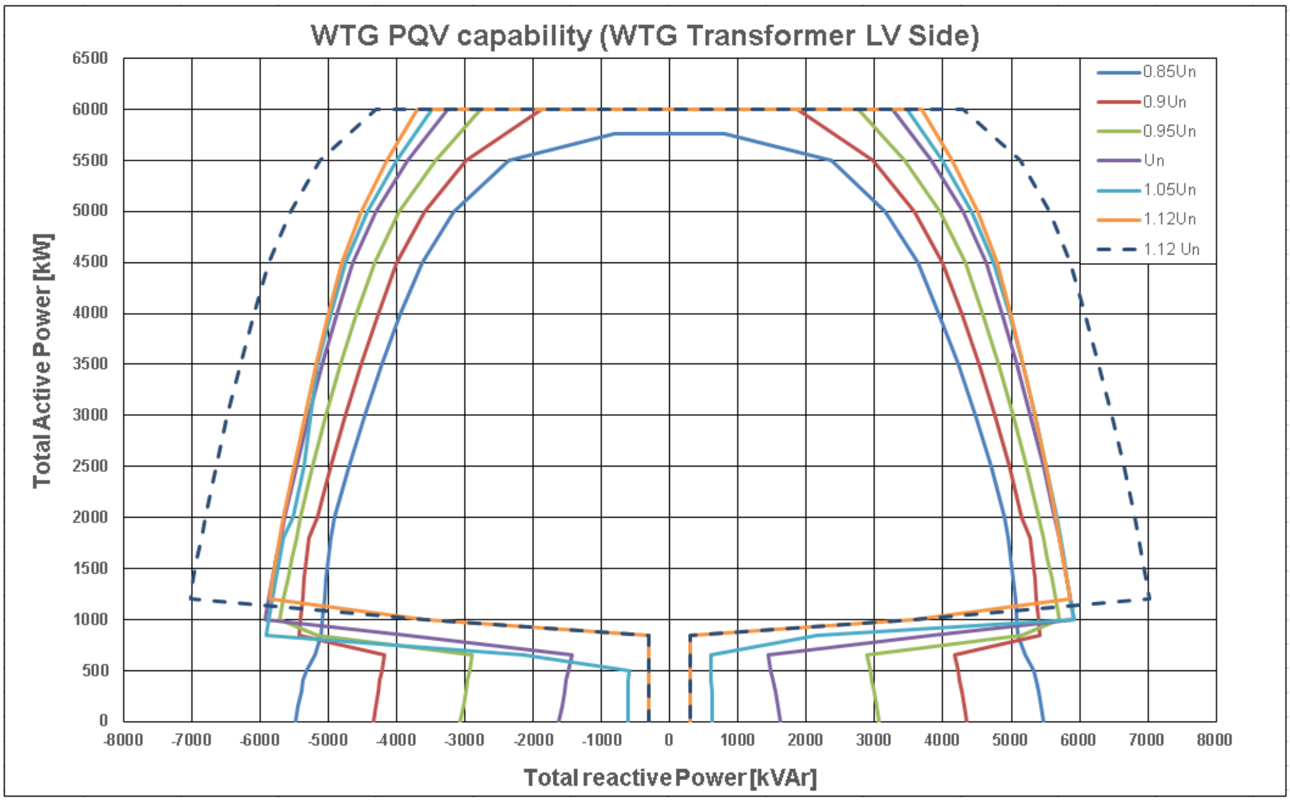

Figure 3. Reactive power capability curves, 50 Hz wind turbine, at LV side of wind turbine transformer.

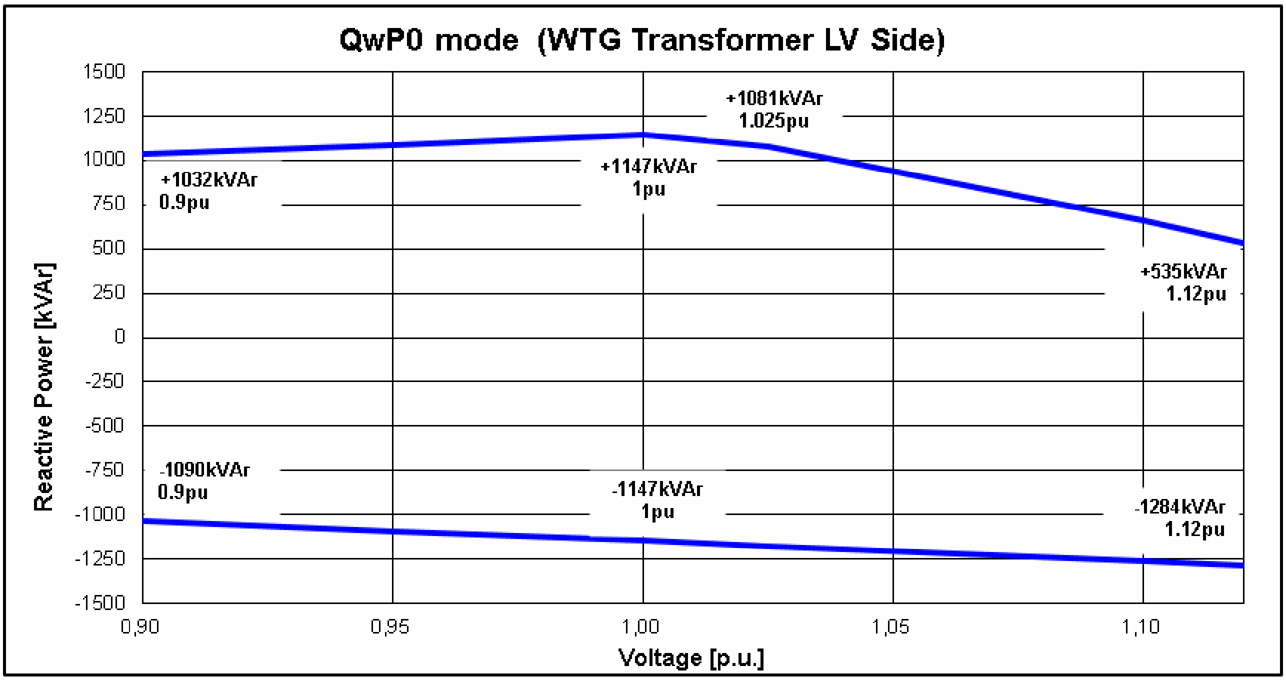

Figure 4. Reactive power capability at no wind (QwP0)

All data are subject to tolerances in accordance with IEC.

Reactive Power Capability, 60 Hz

General
This document describes the reactive power capability of SG 6.0-170, 60 Hz wind turbines during active power production. SG 6.0-170 wind turbines are equipped with a B2B Partial load frequency converter which allows the wind turbine to operate in a wide power factor range.

Reactive Power Capability Curves
The reactive power capability for the wind turbine at the LV side of the wind turbine transformer will be presented in the following Figures.

Figure 5. Reactive power capability curves, 60 Hz wind turbine, at LV side of wind turbine transformer shows the reactive power capability on the LV side of the wind turbine depending on the generated power at LV terminals.

Figure 6. Reactive power capability at no wind (QwP0). includes reactive power capability at no wind (QwP0).

The SCADA can send voltage references to the wind turbine in the range of 0.92 p.u. to 1.08 p.u. The wind power plant should be designed to maintain the wind turbine voltage references between 0.95 p.u. and 1.05 p.u. during steady state operation.

The tables and figures assume that the phase voltages are balanced, and that the grid operational frequency and component values are nominal. Unbalanced voltages will decrease the reactive power capability. Component tolerances were not considered in determining curve parameters. Instead, the curves and data are subject to an overall tolerance of ± 5 % of the rated power.

The reactive power capability presented in this document is the net capability and accounts for the contribution from the wind turbine auxiliary system, the reactor and the filter.

The reactive power capability described is valid while operating the wind turbine within the limits specified in the Design Climatic Conditions.

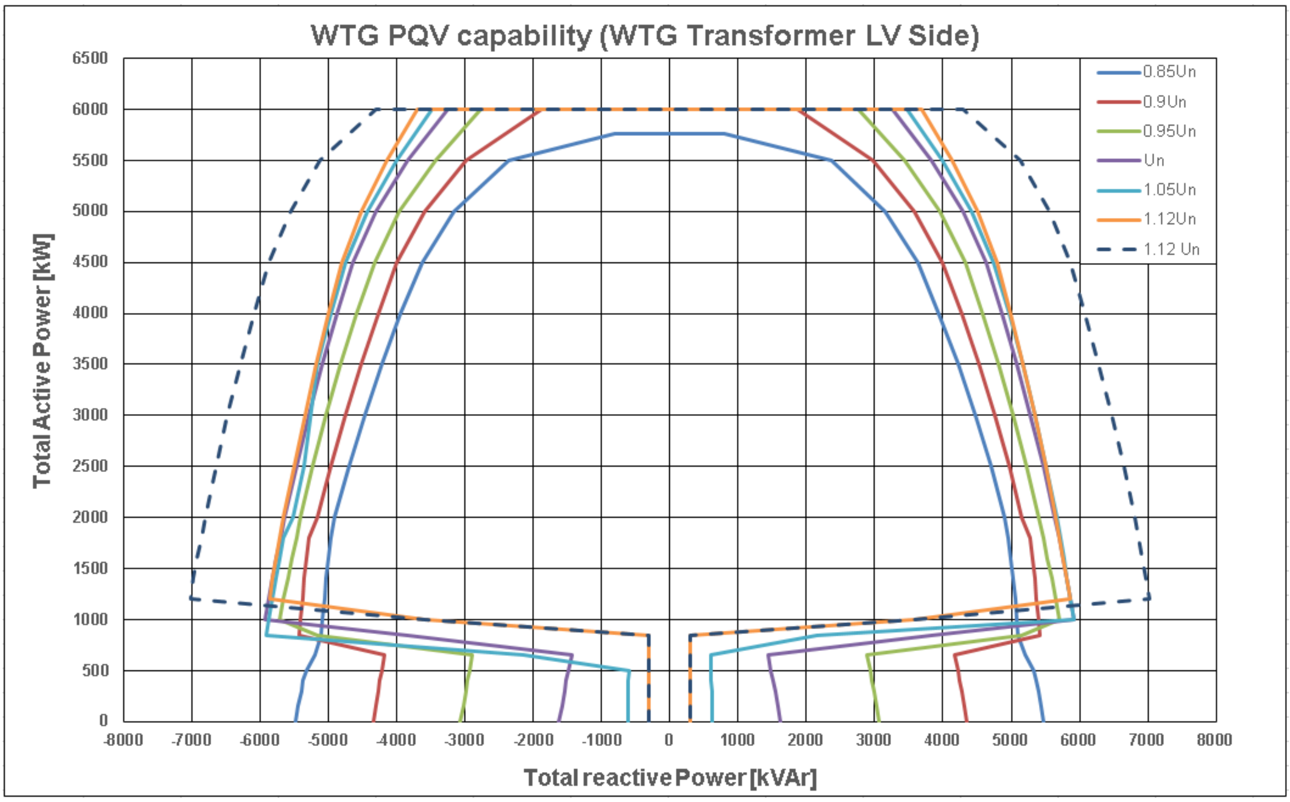

Figure 5. Reactive power capability curves, 60 Hz wind turbine, at LV side of wind turbine transformer

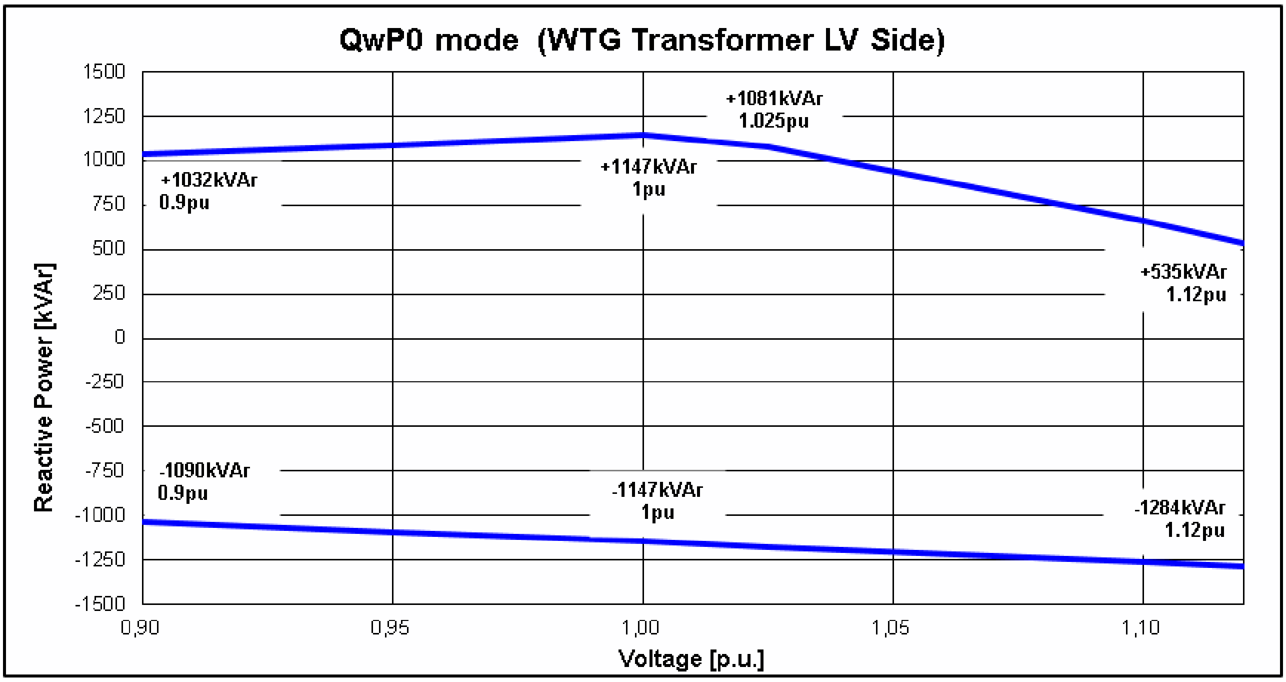

Figure 6. Reactive power capability at no wind (QwP0).

SCADA, System Description

Introduction
This is a general description of the SGRE SCADA System.

The SGRE SCADA system is a system for supervision, data acquisition, control, and reporting for wind farm performance.

Main features
The SCADA system has the following main features:

- On-line supervision and control accessible via Internet.
- Data acquisition and storage of data in a historical database.
- Local storage of data at wind turbines if communication is interrupted and transferred to historical database when possible.
- System access from anywhere using a standard web browser. No special client software or licenses are required.
- Users are assigned individual user names and passwords, and the administrator can assign a user level to each user name for added security.
- Email function can be configured for fast alarm response for both turbine and substation alarms.
- Interface to park pilot functions for enhanced control of the wind farm and for remote regulation, e.g. MW / Voltage / Frequency / Ramp rate.
- Power curve plots and efficiency calculations with pressure and temperature correction (pressure and temperature correction available only if SGRE MET system supplied).
- Condition monitoring integrated with the turbine controller using designated server.
- Ethernet-based system with compatible interfaces (OPC XML / IEC 60870-5-104 / Modbus TCP).
- Virus Protection Solution.
- Back-up & restore.

Wind turbine hardware
Components within the wind turbine are monitored and controlled by the individual local wind turbine controller (STC). The STC can operate the turbine independently of the SCADA system, and turbine operation can continue autonomously in case of, e.g. damage to communication cables.

A turbine interface computer (STIC) placed at the tower base handles the interface between the STC and the central SCADA server. Data recorded in the turbine is stored here temporary. In the event that communication to the central server is temporarily interrupted data is kept in the STIC and transferred to the SCADA server when possible. The STIC is considered part of the wind turbine.

Communication network in wind farm
The communication network in the wind farm must be established with optical fibers. The optimum network design is typically a function of the wind farm layout. Once the layout is selected, SGRE will define the minimum requirements for the network design.

The supply, installation, and termination of the communication network are carried out by the Employer.

SCADA server panel
The central SCADA server panel supplied by SGRE is normally placed at the wind farm substation or control building.

The server panel comprises amongst others:

- The server is configured with standard disk redundancy (RAID) to ensure continuous operation in case of disk failure. Network equipment. This includes all necessary switches and media converters.

- UPS back up to ensure safe shut down of servers in case of power outage.

For large sites or as option a virtualized SCADA solution can be supplied.

On the SCADA server the data is presented online as a web-service and simultaneously stored in an SQL database. From this SQL database numerous reports can be generated.

Employer "client" connection to the SCADA system establishing via the internet through a point to point TCP/IP VPN-connection.

Grid measuring station
The SCADA system includes a GMS located in one / more GMS panels or in the SCADA server panel. Normally the GMS is placed at the wind farm substation or control building.

The heart of the GMS is a PQ meter and the HPPP. The HPPP/GMS can be scaled to almost any arrangement of the grid connection. The HPPP/GMS requires voltage and current signals from VT's and CT's fitted at the wind farm PCC to enable its control functions.

The GMS interfaces to the SGRE SCADA servers and turbines are via a LAN network.

The HPPP can on request be supplied in a high availability (HA) setup with a redundant server cluster configuration.

Note: In small SGRE SCADA systems (typically <10 turbines) and if the small SGRE SCADA system is placed in a turbine the GMS components (HPPP / GMS) may be arranged otherwise.

Signal exchange
Online signal exchange and communications with third party systems such as substation control systems, remote control systems, and/or maintenance systems is possible from both the module and/or the SGRE SCADA server panel. For communication with third party equipment a Modbus TCP, IEC 60870-5-104, and OPC XML compatible interfaces are available as an option.

SGRE SCADA software
The normal SGRE SCADA user interface presents online and historical data. The screen displays can be adjusted to meet individual customer requirements.

Historical data are stored in an MS SQL database as statistical values and can be presented directly on the screen or exported for processing in MS Access or Excel via a ODBC connection.

The SGRE SCADA software also serves as user interface to the HPPP functions.

Virus protection solution
A virus protection solution can be offered as a part of the Service Agreement(SA). An anti-virus client software will in that case be installed on all MS-Windows based components at the SCADA system and the WTGs.

The virus protection solution is based on a third party anti-virus product. Updates to the anti-virus client software and pattern files are automatically distributed from central SGRE based servers.

Back-up & restore
For recovery of a defect SCADA system or component, the SGRE SCADA system provides back-up of configuration files and basic production data files. Both configuration and selected production data are backed up automatically on a regular time basis for major components. The back-up files are stored both locally on the site servers and remotely on SGRE back-up storage servers.

Codes and Standards

The wind turbine is designed and certified with an external certification body according to:

1) Operational Document: OD-501, Type Certification Scheme
2) OD501-T01 Type Certificate & Provisional Type Certificate template Wind Turbine
3) IEC 61400-22:2010 Ed.1, Wind turbines – Part 22: Conformity testing and certification
4) EN 61400-1:2018, Ed.4, Wind turbine generator systems Part 1: Safety requirements, (IEC 61400-1:2005, modified)
5) IEC 61400-1:2018 Ed.4 Wind turbines –. Part 1: Design requirements
6) DIBt - Richtlinie für Windenergieanlagen - Oktober 2012, korrigierte Fassung März 2015
7) IEC 61400-11:2006, Wind turbine generator systems Part 11: Acoustic noise measurement techniques
8) IEC 61400-12:2005, Ed.1, Wind Turbine Generator Systems Part 12: Wind turbines power performance testing
9) IEC 61400-13: 2015 Wind Turbine Generator Systems - Part 13: Measurement Of Mechanical Loads
10) IEC 61400-23 Ed. 1.0 EN :2014 Wind turbines - Part 23: Full-scale structural testing of rotor blades
11) VDI 2230 Blatt 1, 2016, Bolt calculation
12) ISO 898-1:2013Mechanical properties of fasteners made of carbon steel and alloy steel -- Part 1: Bolts, screws and studs with specified property classes -- Coarse thread and fine pitch thread
13) EN 10029:2010, Hot rolled steel plates 3 mm thick or above - Tolerances on dimensions, shape and mass
14) DS/EN 10083:2008, Quenched and tempered steels - Part 1: Technical delivery conditions for special steels (Main shaft)
15) DS/EN 1563:2012, Founding - Spheroidal graphite cast irons
16) DS/EN 10025-1:2004, Hot rolled products of structural steels - Part 1: General technical delivery conditions
17) DS/EN 10025-2:2006, Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels
18) DS/EN 10025-3:2004, Hot rolled products of structural steels - Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels
19) EN 1993-1-8:2005/AC:2009: Eurocode 3: Design of steel structures
20) EN 1999 Design of aluminium structures
21) ISO/TS 16281:2008 Rolling bearings - Methods for calculating the modified reference rating life for universally loaded bearings
22) DIN ISO 281 Rolling bearings - Dynamic load ratings and rating life - Life modification factor aDIN and calculation of the modified rating life
23) DIN ISO 76:2006 Rolling bearings - Static load ratings
24) ISO/TS 16281:2008 + Cor. 1:2009 Rolling bearings - Methods for calculating the modified reference rating life for universally loaded bearings
25) DNV-DS-J102:2010 Design and Manufacture of Wind Turbine Blades, Offshore and Onshore Wind Turbines
26) OD-501-2ed.1.0 Conformity Assessment and Certification of wind turbine gearboxes by RECB
27) IEC 61400-4:2012 Wind turbines -- Part 4: Design requirements for wind turbine gearboxes
28) EN 61000-6-2:2005 Electromagnetic compatibility (EMC) - Part 6-2: Generic standards – Immunity for industrial environments

29) EN 61000-6-4:2007 Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments
30) EN 60204-1:2006 (+correct 2010) Safety of machinery - Electrical equipment of machines - Part 1: General requirements
31) EN 61439-1:2014 Low-voltage switchgear and control gear assemblies. General rules
32) EN 61439-2:2011 Low-voltage switchgear and control gear assemblies. Power switchgear and control gear assemblies
33) IEC 61400-24 Ed. 1.0 (2010) Wind turbines - Part 24: Lightning protection
34) DS/EN 60076 – 16:2018 – Power transformers - Part 16: Transformers for wind turbine applications
35) IEC 61400-21:2008 Wind turbine generator systems - Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines
36) Low Voltage Directive 2014/35/EU
37) EMC Directive 2014/30/EU
38) EN 61000-6-2:2005 Electromagnetic compatibility (EMC) - Part 6-2: Generic standards – Immunity for industrial environments
39) ISO 9001:2015 Quality management systems – Requirements2004/108/EF EMC Directive

Other Performance Features

Siemens Gamesa Renewable Energy (SGRE) offers the following optional performance features for SG 6.0-170 that can optimize your wind farm by boosting performance, enhancing environmental agility, supporting compliance with legal regulation, and supporting grid stability.

High Temperature Derated operational mode (also known as Power Derating due to component temperature)

Ventilation and cooling systems are designed to allow the WTG operation at rated power up to a certain external nominal temperature and a certain altitude. For sites located beyond 1000m above the sea level, the air density reduction affects the turbine components ventilation capacity, reducing the maximum operational temperature at rated power. However, this maximum ambient temperature can be extended by reducing the delivered power.

Considering the individual components requirements in temperatures at different altitude levels, and their dissipated heat at different power limits, several curves power-temperature will be generated. These curves will define the envelopes inside which SG 6.0-170 could operate assuring the integrity of all components.

The control system, considering the defined turbine type, will dynamically adjust the maximum allowed power as a function of component temperature.

Ice Detection System

A default IDS is included in SG 6.0-170. This system is required in order to prevent the turbine operating under non desirable ice conditions that could represent an out-of-design situation with risk for the turbine integrity or H&S.

The default IDS can be improved by application of additional features, described as follows:

- Ice on nacelle sensor (optional kit). Additional sensor is installed to detect ice on nacelle.
- Improved ice on blade detection algorithm (optional, only available when blade de-icing system is installed). It requires additional hardware. It is a more complex ice detection algorithm defined based on ice probability calculation, and it is a valuable complement for improving the blade de-icing system performance.

Noise Reduction System

The Noise Reduction System NRS is an optional module available with the basic SCADA configuration and it therefore requires the existence of a SGRE SCADA system to work.

The purpose of this system is to limit the noise emitted by any of the functioning turbines and thereby comply with local regulations regarding noise emissions. This allows wind farms to be located close to urban areas, limiting the environmental impact that they imply.

Bat Protection System

To support the installation of wind turbines in areas that constitute a natural habitat for bats, SGRE has developed a Bat Protection System. Bats are usually more active at certain times of the night and at certain times of the year, depending on the local habitat and/or migration routes. The purpose of the SGRE Bat Protection System is to monitor the local environmental conditions in order to reduce the risk of impact on bats.

Specific environmental conditions can be monitored by means of dedicated additional sensors: temperature, light, humidity and rainfall. If conditions for the existence of bats are met, the Bat Protection System tool will request the wind turbines to be paused. As soon as one of the conditions is no longer met, the affected wind turbine will return to its initial status prior to receiving the pause order from the tool, depending on the configured hysteresis values.

The tool does not require all the sensors associated with the conditions to be installed and, depending on each site, the sensors needed will be configured. If there is no sensor for a specific environmental variable, condition is configured as fulfilled.

Additionally, Bat Protection System can be configured to be triggered depending on calendar (day/time), wind speed range or wind direction.

Bird Detection System

The Bird Detection System is a stand-alone system that monitors the wind farm’s surrounding air space and detects flying birds in real time. At the same time, it is capable of handling real-time actions related to bird detection, such as warning and deterring birds at risk of colliding with the wind turbines or automatic shutdown of the selected wind turbines.

Generic Site Roads and Hardstands requirements

SG 6.0-170

Document ID and revision	Status	Date (yyyy-mm-dd)	Language
D2165151/006	Approved	2020-12-13	en-US

Original or translation of
Original

File name
D2165151_006- Site roads and Hardstands SG 6.0-170.docx/.pdf

Updates made since the previous revision
Migrated to new templated. For further details see document history section.

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Table index

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Document history

Revision:	Change notes	Responsible
002	- Transfer to PCD template and updates for SRD floating gate - Small changes for clarification implemented (e.g. self-off-loading tower section clamp system not considered) - Hardstand layouts updated - Section 3.2.4.1 added (T-flange requirements) - Section 7.2 added (Turning radii..)	Christian Kielhorn
003	- Include table and figure index - 1.Aim and Scope excluded T100 from - 2. Definitions and acronyms • Auxiliary crane → Pre-installation crane • Retention crane → Tailing crane • Pneumatic crane → Mobile crane • Mobile crane divided into Telescopic and Lattice mobile crane • Remove Tower crane Each previous change uploaded in the document - 3.1.2. Road composition and structure: *maximum load* to *minimum load* - 3.1.3. Road width: complete dimensions in section diagrams - 3.1.4. Turning radii – General: change of figures and description - 3.1.5 Gradients and grade changes update value KV, new requirement transition gradient changes. - 3.1.6. Intersection and turning areas • Change of title to passing areas and turning points • Add HSE conditions and reverse manoeuvre - 3.1.7. Drainage - 3.2.4. Hardstand dimensions • Change introduction note transferred from the Annex. • Qs definition table • Change format of dimension table (depending on Qs) followed by sketches. • Change bearing capacity to legend in each sketch • Add self-offloading platforms STG 03 and STG 04 • Remove JIT hardstands and its dimensions in the tables - 4.2.6. Requirements for assembly the main crane: table updated - 5. Work execution control plan removed - Component weight updated in Annex 1 - Section 7.2 changed (Turning radii.) to Section 5.2 Transports requirements.	Soares, Keith
004	- Include table and figure index - 2. Definitions and acronyms • Auxiliary crane → Pre-installation crane • Retention crane → Tailing crane • Pneumatic crane → Mobile crane • Mobile crane divided into Telescopic and Lattice mobile crane • Remove Tower crane Each previous change uploaded in the document	Soares, Keith

	- 3.1.2. Road composition and structure: *maximum load* to *minimum load* - 3.1.3. Road width: complete dimensions in section diagrams - 3.1.4. Turning radii – General: change of figures and description - 3.1.5 Gradients and grade changes update value KV, new requirement transition gradient changes. - 3.1.6. Intersection and turning areas • Change of title to passing areas and turning points • Add HSE conditions and reverse manoeuvre - 3.1.7. Drainage - 3.2.4. Hardstand dimensions • Change introduction note transferred from the Annex. • Qs definition table • Change format of dimension table (depending on Qs) followed by sketches. • Change bearing capacity to legend in each sketch • Add self-offloading platforms STG 03 and STG 04 • Remove JIT hardstands and its dimensions in the tables - 4.2.6. Requirements for assembly the main crane: table updated - 5. Work execution control plan removed - Component weight updated in Annex 1 - Section 7.2 changed (Turning radii.) to Section 5.2 Transports requirements.	
005	- Document format updated.	Soares, Keith
006	- 1. Aim and scope: • Updated machine power • Updated tables with new tower models. - 3.1.2. Included Design of the windfarm internal roads - 3.1.3. Road composition and structure: • Updated requirements. • Included the complementary documentation for Quality requirements. - 3.1.4 Road Width: • new note about the minimum road width requirement per region/project. - 3.2 Hardstands: Reviewed the general requirements. - 3.2.1 Hardstand design: new requirements for the hardstands design. - 3.2.2. Bearing capacity: Updated table with new tower models. - 3.2.3 Hardstand composition and structure: updated the requirements. - 3.2.3. Hardstand dimensions: updated the table according to the new tower models. - 3.2.4. Hardstand dimensions • Remove self-offloading platforms STG 03 and STG 04 - 3.2.5. Requirements for assembly the main crane: updated.	Soares, Keith

	- 5.1. Weights and dimensions for SG 6.0-170: updated. - 5.2. Transport requirements: Updated info. - 5.3. Quality tests and requirements for civil works projects: included a new referenced documentation.	

1. Aim and scope

The aim of this specification is to describe the minimum geometrical requirements of the roads and platforms required for a safe component transportation and assembly of the wind turbines. Additionally, it includes the minimum deliverables that will be needed from SGRE to start with the transportation and erection works. The scope includes all W.F. with the following WTG models and erection strategies:

Tower	No. of tubular steel section	Power	Blade
T100	6	6.2	SG170
T101.5	6	6.2	
T115	5	6.2	
T135	6	6.2	
T145	8	6.2	
T165MB	3	6.2	

Table 1 WTG models

Tower	STG3	STG4 (SGRE Standard)
T100	✔	✔
T101.5	✔	✔
T115	✔	✔
T135	✔	✔
T145	✔	✔
T165MB	✔	✔

Table 2 SGRE strategies

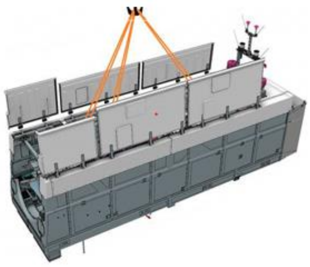
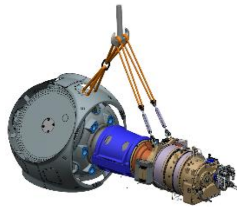
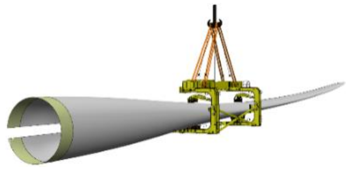
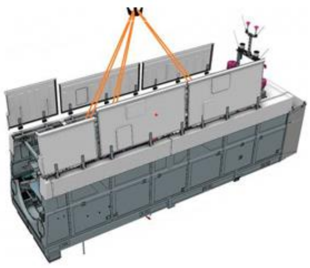
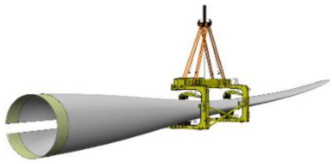
Strategy	Nacelle	DT	Hub	Blade
Strategy 3	**Modular** 	**DT/Hub** 		**Blade To Blade (SBI)** 
Strategy 4	**Modular** 	**DT** 	**Hub** 	**BladeTo Blade (SBI)** 

Table 3 components of each strategy

Note:

This specification sets a guide to be followed for the design and construction of a wind farm civil engineering project. The project undertaken in accordance with this specification must be reviewed and approved by SGRE prior to execution. However, the civil designer is solely responsible for making sure that the design complies with this specification, the contract requirements and local norms and standards.

2. Definitions and acronyms

Acronyms	Definition
SGRE	Siemens Gamesa Renewable Energy
Main crane	Capable of lifting any component to the highest point of the wind turbine.
Pre-installation crane	Used for installing elements at the lower part of the tower.

Tailing crane	Supports the main and pre-installation crane for mounting and unloading components.	
Mobile crane	Telescopic mobile crane	
	Lattice boom mobile crane	
NTC	Narrow-Track Crane	
WTC	Wide-Track Crane	
Intermediate hardstand	The work area for wind turbine assembly is parallel and close to the internal roads of the wind farm.	
End-of-road hardstand	Work area for wind turbine assembly at the end of internal wind farm roads.	
Wind farm access roads	These roads do not pass by asphalt roads and they are used to transport components and disassembled cranes.	
Wind farm internal roads	Roads that pass between wind turbines for the transportation of components and with the capacity for transporting cranes.	
SP	Standard Proctor	
MP	Modified Proctor	
WTG	Wind Turbine Generator	

Table 4 Acronyms and definitions

3. Description

3.1. Roads

3.1.1. Reference legislation

The legislation of the corresponding country on the design of civil engineering must be applied. If there is no such legislation, the legislation given as a reference in the annexes should be followed as a guide.

3.1.2. Design of the windfarm internal roads

In case there is no legislation for the road design the dimensioning of the road pavement should be based on the AASHTO method for roads with a low volume of traffic (Part 2, Chapter 4). This methodology is based on an empirical formula that relates the characteristics of the pavement layers with their performance, in order to determine whether the road pavement section will be capable of bearing the traffic loads to which it will be applied.

The design of the road and the geotechnical report will be provided to Siemens Gamesa together with the quality control of the roads during the handover of the civil works and before starting with the transportation and the erection process.

3.1.3. Road composition and structure

Wind farm access roads must support a **minimum load** of 12t per axle corresponding to the transportation of wind turbine elements and crane elements.

Internal wind farm roads must support a **minimum load** of:

- Without mounted crane movement:
  - 1.4 kg per cm² in the case of crawler cranes (NTC and WTC).
  - 22.5t per axle in the case of mobile cranes.
- With mounted crane movement:
  - 2.45 kg per cm² in the case of crawler cranes (NTC and WTC).
  - 22.5t per axle in the case of lattice boom mobile cranes.
  - 24.5t per axle in the case of telescopic mobile cranes.
  - 14.7t per axle in the case of pre-installation telescopic mobile cranes.

The dimensions of the roadbed must be in accordance with the number of WTGs at the wind farm, allowing for the number of transport vehicles per WTG.

Tests must be carried out on the material used for the subgrade and for the roadbed, in order to control the compaction of the different layers and ensure that the civil works are correctly executed. The quality control and the requirements for the civil works design is defined according to the ***5.3 Quality tests and requirements for civil works plan projects.***

With the trace material, once analyzed, suitable compaction means must be used to find a subgrade of enough elasticity modulus value. The elasticity module will be measured from the compressibility module of the second cycle of the loading plate test as per DIN 18134 (or in its absence, NLT-357), the acceptance criteria will be indicated in the road section design.

The dry density required after compaction for the different types of materials forming the roadbed is 98% of that obtained in the PM test or above.

Fill material will be compacted in layers to a maximum thickness of 30 cm to ensure the effectiveness of the machinery along the entire section.

Where expansive material (expansive clay, etc.) or loose soil conditions are indicated in the geotechnical report, the use of geosynthetics is strongly recommended (at least with the soil reinforcement and separation functions).

The elasticity module of the finished roadbed must be measured based on the compressibility module of the second cycle of the load plate test as per DIN 18134 (or in its absence, NLT-357), and the result must never be less than E_{v2}=80 MPa (*). Likewise, the relation between the first and second load cycle must be less than 3.

(*) In countries where the load plate is not usually used, use the following relationship to obtain the acceptance criteria for the roadbed built:

$$E = \frac{\pi \cdot (1 - v^2)}{3} \cdot Ev_2$$

E=π*(1-v2)3*Ev2

- E: elasticity module
- v: Poisson's ratio
- Ev2: second plate loading test cycle compressibility module

Additionally, remember that the dry density required after compaction for the different types of materials forming the roadbed is 98% of that obtained in the MP test or above.

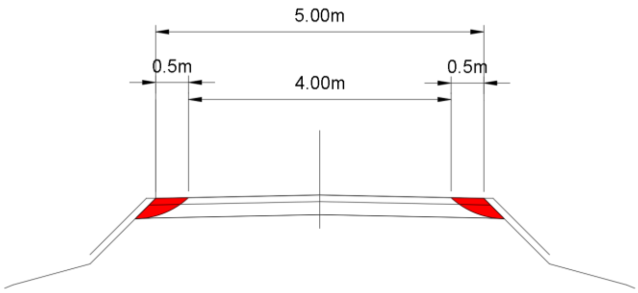
3.1.4. Road width

The road width will vary for curves according to the following section "Turning Radii"

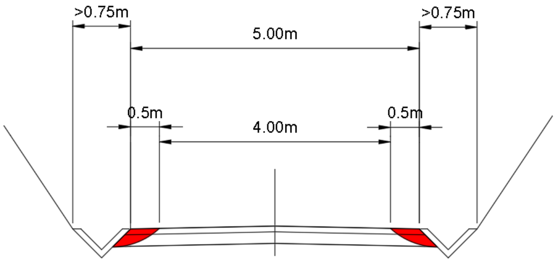
Minimum road width	
A. Wind farm access road transportation of components	**As a minimum and usable 4.0m*** + 2 x 0.50m free of obstacles
B. Internal wind farm road with crane movement	**Pneumatic Crane** **As a minimum and usable 4.0m** + 2 x 0.75m free of obstacles
	WTC • Usable 12 to 14m* • 4m + 3m parallel tread (making 12 to 14 m)
	NTC **As a minimum and usable 7m**
C. Access road to the wind farm Transportation of components and Internal roads of the wind farm without crane movement. (Wind Farms in the United States)	**As a minimum and usable 5m** + 2 x 0.8m free of obstacles
Note: **Usable m (meters) - Space capable of bearing the loads to which the road will be submitted without the risk of caving-in, sliding or sinking. Furthermore, the last 50cm prior to the curbs on these roads (not included in the usable meters) are not valid for withstanding weights, due to the danger of horizontal creep of the ground. Thus, the carrier transporting the nacelle and heavy haulers in general must never go beyond these limits under any circumstances whatsoever.** **This table marks the minimum requirement for the road width as general.** **They may vary considering the regions and specific conditions for each project.** *Width based on crane model	

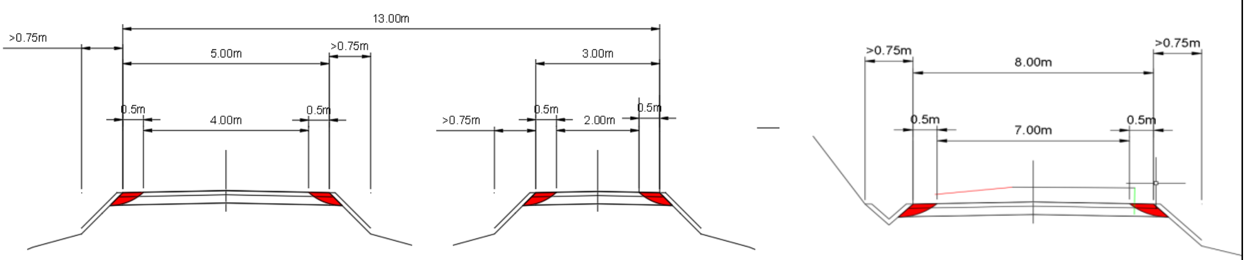
Table 5 Minimum road width in access and internal roads

A. Wind farm access road Transportation of components



B. Internal wind farm road with crane movement





C. Access road to the wind farm. Transportation of components and Internal wind farm road without circulation of cranes (e.g wind farms in the United States)

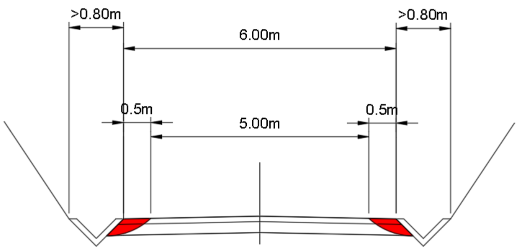


Figure 1 Minimum road width in access and internal roads

For curves with an interior cleared profile, the inside curb of the curve must be pipelined or have a maximum depth of 10 cm.

The slope of cutting on internal roads must be limited in accordance with the wind farm's geotechnical survey and determined by the crane being used for assembly. The most restrictive case is movement of NTC without dismounting.

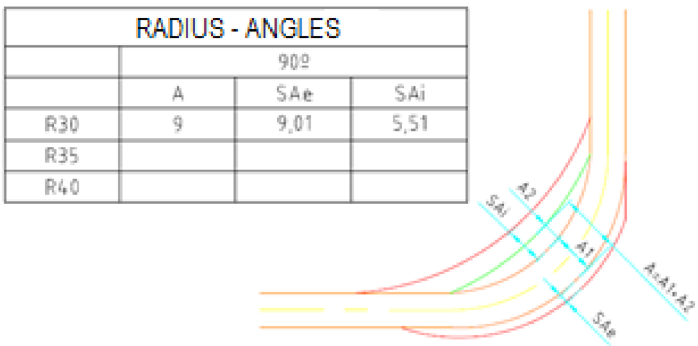
3.1.5. Turning Radii – General

The smaller the curve radius of the alignment curve, the greater the road width must be (difference between outside and inside radius) at the curve.

Blade transportation is considered a limiting element in the calculation of curve radii.

The following example table is completed for each model with these widths:

- A: Road width
- SAE: Exterior widening
- SAI: Interior widening



RADIUS - ANGLES			
	90º		
	A	SAe	SAi
R30	9	9,01	5,51
R35			
R40			

Figure 2 Turning radius at the curve

The conclusions of the study will be reflected in a table where:

- A: is the width of the road necessary for transport (A = A1 + A2)
- A1: represents the road width (at least 5 m at each point of trajectory = baseline), which may be increased depending on the width necessary for maneuvering the vehicle
- A2: Is the occupation of the vehicle when maneuvering cannot adjust to the A1 road width
- SAi: Is the maximum interior sweep of the vehicle or its cargo
- SAe: Is the maximum exterior sweep of the vehicle or its cargo
- R30: Represents the radius curve at the center of the road
- 90º: Represents the angle formed by two straight sections of road joined by a curve of a given radius

This study was make taking in to account an estimate vehicle (General vehicle). Later, each region will carry out a study of turning radii with its most restrictive vehicles. The general results analysis for turbine model is defined according to the ***5.2 Transport requirements.***

Besides, per each specific project, inner and outer widening for each curve along the route should be studied per transport simulation.

3.1.6. Gradients and grade changes

	Longitudinal Gradients (%)				Transversal Gradients (%)	
	Maximum		Minimums		Maximum	Minimum
	Straight section	Curved section	Straight section	Curved section	Straight/ curved section	
A. Wind farm access road and internal wind farm road	>10 and ≤13 without concreting if gradient < 200 m. (1) >10 and ≤13 improved concreting or paving if gradient > 200 m.(1) >13 and ≤15 improved concreting or paving + 6x6 tractor unit >15 need for towing study	Up to 7 without concreting (1) >7 and ≤10 improved concreting or paving (1) >10 need for towing study	0.50	0.50	2	0.20
B. Access and internal roads reverse driving	≤ 3 up to a max. of 1000 m without concreting. >3 and ≤5 max. 1000m improved concreting or paving	<2 up to max. 500 m without concreting. ≥2 and ≤3 max. 500 m improved concreting or paving	0.50	0.50	2	0.20
(1) SGRE standard values are ≤13 % for longitudinal gradients and <10 % for curved sections. (2) Improved paving: Roadbed with friction coefficient of at least 0.35						

Table 6 Gradients and grade changes

The transport vehicles used to transport various components of the turbine up to the site must be equipped with self-steering rear axles.

For gradients near 10% without concreting, 6 x 4 tractor units or four-wheel drive truck will be required.

In the specified cases in which road paving must be improved, the solution to be used and the envisaged friction coefficient must be submitted so that transport can be executed.

In the specified cases in which road paving must be improved, the technical characteristics of the solution to be used must be submitted, as well as the friction coefficient for the roadway layer envisaged for said solution, thereby ensuring that all components are transported correctly.

If the longitudinal gradient is >13% and ≤15%, improved concreting or paving will be required, and a 6 x 6 tractor unit used. This means that the slope will also have to be reviewed since it is not within SGRE standards.

In the extreme case that a longitudinal gradient in a straight section is >15% and/or is >10% in a curved section, a towing study must be conducted in addition to improving the road paving along the affected section. This study must be conducted by the logistics company in charge of supplying the wind farm with the wind turbine components.

Regarding to guarantee the proper transitions between gradient changes, the minimum straight-line total length of the convoy must be kept in mind. According to the complexity of the wind farm project, these points must be analyzed and discussed to find the proper solution.

Ltot: Total length of the convoy.

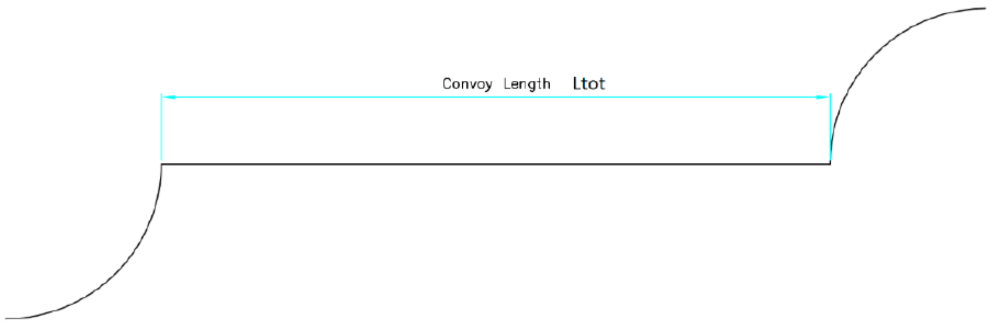


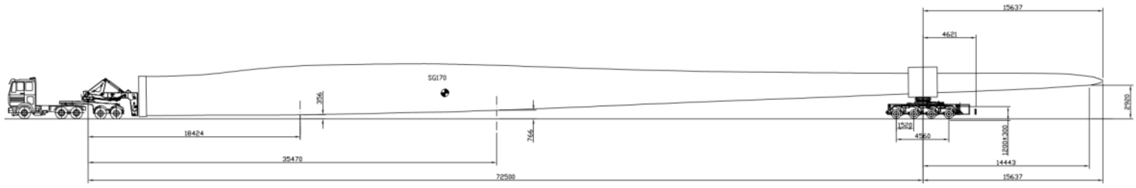
Figure 3 Transitions between gradient changes

For the calculation of the more restrictive Kv that appears in this document, estimated generic vehicles have been considered. This does not mean that there are not others that improve or even worsen the Kv figure. It is advisable to carry out a specific study in each region of the SGRE, with the vehicles planned to be used in local projects.

The kv value considered in the wind farm design for this WTG model shall be, **as a minimum:**

KV= 550m

With the information we have now, **the most restrictive transport would be the SG170 blade on dolly.** Bearing in mind that all the axles of the platform would be in contact with the ground. Considering that all the axles of the platform would be in contact with the ground and a rear overhang of 15,64m. Which of course will be different considering the restrictions of each country. The overhang may differ according to the restrictions of each country, which should be considered.



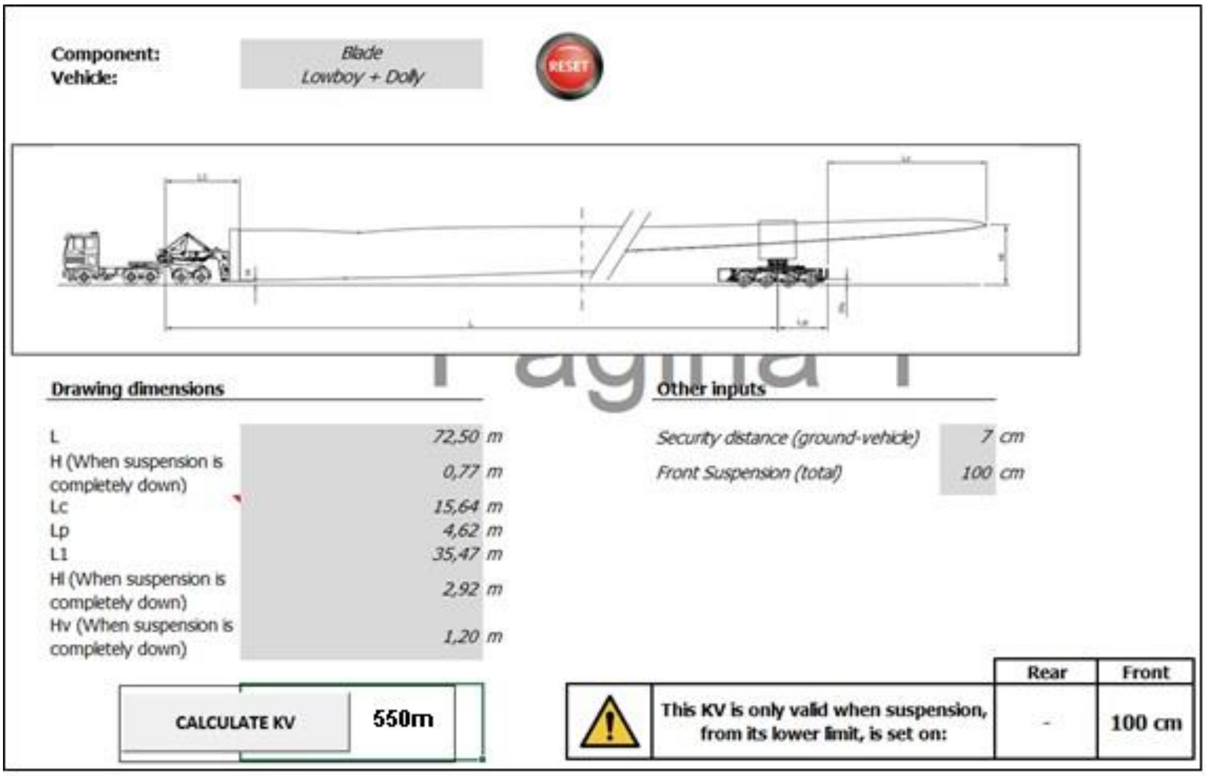


Figure 4 The most restrictive transport and its respective KV

The value above is for reference only. Depending on the complexity of the terrain, the Kv value that minimizes LCoE (levelized cost of energy) might be higher (flat wind farm) or lower (mountainous wind farm). Prior to signing the contract, a specific study shall be done in order to define the proper Kv for the wind farm, considering development constraints in force and locally available transports in order to adapt logistics means accordingly.

The specific study could include nonstandard solutions and extra resources for each solution.

The roads must be smooth, removing, as far as possible, any protrusions such as stones, rocks, etc., which could damage the nacelle platform or the tower sections and hinder transportation.

3.1.7. Passing areas and turning points

Parking areas will be created at intervals of approximately 5 km, attempting to take advantage of the areas where there are less actions to be performed if possible and they must have an extra width of 5 m with a minimum length equal to the total length of the convoy (Ltot) with a greater length. It is important to consider the entry and exit areas to facility access to the area. The waiting areas must be clear of any obstacle, leveled, compacted and drained. QHSE will determine the number of rest areas that must be

created.

The turning points must be defined according with the maximum allowed reverse maneuver as described at the item ***3.1.5 Gradients and grade changes.***

Where dead end roads are constructed or where loaded transports must turn around prior to delivery to the Installation Area, turning Areas are required to avoid long reverse driving. For each wind farm project, these points must be analyzed to find the proper solution.

(Note) Truck length* - The turning area will be different considering two situations: Loaded truck and empty truck. The additional area must be considered around the turning point - cleared of obstacles and levelled to allow oversail/ overhang during transportation. The turning point could be adapted regarding the orography and/or complexity of the windfarm terrain, the new geometry must be approved by SGRE in order to comply with the transport requirements.

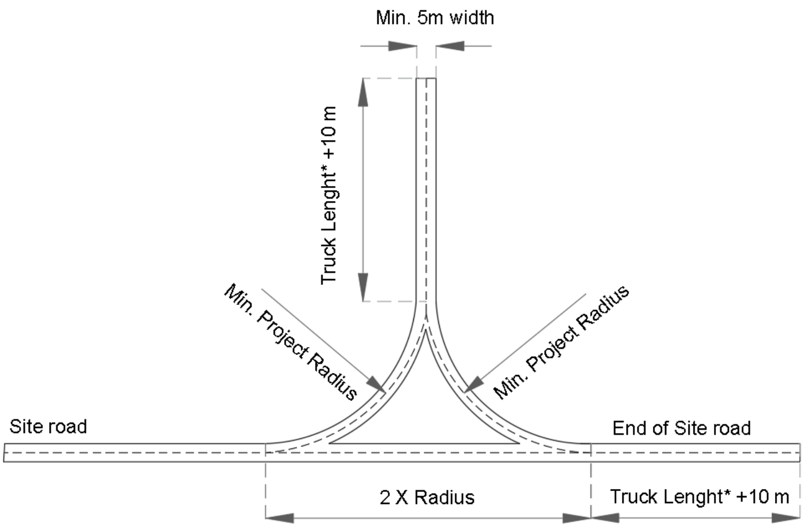


Figure 5 Turning point geometry suggestion

3.1.8. Drainage

The surface drainage system must be of a size to collect any rainwater from the roadway layer as well as any water collected from small flows of runoff water intercepted by the road or even, where applicable, to provide continuity for any larger natural watercourses also intercepted. The calculation will be considered for a return period of 25 years for transverse drainage and 10 years for longitudinal drainage works.

3.2. Hardstand composition and structure

The hardstands will include a crane work area and areas defined as storage areas. The main components will be stored on the storage area and they will be hoisted by the cranes from the hardstand – crane work area, as a standard concept. Regarding the high-power and communications networks avoid placing them across the hardstand. If this cannot be avoided, then the network must be pipelined, and the pipes covered with concrete.

3.2.1. Hardstand design

The design of the hardstand section must be done based on the geotechnical report and the load transferred by the crane support legs, also it must be considered the use of crane mats if any, under the crane support.

The structural verifications that must be performed and the criteria to be used is as follows:

- For the bearing capacity analysis, Meyerhof and Hanna (1978) methodology will be used.
- The safety factor for the verification of the bearing capacity will be 2, for both long term and short term.
- For the analytical calculation of the settlements, the Steinbrenner methodology will be used.
- The maximum differential settlement under the crane support leg will be 25mm.

When it comes to unfavorable geotechnical conditions, in addition to the verifications carried out with analytical methodologies, described above, it will be necessary to develop a finite element model (FEM) to compare and contrast the results obtained with analytical methodologies.

The design of the hardstand and the geotechnical report will be provided to Siemens Gamesa together with the quality control of the hardstand, during the handover of the civil works and before starting with the erection process.

3.2.2. Bearing capacity

	Crane work area	Component storage area	Boom assembly area
SGRE standard	2	2	2
Without crane mats	3 (T100m) 3 (T101.5m) 3 (T115m) 4 (T135m) 5 (T145m) 5 (T165m)	2	2

Table 7 Load- bearing capacity (kg/cm2)

The composition of the crane work area must have a good subgrade, Ev2=60MPa or above. Transmitted loads must be 2kg/cm2 (approx 0.2MPa). A surface of 30 m² must be laid, 6 crane mats (5 m x 1 m) per crane leg or crane chain.

If opting not to use crane mats, the necessary bearing capacity will be 3 kg/cm² for T100m, T101.5m and T115m, 4 kg/cm² for T135m and 5 kg/cm² for T145m and T165m tower models. The possible supply of crane mats is not included in the scope of SGRE, whereby if opting to use crane mats, the cost thereof shall be incurred by the Contracting Party.

3.2.3. Hardstand composition and structure

In the hardstand, the upper level of the subgrade must be above the highest foreseeable level of the water table. Where expansive material (expansive clay, etc.) or loose soil conditions are indicated in the geotechnical report, the use of geosynthetics is strongly recommended (at least with the soil reinforcement and separation functions).

The fill material will be compacted on the hardstands and in the storage areas in layers to a maximum thickness of 30 cm to ensure the effectiveness of the machinery along the entire section. The compaction level will be such that the dry density after compaction is 95% MP or higher. The elasticity module of the subgrade must be measured based on the compressibility module of the second cycle of the load plate test as per DIN 18134 (or in its absence, NLT-357), 600 o 762mm plate will be used for this test, the acceptance criteria will be indicated in the hardstands section design.

Regarding the finished hardstand, the compaction level will be such that the dry density after compaction is 98% MP or higher. The elasticity module of the finished hardstand surface must be measured based on the compressibility module of the second cycle of the load plate test as per DIN 18134 (or in its absence, NLT-357), and the result must never be less than Ev2>80 MPa. Likewise, the relation between the first and second load cycle must be less than 3.

In case there is a doubt about the hardstand capacity, it will be necessary to execute at least one borehole, in the center of the crane area, with core recovery and a depth of 8m. During the execution of the borehole, the following works should be conducted:

- SPT: from the surface where a test must be performed every meter.
- Extracting non-disturbed samples, plus laboratory test (triaxial tests or direct shear tests).
- Determining the ground water level depth, if encountered.
- Collect sampling for laboratory characterization of all the encountered materials.

The storage areas that are at the same level and position of the crane work area (for towers and nacelle), the requirements for the subgrade and finished layer are the same as above-mentioned. For the blade storage areas, the compaction level of the subgrade will be such that the dry density after compaction is 95% MP or higher. The transmitted loads, at least, must be 2kg/cm2 (approx. 0.2MPa). In case of need of granular layer, the compaction level will be such that the dry density after compaction is 98% MP or higher.

In case the subgrade of the storage areas is good enough to withstand the loads, no layer of granular material will be needed, but this must be justified accordingly in the design.

Tests must be carried out on the material used for the subgrade and for the roadbed, in order to control the compaction of the different layers and ensure that the civil works are correctly executed. The quality control and the requirements for the civil works design is defined according to the ***5.3 Quality tests and requirements for civil works plan projects.***

Before the arrival of the transport vehicles and crane, the hardstand must be accepted by SGRE for the works to commence.

3.2.4. Hardstand gradients

Crane Type	Hardstand gradients (%)			
	Crane work area		Component storage area	
	Maximum	Minimum	Maximum	Minimum
NTC or Mobile cranes	3	0.2	2	0.2
WTC	0.5			

Table 8 Hardstand gradients (%)

The minimum slope in the crane work area as well as the storage area is 0.2%, for the drainage of surface water; concave areas that may result in the formation of pools and the consequential drift of material under heavy loads cannot be accepted. Furthermore, take care that the hardstand or storage area surface must not drain off onto its access road.

3.2.5. Hardstand dimensions

Hardstand layout considers standard SGRE assembly strategy 4

(Note) – Following hardstand layouts covering tailing crane offloading.

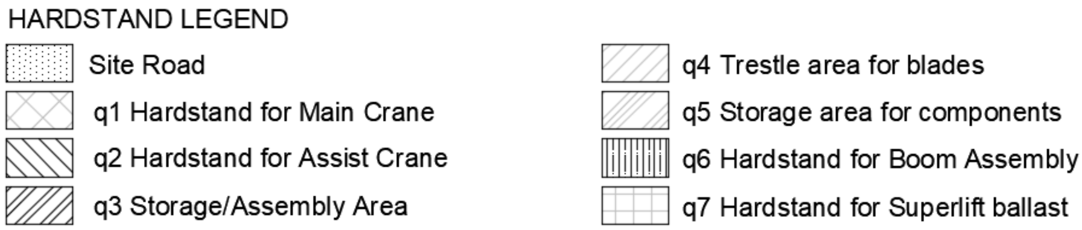
Use of clamp system doesn't require cranes for off-loading but additional space for maneuvering of trailers to release the tower sections is needed. The system is not available for all regions and must confirmed by SGRE before building the windfarm. Bear in mind, once chose the hardstands without to consult or to require a confirmation from SGRE is responsibility of the civil designer the decision. The different concept reflects an impact in hardstand layout, assembly phase and costs. Unusual situations must be evaluated and approved project specific.

Position of blade fingers is depending on location of transport equipment (TEQ) on blade -> Use of TEQ concept and/or positioning on blade might be different per region. Final location of blade fingers must be evaluated and approved project specific.

Area	Description
q1	Hardstand for main crane

q2	Hardstand for assistant crane
q3	Storage area for containers and miscellaneous items
q4	Blade storage area and blade fingers hardstand
q5	Storage area for components
q6	Hardstand for boom assembly
q7	Free obstacles area for rotation superlift ballast or suspended ballast of main crane

Table 9 Installation area codes and description



3.2.5.1. T100m-T101.5 tubular steel tower Hardstand with strategy 3

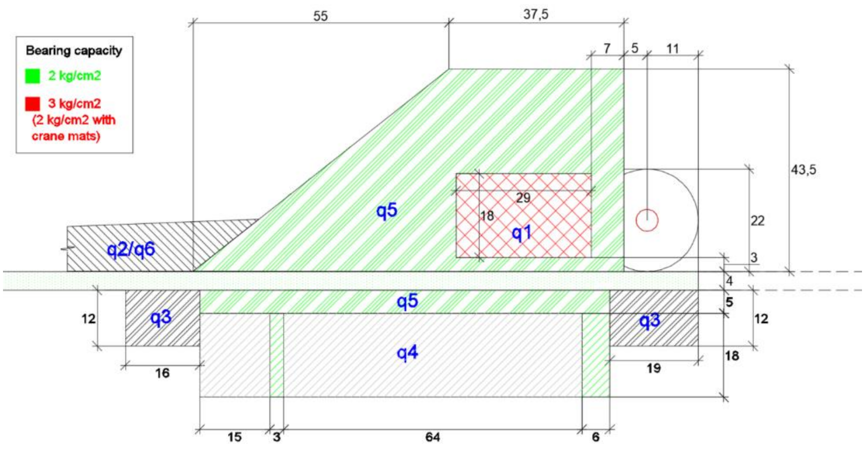
- Tailing crane offloading T100m-101.5m

Storage conditions	Width x length
Total Storage	q1 .... 29m x 18m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 37.5m x 43.5m + (55m x 43.5m)/2 – q1 +88m x 5m + reinforced road part*
Partial storage (SGRE standard)	q1 .... 29m x 18m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 31.5m x 43.5m + (46m x 43.5m)/2 – q1 + 88m x 5m + reinforced road part*

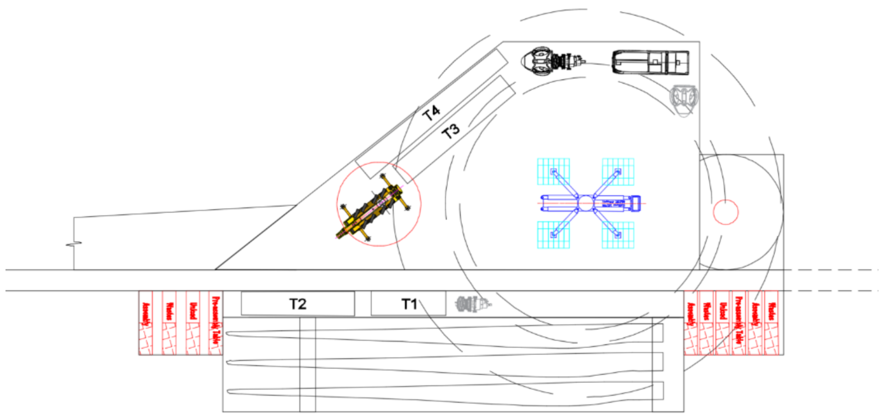
*Referred to 3.1.4 Road width

Table 10 Dimensions of the areas of model T100m-101.5m with strategy 3 – Tailing crane offloading

- Total storage – Assembly in 1 phase



T100m



T101.5

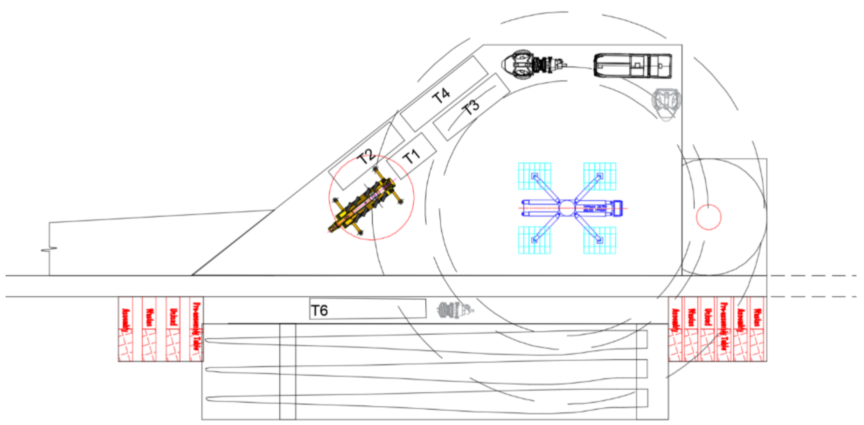
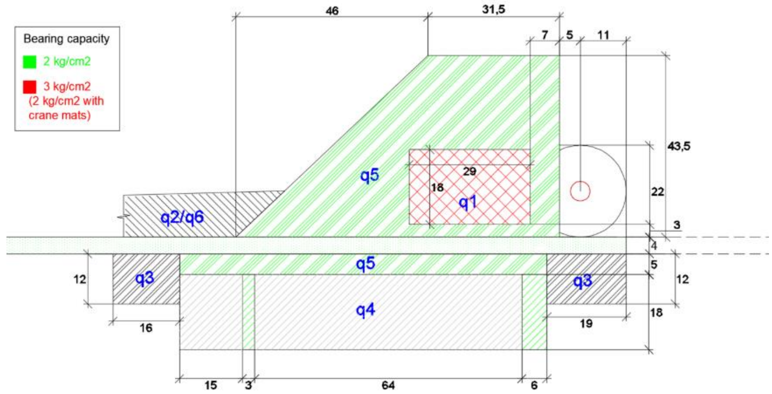
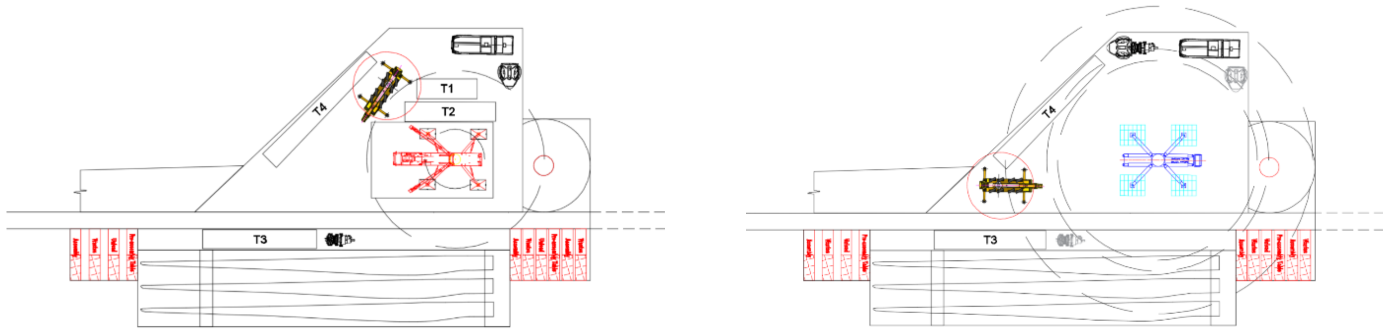


Figure 6 Model T100m-T101.5m – Total storage assembling with strategy 3 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE Standard)



T100M



T101.5m

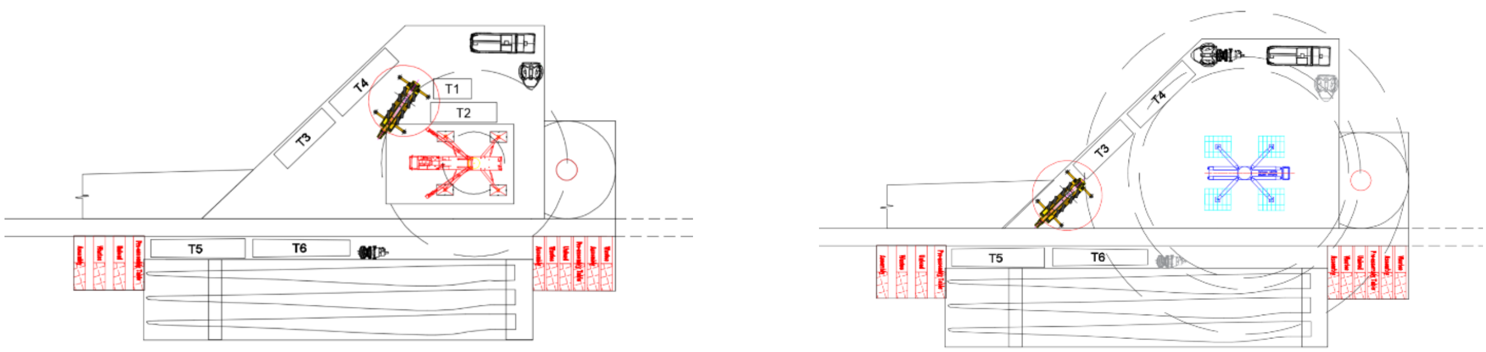


Figure 7 Model T100m-T101.5m – Partial storage assembling with strategy 3 in 2 phases

3.2.5.2. T100m-T101.5m tubular steel tower Hardstand with strategy 4

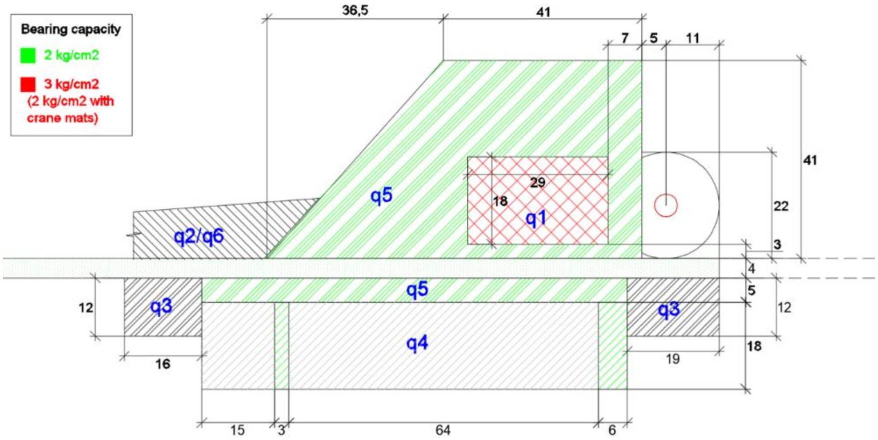
- Tailing crane offloading T100m-T101.5m

Storage conditions	Width x length
Total Storage	q1 .... 29m x 18m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 41m x 41m + (36.5m x 41m)/2 – q1 + 88m x 5m + reinforced road part*
Partial storage (SGRE standard)	q1 .... 29m x 18m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 33.5m x 41m + (36.5m x 41m)/2 – q1 + 88m x 5m + reinforced road part*

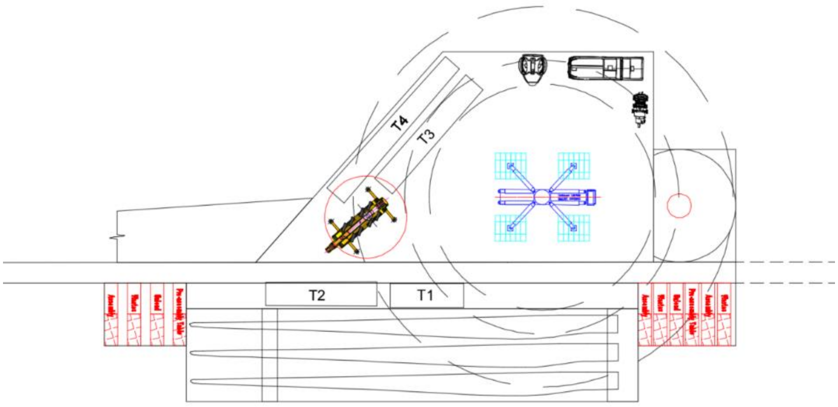
Table 11 Dimensions of the areas of model T100m-T101.5m with strategy 4 – Tailing crane offloading

*Referred to 3.1.4 Road width

- Total storage – Assembly in 1 phase



T100m



T101.5m

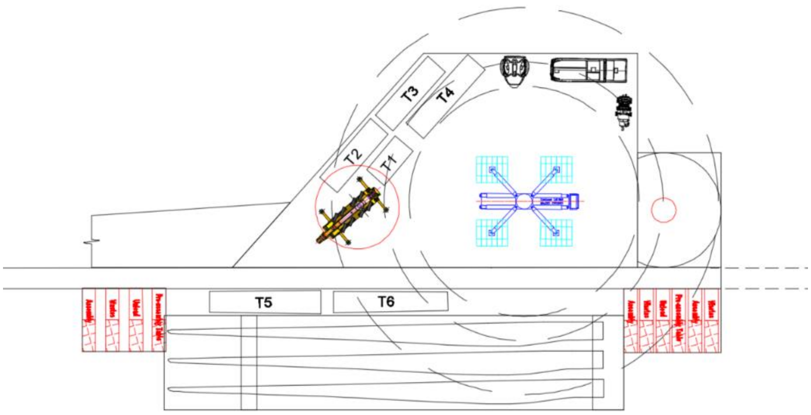
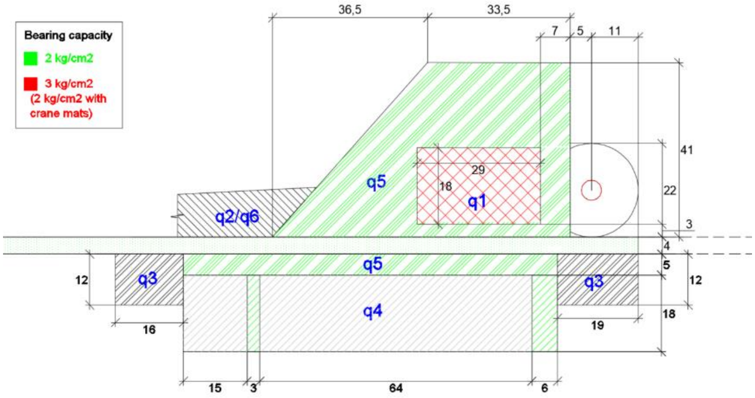
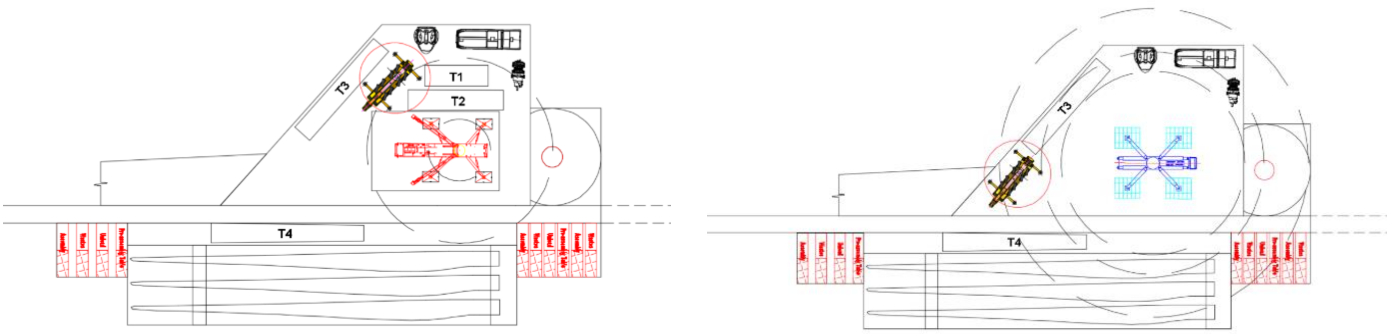


Figure 8 Model T100m-101.5m – Total storage assembling with strategy 4 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard)



T100m



T101.5m

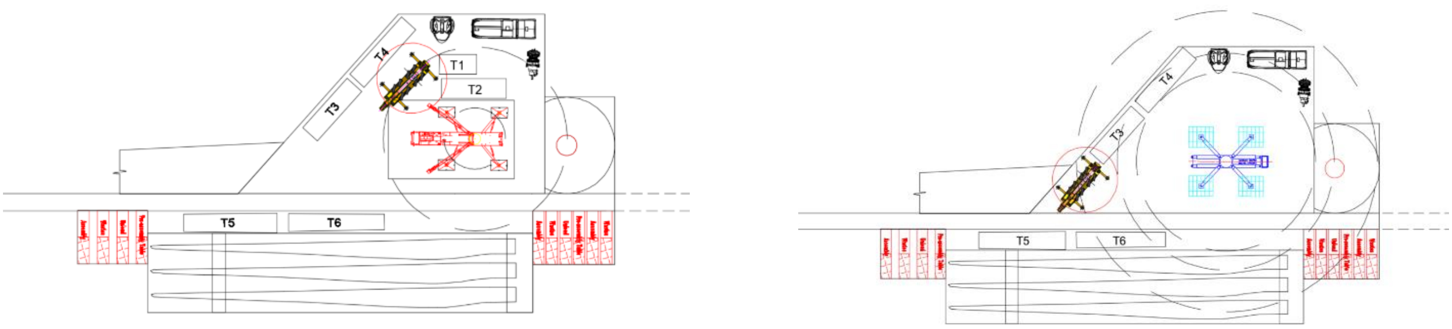


Figure 9 Model T100m-101.5m – Partial storage assembling with strategy 4 in 2 phases

3.2.5.3. T115m tubular tower Hardstand with strategy 3

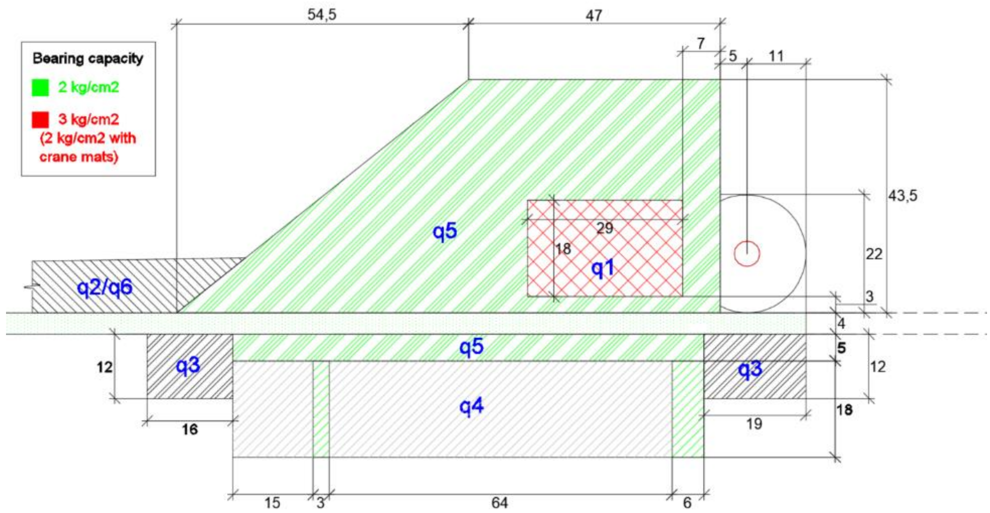
- Tailing crane offloading

Storage conditions	Width x length
Total Storage	q1 .... 29m x 18m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 47m x 43.5m + (54.5m x 43.5m)/2 – q1 +88m x 5m + reinforced road part*
Partial storage (SGRE standard)	q1 .... 29m x 18m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 38.5m x 43.5m + (43.5m x 43.5m)/2 – q1 + 88m x 5m + reinforced road part*

*Referred to 3.1.4 Road width

Table 12 Dimensions of the areas of model T115m with strategy 3 – Tailing crane offloading

- Total storage – assembly in 1 phase



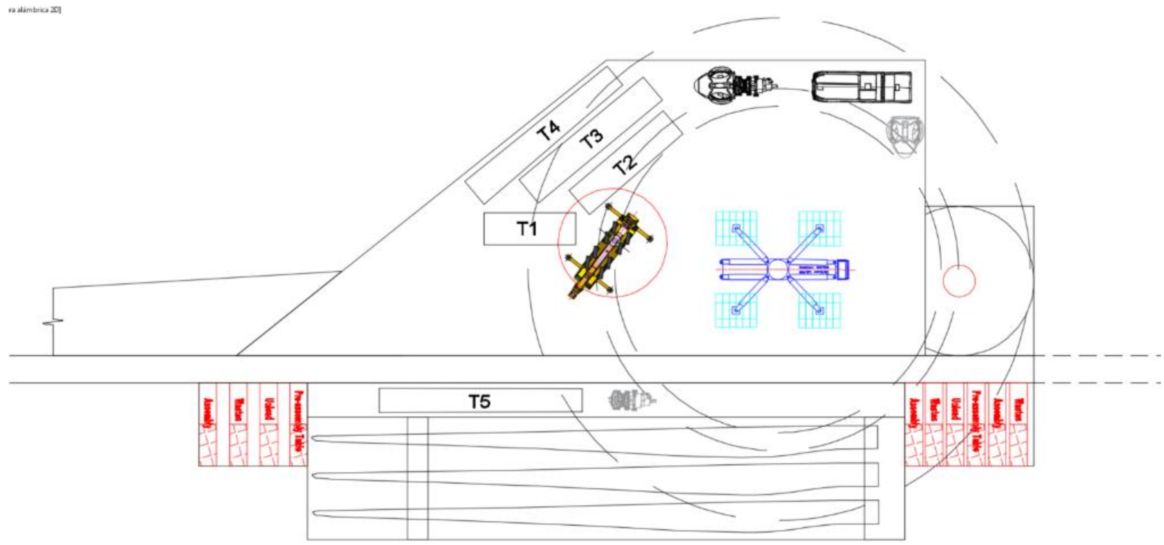
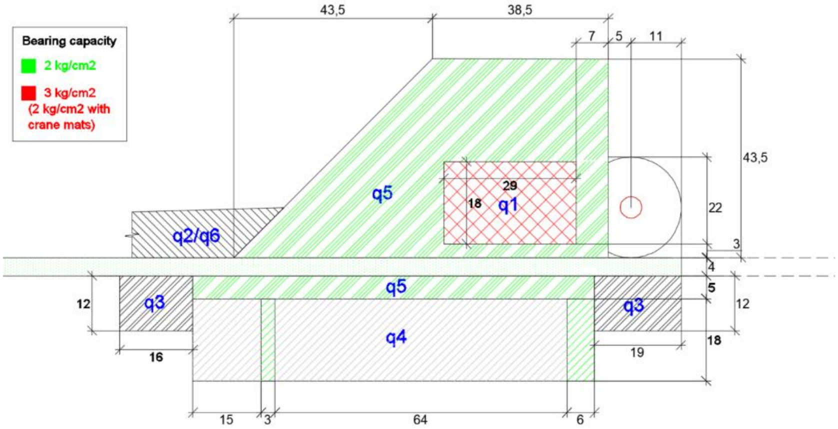
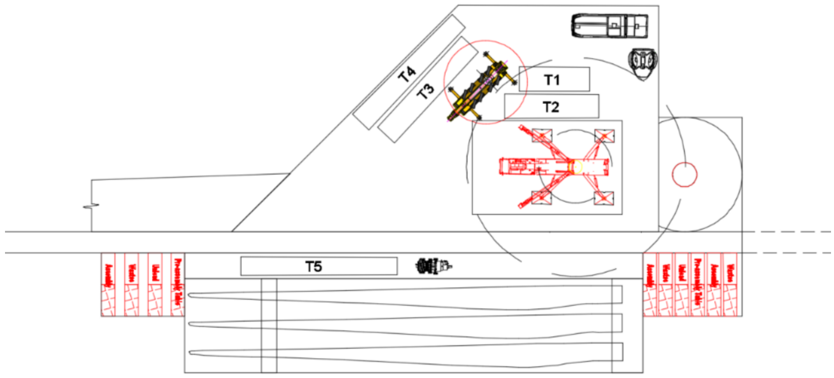


Figure 10 Model 115m – Total storage assembling with strategy 3 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard)





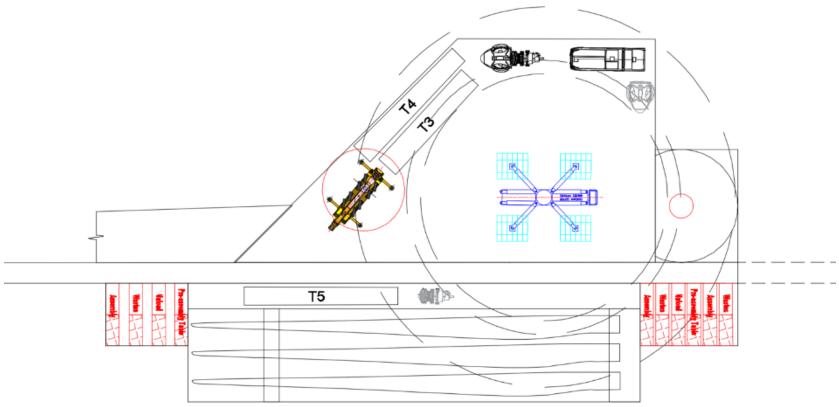


Figure 11 Model T115m – Partial storage assembling with strategy 3 in 2 phases

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3.2.5.4. T115m tubular steel tower Hardstand with strategy 4

- Tailing crane offloading T115m

Storage conditions	Width x length
Total Storage	q1 .... 29m x 18m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 44.5m x 41m + (50m x 41m)/2 – q1 + 88m x 5m + reinforced road part*
Partial storage (SGRE standard)	q1 .... 29m x 18m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 39.5m x 41m + (42.5m x 41m)/2 – q1 + 88m x 5m + reinforced road part*

*Referred to 3.1.4 Road width

Table 13 Dimensions of the areas of model T115m strategy 4 – Tailing crane offloading

- Total storage – Assembly strategy in 1 phase

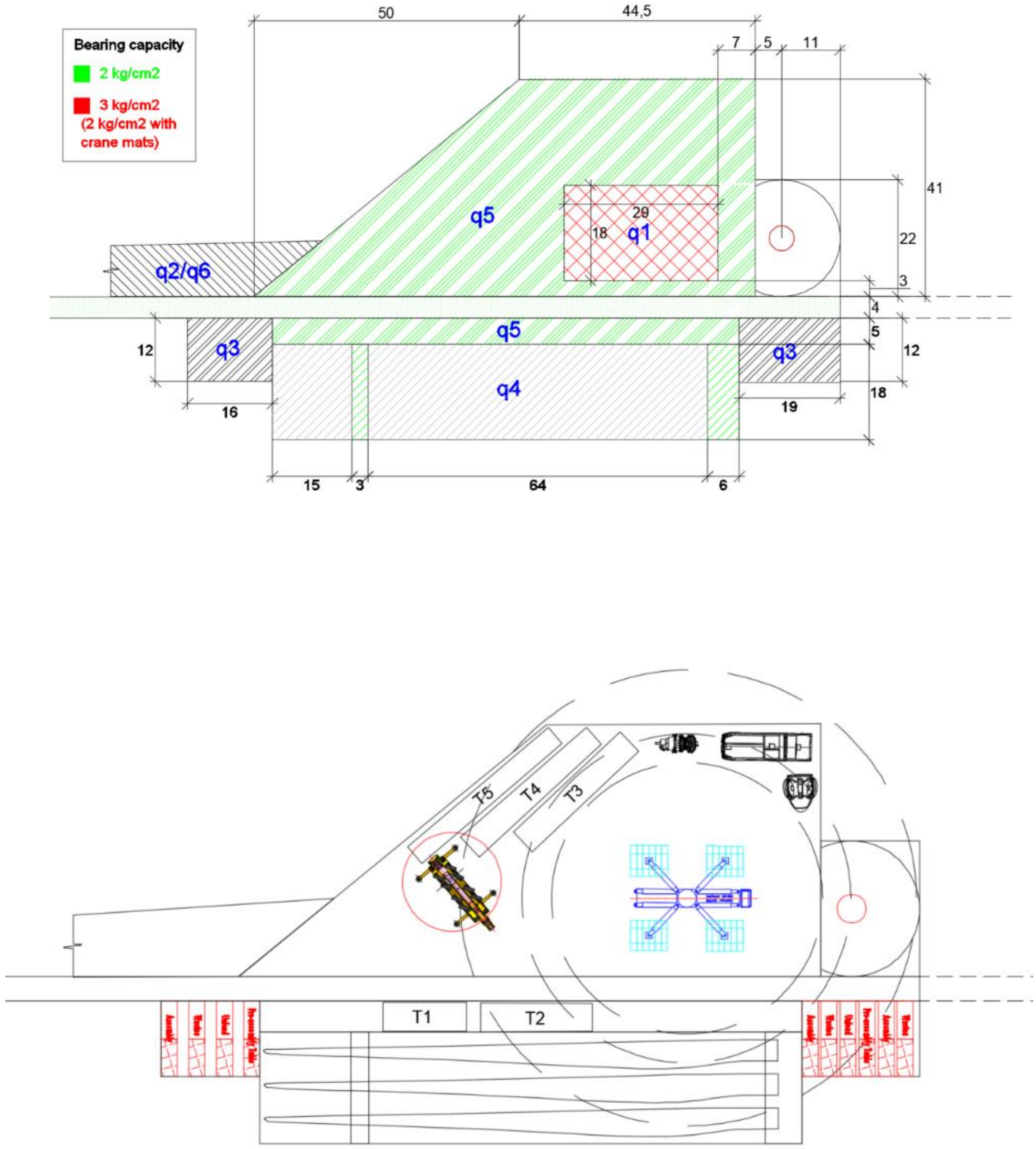


Figure 12 Model T115m – Total storage assembling with strategy 4 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard)

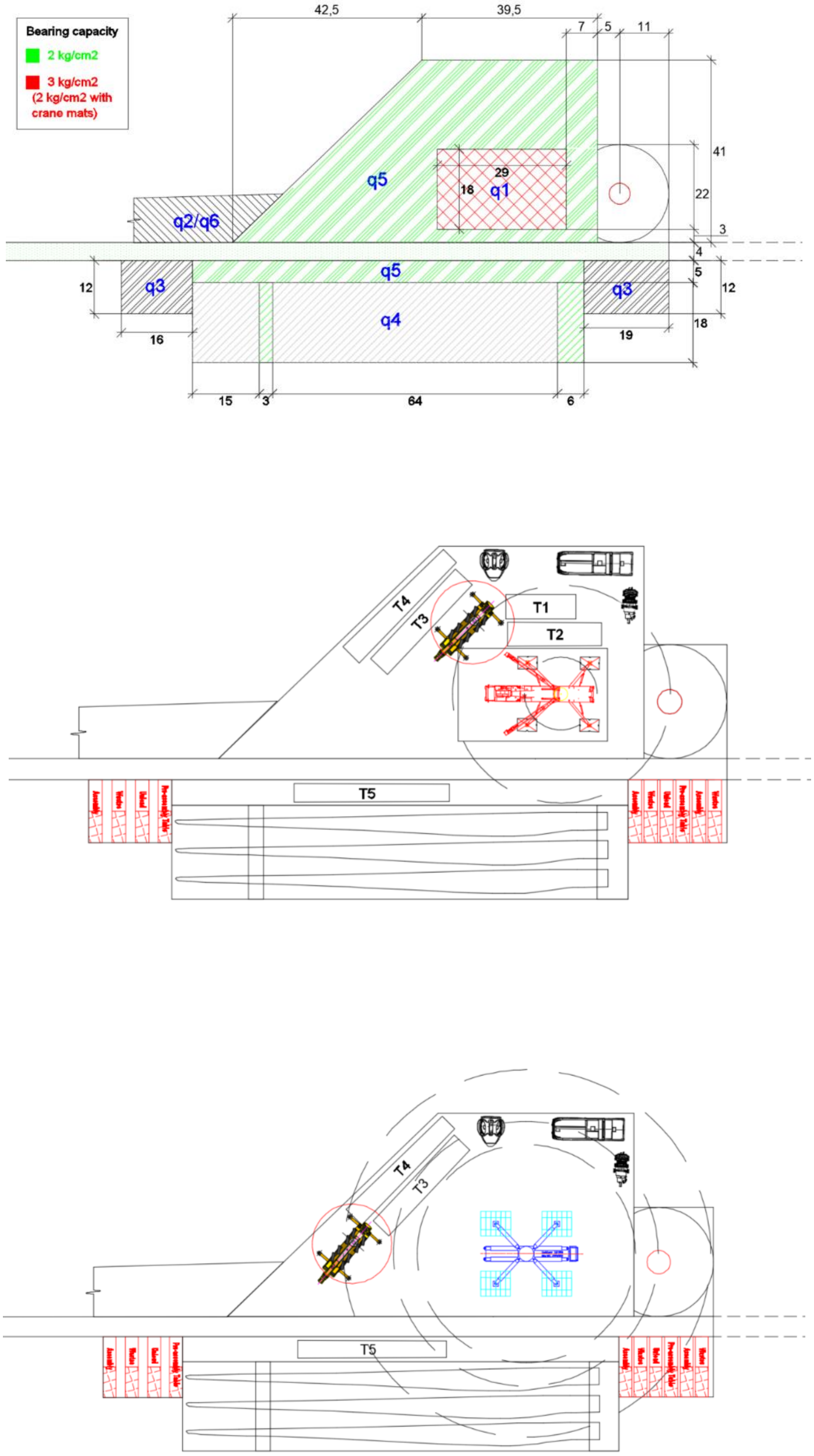


Figure 13 Model T115m – Partial storage assembling with strategy 4 in 2 phases

3.2.5.5. T135m tubular steel tower Hardstand with strategy 3

- Tailing crane offloading T135m

Storage conditions	Width x length
Total Storage	q1 .... 29m x 18m q3 .... 16m x 12m .... + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 50m x 43.5m + (45m x 43.5m)/2 – q1 +88m x 5m + reinforced road part*
Partial storage (SGRE standard)	q1 .... 29m x 18m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 41m x 45.5m + (45m x 45.5m)/2 – q1 + 88m x 5m + reinforced road part*

*Referred to 3.1.4 Road width

Table 14 Dimensions of the areas of model T135m strategy 3 – Tailing crane offloading

- Total storage – Assembly in 1 phase

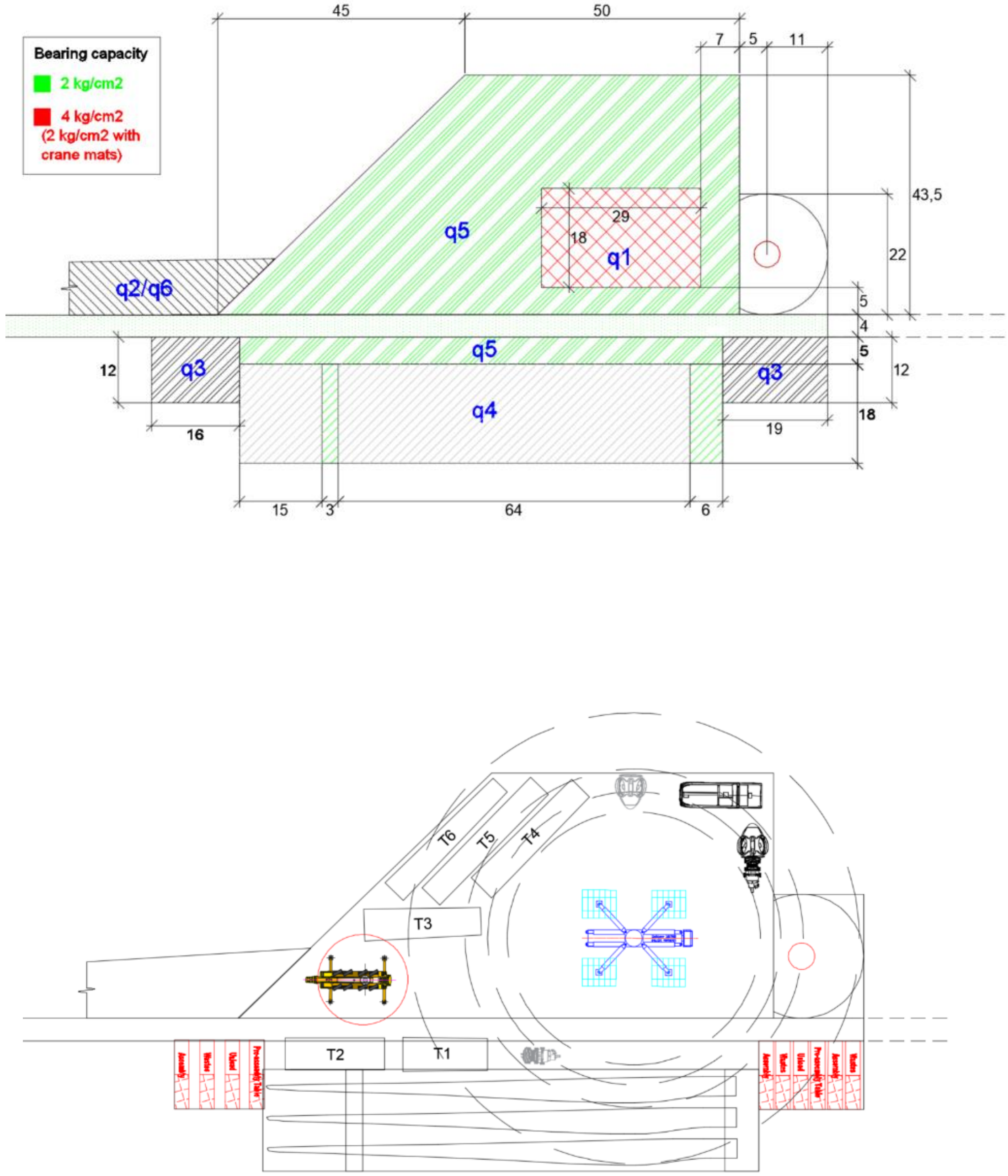


Figure 14 Model T135m – Total storage assembling with strategy 3 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard)

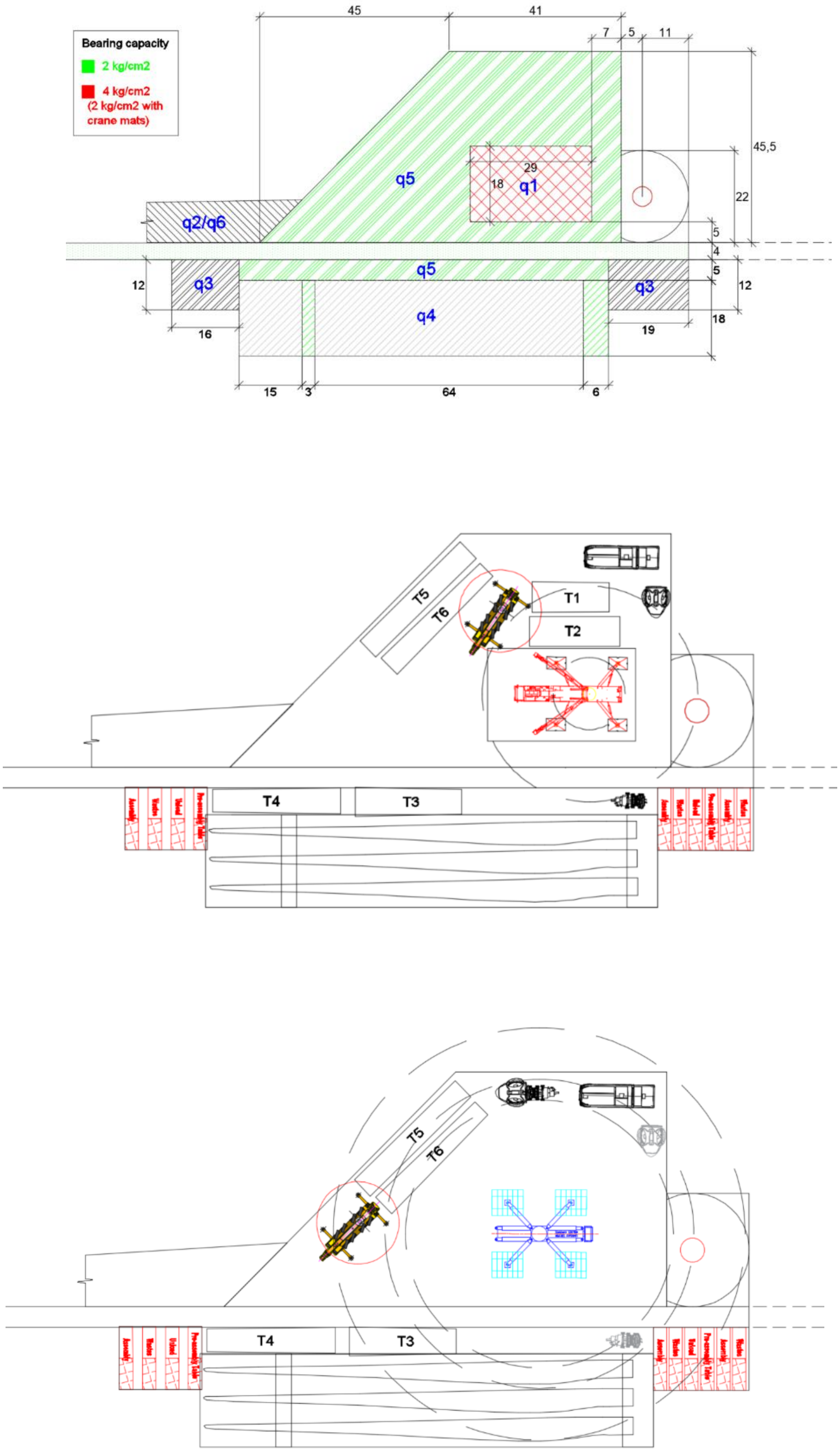


Figure 15 Model T135m -.Partial storage assembling with strategy 3 in 2 phases

3.2.5.6. T135m tubular steel tower Hardstand with strategy 4

- Tailing crane offloading

Storage conditions	Width x length
Total Storage	q1 .... 29m x 18m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 50m x 51m + (38.5m x 51m)/2 – q1 + 88m x 5m + reinforced road part*
Partial storage (SGRE standard)	q1 .... 29m x 18m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 40.5m x 49.5m + (41.5m x 49.5m)/2 – q1 + 88m x 5m + reinforced road part*

*Referred to 3.1.4 Road width

Table 15 Dimensions of the areas of model T135m with strategy 4 – Tailing crane offloading

- Total storage – Assembly in 1 phase

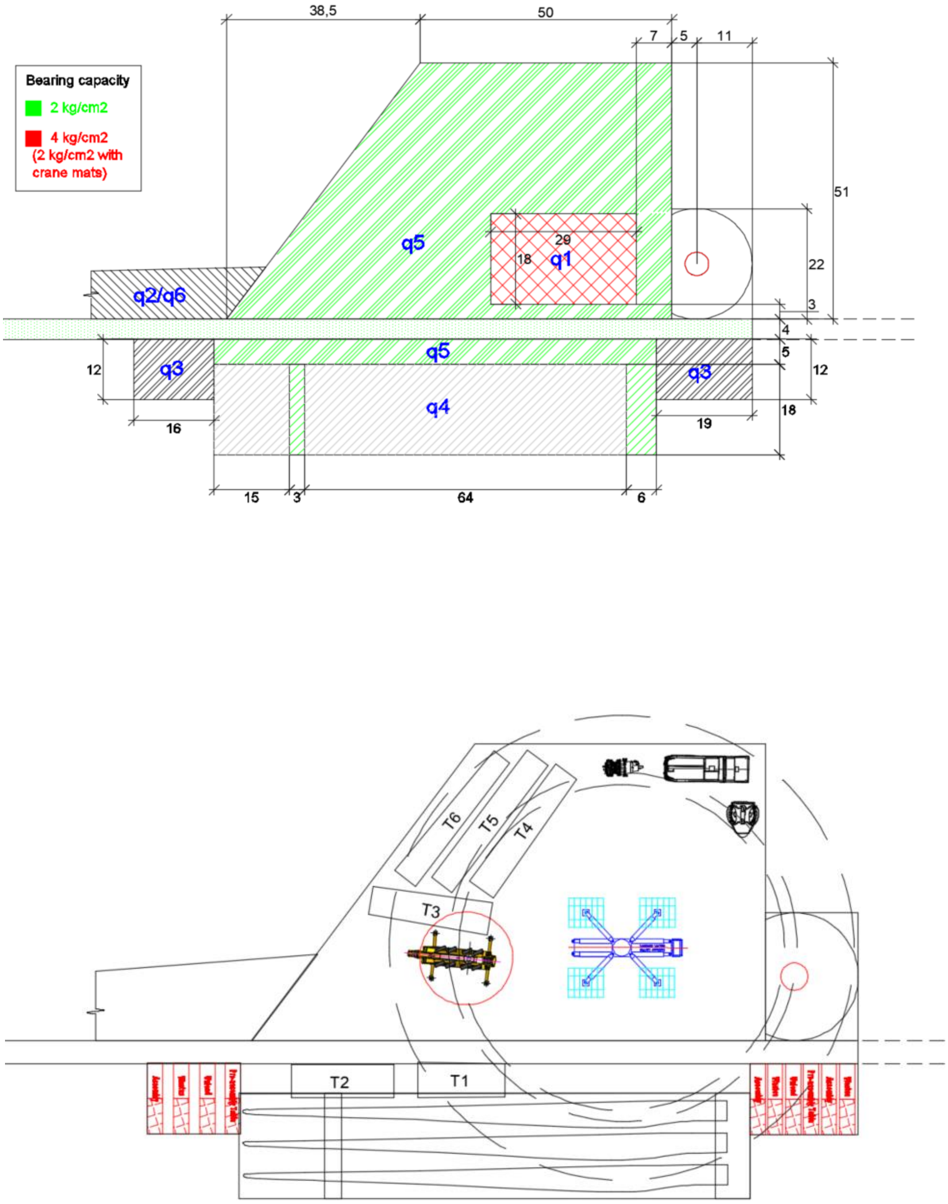


Figure 16 Model T135m – Total storage assembling with strategy 4 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard)

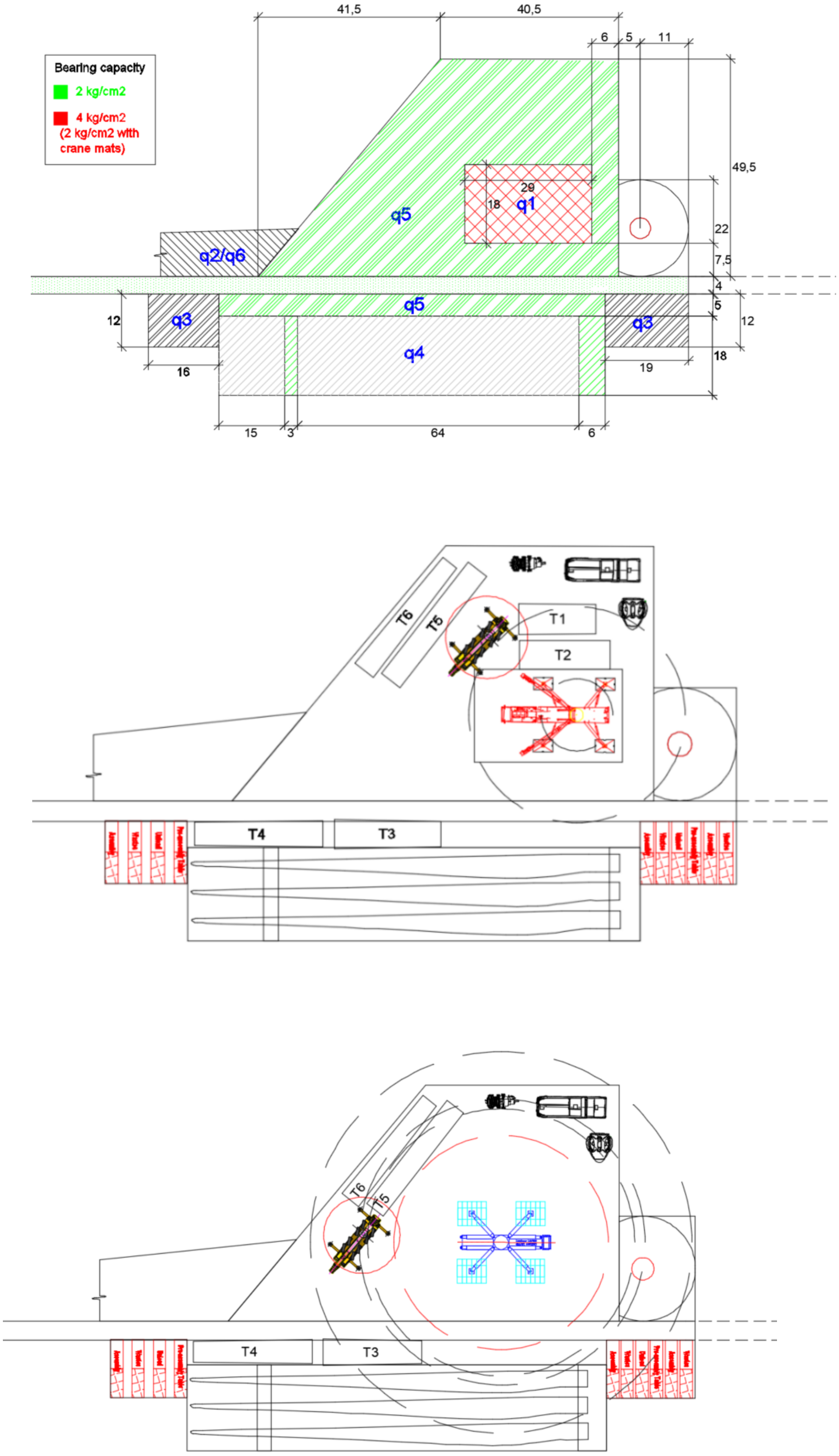


Figure 17 T135m – Partial storage with strategy 4 in 2 phases

3.2.5.7. T145m steel tower Hardstand with strategy 3

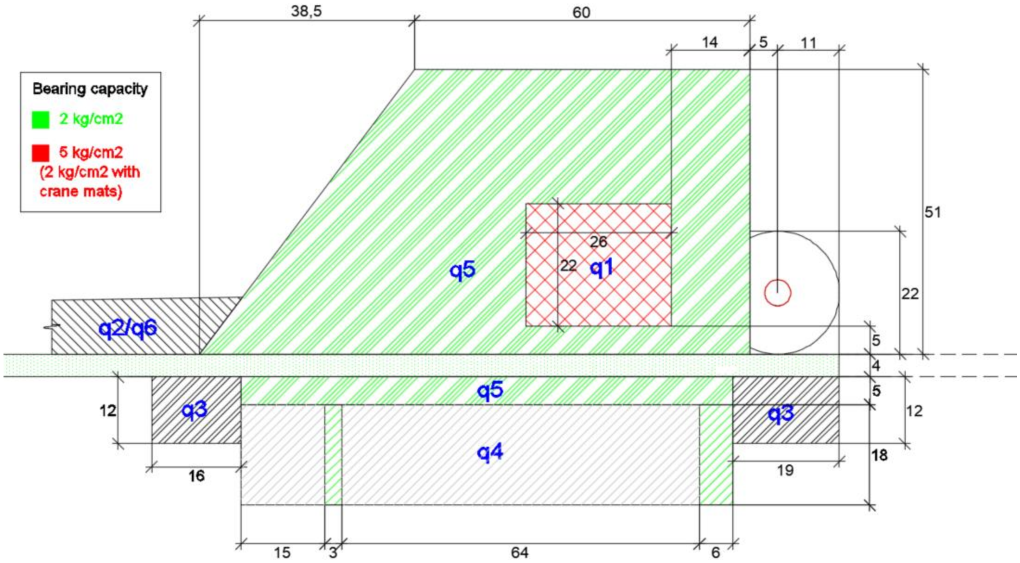
- Tailing crane offloading

Storage conditions	Width x length
Total Storage	q1 .... 26m x 22m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 60m x 51m + (38.5m x 51m)/2 – q1 +88m x 5m + reinforced road part*
Partial storage (SGRE standard)	q1 .... 34m x 23m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 50m x 49.5m + (41m x 49.5m)/2 – q1 + 88m x 5m + reinforced road part*

*Referred to 3.1.4 Road width

Table 16 Dimensions of the areas of model T145m with strategy 3 – Tailing crane offloading

- Total storage – Assembly in 1 phase



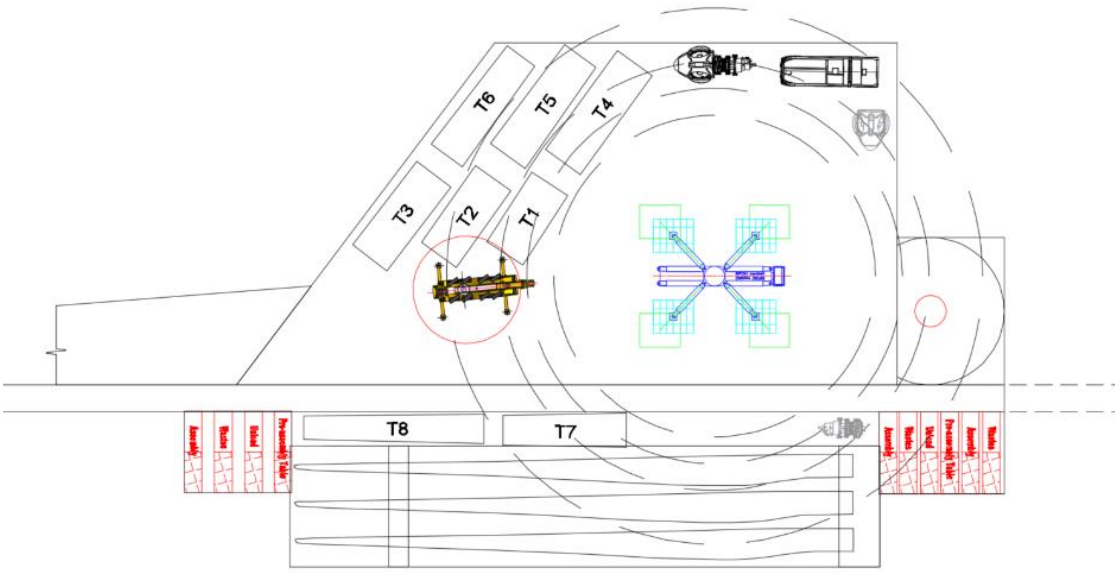


Figure 18 Model T145m – Total storage assembling with strategy 3 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard)

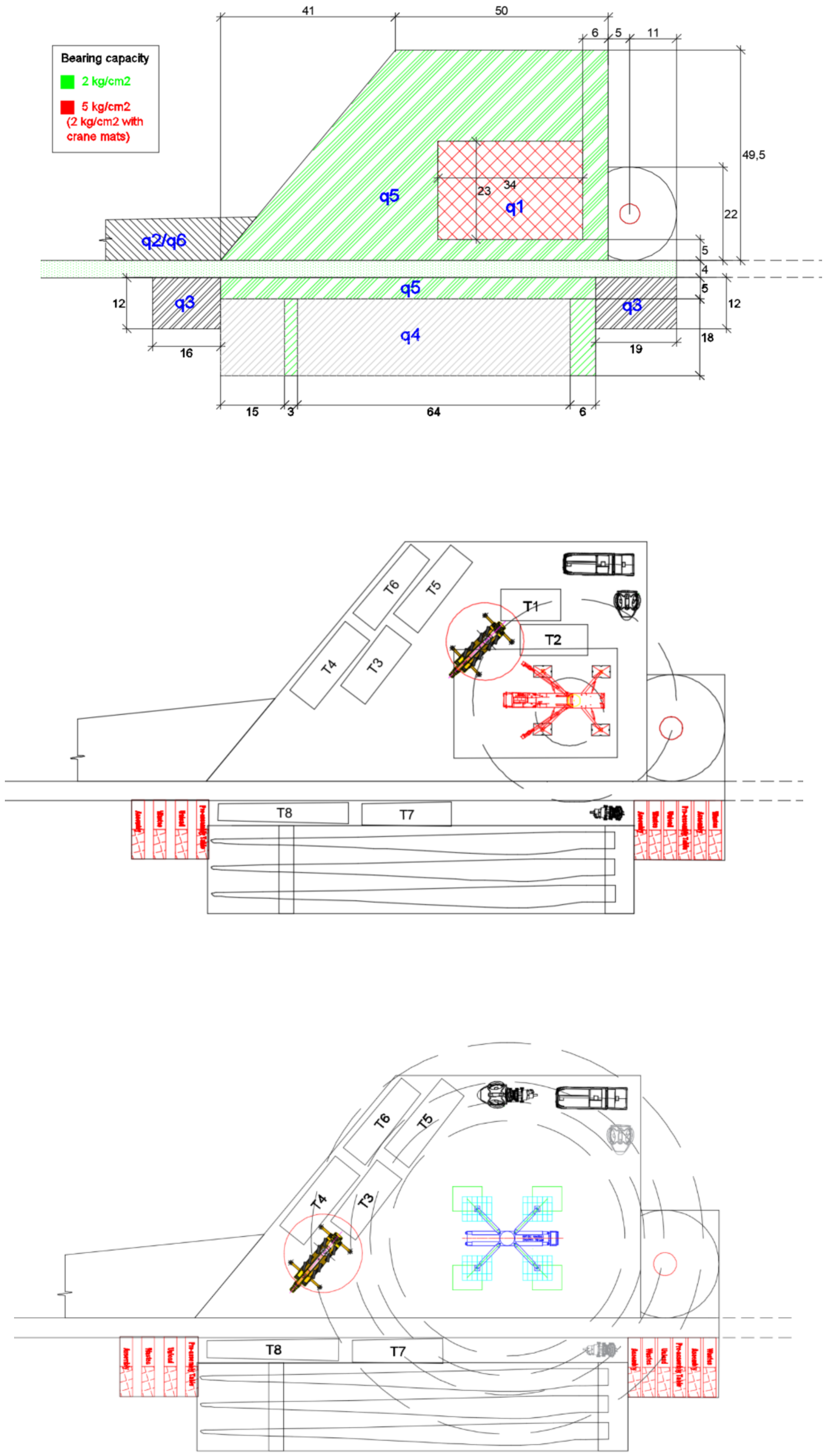


Figure 19 Model T145m – Partial storage assembling with strategy 3 in 2 phases

3.2.5.8. T145m tubular steel tower Hardstand with strategy 4

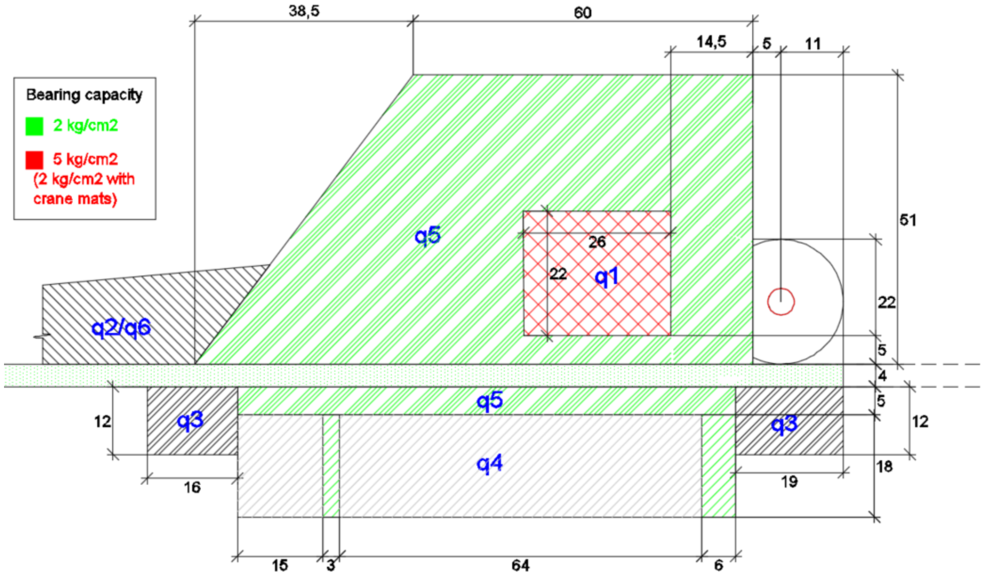
- Tailing crane offloading

Storage conditions	Width x length
Total Storage	q1 .... 26m x 22m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 60m x 51m + (38.5m x 51m)/2 – q1 + 88m x 5m + reinforced road part*
Partial storage (SGRE standard)	q1 .... 34m x 23m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 50m x 49.5m + (41m x 49.5m)/2 – q1 + 88m x 5m + reinforced road part*

*Referred to 3.1.4 Road width

Table 17 Dimensions of the areas of model T145m with strategy 4 – Tailing crane offloading

- Total storage – Assembly in 1 phase



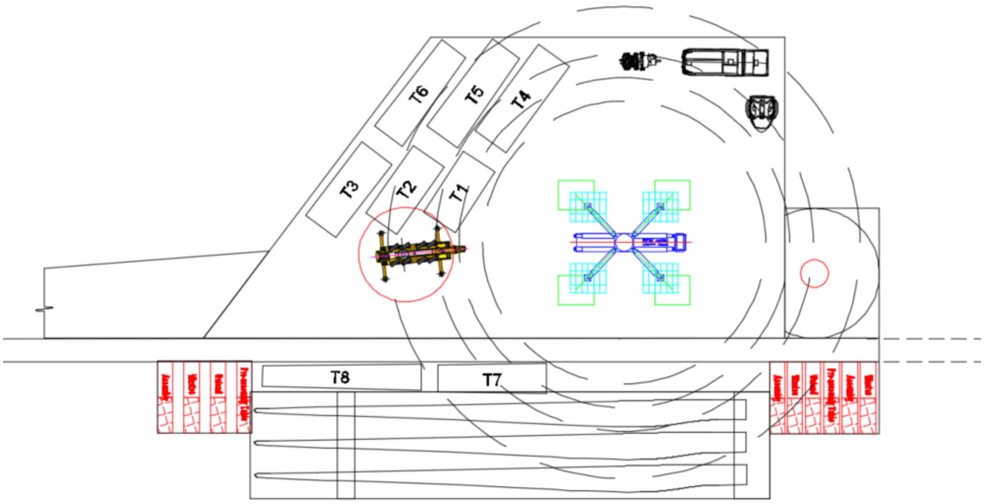


Figure 20 Model T145m – Total storage assembling with strategy 4 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard)

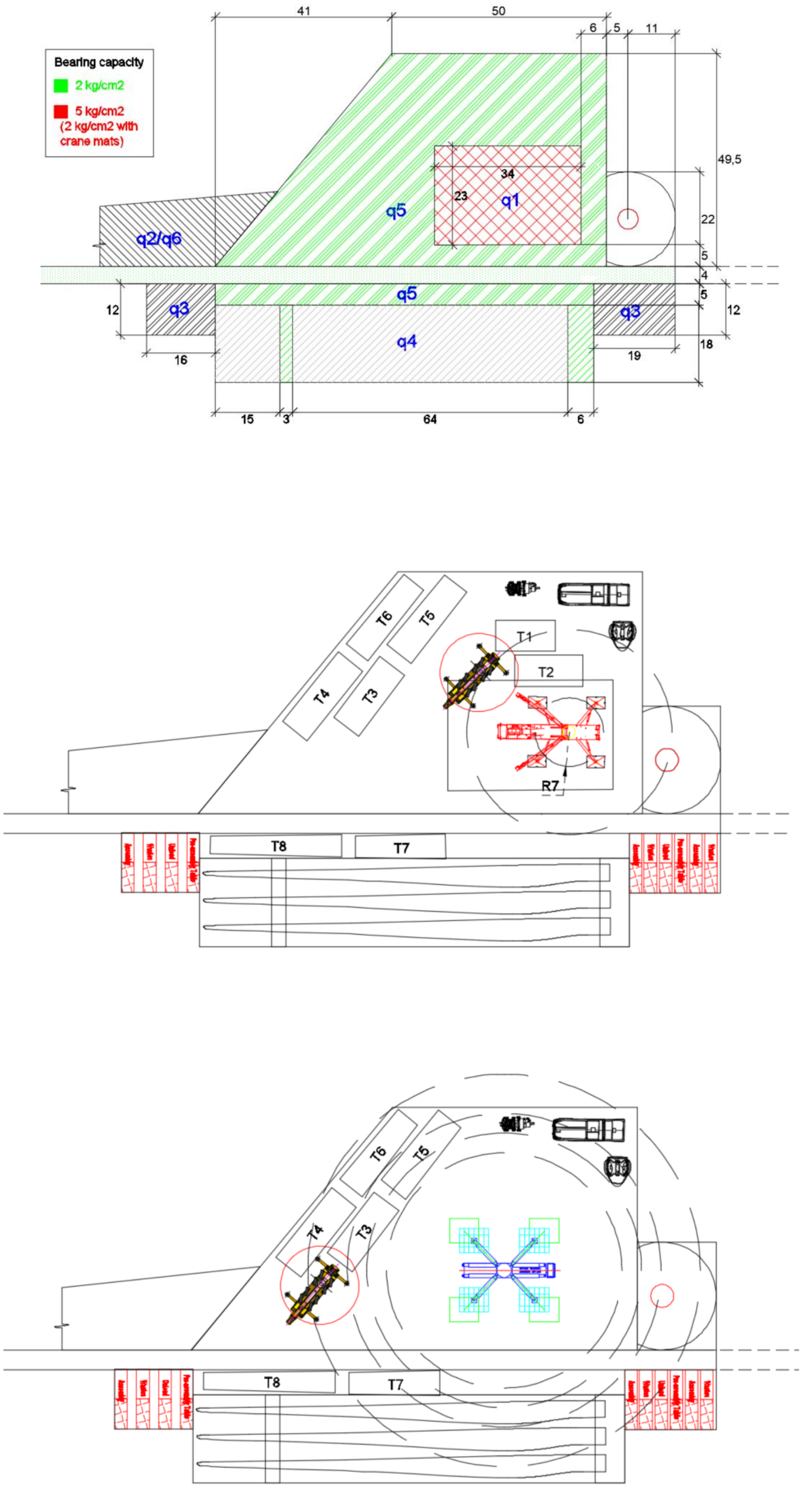


Figure 21 Model T145 – Partial storage assembling with strategy 4 in 2 phases

3.2.5.9. T165m tubular steel tower Hardstand with strategy 3

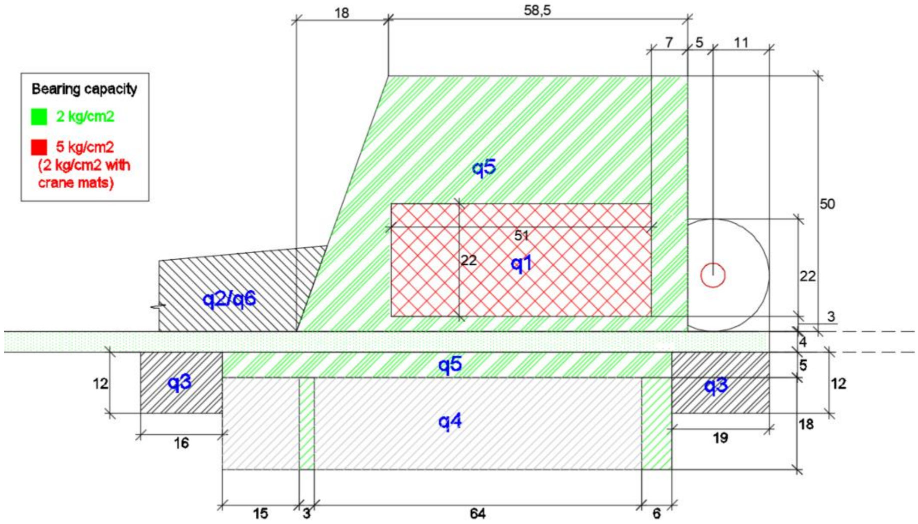
- Tailing crane offloading

Storage conditions	Width x length
Total Storage	q1 ..... 51m x 22m q3 ..... 16m x 12m + 19m x 12m q4 ..... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 ..... 58.5m x 50m + (18m x 50m)/2 – q1 + 88m x 5m + reinforced road part*
Partial storage (SGRE standard)	q1 ..... 51m x 22m q3 ..... 16m x 12m + 19m x 12m q4 ..... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 ..... 53m x 42m + (14.5m x 42m)/2 – q1 + 88m x 5m + reinforced road part*

*Referred to 3.1.4 Road width

Table 18 Dimensions of the areas of model T165m with strategy 3 – Tailing crane offloading

- Total storage – Assembly in 1 phase



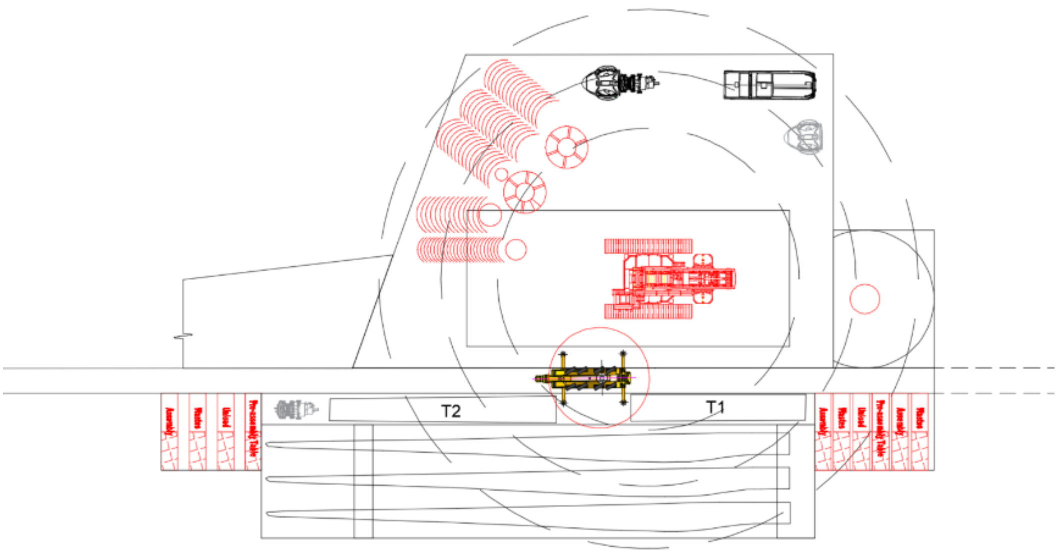


Figure 22 Model T165m – Total storage assembling with strategy 3 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard)

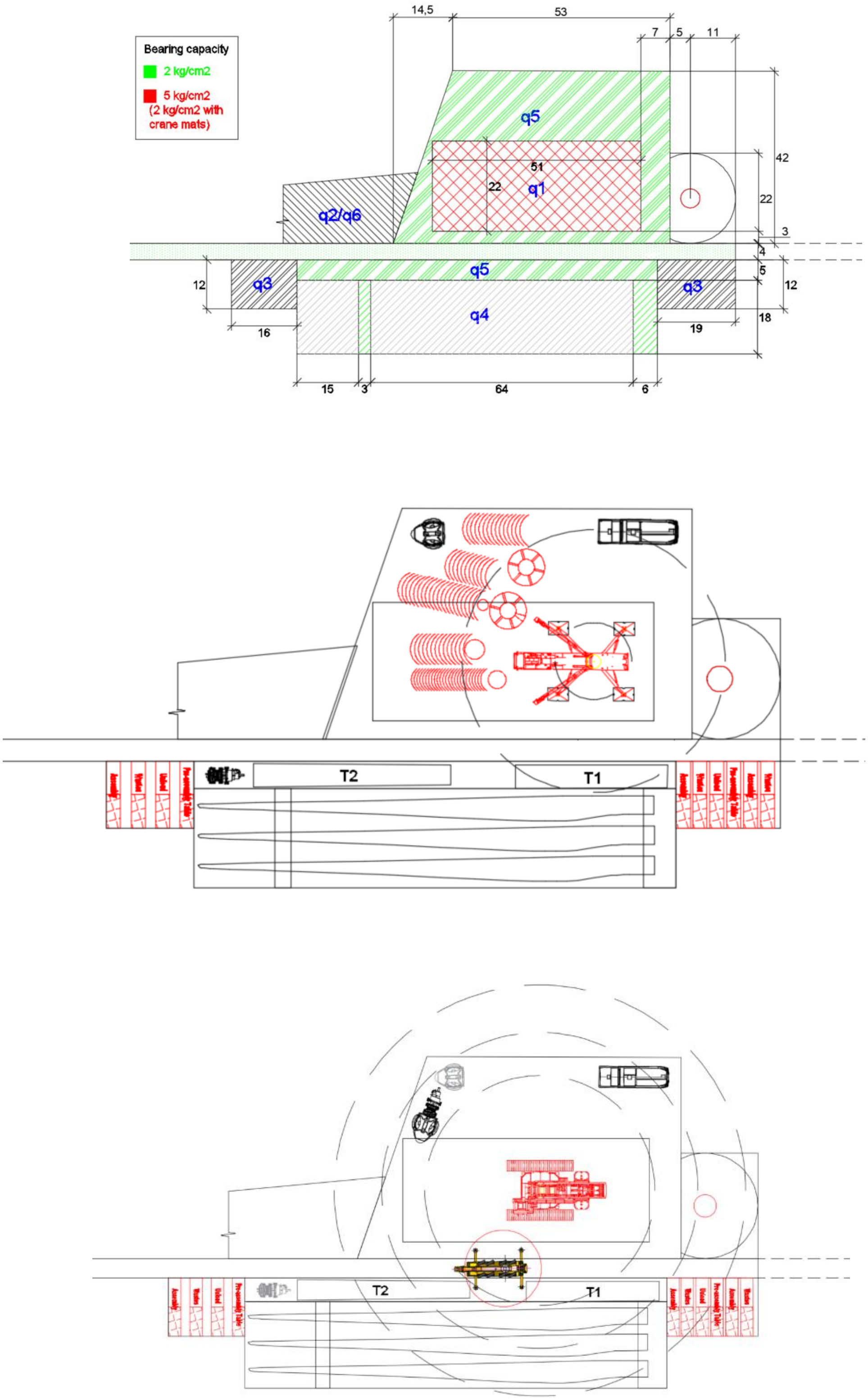


Figure 23 Model T165m – Partial storage assembling with strategy 3 in 2 phases

3.2.5.10. T165m tubular steel tower Hardstand with strategy 4

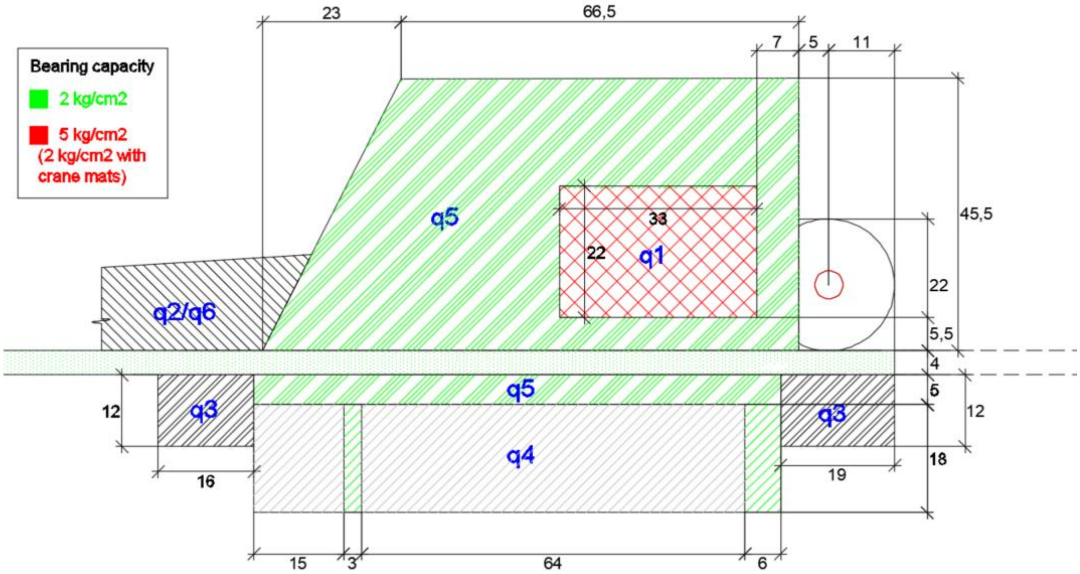
- Tailing crane offloading T115m

Storage conditions	Width x length
Total Storage	q1 .... 33m x 22m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 66.5m x 45.5m + (23m x 45.5m)/2 – q1 + 88m x 5m + reinforced road part*
Partial storage (SGRE standard)	q1 .... 33m x 22m q3 .... 16m x 12m + 19m x 12m q4 .... 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m) q5 .... 47.5m x 45.5m + (18m x 45.5m)/2 – q1 + 88m x 5m + reinforced road part*

*Referred to 3.1.4 Road width

Table 19 Diemensions of the areas of the model T165m with strategy 4 – Tailing crane offloading

- Total storage – Assembly in 1phase



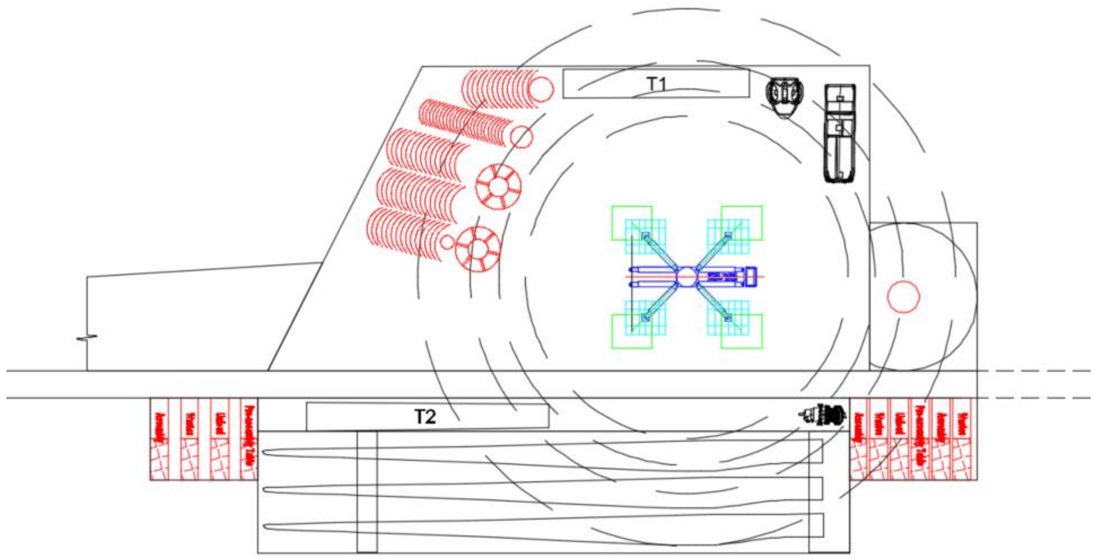


Figure 24 Model T165m – Total storage assembling with strategy 4 in 1 phase

- Partial storage – Assembly in 2 phases ()SGRE standard)

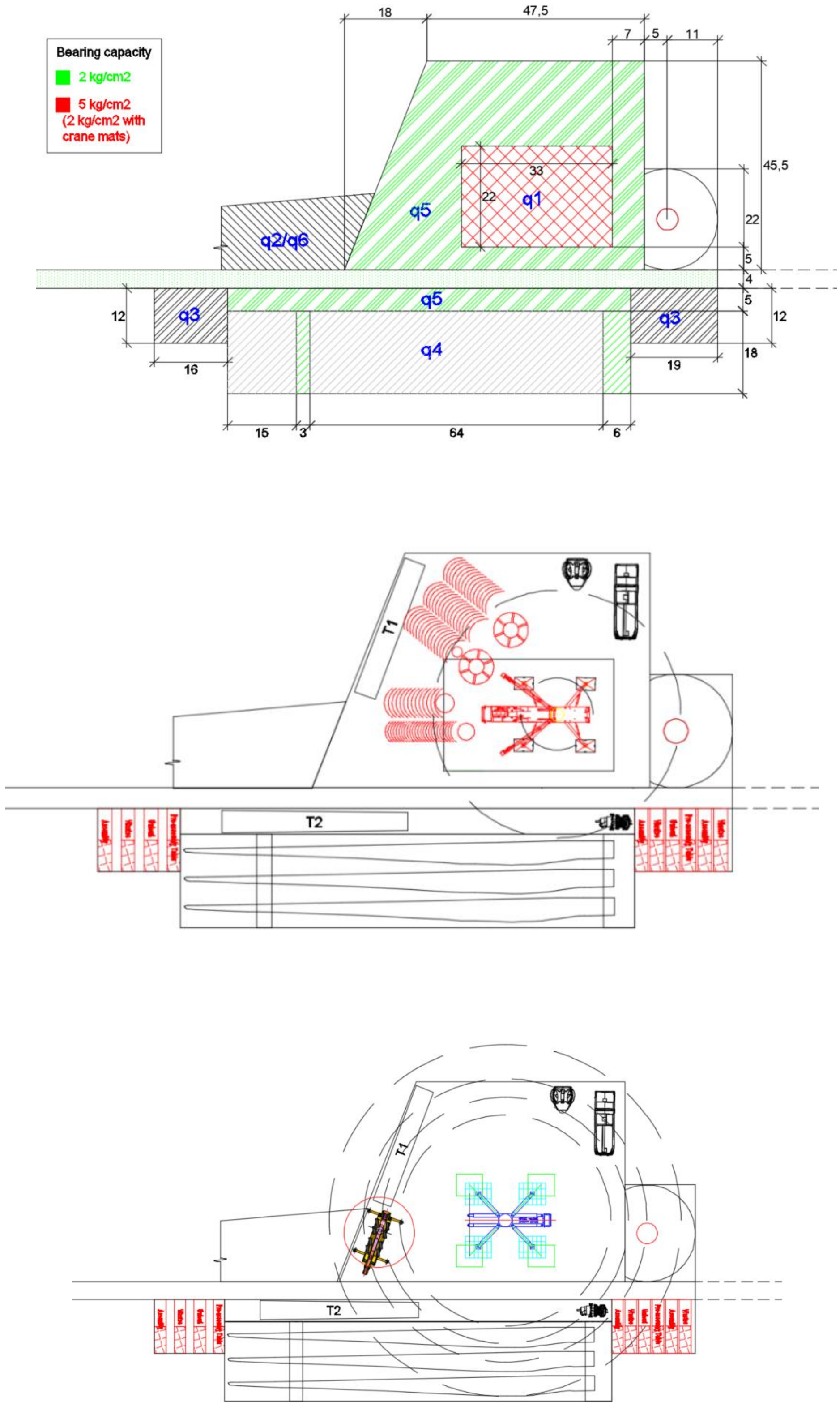


Figure 25 Model T165m – Partial storage assembling with strategy 4 in 2 phases

In all hardstands, 2 additional areas of 19 m x 12 m and 16 m x 12 m will be required for storing the containers and miscellaneous items. These areas must be close to the hardstand. They can be positioned alongside the foundation providing they remain accessible for removing material by boom truck or telescopic forklift.

The blade storage area will be formed by two different zones. The first one-part is two “fingers" and these must be levelled and elevated as a minimum 1m over the surrounding terrain to avoid blade touching the ground and be able to operate the blade lifting yoke (clamper).

There must be provided also, the second part an accessible Working Area between the fingers and tip end of the blade. The working area must be levelled with the adjoining road where the blades are offloaded from. It is necessary to remove any high obstacles and trip hazards within this area to ensure safe operation.

If the blade storage area is higher or lower than the adjoining road, this must be approved by Siemens Gamesa as it will have an impact on the delivery of the blades.

The dimensions of the vehicle and crane work areas as well as the storage areas inevitably determine the configurations of the equipment used for assembly. For this reason, this section also defines some of the standard or normal conditions used to define the basic prices as well as relevant exceptional cases.

The recommendable distance from the center of the ring to the start of the useable surface of the hardstand will be 5 m. (Each specific case may be studied).

The concrete foundation pedestal and hardstand must have the same level where possible.

It can be lower with prior approval from SGRE.

If design requirements call for the foundation pedestal level to differ from the ground surface potentially the level of standard hardstand layout will differ from foundation pedestal, too. In case of a project specific evaluation together with SGRE is required (e.g adaptation of hardstand level to foundation pedestal level or change of crane set up and updated of size of the hardstand).

(Note: If opting for an elevated foundation due to design reasons, its height in relation to the hardstand should be considered as tower height.)

Intermediate hardstand adjacent to the road, but at a different level, must have a separate hardstand entrance and exit. Otherwise it must be considered end-of-road hardstand.

For end-of-road hardstands, the foundation should be at the end of the hardstand, avoiding having the foundation at the entrance of the hardstand as much as possible.

The hardstand and road must be at the same level to be able to operate support cranes located partially on hardstand and road.

3.2.6. Requirements for tower assembly with T-flange configuration between section 1 and 2

A compacted area around the tower (on top of foundation) need to be prepared in advance of start of 1st tower section installation. This is needed to enable tower access from all sides for installation of T-flange bolt joints with e.g. cherry picker (man basket).

The compacted area needs to have a minimum width of 10m for operation of cherry picker.

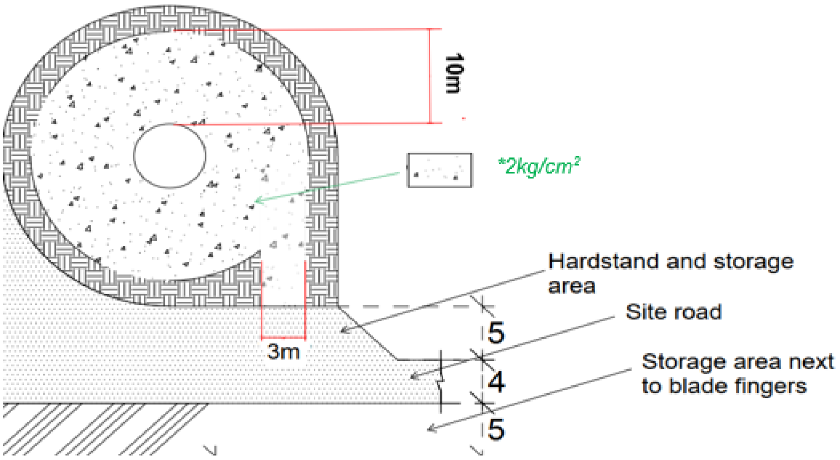


Figure 26 Example of hardstand layout and access road/ramp

Note:

If an elevated foundation is applicable a road/ramp for access to compacted must be created, too. Maximum gradient of 15% must be considered.

*The bearing capacity for the backfilling is a recommendation for complying with the CNS requirements. This number needs to fulfill also the foundation design requirements.

3.2.7. Requirements for assembly the main crane

		T100m	T101.5m	T115m	T135m	T145m	T165m MB
Mobile/ Crawler cranes	**Wheeler Crane**	Area for assembly and disassembly on each hardstand and along site road					
	NTC						
	WTC	Assembly area at the beginning and end of the Wind Farm or each branch					
Dimensions	**In a straight line**	119m	120m	134m	150m	160m	177m
	Wide	3m	3m	3m	3m	3m	3m

Table 20 Requirements for assembly the main crane

If there are several branches far away from one another, an area must be prepared for assembling and disassembling the boom of the main crane at the beginning and end of each wind farm branch or on each hardstand depending on the crane model to be used.

The boom assembly configuration and area may vary according to the crane models to be used.

If there are very steep gradients, power lines, etc., more assembly and disassembly areas for the boom of the main crane may be needed on each hardstand.

This area must have a minimum length in a straight line equal to:

- 100m tower: Tower height + 19m and a minimum width of 3m, with two 6m x 6m supporting areas (depending on the crane, the location of the crane and the boom configuration)
- 101.5m tower: Tower height + 19m and a minimum width of 3m, with two 6m x 6m supporting areas (depending on the crane, the location of the crane and the boom configuration)
- 115m tower: Tower height + 19m and a minimum width of 3m, with two 6m x 6m supporting areas (depending on the crane, the location of the crane and the boom configuration)
- 135m tower: Tower height + 15m and a minimum width of 3m, with two 6m x 6m supporting areas (depending on the crane, the location of the crane and the boom configuration)
- 145m tower: Tower height + 15m and a minimum width of 3m, with two 6m x 6m supporting areas (depending on the crane, the location of the crane and the boom configuration)
- 165m tower: Tower height + 12m and a minimum width of 3m, with two 6m x 6m supporting areas (depending on the crane, the location of the crane and the boom configuration)

There must be areas without vegetation, flat and compacted with a surface area of 8 m x 12 m, every 24 m along the boom for assembly for the tailing cranes operation:

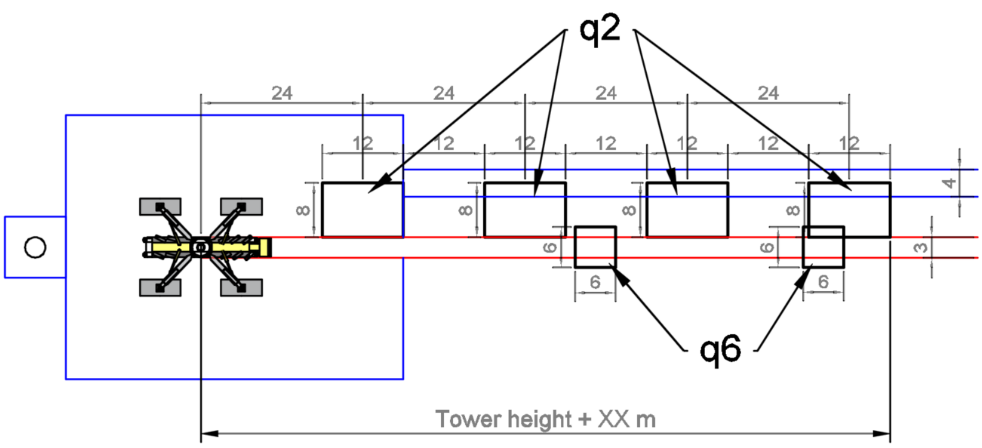


Figure 27 Distribution areas for main crane boom assembly

This area must also be as horizontal as possible, and any gradient should preferably be upward (in the direction in which the boom assembly advances). Were it downward, the boom assembly conditions would be more complex, increasing the crane means required for the assembly process. This would not be a SGRE standard and a specific study would need to be done.

Furthermore, the subgrade for assembly and disassembly of the boom, including the pre-installation crane positioning areas, must have a supporting capacity over the entire area at work level of 2 kg/cm² (approx. 0.2 MPa).

The areas for mounting and dismounting the main crane should be next to a hardstand but not overlap the hardstand area. Furthermore, they will be laid out as parallel as possible to the road reaching the hardstand, but without overlapping it, **in order to avoid invading the outgoing WF road in case of.**

3.3. Safety distance from power lines

The Orders and Regulations in force in each country must be considered where high and low-voltage lines pass over the internal wind farm roads or wind farm access roads.

Distance limits for working areas are included as a reference.

U_n	D_{PEL-1}	D_{PEL-2}	D_{PROX-1}	D_{PROX-2}
≤ 1	50	50	70	300
3	62	52	112	300
6	62	53	112	300
10	65	55	115	300
15	66	57	116	300
20	72	60	122	300
30	82	66	132	300
45	98	73	148	300
66	120	85	170	300
110	160	100	210	500
132	180	110	330	500
220	260	160	410	500
380	390	250	540	700

Table 21 3.3 Safety distance from power lines to work areas

(Note)

The distances for intermediate voltage values will be calculated using linear interpolation.

Where:

- U_n - Rated voltage of the installation (kW).
- D_{PEL-1} - Distance to the outer limit of the danger area whenever there is a risk of voltage stressing due to lightning (cm).
- D_{PEL-2} - Distance to the outer limit of the danger area when there is no risk of overvoltage due to lightning (cm).

- D_{PROX-1} - Distance to the outer limit of the danger area whenever it is possible to mark out the work area accurately and control that this is not exceeded during the carrying-out of the work (cm).
- D_{PROX-2} - Distance to the outer limit of the danger area whenever it is not possible to mark out the work area accurately and control that this is not exceeded during the carrying-out of the work (cm).

4. Additional documentation

Document to be completed based on the wind farm conditions. This document will present the data for road width, longitudinal and transversal gradients, load-bearing capacity of hardstands and hardstand sizing for each wind turbine and crane model needed for assembly.

These data will give a visualization of each wind turbine of the wind farm and they will convey any needed extra methods or measures in addition to the SGRE standards.

5. Annexes

5.1. Weights and dimensions for SG 6.0-170

100m tower

Element	W (kg)	L (m)	Ø Lower flange (m)	Ø Upper Flange (m)
Section 1	84,030	14.30	4.70	4.70
Section 2	79,750	21.56	4.70	4.49
Section 3	76,060	26.88	4.49	4.49
Section 4	75,790	34.45	4.49	3.50

Table 22 Weights and dimensions of T100m

101.5m tower

Element	W (kg)	L (m)	Ø Lower flange	Ø Upper Flange
Section 1	61,270	8.46	4.50	4.50
Section 2	69,800	14.84	4.50	4.50
Section 3	57,630	15.12	4.50	4.50
Section 4	53,450	17.64	4.50	4.50
Section 5	48,050	21.00	4.50	4.10
Section 6	49,720	21.85	4.10	3.50

Table 23 Weights and dimensions of T101.5

115m tower

Element		W (kg)	L (m)	Ø Lower flange (m)	Ø Upper Flange (m)
50A	Section 1	84,960	13.56	4.70	4.70
	Section 2	84,330	18.20	4.70	4.44
	Section 3	84,550	23.80	4.44	4.43
	Section 4	71,770	26.88	4.43	4.02
	Section 5	63,860	29.97	4.02	3.50
51A	Section 1	86,800	11.78	4.80	4.80
	Section 2	84,640	17.92	4.80	4.79
	Section 3	81,560	21.84	4.79	4.79
	Section 4	77,290	28.00	4.79	4.79
	Section 5	72,510	32.77	4.79	3.50

Table 24 Weights and dimensions of T115m

135m tower

Element		W (kg)	L (m)	Ø Lower flange (m)	Ø Upper Flange (m)
50A	Section 1	90,710	15.00	6.00	5.68
	Section 2	83,940	47.64	5.68	5.68
	Section 3	85,050	20.72	5.68	4.83
	Section 4	84,470	24.92	4.83	4.42
	Section 5	69,790	27.44	4.42	4.42
	Section 6	56,930	26.69	4.42	3.50

Table 25 Weights and dimensions of T135

145m tower

Element	W (kg)	L (m)	Ø Lower flange (m)	Ø Upper Flange (m)
Section 1	83,350	12.32	6.40	6.40
Section 2	82,480	14.00	6.40	6.40
Section 3	83,110	15.68	6.40	6.40
Section 4	83,910	18.20	6.40	6.40
Section 5	73,260	18.48	6.40	5.75
Section 6	62,220	18.48	5.75	5.10
Section 7	50,400	18.48	5.10	4.45
Section 8	64,480	26.89	4.45	3.50

Table 26 Weights and dimensions of T145

165 MB tower

Element	W (kg)	L (m)	Ø Lower flange (m)	Ø Upper Flange (m)
Concrete (MB)	-	98.94	9.29	4.53
Section 1	83,160	27.77	4.30	4.29
Section 2	72,290	36.00	4.29	3.50

Table 27 Weights and dimensions of T165 MB

Nacelle, incl. TU and GEN

Element	W (kg)	L (m)	Width (m)	Height (m)
Nacelle	103,508	15.03	4.20	3.50

Table 28 Weights and dimensions of Nacelle

Full Drive Train

Element	W (kg)	L (m)	Width (m)	Height (m)
Drive Train	80,790	7.60	3.20	3.13

Table 29 Weights and dimensions of full drive train

Hub

Element	W (kg)	L (m)	Width (m)	Height (m)
Hub	55,000	5.20	4.72	4.10

Table 30 Weights and dimensions of HUB

Blades

Element	W (kg)	L (m)	Width (m)	Height (m)
Blade SG5.X-170	25,000	83.50	4.50	3.40

Table 31 Weights and dimensions of Blades

Transformer Unit

Element	W (kg)	L (m)	Width (m)	Height (m)

TU	16,300	-	-	-

Table 32 Weights and dimensions of Transformer unit

Generator

Element	W (kg)	L (m)	Width (m)	Height (m)
GEN	16,500	-	-	-

Table 33 Weights and dimensions of Generator

5.2. Transport requirements

(Note): The data represented below is the result of the of the study was obtained from the modelling, showing the following widening according to the cargo and bed. The values are a reference considering the transport from the item ***3.1.5 Gradients and grade changes.*** For each windfarm and region, please bear in mind some changes could be possible. Concerning this, a new study must be done by Logistics department according with the transport available per region/project to avoid some nonconformities.

5.3. Quality tests and requirements for civil works projects

The quality control and the requirements for the civil works design is defined according to the ***GD483525-EN, Quality Test Plan for Roads and Hardstands.***

5.4. Legislations

Siemens Gamesa and its affiliates reserve the right to change the above specifications without prior notice.

Tower Dimensions

SG 6.0-170

Tower Dimensions

SG 6.0-170 is offered with an extensive tower portfolio ranging from 100m-165m, including the baseline 115m and 165m catalogue towers. All towers are designed in compliance with local logistics requirements.

Preliminary information:

- Tower hub height 115m IIIA. Tapered tubular steel tower.

	Section 1	Section 2	Section 3	Section 4	Section 5
External diameter upper flange (m)	4,50	4,50	4,50	4,30	3,57
External diameter lower flange (m)	4,50	4,50	4,50	4,50	4,30
Section's height (m)	11,21	17,92	23,24	28,84	26,89
Total weight (T)	83.7	83.6	83.2	70.8	61.1
Volumen (CBM)	228	363	470	584	498

- Tower hub height 165m IIIA. Hybrid design (concrete + steel)

	Concrete Section 1	Steel Section 2	Steel Section 3	Steel Section 4
External diameter upper flange (m)	4,668	4,300	4,300	3,574
External diameter lower flange (m)	7,888	4,300	4,300	4,300
Section's height (m)	100,29	17,970	21,385	21,531

Information about other tower heights and logistic will be available upon request.

SGRE and its affiliates reserve the right to change the above specifications without prior notice.

Foundation loads T115-50A

SG 6.0-170

Foundation loads T115-50A

Design code information

The foundation loads are calculated according to the design code and different climate conditions shown in Table 1.

Description	Unit	Value	Value
Design code	-	IEC-61400-1 Ed3	IEC-61400-1 Ed3
IEC Class	-	3A	3B
Design life time according to IEC	years	20	25
Annual average wind speed at hub height, V_{ave}	m/s	7.5	7.5
Extreme wind speed at hub height (10-min with 50 years return period), V_{ref}	m/s	37.5	37.5
Mean turbulence intensity at 15 m/s, I_{ref}	-	0.16	0.14
Average air density, ρ	kg/m^3	1.225	1.225

Table 1 Design code information and climatic conditions

Coordinate system

The axis system used for presentation of the tower bottom loads is depicted in Figure 1:

Co-ordinate system at Tower bottom (tower bottom): Location at tower bottom, at the upper surface of flange of foundation steel section.

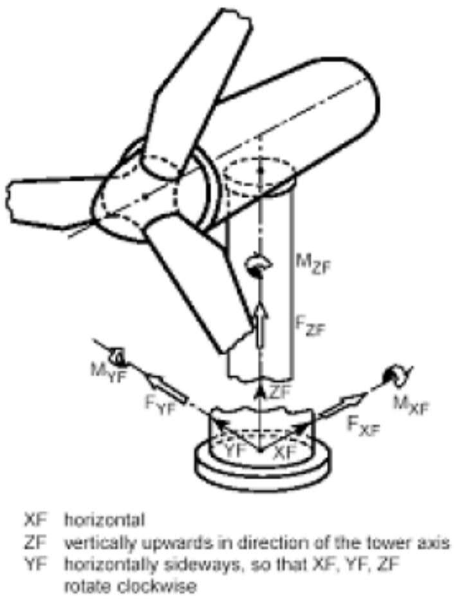


Figure 1 Coordinate system

Rotational stiffness

The foundation rotational stiffness requirements are specified by SGRE for each wind turbine, in order to operate the turbine correctly at the natural frequency of the entire unit.

If this condition is not met, the loads provided by SGRE for the foundation loads will no longer be valid.

In the case of pile foundations, SGRE will supply the minimum foundation horizontal stiffness value to be guaranteed in the design.

The value for SG 6.0-170 T115-50A is shown in Table 2:

WTG	SG 6.0-170 T115-50A
Minimum rotational stiffness of the foundation	1.5E+11 Nm/rad

Table 2 SG 6.0-170 T115-50A Minimum rotational stiffness

The minimum rotational stiffness of the foundation comes from the aeroelastic model of the complete wind turbine. In case these values drive the foundation designs, lower values can be evaluated if they keep assuring the adequate dynamic behaviour of the wind turbine.

Extreme load
The extreme loads for the design of the SG 6.0-170 T115-50A foundations are shown in Table *3*.

Load case	Load factor	F_x (kN)	F_y (kN)	F_z (kN)	F_{xy} (kN)	M_x (kNm)	M_y (kNm)	M_z (kNm)	**M_{xy} (kNm)**
Dlc22_3bn_V11.0_n_s7	**1,1**	1688,55	55,55	-7508,71	1689,47	4580,25	196184,46	412,39	**196237,91**
Dlc22_3bn_V11.0_n_s7	**1.0**	1535,05	50,5	-6826,1	1535,88	4163,87	178349,5	374,9	**178398,1**

Table 3 SG 6.0-170 HH115m Factored/Unfactored Extreme loads at tower bottom

The loads provided by Siemens Gamesa as “Extreme Loads” in this section are the maximum static loads for the specific wind turbine calculated according to IEC 61400 or DIBt standard for each site class. These loads must not be combined with any other type of load. They include the dynamic behaviour of the structure and correspond to the most unfavourable case at the base of the wind turbine among the different load cases, according to IEC 61400 or DIBt. Therefore, the loads provided by Siemens Gamesa as “Extreme Loads” are directly the foundation design loads. They shall not be divided or combined with any other load.

Characteristic load
Characteristics loads (maximum M_{xy} bending moment load combination of groups N, E and T according to GL2012 Sec. 5.4.3.1.3, or equivalent groups N-T according to IEC 61400-1 2006) have been estimated as shown in Table 4:

Load case	F_x (kN)	F_y (kN)	F_z (kN)	F_{xy} (kN)	M_x (kNm)	M_y (kNm)	M_z (kNm)	**M_{xy} (kNm)**
Dlc62_V42.5_060_s9	1535,05	50,5	-6826,1	1535,88	4163,87	178349,5	374,9	**178398,1**

Table 4 SG 6.0-170 HH115m Characteristics Loads at the base of the tower

Quasi-permanent load
Loads according to GL2010, considering DLC 1.1 and 6.4 with a probability of exceedance of pf = 10^{-2} (equivalent to 1750 h in 20 years) with $\gamma F = 1.0$ have been estimated as shown in Table 5:

pf=0.01000	Tower loads at section							
Section Height from bottom (m)	Fx (KN)	Fy (KN)	Fxy (KN)	Fz (KN)	Mx (KNm)	My (KNm)	Mxy (KNm)	Mz (KNm)
0	1002.07	123,15	1002,48	-6629,52	18223,36	119459,49	**119805,99**	4928,71

Table 5 SG 6.0-170 HH115m Quasi Permanent Loads at tower bottom

No gap between the foundation and the ground shall be verified for the loads of Table *5*.

Fatigue load

The equivalent fatigue loads are provided for the design foundations in Table 6, calculated for 10^7 cycles:

	Load factor	m	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kNm)	**M_y (kNm)**	M_z (kNm)
Tower Bottom	1	4	563,31	361,63	177,3	22054,68	**39810,03**	10283,41
Tower Bottom	1	7	558,57	361,77	174,53	26918,71	**50074,58**	10803,68

Table 6 SG 6.0-170 HH115m equivalent fatigue loads at the base of the tower

In the above table, the "m" values correspond to the Wöhler gradient, which has a value of m=4 for embedded steel and m=7 reinforcement in reinforced concrete.

Table 7 shows the mean fatigue loads for the design of the SG 6.0-170 T115-50A foundation:

Load factor	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kNm)	**M_y (kNm)**	M_z (kNm)
1	473,93	-6,23	-6694,21	4669,6	**56807,04**	133,54

Table 7 SG 6.0-170 HH115m Mean Fatigue Loads at base of tower

The preliminary Markov Matrix to be used for the fatigue verifications is the following:

Markov_TOWER_My_
0.000m.xlsx

Interface

The junction between tower and foundation shall be performed using the interfaces provided by SGRE (including levelling and positioning systems).

For SG 6.0-170 T115-50A foundation a post-tensioned bars cage interface is included. The bars cage must be assembled with the T115 bottom T-flange.
The T- flange main dimensions are illustrated from Table 8 and Figure 2.

ON-SG5X-T115-50A (T-interface)		**BOTTOM**
Flange thickness with neck	tflt	0.160
Flange thickness without neck	tfl	0.100
Flange width	wfl	0.350
Neck shell thickness	tsh	0.066
BCD diameter	dBCD	4.146/4.554
Neck shell center diameter	dM pl,2	4.350
Bolt holes diameter	Dbh	0.054
Number of bolts	nmet	104*2
Bolt metric	met	48

Table 8 Tower bottom interface

Initial preload:
755 kN

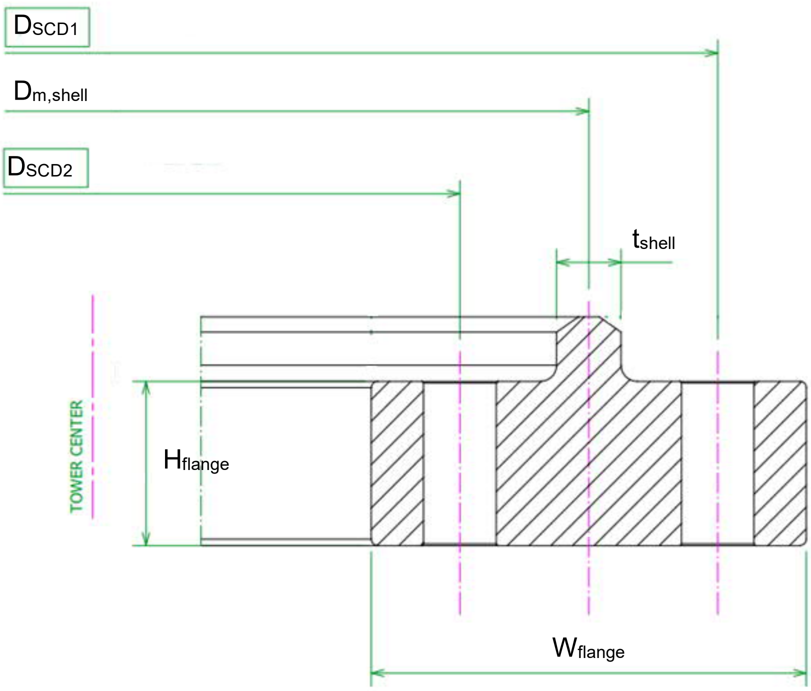


Figure 2 Illustration of important dimensions

Bars cage:
Bars cage information can be seen below

DIMENSIONS		
Dped (m)	6.0	Pedestal diameter
N rows	2	Number of rows
D (m)	4.35	Mean diameter of the tower
Nbars	208	Total number of bars
s (m)	0.204	Distance between rows
Bar metric	M48	Metric of the threaded bars
Øext ducts (mm)	58	External diameter of protection ducts for threaded bars
Wtow (m)	0.350	Width of the tower flange
Htow (m)	0.100	Thickness of the tower bottom flange
Neck (m)	0.066	Neck thickness of the tower flange
Wtem (m)	0.662	Width of the upper template
Htem (m)	0.156	Thickness of the upper template
Øh,tem (mm)	51	Diameter of the holes of the upper template
Wgro (m)	0.880	Width of the grout
Hgro (m)	0.160	Thickness of the grout layer (measured between lower faces of upper template and grout)
Hupp (m)	0.400	Height of concrete with different strength
Wlow (m)	0.613	Width of the lower template
Hlow (m)	0.117	Thickness of the lower template
Øhlow (mm)	51	Diameter of holes in the lower template
Lbup (mm)	0.280	Top exposed length
Lblow (mm)	0.135	Bottom exposed length

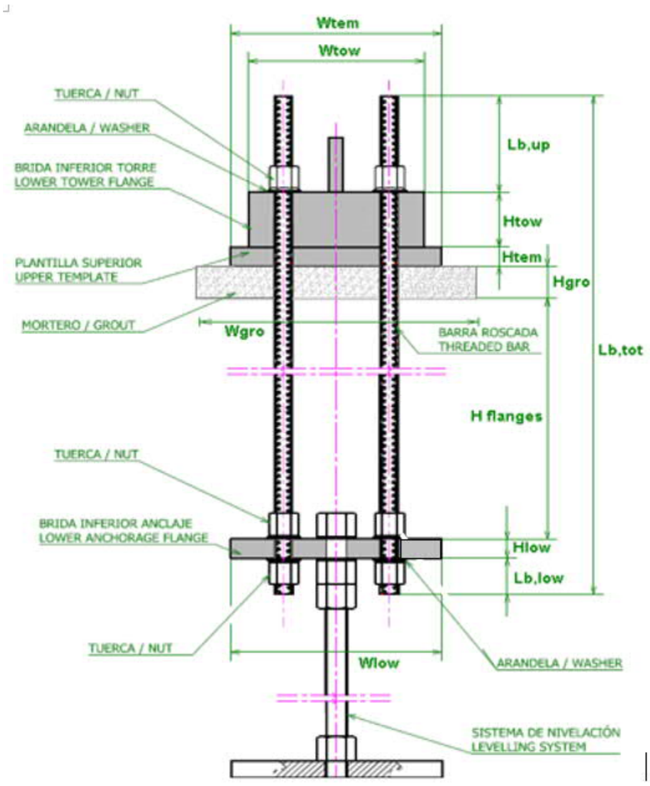


Figure 3 Overall sketch of bars cage

The scheme for upper and lower ends of bars is illustrated on Figure 4.

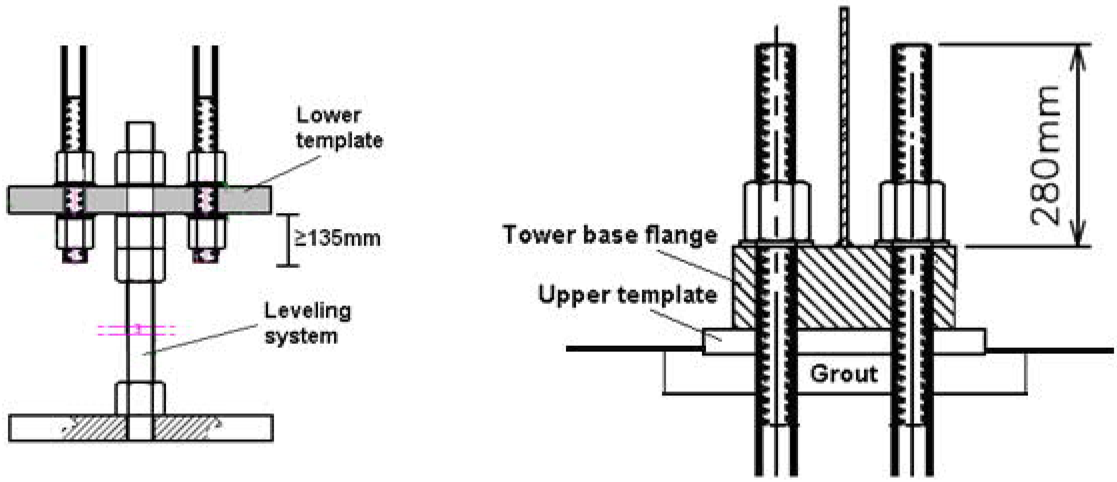


Figure 4 Schemes for upper and lower ends of bars

Threaded bars are as follows:

- 208 (104x2) bars with threaded ends
- BC can be used with bolt length between 3000mm and 4000mm (3000mm, 3500 and 4000mm). Keep in mind that the foundation is calculated with 4000mm bolt length.
- Each bar length is available according to both ISO and ASTM regulation

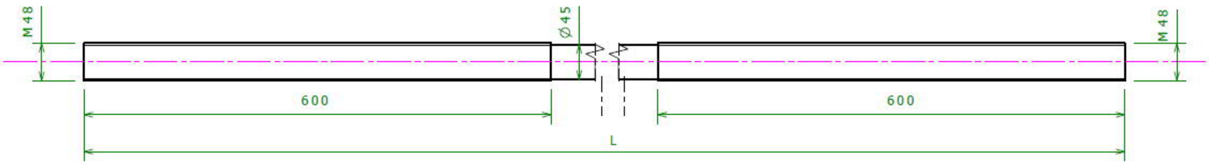


Figure 5 Threaded bars (dimensions in mm)

In order to achieve proper finish of the bars cage installation the following details showed in Figure 6 must be carried out:

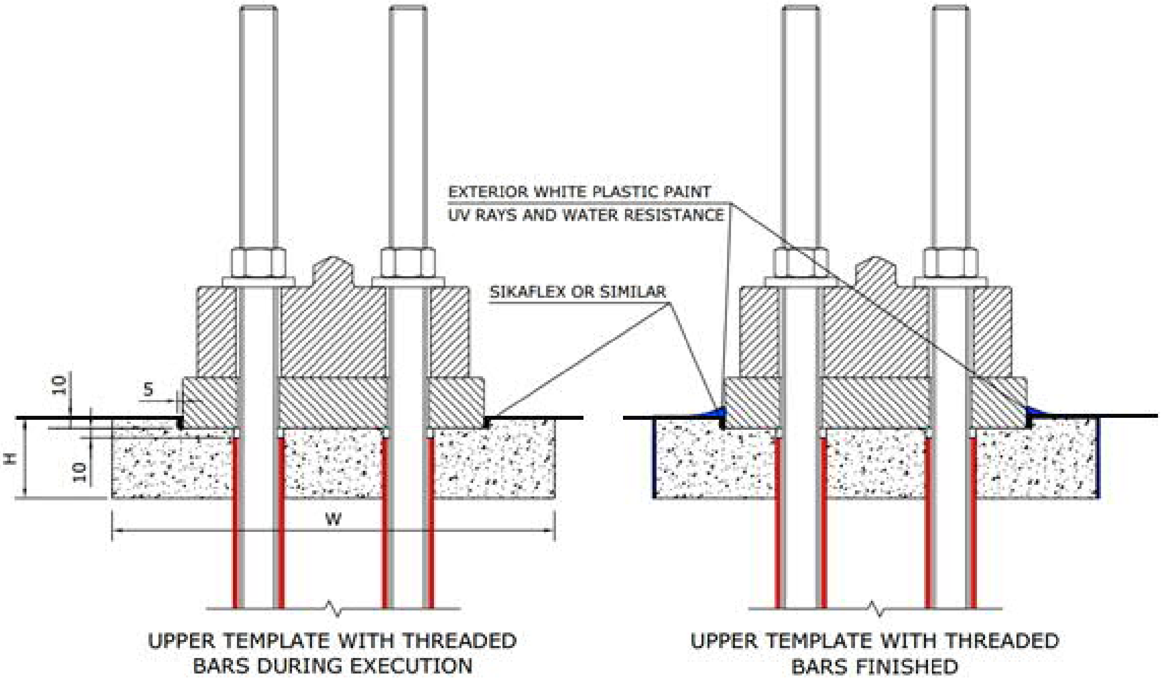


Figure 6 Bars cage finish

Plastic paints allowed are: Masterseal 6100 FX (BASF), Nitocote CM660 (FOSROC), Sikalastic 560 (SIKA).

Bolted connection is as follows:

- 3 nuts per bar (2 at lower template and 1 at tower flange)
    - M48 (ISO 4032) 10.9 for threaded bars according to ISO regulations.
    - Full strength hex nut M48
- Corrosion protection: hot dip galvanized (HDG)

- 2 washers per bar (1 at the bottom of the lower template and 1 at tower flange)
    - 1 Washer M48 (ISO 7089) 300HV for threaded bars according to ISO regulation for lower template
    - 1 Washer Hard Thick 48-300HV-HDG for tower flange
- Corrosion protection: hot dip galvanized (HDG)

- A protective cap per bar
    - M48 for threaded bars according to ISO regulations.
    - End cap for threaded bars according to ASTM regulation

- A protective sleeve per bar (see necessary length in the following figure:
    - Material: PVC
    - Minimum inner diameter: 51mm
    - Maximum outer diameter: 58mm
    - Minimum thickness: 2mm

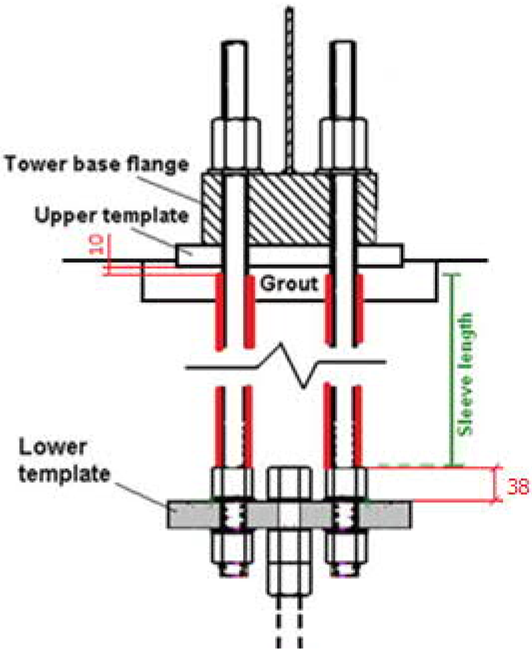


Figure 7 Length of protective sleeve

Upper template:
Upper template design can be made with the following

- One-piece design
- Segmented 4x segments

Dimensions do not change

The geometry of this template is defined in the following figure:

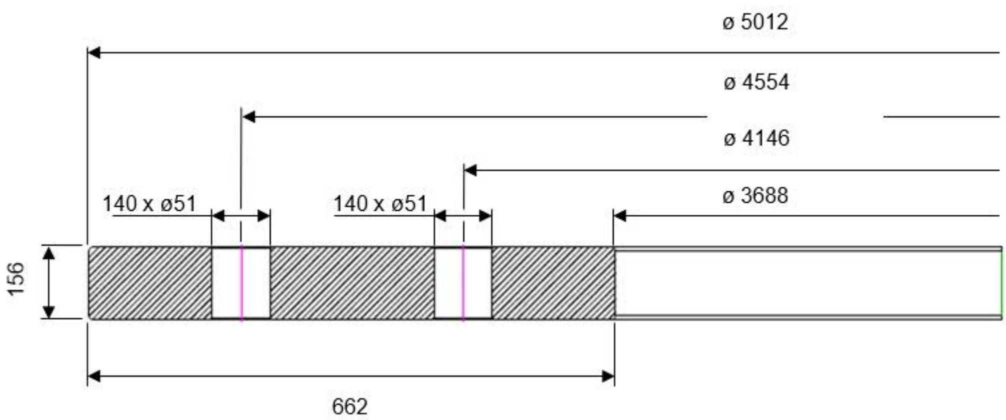


Figure 8 Sketch of the upper template (dimensions in mm)

Lower template:
Lower template design can be made with the following

- Only design in 4x segments

The geometry of a single tower lower template is defined in the following figure:

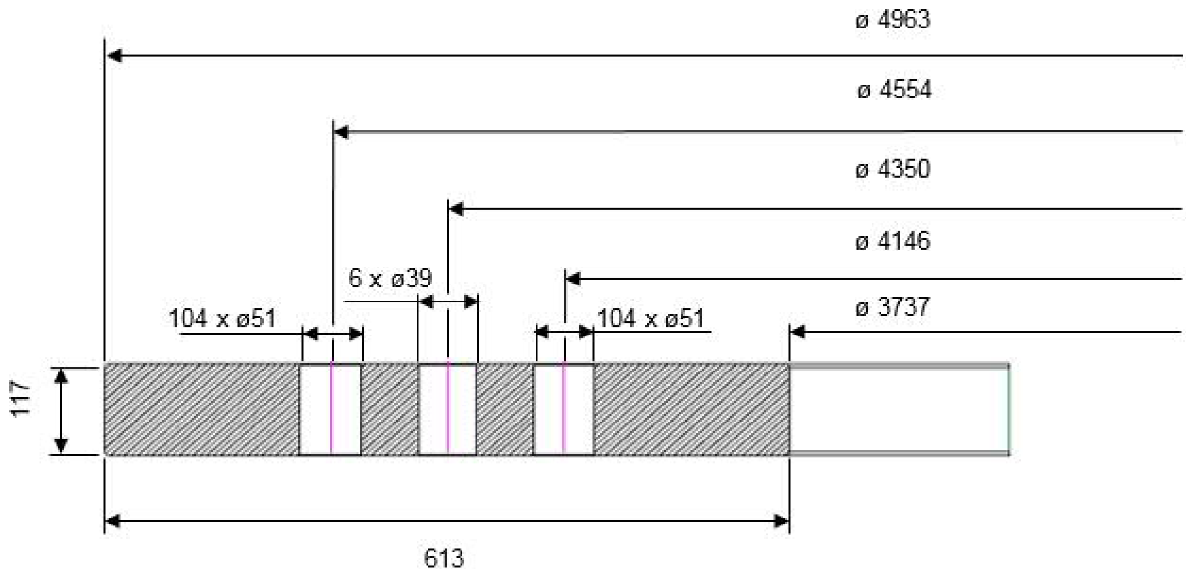


Figure 9 Sketch of the lower template (dimensions in mm)

Levelling system:
12 levelling legs are necessary in order to carry out the assembly of the bar cage.

Note: the position of the lower template within the height of the levelling leg can vary, as shown in the following figure. This position can be combined with the available bar lengths and the exposed length under the lower template, in order to suit the height of the bar cage to the foundation.

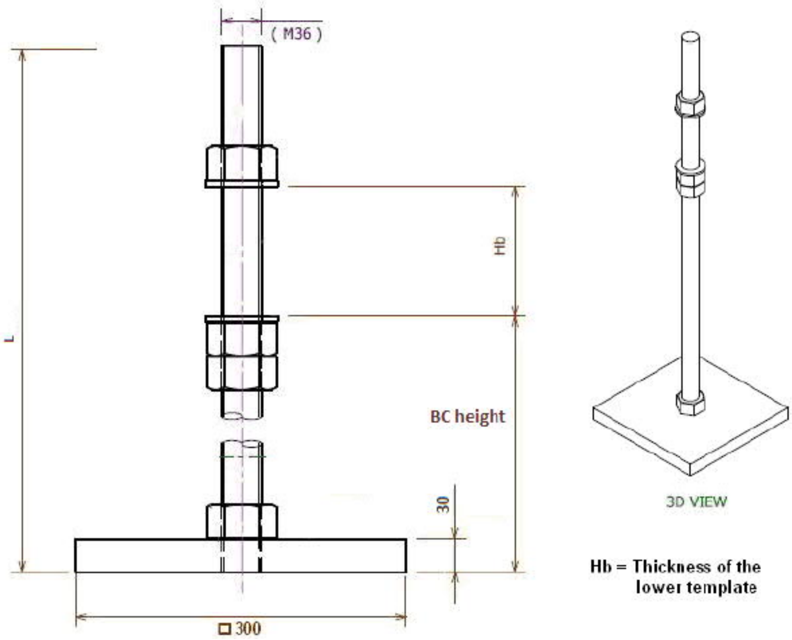


Figure 10 Sketch of the levelling legs (dimensions in mm)

Other characteristics:

- Minimum grout thickness of 170 mm and minimum grout width of 880 mm
- Minimum grout characteristic strength: 85 MPa (12328.21 psi)
- Grout type: Masterflow 9400 (BASF), Sikagrout 3200 or another grout with similar characteristics
- Grout must be embedded in the upper part of the pedestal, in order to consider that it is confined.
- Upper template should be embedded 10 mm in the grout, as it is shown in Figure 6 and Figure 11

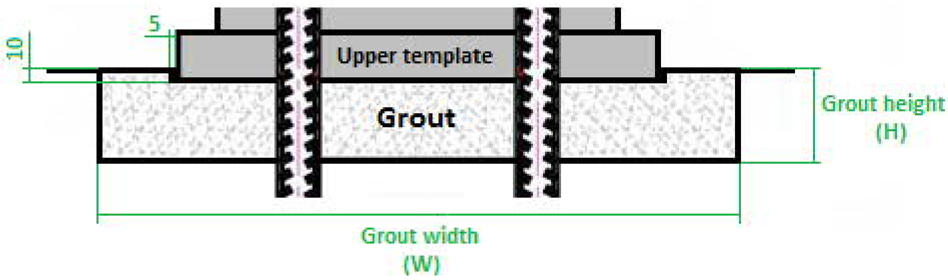


Figure 11 Scheme of grout disposal

- Minimum concrete characteristic strength in the top 600 mm of the pedestal: 50 MPa (7251.89 psi)
- Minimum characteristic strength (rest of foundation): 45 MPa (6526.70 psi)
- Minimum pedestal dimensions: Ø6000mm x 600mm

Electrical conduit diagram:
The electrical conduit diagram and lay-out of the main electrical components is as shown in the following figure:

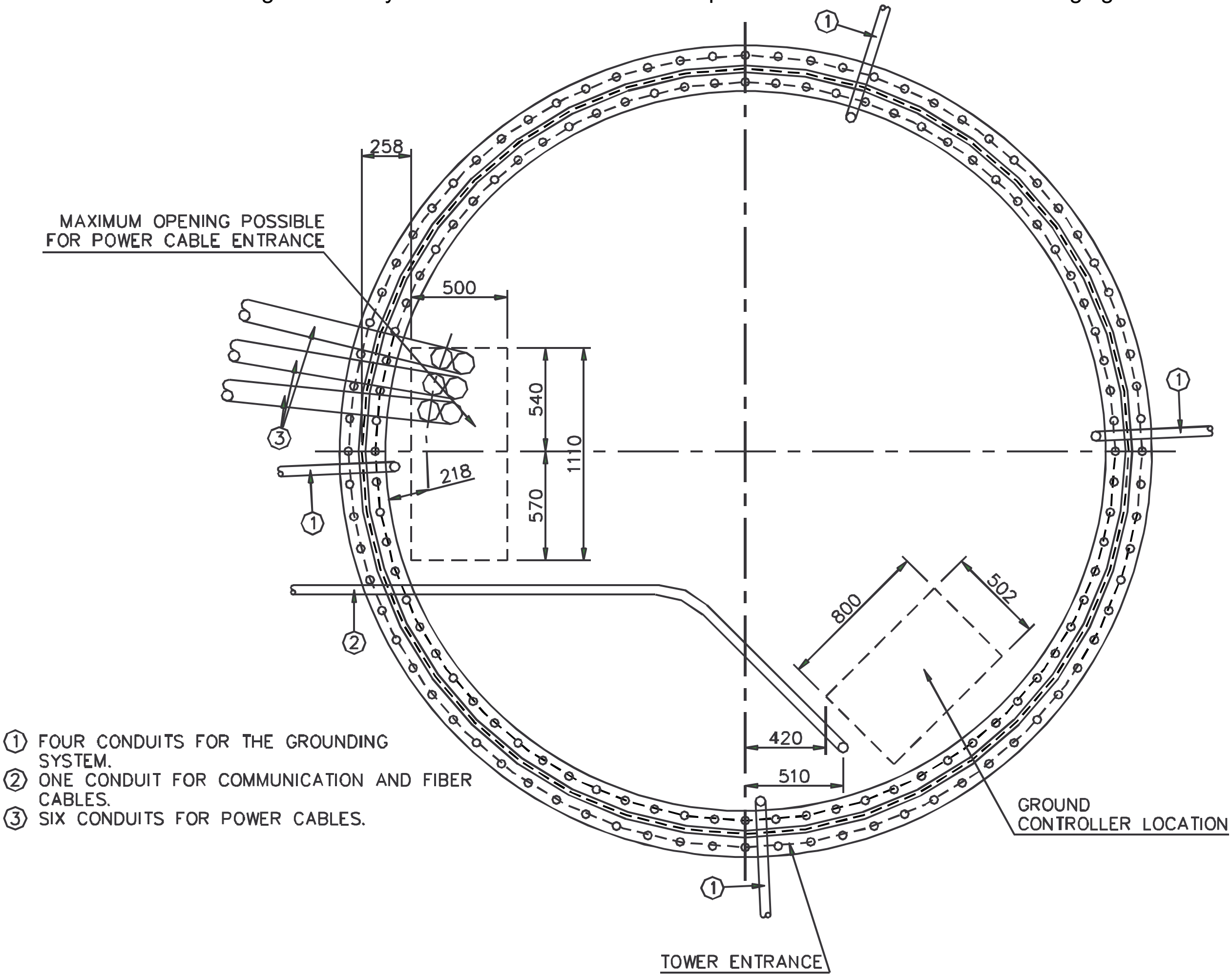


Figure 12 Electrical conduit diagram. Dimensions in mm.

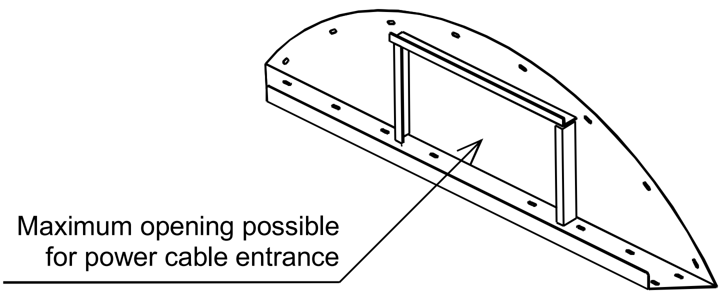


Figure 13 Bottom view of the power cable passing area

Tower access ladder:
In order to guarantee proper integration between foundation terrain level and tower access ladder, H and L values must be the ones below according to

- L = 6010 mm
- H = 395 mm

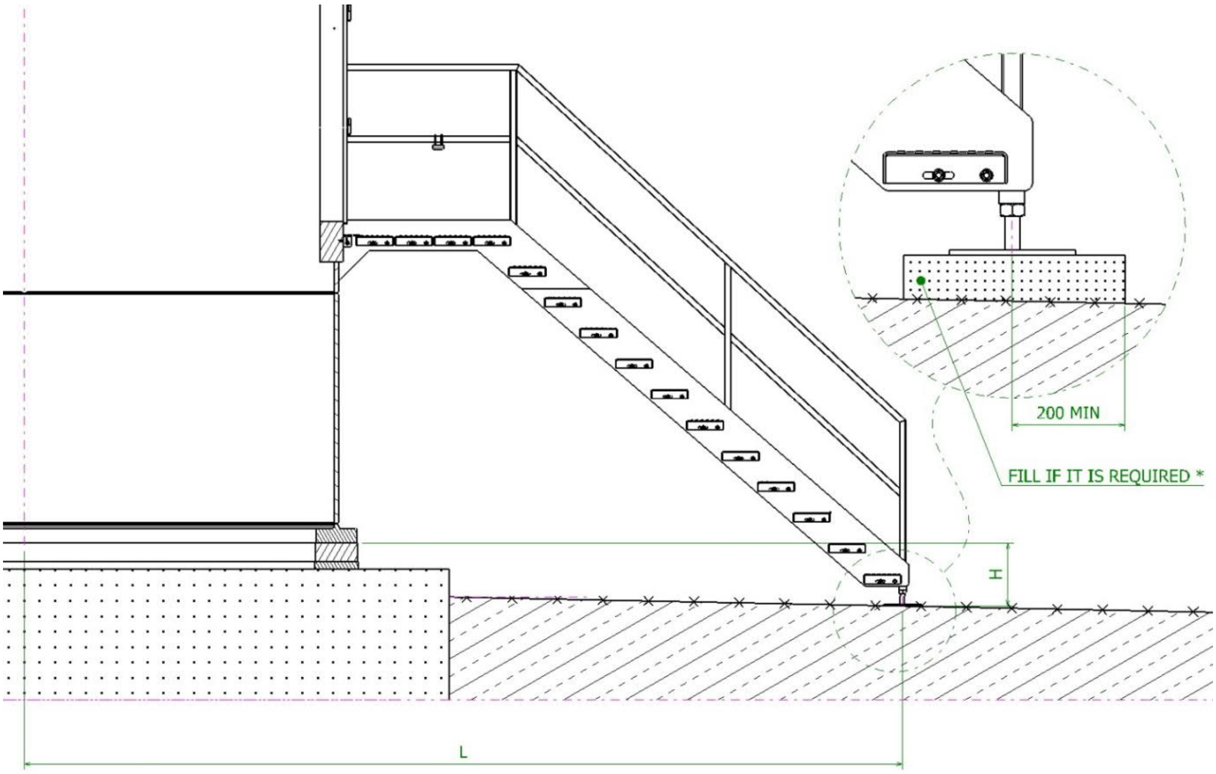


Figure 14 Refill terrain level

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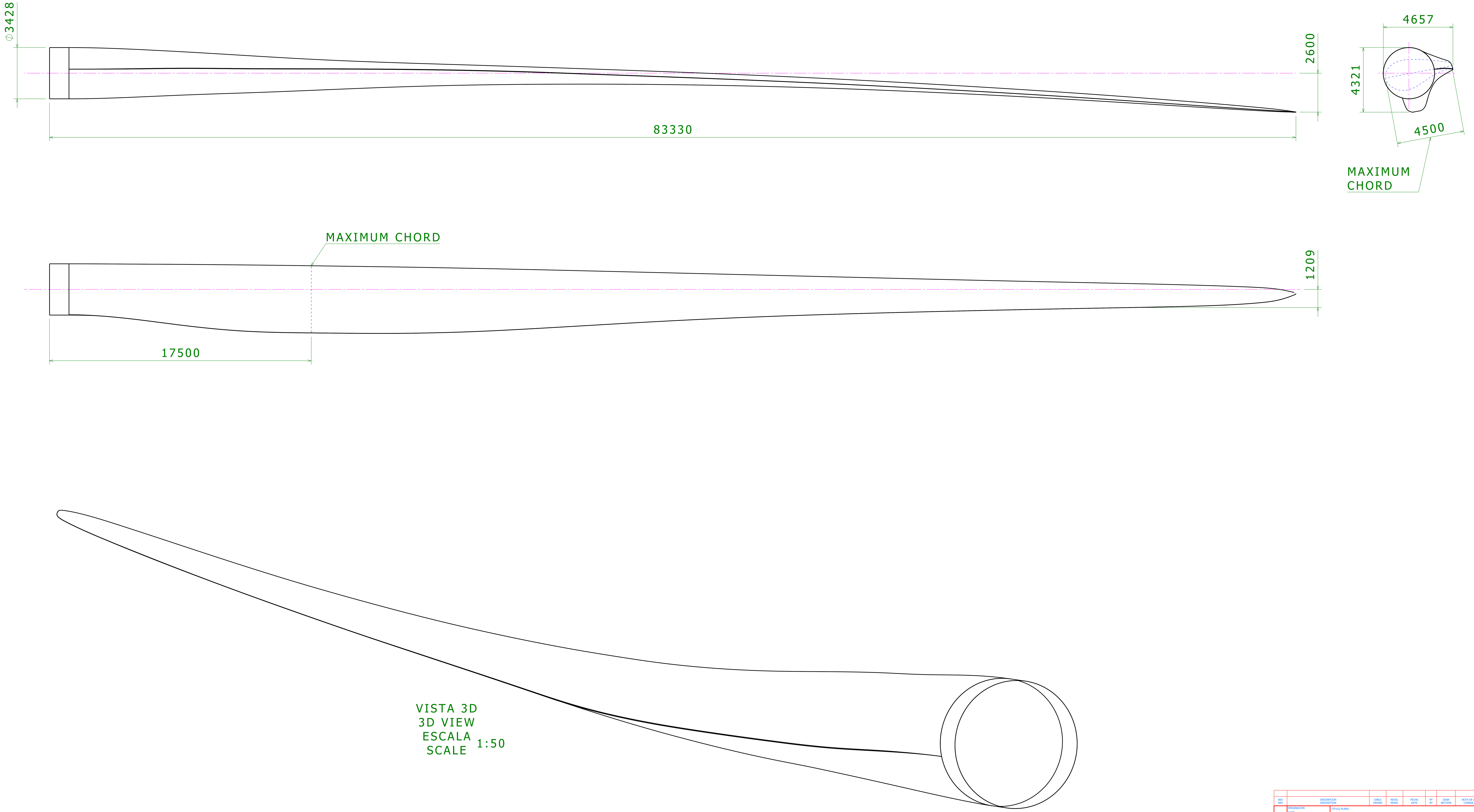

TITULO PLANO	SG 6.0-170 BLADE SALES DRAWING
DRAWING TITLE	SG 6.0-170 BLADE SALES DRAWING
ESCALA / SCALE	1:125
PLANO Nº / DRWG No.	GD410140
REV.	R01
FORMATO / FORMAT	A1
HOJA / SHEET	1 DE / OF 1

STATUS DE ULTIMA REVISION / LAST REVISION STATUS

DIBUJADO / DRAWN	JVICENTE	FECHA / DATE	12.11.2019
VERIFICADO / VERIFIED	PBONAFUENTE	FECHA / DATE	SEE PDM
REVISADO / REVIEWED	MMARTINEZ	FECHA / DATE	SEE PDM
APROBADO / APPROVED	MATUTXA	FECHA / DATE	SEE PDM

SIEMENS Gamesa RENEWABLE ENERGY

Delineacion de acuerdo a: PDM-TEC-011
Drawing Practice to: PDM-TEC-018

Cualquier alteracion esta sujeta a la aprobacion del departamento de diseño
Any alterations are subject to the approval of the design department

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