Renexia

SOCIETÀ PER AZIONI SOGGETTA ALL'ATTIVITÀ DI DIREZIONE E COORDINAMENTO DI TOTO HOLDING S.P.A.
VIALE ABRUZZO 410 - 66100 CHIETI (CH) ITALY

PROGETTO PER LA REALIZZAZIONE DI UN IMPIANTO PER LA PRODUZIONE DI ENERGIA MEDIANTE LO SFRUTTAMENTO DEL VENTO NEL TERRITORIO COMUNALE DI FOGGIA (FG) E TROIA (FG)

PROGETTO DEFINITIVO

prima emissione: febbraio 2022

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Developer Package

SG 6.2-170

Document ID and revision	Status	Date (yyyy-mm-dd)	Language
D2056872/032	Approved	2022-04-20	en-US

Original or translation of
Original

File name
D2056872_032 SGRE ON SG 6.2-170 Developer Package/.pdf

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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 A/S and its affiliates in the Siemens Gamesa group including Siemens Gamesa Renewable Energy S.A. and its subsidiaries (hereinafter “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 6.2-170 and the different product variants 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 of the wind turbine. Consequently, SGRE and its affiliates reserve the right to change the below specifications without prior notice. Information contained within the Developer Package may not be treated separately or out of the context of the Developer Package.

SIEMENS Gamesa RENEWABLE ENERGY

Table of contents

1. Introduction

The SG 6.2-170 is a new wind turbine of the next generation Siemens Gamesa Onshore Geared product platform called Siemens Gamesa 5.X, which builds on the Siemens Gamesa design and operational experience in the wind energy market.

With a new 83.3 m blade and an extensive tower portfolio including hub heights ranging from 100 m to 165 m, the SG 6.2-170 aims at becoming a new benchmark in the market for efficiency and profitability.

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

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

2. Technical Description

2.1. 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.

2.2. Blades

Sieemns Gamesa 5.Xblades are 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 Siemens Gamesa 5.X blades use a blade design based on SGRE proprietary airfoils.

2.3. 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.

2.4. 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.

2.5. Main Shaft

The low speed main shaft is casted 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.

2.6. Main Bearings

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

2.7. Gearbox

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

2.8. 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.

2.9. Mechanical Brake

The mechanical brake is fitted to the non-drive end of the gearbox.

2.10. 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.

2.11. Nacelle Cover

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

2.12. Tower

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

2.13. Controller

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

2.14. 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.

2.15. 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.

2.16. 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.

2.17. Operation Systems

The wind turbine operates automatically. It is self-starting when the aerodynamic torque reaches a certain value. Below rated wind speed, the 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.

If high wind derated mode is enabled, 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.

3. 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	83,5 m
Max chord	4.5 m
Aerodynamic profile	Siemens Gamesa proprietary airfoils
Material	G (Glassfiber) – CRP (Carbon Reinforced Plastic)
Surface gloss	Semi-gloss, < 30 / ISO2813
Surface color	Light grey, RAL 7035 or

Aerodynamic Brake	
Type	Full span pitching
Activation	Active, hydraulic

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

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	6.0MW/6.2 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	MySite360

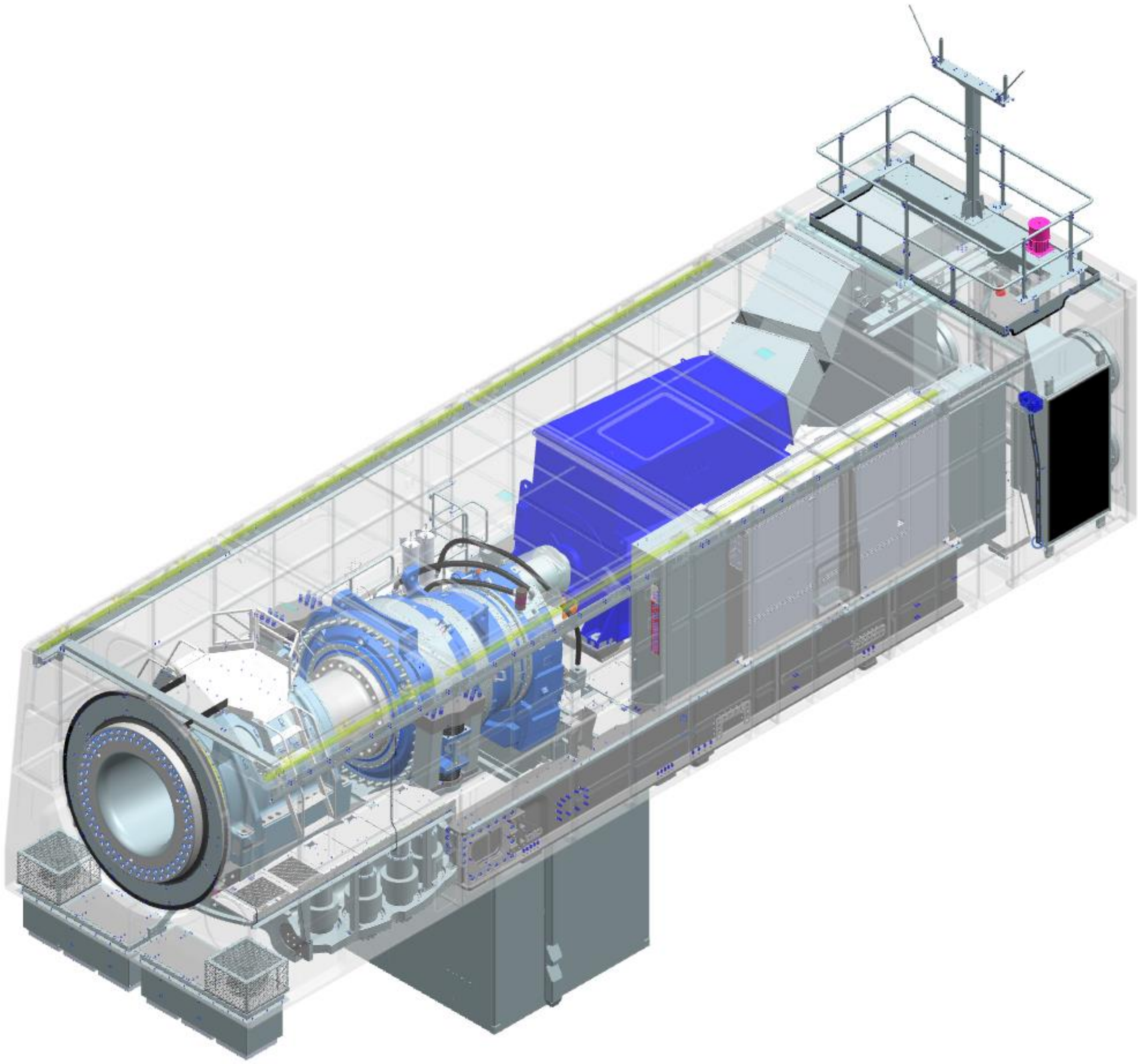
Tower	
Type	Tubular steel / Hybrid
Hub height	100m to 165 m and site-specific
Corrosion protection	
Surface gloss	Painted
Color	Semi-gloss, <30 / ISO-2813 Light grey, RAL 7035 or White, RAL 9018

Operational Data	
Cut-in wind speed	3 m/s
Rated wind speed	11.0 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	Different modules depending on restriction

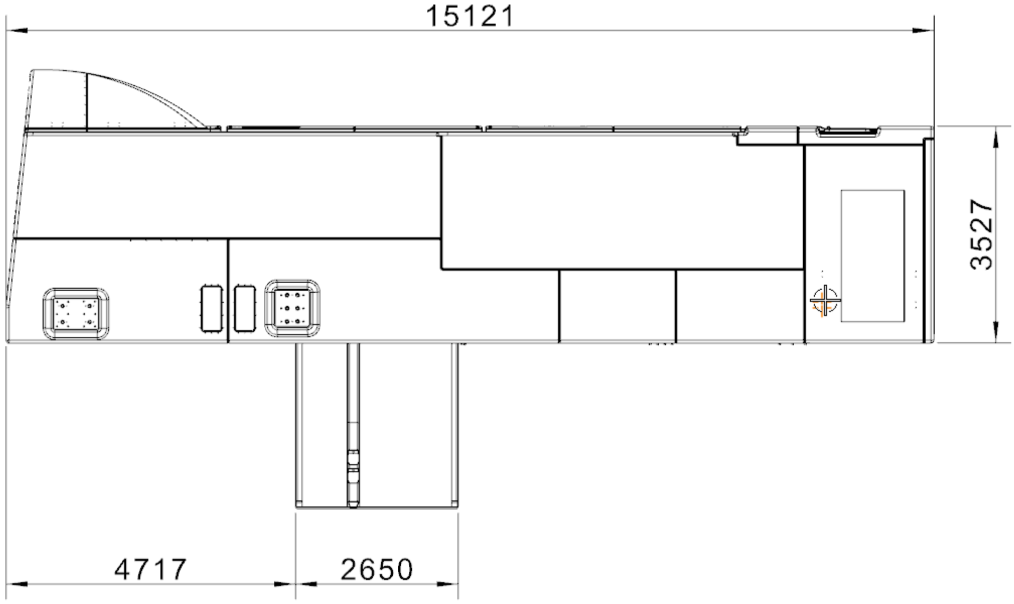
4. Nacelle Arrangement

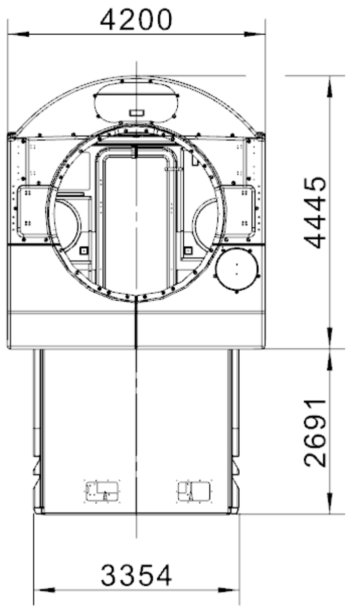
The design and layout of the nacelle are preliminary and may be subject to changes during the development of the product.



5. Nacelle dimensions

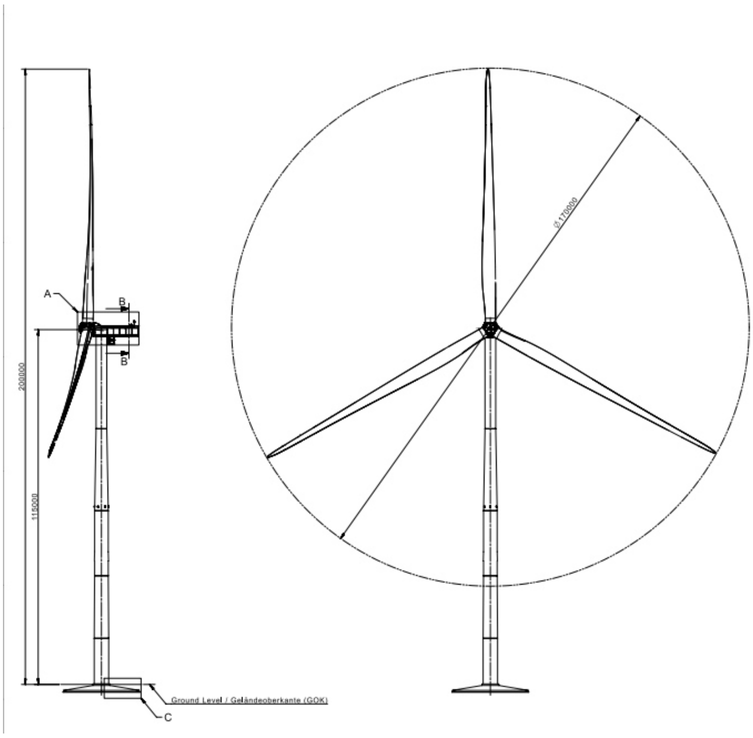
The design and dimensions of the nacelle are preliminary and may be subject to changes during the development phases of the product.



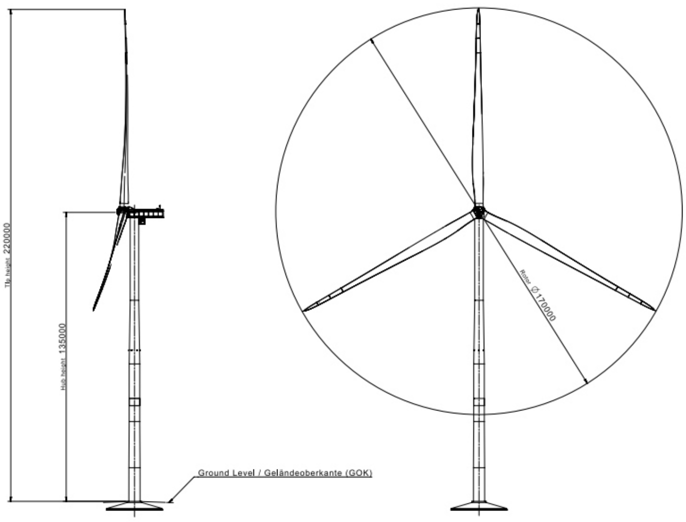


6. Elevation Drawing

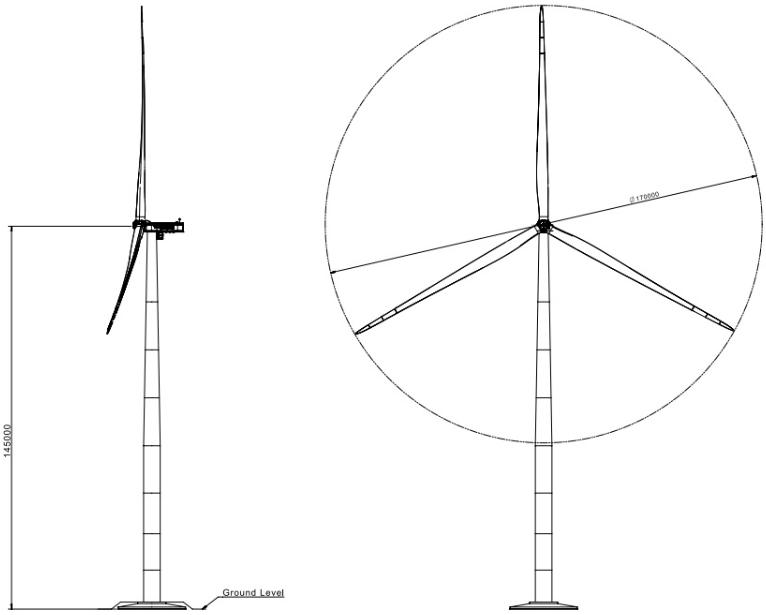
6.1. SG 6.2-170 115 m



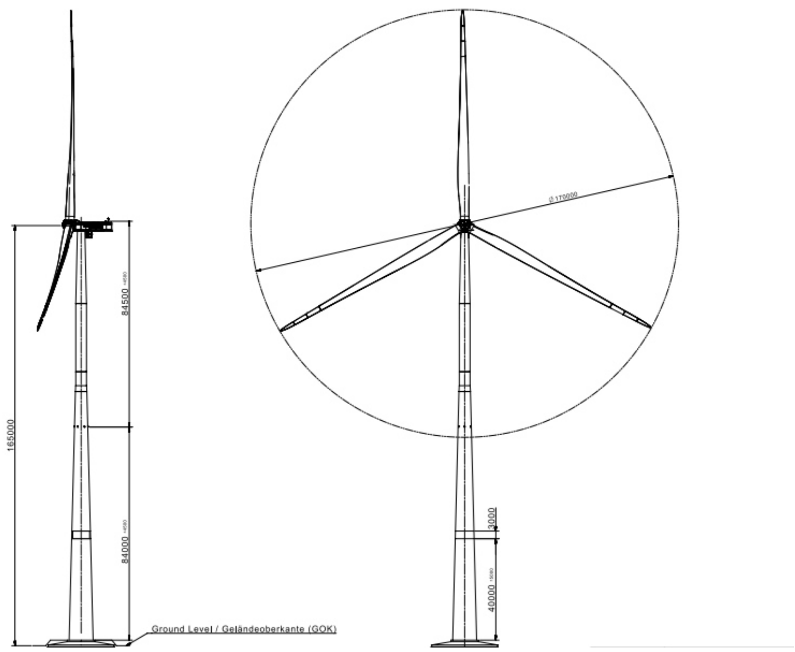
6.2. SG 6.6-170 135 m



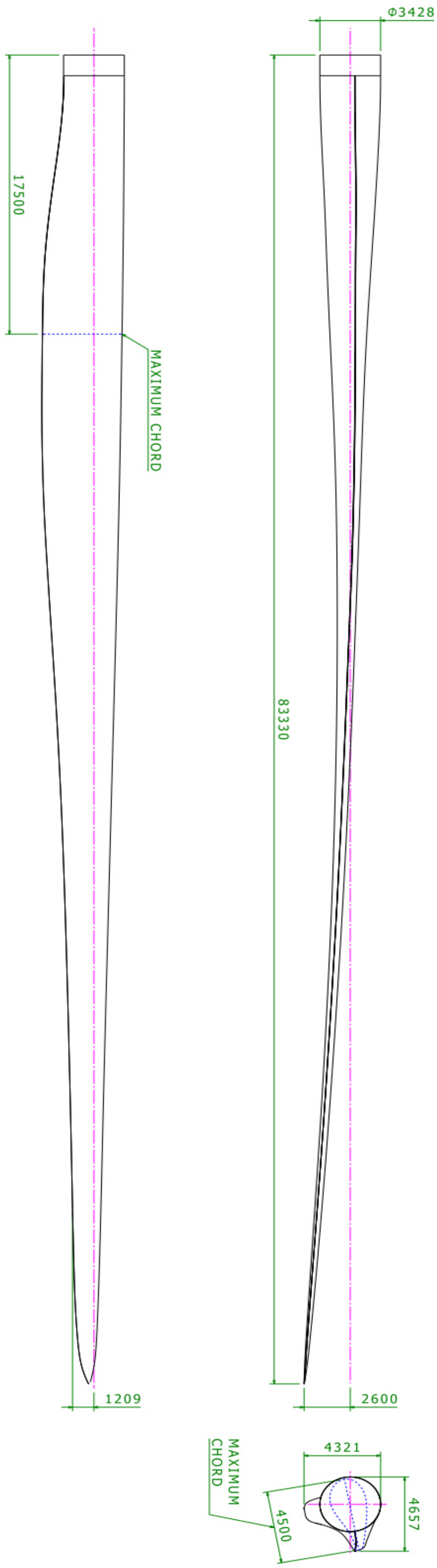
6.3. SG 6.2-170 145 m



6.4. SG 6.2-170 165 m



7. Blade Drawing



Dimensions in millimeter

8. Tower Dimensions

SG 6.2-170 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. Information about other tower heights and logistic will be available upon request.

8.1. Tower hub height 100m IIIA. Tapered tubular steel tower

T100-51A_Rev01a	Section 1	Section 2	Section 3	Section 4
External diameter upper flange (m)	4,700	4,493	4,493	3,503
External diameter lower flange (m)	4,700	4,700	4,493	4,493
Section's height (m)	14,300	21,560	26,880	34,450
Flange type [bottom-top]	T-T	T-L	L-L	L-Top
Total weight (kg)	84983	79746	76060	75793
Total Tower weight (kg)	316582			

8.2. Tower hub height 101.5m IIIA. Tapered tubular steel tower

T101.5-50A_Rev03f	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
External diameter upper flange (m)	4,297	4,500	4,495	4,495	4,100	3,503
External diameter lower flange (m)	4,500	4,500	4,500	4,495	4,495	4,100
Section's height (m)	9,930	16,520	13,440	15,960	21,000	21,850
Flange type [bottom-top]	T-T	T-L	L-L	L-L	L-L	L-Top
Total weight (kg)	65558	70497	47749	47266	47619	49717
Total Tower weight (kg)	328408					

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

T115-50A_Rev01a	Section 1	Section 2	Section 3	Section 4	Section 5
External diameter upper flange (m)	4,700	4,436	4,427	4,021	3,503
External diameter lower flange (m)	4,700	4,700	4,436	4,427	4,021
Section's height (m)	13,284	18,200	23,800	27,160	29,970
Flange type [bottom-top]	T-T	T-L	L-L	L-L	L-Top
Total weight (kg)	85636	85143	85408	73226	64918
Total Tower weight (kg)	394329				

8.4. Tower hub height 115m CS Brazil. Tapered tubular steel tower

T115-51A_Rev00a	Section 1	Section 2	Section 3	Section 4	Section 5
External diameter upper flange (m)	4,800	4,793	4,793	4,793	3,503
External diameter lower flange (m)	4,800	4,800	4,793	4,793	4,793
Section's height (m)	11,780	17,920	21,840	28,000	32,770
Flange type [bottom-top]	T-T	T-L	L-L	L-L	L-Top
Total weight (kg)	86804	84644	81556	77286	72512
Total Tower weight (kg)	402801				

8.5. Tower hub height 115m CS Germany. Tapered tubular steel tower

T115-53A_Rev01a	Section 1	Section 2	Section 3	Section 4	Section 5
External diameter upper flange (m)	4,500	4,394	4,386	4,021	3,503
External diameter lower flange (m)	4,500	4,500	4,394	4,386	4,021
Section's height (m)	12,292	16,520	21,280	30,240	32,082
Flange type [bottom-top]	T-T	T-L	L-L	L-L	L-Top
Total weight (kg)	84720	82737	81957	80443	70030
Total Tower weight (kg)	399887				

8.6. Tower hub height 135m IIIA. Tapered tubular steel tower

T135-50A_Rev00a	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
External diameter upper flange (m)	5,682	5,678	4,829	4,425	4,420	3,503
External diameter lower flange (m)	6,000	5,682	5,678	4,829	4,425	4,420
Section's height (m)	15,000	18,200	21,280	24,920	26,880	26,134
Flange type [bottom-top]	T-L	L-L	L-L	L-L	L-L	L-Top
Total weight (kg)	91066	84192	84470	81538	68371	58393
Total Tower weight (kg)	468031					

8.7. Tower hub height 145m IIIA. Tapered tubular steel tower

T145-50A_Rev05a	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8
External diameter upper flange (m)	6,400	6,400	6,400	6,400	5,750	5,100	4,450	3,503
External diameter lower flange (m)	6,400	6,400	6,400	6,400	6,400	5,750	5,100	4,450
Section's height (m)	12,320	14,000	15,680	18,200	18,480	18,480	18,480	26,890
Flange type [bottom-top]	T-L	L-L	L-L	L-L	L-L	L-L	L-L	L-Top
Total weight (kg)	80114	77176	78261	79343	69384	58990	47835	60514
Total Tower weight (kg)	551617							

8.8. Tower hub height 155m IIIA. Tapered tubular steel tower

T155-50A_Rev05b	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8
External diameter upper flange (m)	6,575	6,575	6,575	6,575	6,575	5,376	4,440	3,503
External diameter lower flange (m)	6,600	6,575	6,575	6,575	6,575	5,975	5,376	4,440
Section's height (m)	12,320	13,440	14,560	16,240	18,480	18,480	28,840	29,970
Flange type [bottom-top]	T-L	L-L	L-L	L-L	L-L	L-L	L-L	L-Top
Total weight (kg)	78474	75998	76203	77064	75154	65058	77220	65606
Total Tower weight (kg)	590777							

8.9. Tower hub height 165m CS Germany. Hybrid

T165-53A-MB_Rev02a	Concrete	Section 1	Section 2
External diameter upper flange (m)	4,528	4,292	3,503
External diameter lower flange (m)	9,148	4,300	4,292
Section's height (m)	94,69 [1)]	29,710	36,000
Flange type [bottom-top]		L-L	L-Top
Total weight (kg)		81021	69827
Total Tower weight (kg)		150848	

[1)] Raised foundation (2,3m) not included in concrete height

8.10. Tower hub height 165m IIIA. Hybrid

T165-52A-WTC_Rev01a	Concrete	Section 1	Section 2
External diameter upper flange (m)	4,920	4,271	3,503
External diameter lower flange (m)	9,400	4,500	4,271
Section's height (m)	108,000	26,320	28,380
Flange type [bottom-top]		L-L	L-Top
Total weight (kg)		68682	59345
Total Tower weight (kg)		128027	

9. Design Climatic Conditions

The design climatic conditions are the boundary conditions at which the turbine can be applied without supplementary design review. The specification in this document applies to SG 6.2-170

Applications of the wind turbine in more severe conditions may be possible, depending upon the overall circumstances.

All references made to standards such as the IEC and ISO are further specified in the document “Codes and Standards”. The design lifetime presented in the below table only applies to the fatigue load analysis performed in accordance with the presented IEC code. The term design lifetime and the use thereof do not constitute any express and/or implied warranty for actual lifetime and/or against failures on the wind turbines. Please see document for “design lifetime of wind turbine components” for more information.

Subject	ID	Issue	Unit	Value	
0. Design lifetime	0.0	Design lifetime definition	-	IEC 61400-1[1]	
	0.1	Design lifetime	years	20	25
1. Wind, operation	1.1	Wind definitions	-	IEC 61400-1	
	1.2	IEC class	-	IIIA	IIIB
	1.3	Mean air density, ρ	kg/m³	1.225	1.225
	1.4	Mean wind speed, V_{ave}	m/s	7.5	7.5
	1.5	Weibull scale parameter, A	m/s	8.46	8.46
	1.6	Weibull shape parameter, k	-	2	2
	1.7	Wind shear exponent, α	-	0.20	0.20
	1.8	Reference turbulence intensity at 15 m/s, I_{ref}	-	0.16	0.14
	1.9	Standard deviation of wind direction	Deg	-	-
	1.10	Maximum flow inclination	Deg	8	8
	1.11	Minimum turbine spacing, in rows	D	-	-
	1.12	Minimum turbine spacing, between rows	D	-	-
2. Wind, extreme	2.1	Wind definitions		IEC 61400-1	
	2.2	Air density, ρ	kg/m³	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	-	N/A	
3. 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, operation, $T_{max, o}$	Deg.C	40 [2, 3]	
	3.5	Maximum temperature at 2 m, stand-still, $T_{max, s}$	Deg.C	50	
4. Corrosion	4.1	Atmospheric-corrosivity category definitions	-	ISO 12944-2	
	4.2	Internal nacelle environment (corrosivity category)	-	C3H (std) ≥C3H (high C)	

[1] All mentioning of IEC 61400-1 refers to to IEC 61400-1:2018 Ed4.
[2] Maximum power output may be limited after an extended period of operation with a power output close to nominal power. The limitation depends on air temperature and air density as further described in the High Temperature Ride Through specification.
[3] When ambient temperature exceeds 40deg turbine will go into extended operation. Turbine will not stop until component temperature thresholds are exceeded. Actual turbine stop is expected between 42-45deg.

Subject	ID	Issue	Unit	Value
	4.3	Exterior environment (corrosivity category)	-	C3H (std) ≥C3H (high C)
5. Lightning	5.1	Lightning definitions	-	IEC61400-24:2010
	5.2	Lightning protection level (LPL)	-	LPL 1
6. 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/m^3
	6.3	Concentration of particles	mg/m^3	Peak Dust Concentration (95% time) → 0.5 mg/M^3
7. Hail	7.1	Maximum hail diameter	mm	20
	7.2	Maximum hail falling speed	m/s	20
8. Ice	8.1	Ice definitions	-	-
	8.2	Ice conditions	Days/yr	7
9. Solar radiation	9.1	Solar radiation definitions	-	IEC 61400-1
	9.2	Solar radiation intensity	W/m^2	1000
10. Humidity	10.1	Humidity definition	-	IEC 61400-1
	10.2	Relative humidity	%	Up to 95
11. 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.		
12. Precipitation[4]	12.1	Annual precipitation	mm/yr	1100

[4] The specified maximum precipitation considers standard liquid Leading Edge Protection. For sites with higher annual precipitation and/or longer lifetime, it is recommended to consider optional reinforced Leading Edge Protection.

10. Power Derating Curves by Ambient Temperature

10.1. SG 6.2-170 AM0 STD

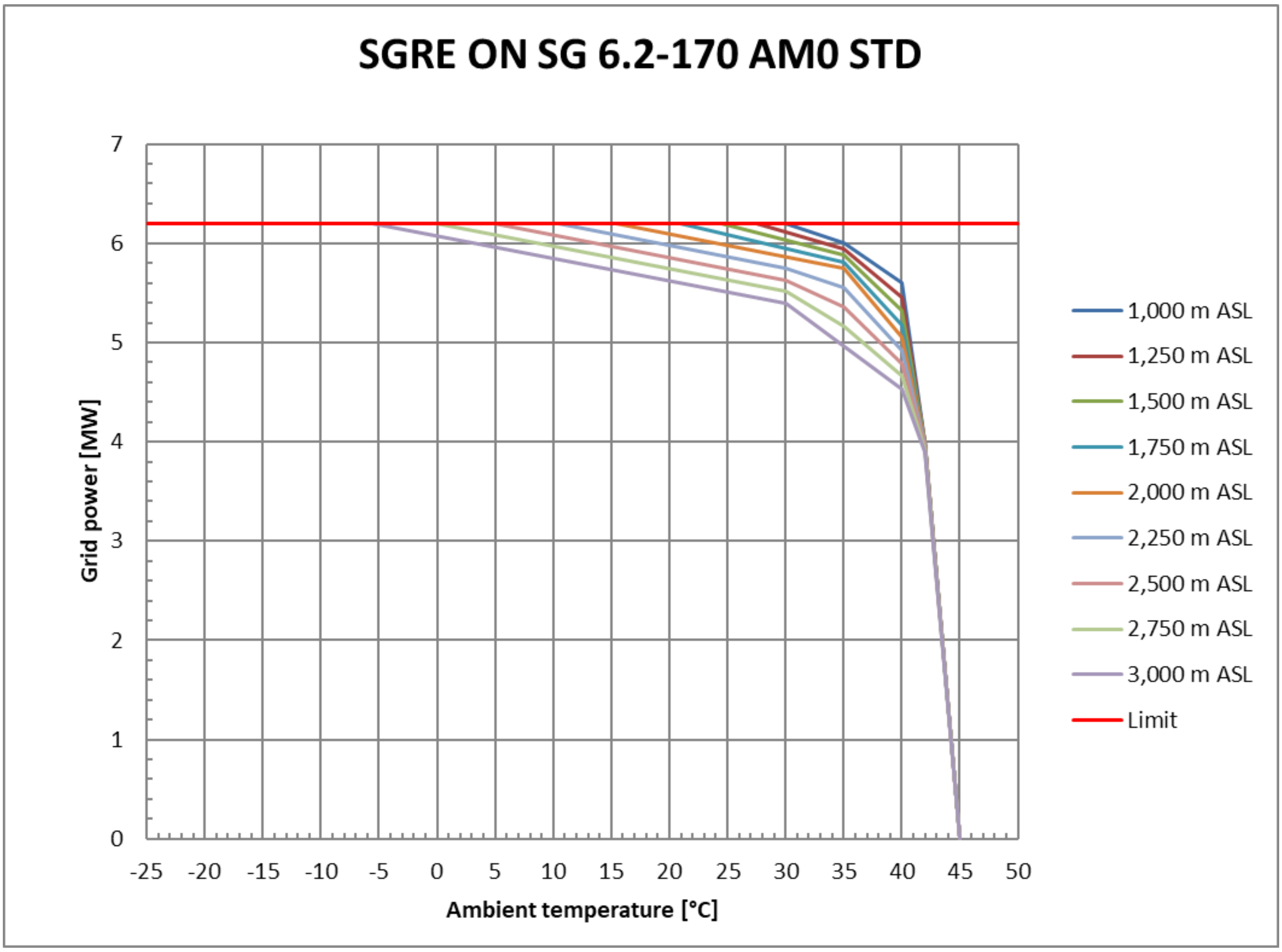


Figure 1: SG 6.2-170 AM0 STD power derating curves by ambient temperature and altitude

Table 1: SG 6.2-170 AM0 STD grid power as function of ambient temperature and altitude

SGRE ON SG 6.2-170 AM0 STD		6.20	MW	8.83	RPM		15-10-2021 / Z003FEFJ
Altitude						**1,000 m ASL**	
Temp.	**°C**	**30**	**35**	**40**	**42**	**45**	
Power	**MW**	**6.2**	**6**	**5.6**	**4**	**0**	
Load	**-**	**1**	**0.97**	**0.9**	**0.65**	**0**	
Altitude						1,250 m ASL	
Temp.	°C	27.5	35	40	42	45	
Power	MW	6.2	5.94	5.46	4	0	
Load	-	1	0.96	0.88	0.65	0	
Altitude						1,500 m ASL	
Temp.	°C	24.5	35	40	42	45	
Power	MW	6.2	5.88	5.32	4	0	
Load	-	1	0.95	0.86	0.65	0	
Altitude						1,750 m ASL	
Temp.	°C	21	35	40	42	45	
Power	MW	6.2	5.81	5.18	4	0	
Load	-	1	0.94	0.84	0.65	0	
Altitude						**2,000 m ASL**	
Temp.	**°C**	**15.5**	**35**	**40**	**42**	**45**	
Power	**MW**	**6.2**	**5.75**	**5.05**	**4**	**0**	
Load	**-**	**1**	**0.93**	**0.81**	**0.65**	**0**	
Altitude						2,250 m ASL	
Temp.	°C	10.5	30	35	40	42	45
Power	MW	6.2	5.75	5.55	4.92	3.97	0
Load	-	1	0.93	0.9	0.79	0.64	0
Altitude						2,500 m ASL	
Temp.	°C	5	30	35	40	42	45
Power	MW	6.2	5.63	5.36	4.79	3.95	0
Load	-	1	0.91	0.86	0.77	0.64	0
Altitude						2,750 m ASL	
Temp.	°C	0	30	35	40	42	45
Power	MW	6.2	5.52	5.16	4.66	3.92	0
Load	-	1	0.89	0.83	0.75	0.63	0
Altitude						**3,000 m ASL**	
Temp.	**°C**	**-5.5**	**30**	**40**	**42**	**45**	
Power	**MW**	**6.2**	**5.4**	**4.53**	**3.9**	**0**	
Load	**-**	**1**	**0.87**	**0.73**	**0.63**	**0**	

Table 2: SG 6.2-170 AM0 STD ambient temperature as function of grid power and altitude

SGRE ON SG 6.2-170 AM0 STD				6.2	MW		8.83	RPM		15-10-2021 / Z003FEFJ
Altitude	**m ASL**	**1,000**	**1,250**	**1,500**	**1,750**	**2,000**	**2,250**	**2,500**	**2,750**	**3,000**
Power	**MW**				**Ambient temperature (°C)**					
6.2		**-20**	-20	-20	-20	**-20**	-20	-20	-20	**-20**
6.2		**30**	27.5	24.5	21	**15.5**	10.5	5	0	**-5.5**
6.1		**32.5**	30.5	28	24.5	**20**	14.5	9.5	4.5	**-1**
6.0		**35**	33.5	31	28	**24**	19	14	8.5	**3.5**
5.9		**36.5**	35.5	34	32	**28.5**	23.5	18.5	13	**8**
5.8		**37.5**	36.5	35.5	35	**33**	27.5	22.5	17.5	**12.5**
5.7		**39**	37.5	36.5	36	**35.5**	31	27	22	**17**
5.6		**40**	38.5	37.5	36.5	**36**	34	30.5	26.5	**21**
5.5			39.5	38.5	37.5	**37**	35.5	32.5	30	**25.5**
5.4			40	39.5	38.5	**37.5**	36	34.5	31.5	**30**
5.3				40	39	**38**	37	35.5	33	**31**
5.2		**40.5**			40	**39**	38	36.5	34.5	**32.5**
5.1						**39.5**	38.5	37.5	35.5	**33.5**
5.0			40.5			**40**	39.5	38	36.5	**34.5**
4.9				40.5		**40.5**	40	39	37.5	**35.5**
4.8		**41**			40.5			40	38.5	**37**
4.7			41						39.5	**38**
4.6				41			40.5		40	**39**
4.5					41	**41**		40.5	40.5	**40**
4.4		**41.5**					41			**40.5**
4.3			41.5	41.5				41		
4.2					41.5	**41.5**	41.5		41	**41**
4.1								41.5	41.5	
4.0		**42**	42	42	42	**42**				**41.5**
3.9							42	42	42	**42**
3.3		**42.5**	42.5	42.5	42.5	**42.5**	42.5			
3.2								42.5	42.5	**42.5**
2.6		**43**	43	43	43	**43**	43	43	43	**43**
2.0		**43.5**	43.5	43.5	43.5	**43.5**				
1.9							43.5	43.5	43.5	**43.5**
1.3		**44**	44	44	44	**44**	44	44	44	**44**
0.6		**44.5**	44.5	44.5	44.5	**44.5**	44.5	44.5	44.5	**44.5**
0.0		**45**	45	45	45	**45**	45	45	45	**45**

10.1.1. SG 6.2-170 AM0 HT

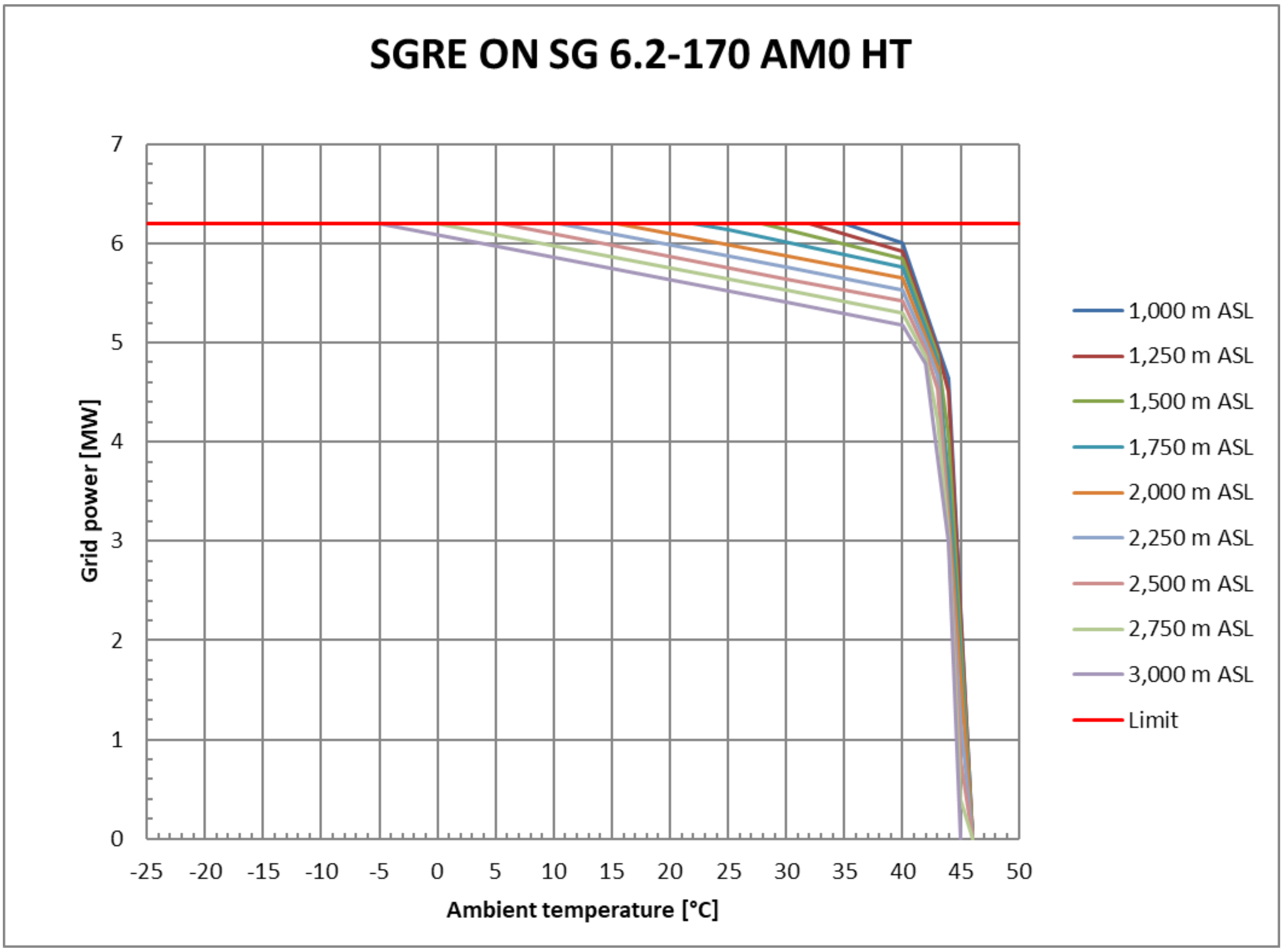


Figure 2: SG 6.2-170 AM0 HT power derating curves by ambient temperature and altitude

Table 3: SG 6.2-170 AM0 HT grid power as function of ambient temperature and altitude

SGRE ON SG 6.2-170 AM0 HT				6.20	MW	8.83	RPM		15-10-2021 / Z003FEFJ
Altitude						**1,000 m ASL**			
Temp.	**°C**	**35**	**40**	**44**	**46**				
Power	**MW**	**6.2**	**6**	**4.64**	**0**				
Load	**-**	**1**	**0.97**	**0.75**	**0**				
Altitude						1,250 m ASL			
Temp.	°C	32	40	43	44	46			
Power	MW	6.2	5.92	4.92	4.51	0			
Load	-	1	0.96	0.79	0.73	0			
Altitude						1,500 m ASL			
Temp.	°C	28	40	43	44	46			
Power	MW	6.2	5.84	4.87	4.06	0			
Load	-	1	0.94	0.79	0.65	0			
Altitude						1,750 m ASL			
Temp.	°C	22	25	40	43	44	46		
Power	MW	6.2	6.14	5.76	4.81	3.61	0		
Load	-	1	0.99	0.93	0.78	0.58	0		
Altitude						**2,000 m ASL**			
Temp.	**°C**	**15.5**	**40**	**43**	**46**				
Power	**MW**	**6.2**	**5.65**	**4.75**	**0**				
Load	**-**	**1**	**0.91**	**0.77**	**0**				
Altitude						2,250 m ASL			
Temp.	°C	10.5	30	40	42	43	44	45	46
Power	MW	6.2	5.76	5.53	4.99	4.66	3.12	1.19	0
Load	-	1	0.93	0.89	0.8	0.75	0.5	0.19	0
Altitude						2,500 m ASL			
Temp.	°C	5.5	30	40	42	43	44	45	46
Power	MW	6.2	5.64	5.42	4.92	4.53	3.08	0.79	0
Load	-	1	0.91	0.87	0.79	0.73	0.5	0.13	0
Altitude						2,750 m ASL			
Temp.	°C	0	30	40	42	43	44	45	46
Power	MW	6.2	5.53	5.3	4.86	4.21	3.04	0.39	0
Load	-	1	0.89	0.85	0.78	0.68	0.49	0.06	0
Altitude						**3,000 m ASL**			
Temp.	**°C**	**-5**	**30**	**40**	**42**	**44**	**45**		
Power	**MW**	**6.2**	**5.41**	**5.18**	**4.79**	**2.99**	**0**		
Load	**-**	**1**	**0.87**	**0.84**	**0.77**	**0.48**	**0**		

Table 4: SG 6.2-170 AM0 HT ambient temperature as function of grid power and altitude

SGRE ON SG 6.2-170 AM0 HT				6.2	MW	8.83	RPM		15-10-2021 / Z003FEFJ	
Altitude	**m ASL**	**1,000**	**1,250**	**1,500**	**1,750**	**2,000**	**2,250**	**2,500**	**2,750**	**3,000**
Power	**MW**				Ambient temperature (°C)					
6.2		**-20**	-20	-20	-20	**-20**	-20	-20	-20	**-20**
6.2		**35**	32	28	22	**15.5**	10.5	5.5	0	**-5**
6.1		**37.5**	35	31.5	26.5	**20**	15	9.5	4.5	**-0.5**
6.0		**40**	38	35	30.5	**24.5**	19.5	14	9	**3.5**
5.9		**40.5**	40	38	34.5	**29**	24	18.5	13.5	**8**
5.8			40.5	40	38.5	**33.5**	28	23	18	**12.5**
5.7				40.5	40	**38**	32.5	27.5	22.5	**17**
5.6		**41**			40.5	**40**	37	32	26.5	**21.5**
5.5			41	41	41	**40.5**	40	36.5	31	**26**
5.4		**41.5**	41.5			**41**	40.5	40	35.5	**30.5**
5.3		**42**		41.5			41	40.5	40	**35**
5.2			42		41.5	**41.5**		41	40.5	**39**
5.1		**42.5**		42	42		41.5	41.5	41	**40.5**
5.0			42.5	42.5		**42**			41.5	**41**
4.9		**43**	43		42.5	**42.5**	42	42	42	**41.5**
4.8		**43.5**		43	43		42.5			**42**
4.7			43.5			**43**		42.5		
4.6		**44**					43			
4.5			44					43	42.5	
4.4				43.5						
4.3										**42.5**
4.2					43.5				43	
4.0				44						
3.9						**43.5**				
3.8							43.5	43.5		**43**
3.6					44				43.5	
3.4		**44.5**								**43.5**
3.3			44.5							
3.1						**44**	44			
3.0				44.5				44	44	
2.9										**44**
2.7					44.5					
2.3		**45**				**44.5**				
2.2			45							
2.1							44.5			
2.0				45						
1.9								44.5		
1.8					45					
1.7									44.5	
1.5						**45**				
1.4										**44.5**

SGRE ON SG 6.2-170 AM0 HT		6.2	MW	8.83	RPM	15-10-2021 / Z003FEFJ				

Altitude	m ASL	1,000	1,250	1,500	1,750	2,000	2,250	2,500	2,750	3,000
Power	MW	Ambient temperature (°C)								
1.1		**45.5**	45.5				45			
1.0				45.5						
0.9					45.5					
0.7						**45.5**		45		
0.5							45.5			
0.3								45.5	45	
0.1									45.5	
0.0		**46**	46	46	46	**46**	46	46	46	**45**

10.2. SG 6.2-170 AM+2 STD

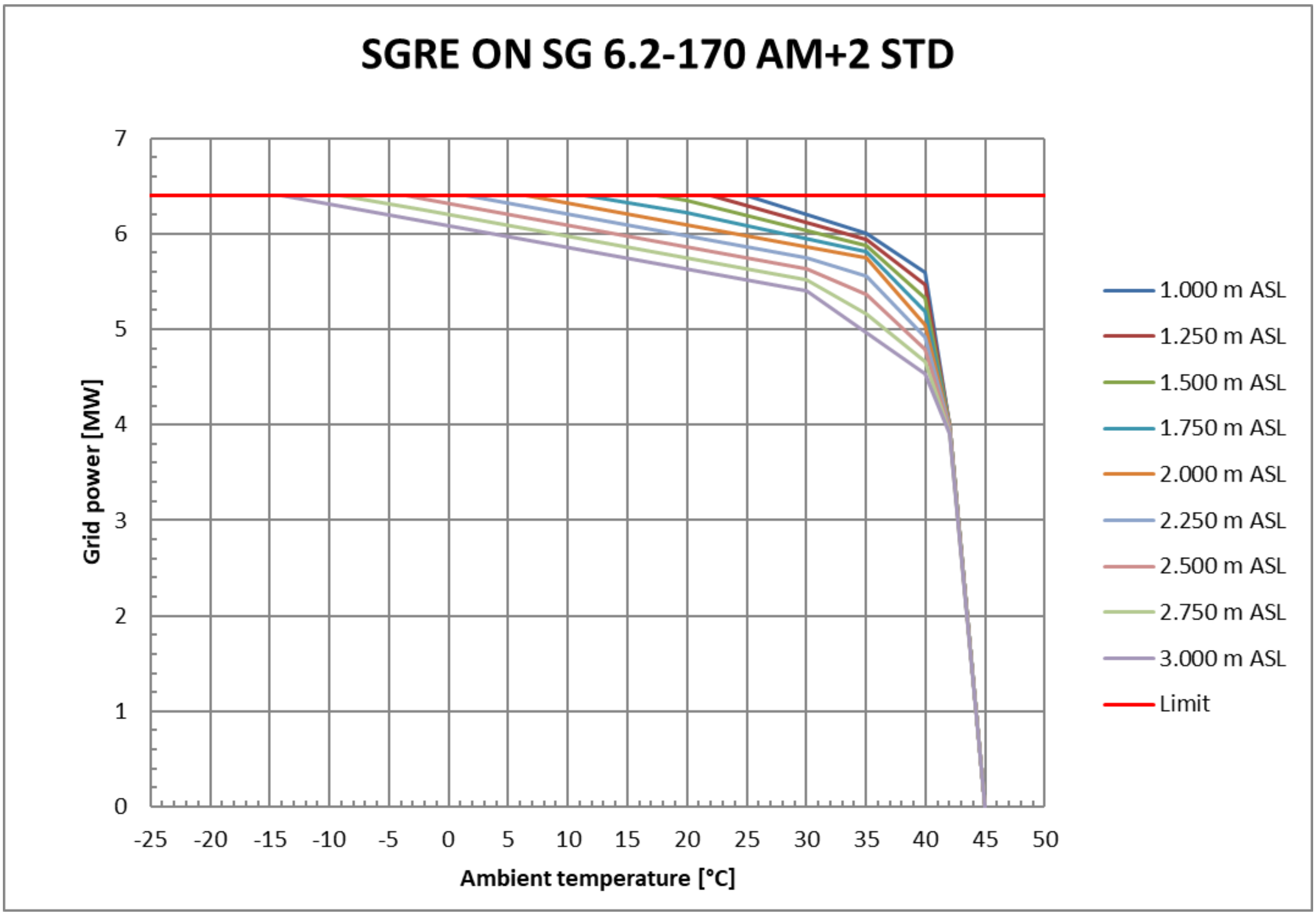


Figure 3: SG 6.2-170 AM0 STD power derating curves by ambient temperature and altitude

SGRE ON SG 6.2-170 AM+2 STD 6,40 MW 8,83 RPM 20-01-2022 / Z003FEFJ

Altitude							**1.000 m ASL**	
Temp.	**°C**	**25**	**35**	**40**	**42**	**45**		
Power	**MW**	**6,4**	**6**	**5,6**	**4**	**0**		
Load	**-**	**1**	**0,94**	**0,88**	**0,63**	**0**		
Altitude							1.250 m ASL	
Temp.	°C	22	35	40	42	45		
Power	MW	6,4	5,94	5,46	4	0		
Load	-	1	0,93	0,85	0,63	0		
Altitude							1.500 m ASL	
Temp.	°C	17,5	20	35	40	42	45	
Power	MW	6,4	6,35	5,88	5,32	4	0	
Load	-	1	0,99	0,92	0,83	0,63	0	
Altitude							1.750 m ASL	
Temp.	°C	11,5	20	35	40	42	45	
Power	MW	6,4	6,22	5,81	5,18	4	0	
Load	-	1	0,97	0,91	0,81	0,63	0	
Altitude							**2.000 m ASL**	
Temp.	**°C**	**6,5**	**35**	**40**	**42**	**45**		
Power	**MW**	**6,4**	**5,75**	**5,05**	**4**	**0**		
Load	**-**	**1**	**0,9**	**0,79**	**0,63**	**0**		
Altitude							2.250 m ASL	
Temp.	°C	1,5	30	35	40	42	45	
Power	MW	6,4	5,75	5,55	4,92	3,97	0	
Load	-	1	0,9	0,87	0,77	0,62	0	
Altitude							2.500 m ASL	
Temp.	°C	-3,5	-2	30	35	40	42	45
Power	MW	6,4	6,36	5,63	5,36	4,79	3,95	0
Load	-	1	0,99	0,88	0,84	0,75	0,62	0
Altitude							2.750 m ASL	
Temp.	°C	-9	-2	30	35	40	42	45
Power	MW	6,4	6,24	5,52	5,16	4,66	3,92	0
Load	-	1	0,98	0,86	0,81	0,73	0,61	0
Altitude							**3.000 m ASL**	
Temp.	**°C**	**-14**	**30**	**40**	**42**	**45**		
Power	**MW**	**6,4**	**5,4**	**4,53**	**3,9**	**0**		
Load	**-**	**1**	**0,84**	**0,71**	**0,61**	**0**		

Table 5: SG 6.2-170 AM0 STD grid power as function of ambient temperature and altitude

SGRE ON SG 6.2-170 AM+2 STD			6,4	MW		8,83	RPM		20-01-2022 / Z003FEFJ

Altitude	m ASL	1.000	1.250	1.500	1.750	2.000	2.250	2.500	2.750	3.000
Power	MW					Ambient temperature (°C)				
6,4		**-20**	-20	-20	-20	**-20**	-20	-20	-20	**-20**
6,4		**25**	22	17,5	11,5	**6,5**	1,5	-3,5	-9	**-14**
6,3		**27,5**	25	21,5	16,5	**11**	6	1	-4,5	**-10**
6,2		**30**	27,5	24,5	21	**15,5**	10,5	5	0	**-5,5**
6,1		**32,5**	30,5	28	24,5	**20**	14,5	9,5	4,5	**-1**
6,0		**35**	33,5	31	28	**24**	19	14	8,5	**3,5**
5,9		**36,5**	35,5	34	32	**28,5**	23,5	18,5	13	**8**
5,8		**37,5**	36,5	35,5	35	**33**	27,5	22,5	17,5	**12,5**
5,7		**39**	37,5	36,5	36	**35,5**	31	27	22	**17**
5,6		**40**	38,5	37,5	36,5	**36**	34	30,5	26,5	**21**
5,5			39,5	38,5	37,5	**37**	35,5	32,5	30	**25,5**
5,4			40	39,5	38,5	**37,5**	36	34,5	31,5	**30**
5,3				40	39	**38**	37	35,5	33	**31**
5,2		**40,5**			40	**39**	38	36,5	34,5	**32,5**
5,1						**39,5**	38,5	37,5	35,5	**33,5**
5,0			40,5			**40**	39,5	38	36,5	**34,5**
4,9				40,5		**40,5**	40	39	37,5	**35,5**
4,8		**41**			40,5			40	38,5	**37**
4,7			41						39,5	**38**
4,6				41			40,5		40	**39**
4,5					41	**41**		40,5	40,5	**40**
4,4		**41,5**					41			**40,5**
4,3			41,5	41,5				41		
4,2					41,5	**41,5**	41,5		41	**41**
4,1								41,5	41,5	
4,0		**42**	42	42	42	**42**				**41,5**
3,9							42	42	42	**42**
3,3		**42,5**	42,5	42,5	42,5	**42,5**	42,5			
3,2								42,5	42,5	**42,5**
2,6		**43**	43	43	43	**43**	43	43	43	**43**
2,0		**43,5**	43,5	43,5	43,5	**43,5**				
1,9							43,5	43,5	43,5	**43,5**
1,3		**44**	44	44	44	**44**	44	44	44	**44**
0,6		**44,5**	44,5	44,5	44,5	**44,5**	44,5	44,5	44,5	**44,5**
0,0		**45**	45	45	45	**45**	45	45	45	**45**

Table 6: SG 6.2-170 AM0 STD ambient temperature as function of grid power and altitude

10.2.1. SG 6.2-170 AM+2 HT

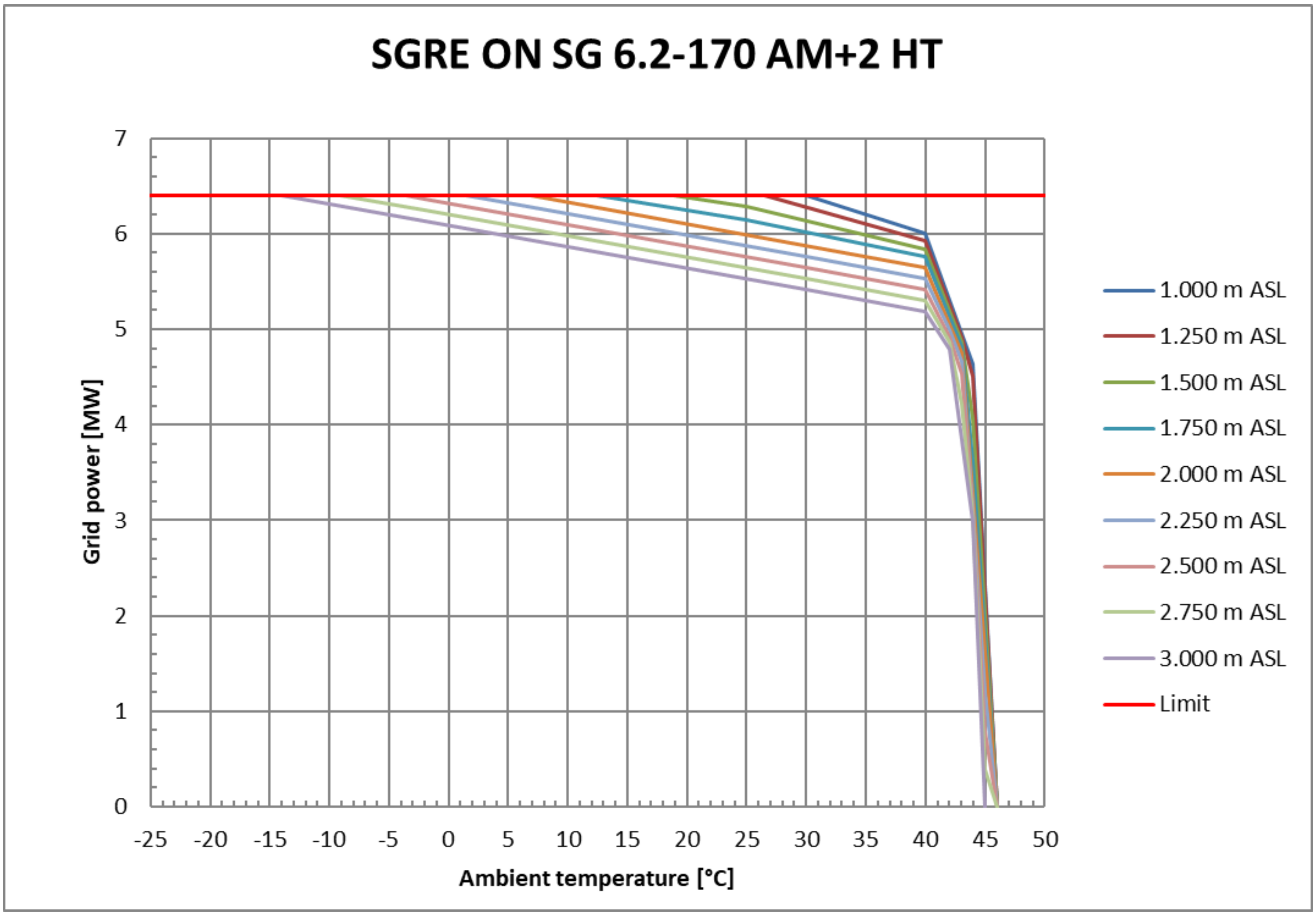


Figure 4: SG 6.2-170 AM0 HT power derating curves by ambient temperature and altitude

SGRE ON SG 6.2-170 AM+2 HT	6,40	MW	8,83	RPM	20-01-2022 / Z003FEFJ

Altitude						**1.000 m ASL**				
Temp.	**°C**	**30**	**40**	**44**	**46**					
Power	**MW**	**6,4**	**6**	**4,64**	**0**					
Load	**-**	**1**	**0,94**	**0,73**	**0**					
Altitude						1.250 m ASL				
Temp.	°C	26,5	40	43	44	46				
Power	MW	6,4	5,92	4,92	4,51	0				
Load	-	1	0,93	0,77	0,7	0				
Altitude						1.500 m ASL				
Temp.	°C	19	25	40	43	44	46			
Power	MW	6,4	6,29	5,84	4,87	4,06	0			
Load	-	1	0,98	0,91	0,76	0,63	0			
Altitude						1.750 m ASL				
Temp.	°C	12,5	25	40	43	44	46			
Power	MW	6,4	6,14	5,76	4,81	3,61	0			
Load	-	1	0,96	0,9	0,75	0,56	0			
Altitude						**2.000 m ASL**				
Temp.	**°C**	**7**	**40**	**43**	**46**					
Power	**MW**	**6,4**	**5,65**	**4,75**	**0**					
Load	**-**	**1**	**0,88**	**0,74**	**0**					
Altitude						2.250 m ASL				
Temp.	°C	1,5	30	40	42	43	44	45	46	
Power	MW	6,4	5,76	5,53	4,99	4,66	3,12	1,19	0	
Load	-	1	0,9	0,86	0,78	0,73	0,49	0,19	0	
Altitude						2.500 m ASL				
Temp.	°C	-3,5	-2	30	40	42	43	44	45	46
Power	MW	6,4	6,36	5,64	5,42	4,92	4,53	3,08	0,79	0
Load	-	1	0,99	0,88	0,85	0,77	0,71	0,48	0,12	0
Altitude						2.750 m ASL				
Temp.	°C	-9	-2	30	40	42	43	44	45	46
Power	MW	6,4	6,25	5,53	5,3	4,86	4,21	3,04	0,39	0
Load	-	1	0,98	0,86	0,83	0,76	0,66	0,48	0,06	0
Altitude						**3.000 m ASL**				
Temp.	**°C**	**-14**	**30**	**40**	**42**	**44**	**45**			
Power	**MW**	**6,4**	**5,41**	**5,18**	**4,79**	**2,99**	**0**			
Load	**-**	**1**	**0,85**	**0,81**	**0,75**	**0,47**	**0**			

Table 7: SG 6.2-170 AM0 HT grid power as function of ambient temperature and altitude

SGRE ON SG 6.2-170 AM+2 HT			6,4	MW		8,83	RPM		20-01-2022 / Z003FEFJ

Altitude	m ASL	1.000	1.250	1.500	1.750	2.000	2.250	2.500	2.750	3.000
Power	MW				Ambient temperature (°C)					
6,4		**-20**	-20	-20	-20	**-20**	-20	-20	-20	**-20**
6,4		**30**	26,5	19	12,5	**7**	1,5	-3,5	-9	**-14**
6,3		**32,5**	29	24,5	17,5	**11,5**	6	1	-4,5	**-9,5**
6,2		**35**	32	28	22	**15,5**	10,5	5,5	0	**-5**
6,1		**37,5**	35	31,5	26,5	**20**	15	9,5	4,5	**-0,5**
6,0		**40**	38	35	30,5	**24,5**	19,5	14	9	**3,5**
5,9		**40,5**	40	38	34,5	**29**	24	18,5	13,5	**8**
5,8			40,5	40	38,5	**33,5**	28	23	18	**12,5**
5,7				40,5	40	**38**	32,5	27,5	22,5	**17**
5,6		**41**			40,5	**40**	37	32	26,5	**21,5**
5,5			41	41	41	**40,5**	40	36,5	31	**26**
5,4		**41,5**	41,5			**41**	40,5	40	35,5	**30,5**
5,3		**42**		41,5			41	40,5	40	**35**
5,2			42		41,5	**41,5**		41	40,5	**39**
5,1		**42,5**		42	42		41,5	41,5	41	**40,5**
5,0			42,5	42,5		**42**			41,5	**41**
4,9		**43**	43		42,5	**42,5**	42	42	42	**41,5**
4,8		**43,5**		43	43		42,5			**42**
4,7			43,5			**43**		42,5		
4,6		**44**					43			
4,5			44					43	42,5	
4,4				43,5						
4,3										**42,5**
4,2					43,5				43	
4,0				44						
3,9						**43,5**				
3,8							43,5	43,5		**43**
3,6					44				43,5	
3,4		**44,5**								**43,5**
3,3			44,5							
3,1						**44**	44			
3,0				44,5				44	44	
2,9										**44**
2,7					44,5					
2,3		**45**				**44,5**				
2,2			45							
2,1							44,5			
2,0				45						
1,9								44,5		
1,8					45					
1,7									44,5	
1,5						**45**				
1,4										**44,5**
1,1		**45,5**	45,5				45			

1,0			45,5						
0,9				45,5					
0,7					**45,5**		45		
0,5						45,5			
0,3							45,5	45	
0,1								45,5	
0,0	**46**	46	46	46	**46**	46	46	46	**45**

Table 8: SG 6.2-170 AM0 HT ambient temperature as function of grid power and altitude

11. Flexible Rating Specifications ®

The SG 6.2-170 is offered with various operational modes that are achieved through the flexible operating capacity of the product, enabling the configuration of an optimal power rating that is best suited for each wind farm. The operating modes are broadly divided into two categories: Application Modes and Noise Reduction System Modes[5].

12. Application Modes

Application Modes ensure optimal turbine performance with maximum power rating allowed by the structural and electrical systems of the turbine. There are multiple Application Modes, offering flexibility of different power ratings. All Application Modes are part of the turbine Certificate.
SG 6.2-170 can offer increased operation flexibility with modes based on AM 0 with reduced power rating. For SG 6.2-170 there are as well two application modes with increased rating. These modes are created with same noise performance of the corresponding Application Mode 0 (full rated power) but with different rating and temperature de-rating than the corresponding Application Mode 0. In addition, the turbine's electrical performance is constant for the full set of application modes, as shown on the table below.
The SG 6.2-170 is designed with a base wind class, applicable to AM 0, of IEC IIIA for 20 year lifetime as well as IEC IIIB for 25 year lifetime. All other Application Modes may be analyzed for more demanding site conditions.

12.1. Full list of Application Modes SG 6.2-170

Rotor Configuration	Application mode	Rating [MW]	Noise [dB(A)]	Power Curve Document	Acoustic Emission Document	Electrical Performance			Max temperature With Max active power and electrical capabilities[6]
						Cos Phi	Voltage Range	Frequency range	
SG 6.2-170	AM +2	6.4	106	D3071271	D3071321	0.9	[0.95,1.12] Un	±3% Fn	25ºC
SG 6.2-170	AM +1	6.3	106	D3071274	D3071333	0.9	[0.95,1.12] Un	±3% Fn	28ºC
SG 6.2-170	AM 0	6.2	106	D2075729	D2359593	0.9	[0.95,1.12] Un	±3% Fn	30ºC
SG 6.2-170	AM-1	6.1	106	D2356499	D2359593	0.9	[0.95,1.12] Un	±3% Fn	33ºC
SG 6.2-170	AM-2	6.0	106	D2356509	D2359593	0.9	[0.95,1.12] Un	±3% Fn	35ºC
SG 6.2-170	AM-3	5.9	106	D2356523	D2359593	0.9	[0.95,1.12] Un	±3% Fn	37ºC
SG 6.2-170	AM-4	5.8	106	D2356539	D2359593	0.9	[0.95,1.12] Un	±3% Fn	38ºC

[5] It should be noted that the definition of various modes as described in this chapter is applicable in combination with standard temperature limits and grid capabilities of the turbine. Please refer to High Temperature Power De-rating Specification and Reactive Power Capability Document for more information
[6] Please Refer to "Power De-rating Specification" for more details'

SG 6.2-170	AM-5	5.7	106	D2356376	D2359593	0.9	[0.95,1.12] Un	±3% Fn	39ºC
SG 6.2-170	AM-6	5.6	106	D2356368	D2359593	0.9	[0.95,1.12] Un	±3% Fn	40ºC

12.2. Noise Reduction System (NRS) Modes ®

The Noise Reduction System is an optional module available with the basic SCADA configuration and it therefore requires the presence of a SGRE SCADA system to work. NRS Modes are noise curtailed modes enabled by the Noise Reduction System. 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.

Noise control is achieved through the reduction of active power and rotational speed of the wind turbine. This reduction is dependent on the wind speed. The Noise Reduction System always controls the noise settings of each turbine to the most appropriate level, in order to keep the noise emissions within the limits allowed. Sound Power Levels correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade.

12.3. List of NRS Modes SG 6.2-170

Rotor Configuration	NRS Mode	Rating [MW]	Noise [dB(A)]	Power Curve Document	Acoustic Emission Document	Max temperature With Max active power and electrical capabilities[7]
SG 6.2-170	N1	6.00	105.5	D2323420	D2359593	30ºC
SG 6.2-170	N2	5.80	104.5	D2314784	D2359593	30ºC
SG 6.2-170	N3	5.24	103.0	D2314785	D2359593	30ºC
SG 6.2-170	N4	5.12	102.0	D2314786	D2359593	30ºC
SG 6.2-170	N5	4.87	101.0	D2314787	D2359593	30ºC
SG 6.2-170	N6	4.52	100.0	D2314788	D2359593	30ºC
SG 6.2-170	N7	3.60	99.0	D2314789	D2359593	30ºC
SG 6.2-170	N8	2.60	98.0	D2460509	D2460507	30ºC

12.4. Control Strategy

The Application Modes are implemented and controlled in the Wind Turbine Controller. The NRS modes are also handled in the SCADA, however it shall also be possible to deploy custom NRS modes from the SCADA to the Wind Turbine Controller.

[7] Please refer to “High Temperature Ride Through” for more details’.

13. Standard Ct and Power Curve, Rev. 0, Mode AM 0

13.1. Standard Power Curve, Application Mode - AM 0

Air density= 1.225 kg/m^3

Validity range:

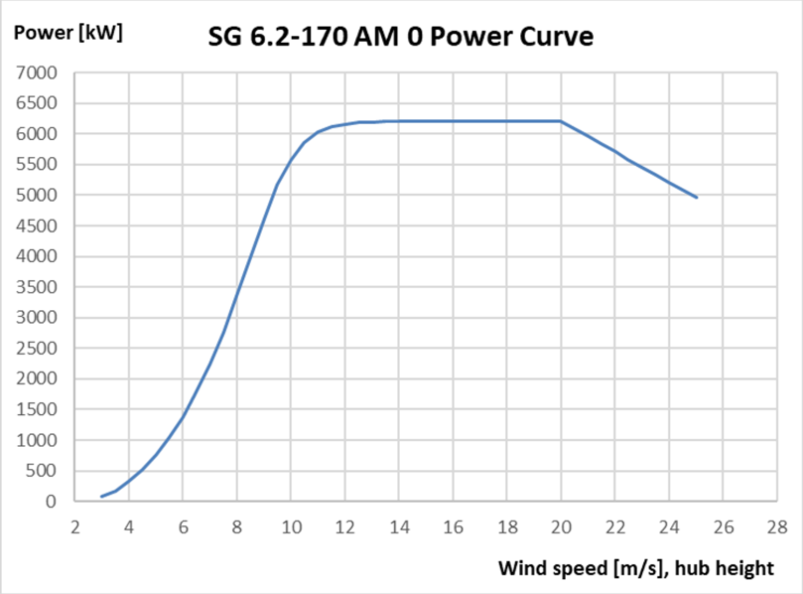
Wind Shear (10min average)	≤ 0.3
Turbulence intensity TI [%] for bin i	$5\%\frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\%\frac{(0.75v_i + 5.6)}{v_i}$
Terrain	Not complex according to IEC 61400-12-1
Upflow β [°]	-2° ≤ β ≤ +2°
Grid frequency [Hz]	± 0.5 Hz

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

Next table shows the electrical power as a function of wind speed in 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.

For a detailed description of Application Mode – AM 0, please refer to latest version of Flexible Rating Specification (D2316244).

SG 6.2-170 Rev. 0, AM 0	
Wind Speed [m/s]	Power [kW]
3.0	89
3.5	178
4.0	328
4.5	522
5.0	758
5.5	1040
6.0	1376
6.5	1771
7.0	2230
7.5	2758
8.0	3351
8.5	3988
9.0	4617
9.5	5166
10.0	5584
10.5	5862
11.0	6028
11.5	6117
12.0	6161
12.5	6183
13.0	6192
13.5	6197
14.0	6199
14.5	6199
15.0	6200
15.5	6200
16.0	6200
16.5	6200
17.0	6200
17.5	6200
18.0	6200
18.5	6200
19.0	6200
19.5	6200
20.0	6200
20.5	6080
21.0	5956
21.5	5832
22.0	5708
22.5	5584
23.0	5460
23.5	5336
24.0	5212
24.5	5088
25.0	4964



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	12624	15003	17272	19392	21337	23092	24653	26018	27192	28185	29009
	2.0	11514	14363	17198	19937	22528	24939	27150	29151	30937	32503	33853
	2.5	10370	13438	16625	19798	22856	25732	28389	30811	32995	34946	36669

Annual Production [MWh] SG 6.2-170 Rev 0, AM 0 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

13.2. Standard Ct Curve, Application Mode - AM 0

Air density= 1.225 kg/m^3

Validity range:

Wind Shear (10min average)	≤ 0.3
Turbulence intensity TI [%] for bin i	$5\% \frac{(0.75 v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75 v_i + 5.6)}{v_i}$
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, substantially horizontal, 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]

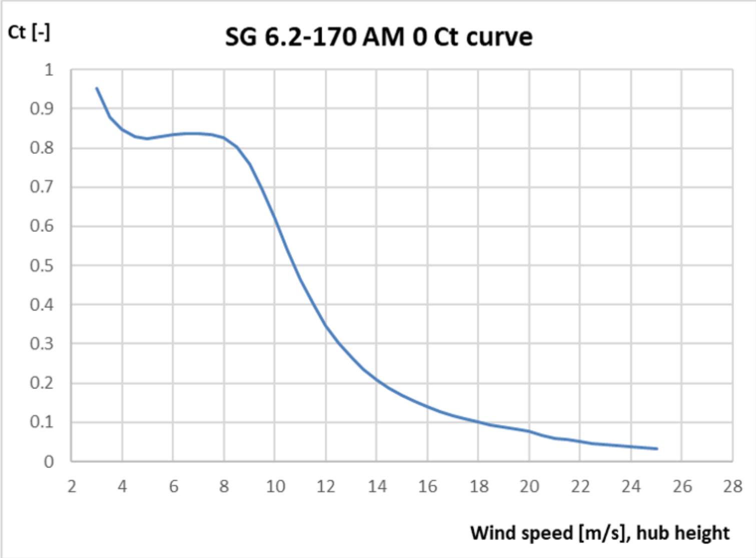
ad = Air density [kg/m^3]

w = Wind speed [m/s]

A = Swept area of rotor [m^2]

For a detailed description of Application Mode - AM 0, please refer to latest version of Flexible Rating Specification (D2316244).

SG 6.2-170 Rev. 0, AM 0	
Wind Speed [m/s]	Ct [-]
3.0	0.953
3.5	0.880
4.0	0.847
4.5	0.828
5.0	0.824
5.5	0.828
6.0	0.833
6.5	0.836
7.0	0.837
7.5	0.835
8.0	0.825
8.5	0.802
9.0	0.759
9.5	0.696
10.0	0.620
10.5	0.541
11.0	0.466
11.5	0.402
12.0	0.347
12.5	0.303
13.0	0.266
13.5	0.235
14.0	0.209
14.5	0.187
15.0	0.169
15.5	0.153
16.0	0.139
16.5	0.127
17.0	0.117
17.5	0.108
18.0	0.100
18.5	0.093
19.0	0.087
19.5	0.082
20.0	0.077
20.5	0.066
21.0	0.060
21.5	0.055
22.0	0.051
22.5	0.047
23.0	0.043
23.5	0.040
24.0	0.037
24.5	0.034
25.0	0.032



14. Standard Ct and Power Curve, Rev. 0, AM 0 – Air Density

14.1. Standard Power Curve, Application Mode – AM 0

Air density= [1.06, 1.27] kg/m^3

Validity range:

Wind Shear (10min average)	≤ 0.3
Turbulence intensity TI [%] for bin i	$5\% \frac{(0.75\mathrm{v_i} + 5.6)}{\mathrm{v_i}} < \mathrm{TI_i} < 12\% \frac{(0.75\mathrm{v_i} + 5.6)}{\mathrm{v_i}}$
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, substantially horizontal, undisturbed air flow, turbine operated within nominal limits according to the Electrical Specification.

Next table shows the electrical power as a function of wind speed in hub height, averaged in ten minutes, for air density range = [1.06, 1.27] kg/m^3. The power curve does not include losses in the transformer and high voltage cables.

For a detailed description of Application Mode – AM 0, please refer to latest version of Flexible Rating Specification (D2316244).

SG 6.2-170 Mode AM 0 Power curves [kW]									
Ws hub [m/s]	Air density [kg/m^3]								
	1.225	1.06	1.09	1.12	1.15	1.18	1.21	1.24	1.27
3.0	89	75	77	80	82	85	88	90	93
3.5	178	145	151	157	163	169	175	181	187
4.0	328	272	282	292	302	312	323	333	343
4.5	522	439	454	470	485	500	515	530	545
5.0	758	644	665	686	706	727	748	769	789
5.5	1040	888	916	944	971	999	1027	1054	1082
6.0	1376	1179	1215	1250	1286	1322	1358	1394	1430
6.5	1771	1521	1566	1612	1657	1703	1748	1794	1839
7.0	2230	1919	1976	2032	2089	2146	2202	2259	2315
7.5	2758	2377	2446	2516	2585	2654	2723	2793	2862
8.0	3351	2893	2977	3060	3144	3227	3310	3392	3474
8.5	3988	3455	3553	3652	3749	3846	3941	4035	4127
9.0	4617	4033	4145	4255	4363	4467	4568	4664	4756
9.5	5166	4586	4706	4820	4928	5029	5122	5208	5288
10.0	5584	5074	5191	5296	5390	5475	5549	5616	5675
10.5	5862	5466	5567	5652	5725	5786	5839	5884	5922
11.0	6028	5753	5830	5891	5940	5981	6013	6040	6063
11.5	6117	5944	5997	6036	6067	6090	6109	6124	6136
12.0	6161	6061	6094	6117	6135	6148	6157	6165	6171
12.5	6183	6128	6147	6160	6169	6176	6181	6184	6187
13.0	6192	6164	6174	6181	6186	6189	6191	6193	6194
13.5	6197	6182	6188	6191	6194	6195	6196	6197	6198
14.0	6199	6192	6194	6196	6197	6198	6198	6199	6199
14.5	6199	6196	6197	6198	6199	6199	6199	6199	6200
15.0	6200	6198	6199	6199	6199	6200	6200	6200	6200
15.5	6200	6199	6199	6200	6200	6200	6200	6200	6200
16.0	6200	6200	6200	6200	6200	6200	6200	6200	6200
16.5	6200	6200	6200	6200	6200	6200	6200	6200	6200
17.0	6200	6200	6200	6200	6200	6200	6200	6200	6200
17.5	6200	6200	6200	6200	6200	6200	6200	6200	6200
18.0	6200	6200	6200	6200	6200	6200	6200	6200	6200
18.5	6200	6200	6200	6200	6200	6200	6200	6200	6200
19.0	6200	6200	6200	6200	6200	6200	6200	6200	6200
19.5	6200	6200	6200	6200	6200	6200	6200	6200	6200
20.0	6200	6200	6200	6200	6200	6200	6200	6200	6200
20.5	6080	6080	6080	6080	6080	6080	6080	6080	6080
21.0	5956	5956	5956	5956	5956	5956	5956	5956	5956
21.5	5832	5832	5832	5832	5832	5832	5832	5832	5832
22.0	5708	5708	5708	5708	5708	5708	5708	5708	5708
22.5	5584	5584	5584	5584	5584	5584	5584	5584	5584
23.0	5460	5460	5460	5460	5460	5460	5460	5460	5460
23.5	5336	5336	5336	5336	5336	5336	5336	5336	5336
24.0	5212	5212	5212	5212	5212	5212	5212	5212	5212
24.5	5088	5088	5088	5088	5088	5088	5088	5088	5088
25.0	4964	4964	4964	4964	4964	4964	4964	4964	4964

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 with a K-factor of 2.0, 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	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10
Density [kg/m^3]	1.225	11514	14363	17198	19937	22528	24939	27150	29151	30937	32503	33853
	1.06	10152	12804	15493	18136	20675	23069	25292	27325	29156	30780	32191
	1.09	10413	13107	15829	18495	21049	23449	25673	27702	29526	31139	32540
	1.12	10667	13401	16151	18838	21403	23808	26030	28054	29871	31474	32862
	1.15	10916	13685	16463	19167	21741	24149	26369	28387	30195	31788	33165
	1.18	11159	13962	16763	19483	22065	24475	26692	28704	30503	32085	33451
	1.21	11397	14231	17055	19788	22376	24787	27000	29005	30795	32367	33722
	1.24	11630	14493	17338	20083	22676	25086	27295	29293	31074	32635	33979
	1.27	11859	14750	17613	20368	22966	25375	27580	29570	31341	32893	34225

Annual Production [MWh] SG 6.2-170 Rev 0, Mode AM 0 wind turbine for the standard version, as a function of the annual mean wind speed at hub height, and for Weibull parameter k=0.

14.2. Standard Ct Curve, Application Mode - AM 0

Air density= [1.06, 1.27] kg/m^3

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, substantially horizontal, 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 * w2 * A)

where

F = Rotor force [N]

ad = Air density [kg/m3]

w = Wind speed [m/s]

A = Swept area of rotor [m^2]

For a detailed description of Application Mode - AM 0, please refer to latest version of Flexible Rating Specification (D2316244).

SG 6.2-170 Mode AM 0 ct curves [-]									
Ws hub [m/s]	Air density [kg/m³]								
	1.225	1.06	1.09	1.12	1.15	1.18	1.21	1.24	1.27
3.0	0.953	0.953	0.953	0.953	0.953	0.953	0.953	0.953	0.953
3.5	0.880	0.880	0.880	0.880	0.880	0.880	0.880	0.880	0.880
4.0	0.847	0.847	0.847	0.847	0.847	0.847	0.847	0.847	0.847
4.5	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828
5.0	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824
5.5	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828
6.0	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833
6.5	0.836	0.836	0.836	0.836	0.836	0.836	0.836	0.836	0.836
7.0	0.837	0.837	0.837	0.837	0.837	0.837	0.837	0.837	0.837
7.5	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835
8.0	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825
8.5	0.802	0.804	0.804	0.804	0.803	0.803	0.802	0.801	0.800
9.0	0.759	0.767	0.767	0.766	0.765	0.763	0.761	0.757	0.753
9.5	0.696	0.716	0.715	0.712	0.709	0.705	0.699	0.693	0.686
10.0	0.620	0.654	0.651	0.646	0.640	0.633	0.625	0.615	0.605
10.5	0.541	0.588	0.582	0.575	0.566	0.556	0.546	0.535	0.524
11.0	0.466	0.521	0.513	0.503	0.493	0.483	0.472	0.461	0.450
11.5	0.402	0.458	0.448	0.438	0.428	0.417	0.407	0.396	0.386
12.0	0.347	0.401	0.391	0.381	0.371	0.361	0.352	0.343	0.334
12.5	0.303	0.351	0.342	0.333	0.324	0.315	0.307	0.299	0.291
13.0	0.266	0.309	0.300	0.292	0.284	0.276	0.269	0.262	0.256
13.5	0.235	0.273	0.265	0.258	0.251	0.244	0.238	0.232	0.226
14.0	0.209	0.243	0.236	0.229	0.223	0.217	0.212	0.207	0.202
14.5	0.187	0.217	0.211	0.205	0.200	0.195	0.190	0.185	0.181
15.0	0.169	0.195	0.190	0.185	0.180	0.175	0.171	0.167	0.163
15.5	0.153	0.176	0.171	0.167	0.163	0.158	0.155	0.151	0.147
16.0	0.139	0.160	0.156	0.152	0.148	0.144	0.141	0.137	0.134
16.5	0.127	0.146	0.142	0.138	0.135	0.132	0.128	0.125	0.123
17.0	0.117	0.134	0.130	0.127	0.124	0.121	0.118	0.115	0.113
17.5	0.108	0.124	0.120	0.117	0.114	0.112	0.109	0.106	0.104
18.0	0.100	0.115	0.112	0.109	0.106	0.104	0.101	0.099	0.097
18.5	0.093	0.107	0.104	0.101	0.099	0.096	0.094	0.092	0.090
19.0	0.087	0.100	0.097	0.095	0.093	0.090	0.088	0.086	0.084
19.5	0.082	0.094	0.091	0.089	0.087	0.085	0.083	0.081	0.079
20.0	0.077	0.088	0.086	0.084	0.082	0.080	0.078	0.076	0.075
20.5	0.066	0.075	0.073	0.071	0.069	0.068	0.066	0.065	0.064
21.0	0.060	0.068	0.067	0.065	0.064	0.062	0.061	0.060	0.058
21.5	0.055	0.063	0.061	0.060	0.058	0.057	0.056	0.055	0.054
22.0	0.051	0.058	0.056	0.055	0.054	0.053	0.051	0.050	0.049
22.5	0.047	0.053	0.052	0.051	0.050	0.048	0.047	0.046	0.046
23.0	0.043	0.049	0.048	0.047	0.046	0.045	0.044	0.043	0.042
23.5	0.040	0.045	0.044	0.043	0.042	0.041	0.040	0.040	0.039
24.0	0.037	0.042	0.041	0.040	0.039	0.038	0.037	0.037	0.036
24.5	0.034	0.039	0.038	0.037	0.036	0.035	0.035	0.034	0.033
25.0	0.032	0.036	0.035	0.034	0.034	0.033	0.032	0.032	0.031

15. Standard Acoustic Emission, Rev. 0. Mode AM 0

Typical Sound Power Levels

The sound power levels are presented with reference to the code IEC 61400-11 ed. 3.0 (2012). The sound power levels (L_{WA}) presented are valid for the corresponding wind speeds referenced to the hub height.

Wind speed [m/s]	3	4	5	6	7	8	9	10	11	12	Up tp cut-out
AM 0	92.0	92.0	94.5	98.4	101.8	104.7	106.0	106.0	106.0	106.0	106.0

Table 1: Acoustic emission, L_{WA}[dB(A) re 1 pW](10 Hz to 10kHz)]

Wind speed [m/s]	6	8
AM 0	87.6	93.9

Table 2: Acoustic emission, L_{WA}[dB(A) re 1 pW](10 Hz to 160 Hz)]

Low Noise Operations

The lower sound power level is also available and can be achieved by adjusting the turbines controller settings, i.e. an optimization of rpm and pitch. The noise settings are not static and can be applied to optimize the operational output of the turbine. Noise settings can be tailored to time of day as well as wind direction to offer the most suitable solution for a specific location. This functionality is controlled via the WebWPS SCADA and is described further in the white paper on Noise Reduction Operations. Furthermore, tailored power curves can be provided which take wind speed into consideration allowing for management of the turbine output power and noise emission level to comply with site specific noise requirements. Tailored power curves are project and turbine specific and will therefore require Siemens Gamesa Siting involvement to provide the optimal solutions. The lower sound power levels may not be applicable to all tower variants. Please contact Siemens Gamesa for further information.

For a detailed description of Application Mode – AM 0, please refer to Flexible Rating Specification (D2316244).

16. Electrical Specifications

Nominal output and grid conditions

Nominal power	6200 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	6350 kW @30°C ext. ambient
Nominal speed..................	1120 rpm-6p (50Hz) 1344 rpm-6p (60Hz)

Generator Protection

Insulation class	Stator H/H Rotor H/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	Air cooling
Internal ventilation	Air
Control parameter............	Winding, Air, Bearings temperatures

Frequency Converter

Operation..........................	4Q B2B Partial Load
Switching	PWM
Switching freq., 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 Capabilities Specification

Nominal grid frequency	50 or 60 Hz
Minimum voltage................	85 % of nominal
Maximum voltage...............	113 % of nominal
Minimum frequency	92 % of nominal
Maximum frequency	108 % of nominal
Maximum voltage imbalance (negative sequence of component voltage).	≤5 %
Max short circuit level at controller's grid Terminals (690 V)	82 kA

Power Consumption from Grid (approximately)

At stand-by,No yawing	10 kW
At stand-by, yawing	50 kW

Controller back-up

UPS Controller system	Online UPS, Li battery
Back-up time.....................	1 min
Back-up time Scada……...	Depend on configuration

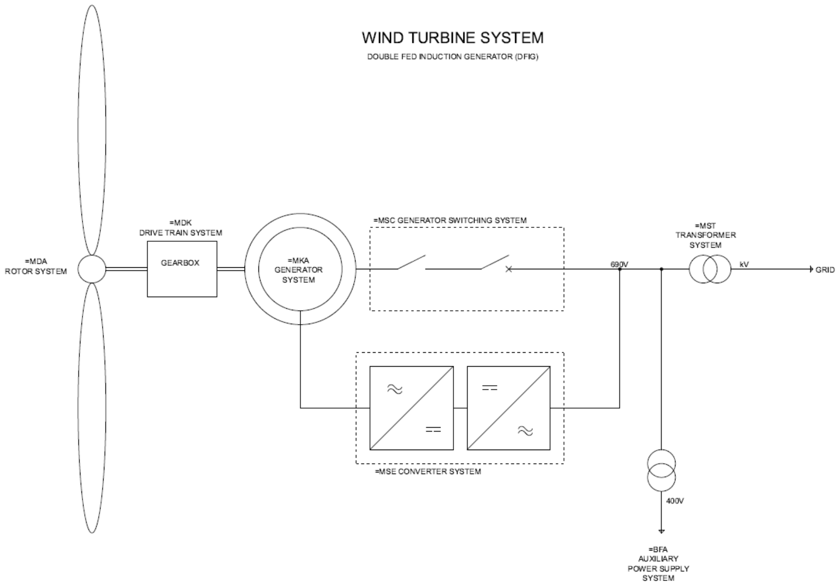
Transformer Specification

Transformer impedance requirement.......................	8.5 % - 10.5%
Secondary voltage	690 V
Vector group	Dyn 11 or Dyn 1 (star point earthed)

Earthing Specification

Earthing system	Acc. to IEC62305-3 ED 1.0:2010
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

17. Simplified Single Line Diagram



18. Transformer Specifications ECO 30 kV

Transformer	
Type	Liquid filled
Max. LV Current	7110 A
Nominal voltage	30/0.69 kV
Frequency	50 Hz
Impedance voltage	9.5% ± 8.3% at ref. 6.5 MVA
Tap changer	±2x2.5% (optional)
Loss (P_0 /$P_{k75^\circ C}$)	4.77/84.24 kW at ref. 7.332 MVA
Vector group	Dyn11
Standard	IEC 60076 EN50708 – ECO Tier 2
Cold Climate Package	(optional)

Transformer Cooling	
Cooling type	KFWF
Liquid inside transformer	K-class liquid
Cooling liquid at heat exchanger	Glysantin

Transformer Monitoring	
Top oil temperature	PT100 sensor
Oil level monitoring sensor	Digital input
Overpressure relay	Digital input

Transformer Earthing	
Star point	The star point of the transformer is connected to earth

19. Switchgear Specifications

The switchgear will be chosen as factory-assembled, type-tested and maintenance-free high-voltage switchgear with single-busbar system. The device will be metal-enclosed, metal-clad, gas-isolated, and conforms to the stipulations of IEC 62271-200.

The switchgear vessel of the gas-insulated switchgear is classified according to IEC as a “sealed pressure system”. It is gas-tight for life. The switchgear vessel accommodates the busbar system and switching device (such as vacuum circuit breaker, three-position switch disconnecting and earthing). The vessel is filled with sulphur hexafluoride (SF6) at the factory. This gas is non-toxic, chemically inert, and features a high dielectric strength. Gas work on site is not required, and even in operation it is not necessary to check the gas condition or refill, the vessel is designed for being gas tight for life.

To monitor the gas density, every switchgear vessel is equipped with a ready-for-service indicator at the operating front. This is a mechanical red/green indicator, self-monitoring and independent of temperature and variations of the ambient air pressure.

MV cables connected to the grid cable- and circuit-breaker feeders are connected via cast-resin bushings leading into the switchgear vessel. The bushings are designed as outside-cone system type “C” M16 bolted 630 A connections according to EN 50181. The compartment is accessible from the front. A mechanical interlock ensures that the cable compartment cover can only be removed when the three-position switch is in the earthed position.

The circuit-breaker operates based on vacuum switching technology. The vacuum interrupter unit is installed in the switchgear vessel together with the three-position switch and is thus protected from environmental influences. The operating mechanism of the circuit-breaker is located outside the vessel. Both, the interrupters and the operating mechanisms, are maintenance-free.

Padlock facilities are provided to lock the switchgear from operation in disconnector open and close position, earth switch open and close position, and circuit breaker open position, to prevent improper operation of the equipment.

Capacitive Voltage detection systems are installed both in the grid cable and the circuit breaker feeders. Pluggable indicators can be plugged at the switchgear front to show the voltage status.

The switchgear is equipped with an over-current protection relay with the functions over current, short circuit and earth fault protection. The relay ensures that the transformer is disconnected if a fault occurs in the transformer or the high voltage installation in the wind turbine. The relay is adjustable to obtain selectivity between low voltage main breaker and the circuit breaker in the substation. The protective system shall cause the circuit breaker opening with a dual powered relay (self-power supply + external auxiliary power supply possibility). It imports its power supply from current transformers, that are already mounted on the bushings inside the circuit breaker panel and is therefore ideal for wind turbine applications.

Trip signals from the transformer auxiliary protection and wind turbine controller can also disconnect the switchgear.

The switchgear consists of two or more feeders*; one circuit breaker feeder for the wind turbine transformer also with earthing switch and one or more grid cable feeders** with load break switch and earthing switch. The switchgear can be operated local at the front or by use of portable remote control (circuit breaker only) connected to a control box at the wind turbine entrance level.

* Up to four feeders.

** SGRE to be contacted for possible feeder configurations of circuit breaker and grid feeder combinations.

The switchgear is located at the bottom of the tower. The main transformer, LV switchgear and converters are located on the nacelle level above the tower.

Grid cables, from substation and/or between the turbines, must be installed at the bushings in the grid cable feeder cubicles of the switchgear. These bushings are the interface/grid connection point of the turbine. It is possible to connect grid cables in parallel by installing the cables on top of each other. The space in the MV cable compartments of the switchgear allows the installation of two connectors per phase or one connector + surge arrester per phase.

The transformer cables are installed at the bottom of the circuit breaker feeder. The cable compartment is accessible from the front. A mechanical interlock ensures that the cable compartment cover can only be removed when the three-position switch is in the earthed position.

19.1. Technical Data for Switchgear

Switchgear	
Make	Siemens / Ormazabal
Type	8DJH, 8DJH 36 / cgmcosmos, cgm.3
Rated voltage	20-40,5(Um) kV
Operating voltage	20-40,5(Um) 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	2/3/4 panels
Grid cable feeder	Cable riser or line cubicle
Circuit breaker feeder	Circuit breaker
Degree of protection, vessel	IP65
Internal arc classification IAC:	A FLR 20 kA 1s
Pressure relief	Upwards
Standard	IEC 62271
Temperature range	-25°C to +45°C
Grid cable feeder (line cubicle)	
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
Three position switch	Closed, open, earthed
Switch mechanism	Spring operated
Tripping mechanism	Stored energy
Control	Local
Coil for external trip	230V AC
Voltage detection system	Capacitive
Protection	
Over-current relay	Self-powered
Functions	50/51 50N/51N
Power supply	Integrated CT supply
Interface- MV/HV Cables	630 A bushings type C
Grid cable feeder	M16 Max 2 feeder cables
Cable entry	From bottom
Cable clamp size (cable outer diameter) *	26 - 38mm 36 - 52mm 50 - 75mm
Circuit breaker feeder	630 A bushings type C
Cable entry	M16 From bottom
Interface to turbine control	
Breaker status	
SF6 supervision	1 NO contact
External trip	1 NO contact

*Cable clamps are not part of switchgear delivery.

20. Grid Connection Capabilities

20.1. Purpose

This document describes the grid performance of the Siemens Gamesa 5.X, 50Hz & 60Hz. 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 assume that the electrical network is designed to be compatible with operation of the wind turbine.

20.2. 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 and Figure 2.

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. This model is a reduced order model, suitable for balanced simulations with time steps between 4-10 ms.

The standard voltage limits for the Siemens Gamesa 5.X, 50 Hz wind turbine are presented in Figure 1 between 0 - 70 seconds.

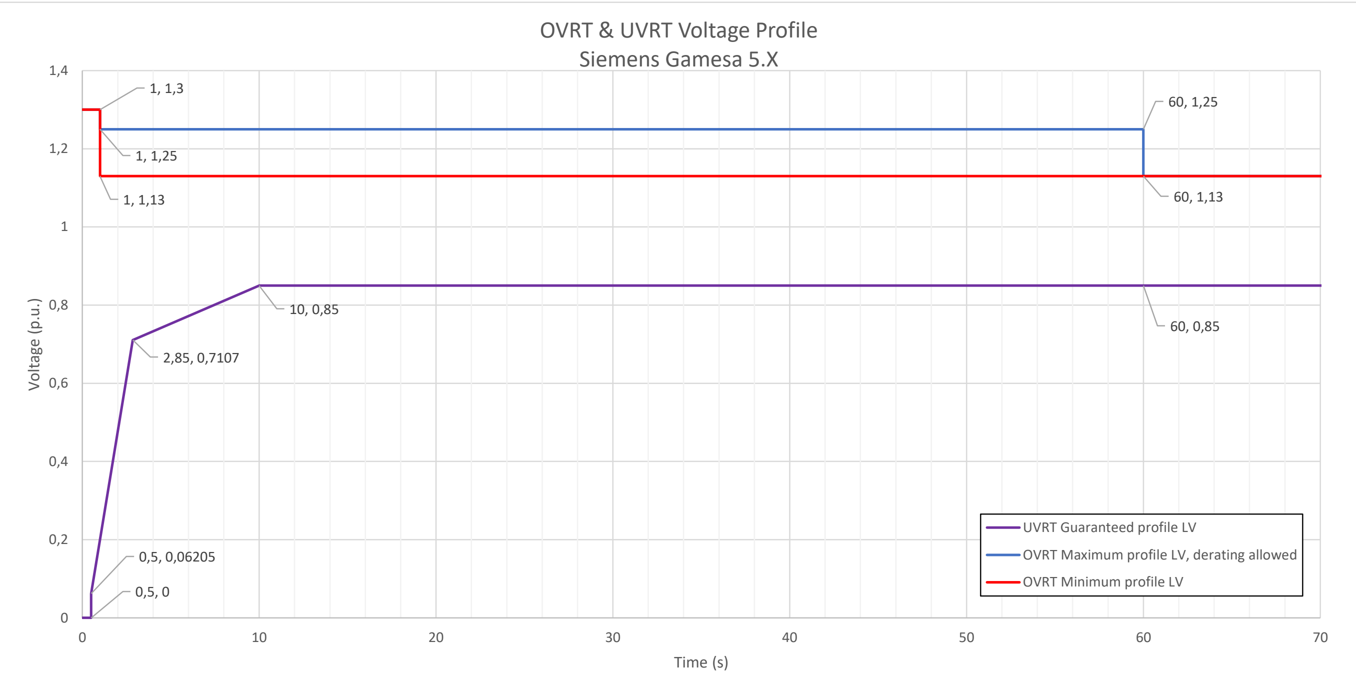


Figure 5. High and Low voltage limits for Siemens Gamesa 5.X, 50 Hz wind turbine in the range of 0-70 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).

20.3. 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.

20.4. Frequency Capability 50Hz

The wind turbine can operate in the frequency range between 46 Hz and 54 Hz, making a difference between a steady state operation (full simultaneity): ±3%, and transients' events (limited simultaneity): ±8% over rated frequency.

Simultaneities of main operation parameters shall be considered for evaluating the permitted operation ranges, mainly:

- Active Power level
- Reactive Power provision
- Ambient Temperature
- Voltage level of operation
- Frequency level of operation

And the total time that the turbine is operating under such conditions.

20.5. Frequency Capability 60Hz

The wind turbine can operate in the frequency range between 55.2 Hz and 64.8 Hz, making a difference between a steady state operation (full simultaneity): ±3%, and transients' events (limited simultaneity): ±8% over rated frequency.

Simultaneities of main operation parameters shall be considered for evaluating the permitted operation ranges, mainly:

- Active Power level
- Reactive Power provision
- Ambient Temperature
- Voltage level of operation
- Frequency level of operation

And the total time that the turbine is operating under such conditions.

20.6. 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 1s, see Figure 1. The wind turbine's target voltage shall stay between 95% and 112% to support the best possible performance by staying within the operation limits. Operation outside this range might lead to power derating.

Beyond ±10% of voltage deviation, automatic voltage support algorithms could execute Reactive Power control, to secure a continuous operation of the Wind Turbine Generator and maximizing the availability, overriding external control and setpoints of Reactive Power.

20.7. 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.

20.8. 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.

20.9. 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.

20.10. Summary of Grid Connection Capabilities

Characteristic	Value	Comments
Rated Voltage	690V	
Maximum Voltage Range	+13% -15%	Q & P deratings due to V-f Simultaneities could apply
Rated Frequency	50 / 60 Hz	
Maximum Frequency Range	± 8%	Q & P deratings due to V-f Simultaneities could apply
Minimum SCR at WTG MV Terminals	V-Direct: ≥ 2.0* Q-Direct: ≥ 3.0**	See note 1.
Minimum X/R at WTG MV Terminals	3.0	
Max. Frequency gradient (ROCOF)	≤ 4 Hz/s	
Allowable Max Negative Sequence Voltage	≤ 5%	
Voltage support after FRT recovery	3s	Configurable by parameter
Power recovery to 95% of Pre- Fault value	< 1000ms	Standard Configuration. Configurable by parameters adjustment.
Voltage support during FRT	Available	Configurable by parameter
Active current priority during Voltage Dip	Available	Configurable by parameter
Active Power damping after Dip	±5% pre-fault level in <2s	Can be affected if Power Recovery Ramps after Voltage Dip is modified
I_Q Injection Curve during FRT	k = 2	Configurable by parameters.
I_Q Response Time (FRT)	≤ 30ms	+20ms for 1 cycle RMS calculation
I_Q Settling Time (FRT)	≤ 60ms	+20ms for 1 cycle RMS calculation -10% +20% required step
Active Power Ramp	+ 20% Prated / s	Standard
Active Power Ramps - Fast Mode	± 25% Prated/s	When commanded by SCADA
Reactive Power Ramp	±5000 kVAr/s	Configurable by parameter see note 2

Note 1.
* SCR ratio can be reduced further if Active Power recovery ramps are limited to a certain value, that secures stable operation, after voltage dip events.
** SCR ratio can be reduced further if Reactive Power Management configuration is done correctly by means of detailed grid studies, trying to avoid voltage saturation extremes in any case (over and under voltage saturation levels).

Note 2.

In weak grids maximum ramp is limited to ±2500 kVar /s further limitation are done when reaching voltage limits

21. Reactive Power Capability - 50 & 60 Hz

21.1. General

This document describes the reactive power capability of Siemens Gamesa 5X, 50/60 Hz wind turbines during active power production. SG 5X wind turbines are equipped with a B2B Partial load frequency converter which allows the wind turbine to operate in a wide power factor range.

The maximum amount of Reactive Power to be generated or consumed depends on a wide range of parameters, some of them not possible to consider in a general way as they are fully dependent on the site, grid and Wind Turbine operation conditions.

Between others, the Reactive Power Capability at a given Operating Conditions depends on existing Active Power, internal temperature of Wind Turbine components, external ambient temperature, Grid conditions (voltage level, frequency level, etc.) and impact, thermally, in high inertial systems. So, the required operation time in worse conditions is also a parameter to be considered.

Online maximum capabilities estimation is executed by the Reactive Power Controller algorithm, to provide the possibility of maximizing the Capabilities in favorable grid and site conditions.

21.2. Reactive Power Capability. Generalities.

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

Figure 6 shows the reactive power capability depending on the generated Active Power at various voltages at the LV terminals, starting by 91% of rated voltage (PQV curves).

Figure 7 shows the reactive power capability depending on the voltage level (QV curve) at full power operation.

Figure 3 includes reactive power capability at no wind operating conditions.

The SCADA can send voltage references to the wind turbine in the range of 92% to 108% (references of 90% to 110% in specific cases). The wind power plant is recommended to be designed to maintain the wind turbine voltage references between 95% and 105% during steady state operation.

The included capability assume that the phase voltages are balanced (unbalance value below the maximum guaranteed, ≤ 5%) and that the grid operational frequency is nominal.

Given the uncertainties in determining the overall Wind Turbine operation state variables tolerances, the given Reactive Power Capability is subjected to a tolerance up to ± 10%.

These figures consider Wind Turbine operation around its expected generator speed for each operation condition (P-n operation curve). Extreme speed excursions caused by specific Wind gusts, up and down from standard value, may cause punctual Reactive Power restrictions due to Generator and Converter limits of voltage and currents. All this is also fully dependent on the Grid conditions of voltage level and external setpoint.

Values of Reactive Power for those operational points in between the shown curves can be calculated by means of linear interpolation.

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

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

21.3. Operation below 90% of rated voltage

Standard operation at voltages in between 85% to 90% over rated is considered a special situation where both Reactive Power and Active Power may be de-rated depending on operation conditions of the Wind Turbine Generator.

Usually, depending on specific local regulations, Under Voltage Ride Through (UVRT) support happens in voltage values below 90% of rated voltage, so this operation case is not compatible as during UVRT support, Reactive Power is internally controlled depending on demands from applicable Grid Codes of Operation. This is also applicable during OVRT transients.

Specific studies should be executed in order to determine the operation and the possible values to be reached in such special operation cases, where and when required.

21.4. Reactive Power / Voltage limiting function

When Wind Turbine operation is close to voltage limits (under-voltage and over-voltage grid protection configured values), a specific Reactive Power / Voltage limiting function acts causing a so-called *Voltage Saturation*. The intention of this algorithm is to avoid a self-trip due to activation of over or under-voltage protections caused by Reactive Power operation of the turbine.

In the maximum configurable values of the voltage protection parameters (permanent operation, 85% and 113%):

- In case of under-voltage, the negative Reactive Power (Inductive, under-excited) is linearly limited from *No_Limit* to *0*, in the voltage range 90% to 85%.
  - ➢ The voltage used for evaluating and executing this Saturation is the minimum of the 3 phase voltages.
- In case of over-voltage, the positive Reactive Power (Capacitive, over-excited) is linearly limited from *No_Limit* to *0*, in the voltage range 112% to 113%.
  - ➢ The voltage used for evaluating and executing this Saturation is the maximum of the 3 phase voltages.

All these levels are possible to be set by parameters, depending on necessities, local requirements and as results of stability studies.

Reactive Power capabilities and curves shown in this document are generated having configured the next saturation values (values by default). This can be observed in figure 2. QV diagram.

- Under-Voltage saturation: 91% to 90% of rated voltage.
- Over-Voltage saturation: 112% to 113% of rated voltage.

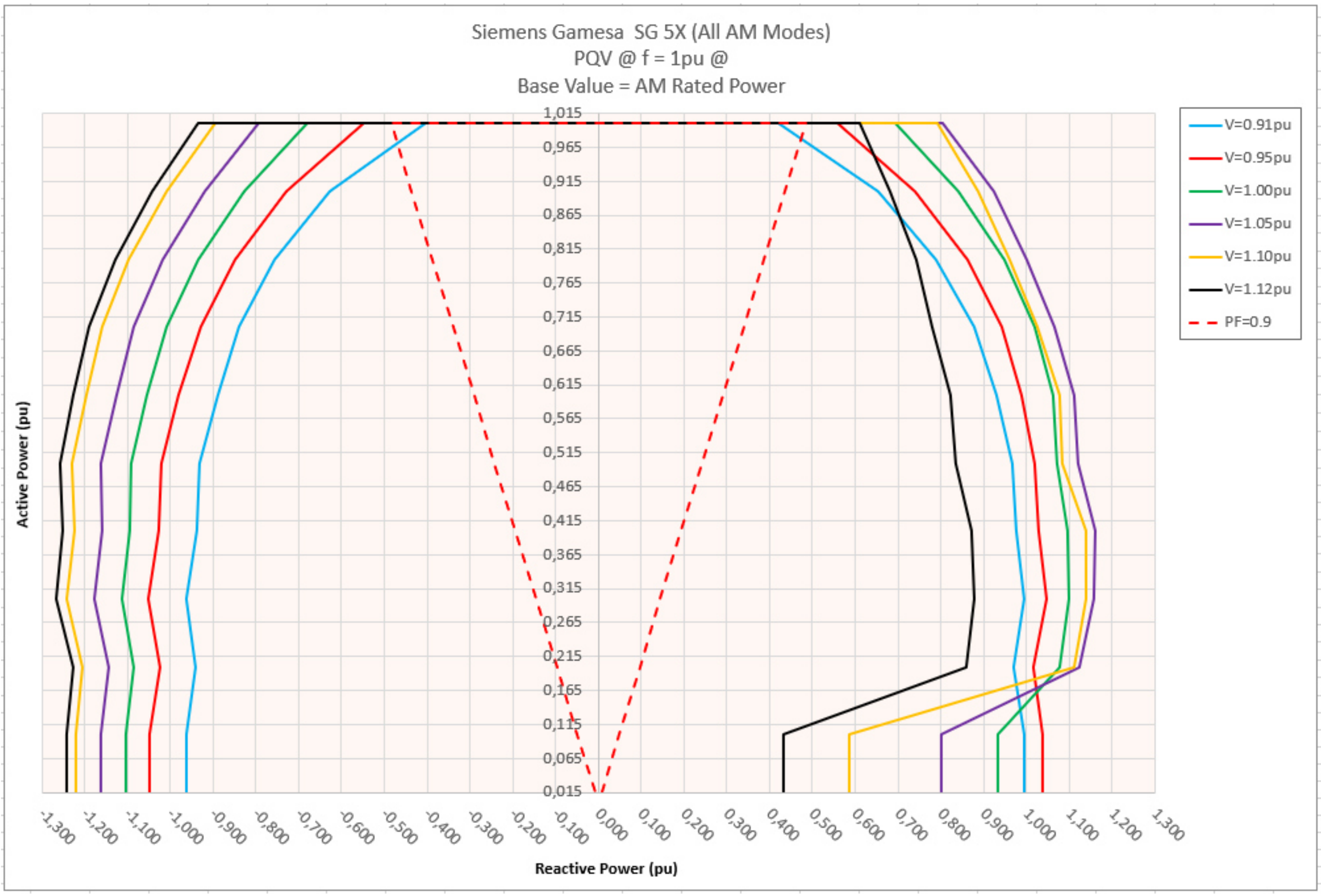


Figure 6: Siemens Gamesa SG 5X Reactive power capability curves (PQV), 50/60 Hz Wind Turbine, at LV terminals.

Note: Voltage Saturation set to 91% and 112% (refer to *Reactive Power / Voltage limiting function* section)

Application mode (AM)	Rating	External Nacelle Temperature
	Kw	ºC
AM 0	**6600**	**20**
AM-1	6500	23
AM-2	**6400**	**25**
AM-3	6300	28
AM-4	**6200**	**30**
AM-5	6100	33
AM-6	**6000**	**35**

Table 9: Application modes definition.

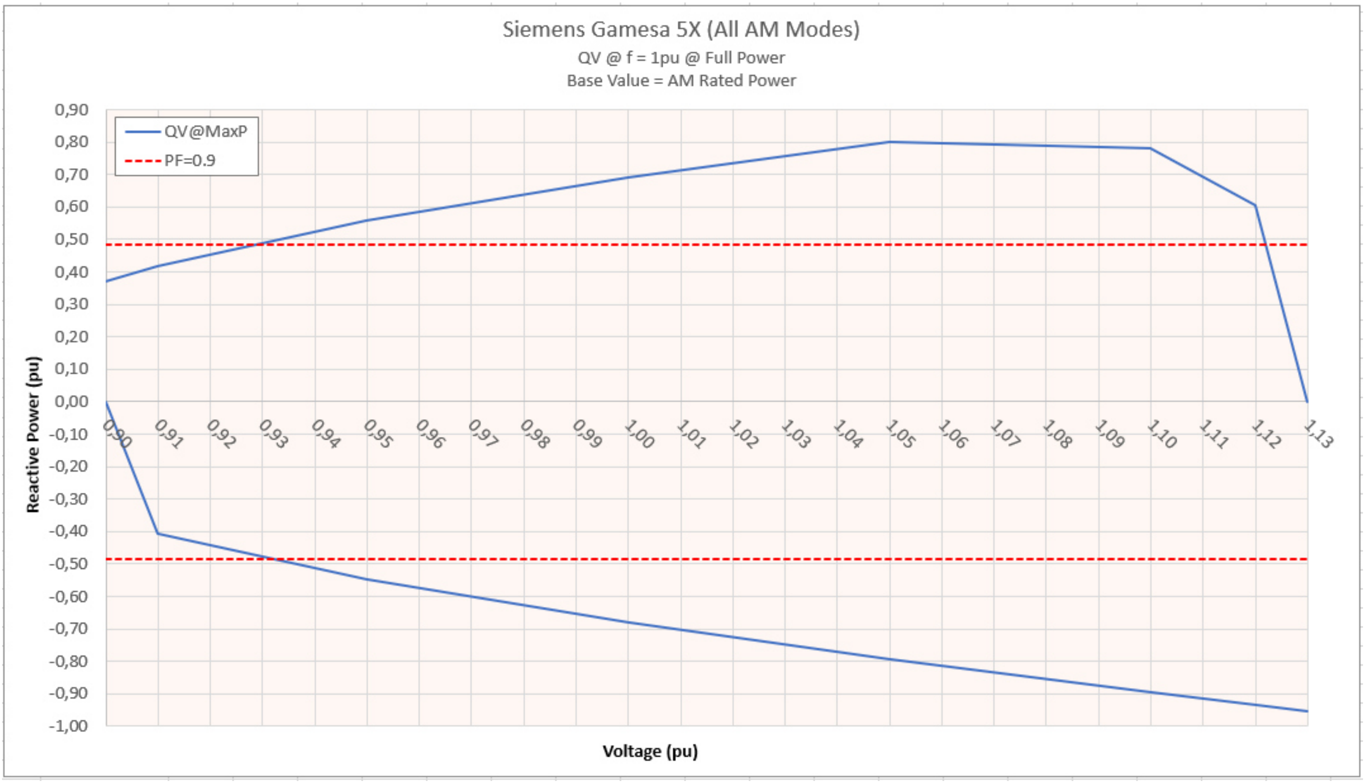


Figure 7: Siemens Gamesa SG 5X → Reactive power capability curves (QV), 50/60 Hz Wind Turbine, at LV terminals, at Full Power operation.

Note: Voltage Saturation set to 91% and 112% (refer to *Reactive Power / Voltage limiting function* section)

Base Value = AM Rated Power		Voltage (pu)							
		0,9	**0,91**	**0,95**	**1**	**1,05**	**1,1**	**1,12**	**1,13**
Active Power (pu)	**0,015***	0,985	0,997	1,038	0,933	0,803	0,586	0,433	0
	0,10	0,985	0,997	1,038	0,933	0,803	0,586	0,433	0
	0,20	0,957	0,969	1,018	1,077	1,124	1,112	0,860	0
	0,30	0,982	0,995	1,047	1,098	1,157	1,140	0,877	0
	0,40	0,962	0,975	1,029	1,095	1,160	1,139	0,873	0
	0,50	0,955	0,968	1,018	1,073	1,121	1,085	0,834	0
	0,60	0,914	0,929	0,990	1,063	1,112	1,076	0,823	0
	0,70	0,861	0,877	0,942	1,019	1,065	1,026	0,781	0
	0,80	0,770	0,789	0,862	0,949	1,001	0,962	0,742	0
	0,90	0,629	0,652	0,741	0,842	0,923	0,888	0,682	0
	1,00	0,373	0,419	0,559	0,693	0,803	0,791	0,611	0

Table 10: Siemens Gamesa SG 5XReactive power capability values (pu), 50/60 Hz Wind Turbine, at LV terminals.

Capacitive / Over-excited operation.

Note: Voltage Saturation set to 91% and 112% (refer to *Reactive Power / Voltage limiting function* section)

* Case of Wind turbine operating with very low wind, but with generator connected to the grid.

Base Value = AM Rated Power		Voltage (pu)							
		0,9	0,91	0,95	1	1,05	1,1	1,12	1,13
Active Power (pu)	**0,015***	0	-0,963	-1,048	-1,105	-1,162	-1,220	-1,242	-1,253
	0,10	0	-0,963	-1,048	-1,105	-1,162	-1,220	-1,242	-1,253
	0,20	0	-0,941	-1,024	-1,085	-1,144	-1,204	-1,228	-1,241
	0,30	0	-0,962	-1,050	-1,114	-1,178	-1,241	-1,266	-1,279
	0,40	0	-0,937	-1,027	-1,093	-1,159	-1,224	-1,250	-1,263
	0,50	0	-0,930	-1,022	-1,092	-1,161	-1,230	-1,257	-1,271
	0,60	0	-0,890	-0,980	-1,054	-1,126	-1,197	-1,225	-1,239
	0,70	0	-0,839	-0,929	-1,008	-1,085	-1,160	-1,189	-1,204
	0,80	0	-0,756	-0,847	-0,934	-1,017	-1,097	-1,129	-1,144
	0,90	0	-0,629	-0,727	-0,828	-0,921	-1,009	-1,044	-1,061
	1,00	0	-0,403	-0,546	-0,679	-0,793	-0,895	-0,934	-0,953

Table 11: Siemens Gamesa SG 5X → Reactive power capability values (pu), 50/60 Hz Wind Turbine, at LV terminals.

Inductive / Under-excited operation.

Note: Voltage Saturation set to 91% and 112% (refer to *Reactive Power / Voltage limiting function* section)

***** Case of Wind turbine operating with very low wind, but with generator connected to the grid.

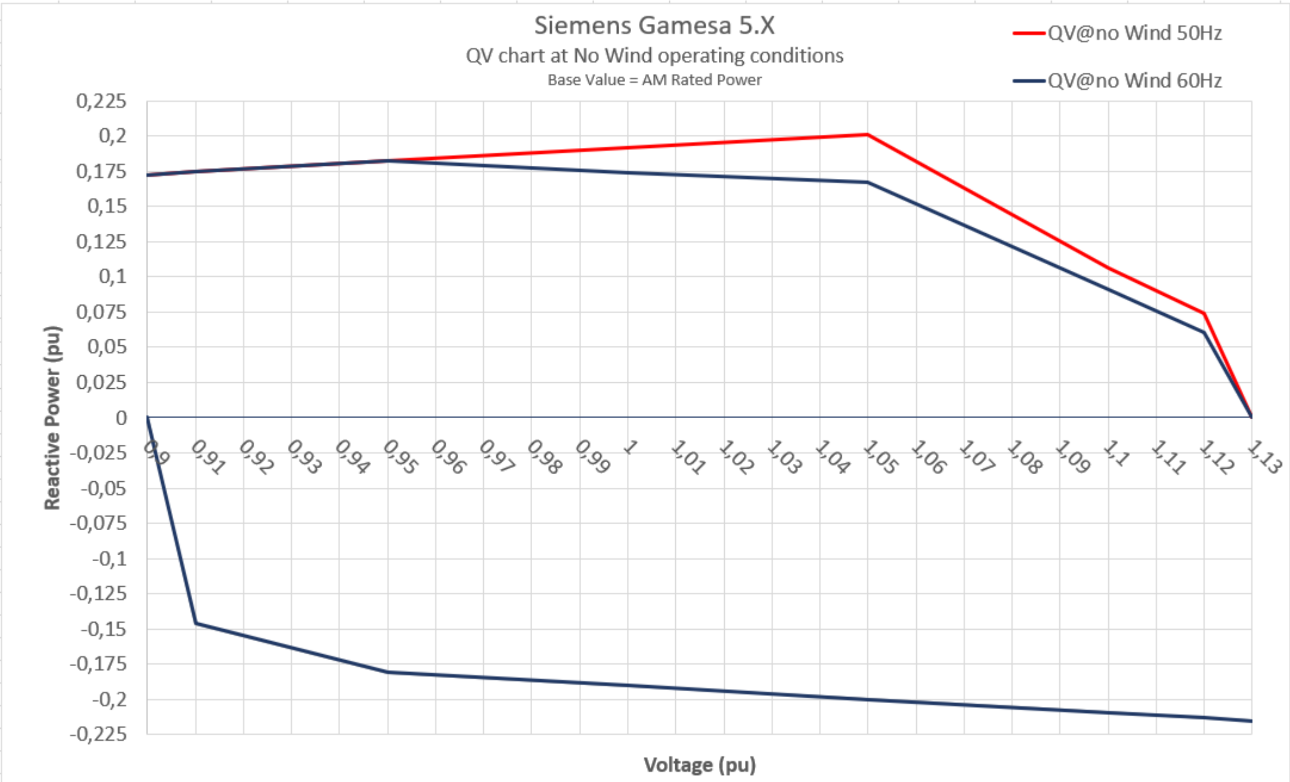


Figure 8: Reactive Power Capability chart (pu) at no wind conditions, at LV terminals, 50/60Hz.

Case of Wind turbine not in operation, with generator stopped or below the connection speed.

Siemens Gamesa 5.X 50Hz Base Value = AM Rated Power		
Voltage (pu)	**Q+ (pu)**	**Q- (pu)**
0,90	0,173	0,00
0,91	0,174	-0,146
0,95	0,182	-0,181
1,00	0,192	-0,190
1,05	0,201	-0,200
1,10	0,107	-0,209
1,12	0,074	-0,213
1,13	0,000	-0,215

Siemens Gamesa 5.X 60Hz Base Value = AM Rated Power		
Voltage (pu)	**Q+ (pu)**	**Q- (pu)**
0,90	0,173	0,000
0,91	0,174	-0,146
0,95	0,182	-0,181
1,00	0,174	-0,190
1,05	0,167	-0,200
1,10	0,091	-0,209
1,12	0,061	-0,213
1,13	0,000	-0,215

Table 12: Reactive Power Capability values (pu) at no wind conditions, at LV terminals, 50/60Hz.

Case of Wind turbine not in operation, with generator stopped or below the connection speed.

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22. SCADA System Description

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

22.1. Main features

The SCADA system has the following main features:

- On-line supervision and control accessible via secured tunnel over the Internet.
- Data acquisition and storage of data in a historical database.
- Temporary local storage of data at wind turbines. If communication is temporary interrupted, data is kept in the Wind Turbine Control and transferred to the SCADA when possible.
- System access from anywhere using a standard web browser. No special client software or licenses are required.
- Users are assigned individual usernames and passwords, and the administrator can assign a user level to each username for added security.
- Email function can be configured for alarm notification. Configuration can also support alarm notification via SMS service.
- Interface to power plant control functions for enhanced control of the wind farm and for remote regulation, e.g. MW / Voltage / Frequency / Ramp rate.
- Interface for integration of substation equipment for monitoring.
- Interface for monitoring of Reactive compensation equipment, control of this equipment is achieved via the SGRE power plant controller
- Integrated support for environmental control such as noise, shadow/flicker, wildlife bat and birds and ice.
- Power curve plots with pressure and temperature correction (pressure and temperature correction available only if SGRE MET system supplied).
- Condition Monitoring System integrated with the turbine controller using virtualized server.
- Ethernet-based system with secure compatible interfaces (OPC UA) for online data access.
- Access to historical - scientific and optional high resolution data via Restfull API.
- Antimalware Solution.
- Back-up & restore feature.

22.2. Wind turbine hardware

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

Data recorded at the turbine is stored at the SICS. In the event that communication to the central server is temporarily interrupted data is kept in the SICS and transferred to the SCADA server when possible.

22.3. 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 typically carried out by the Employer. If specifically agreed the division of responsibility for the communication network can be changed.

22.4. SCADA server cabinet

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

SCADA solutions stands on a Virtualized Server Infrastructure solution which means that the software is run virtually over a non-redundant or redundant hardware server(s) (depending on customer's needs).

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

22.5. Grid measuring station and Wind Farm Controller

The SCADA system includes a grid measuring station located in an Auxiliary cabinet. Normally the grid measuring station is placed at the wind farm substation or control building close to the Point of Connection.

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

The grid measuring station and the Wind Farm Control interfaces to the SGRE SCADA servers and turbines are via a LAN network.

The Wind Farm Control can on request be supplied in a high availability (HA) setup with a redundant server cluster.

Note: In small SGRE SCADA systems (typically <10 turbines) and if the small SGRE SCADA system is placed in a turbine the Wind Farm Control and grid measuring station may be arranged otherwise.

22.6. 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 cabinet. For communication with third party equipment OPC UA and IEC 60870-5-104 are supported.

22.7. SGRE SCADA software

The normal SGRE SCADA user interface presents online and historical data.

Historical data are stored in a database as statistical values and can be presented directly on the screen or exported for processing via a RESTfull API.

The SGRE SCADA software can also serve as user interface to the Wind Farm Control functions.

22.8. Virus protection solution

A virus protection solution is always installed. An anti-virus client software is 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.

22.9. Back-up & restore

For recovery of a defect SCADA system or component, the SGRE SCADA system optionally can provide 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 locally on the site servers. This functionality is optional.

23. Codes and Standards

This document lists codes and standards according to which turbines are designed, manufactured and tested. The scope of this document is limited to the Siemens Gamesa 5.X platform.

SGRE Onshore geared turbines are designed, manufactured, and tested to SGRE's technical drawings, procedures, and processes that are generally in compliance with the applicable sections of the codes and standards listed herein. This list of codes and standards for design, manufacturing, and testing forms a part of the design basis documentation. The edition of the codes and standards is the version used for the certification process which is conducted by an external certifying body.

23.1. General

- IEC-RE Operational Document: OD-501, Type and Component Certification Scheme*
- IEC 61400-5:2020 Wind energy generation systems - Part 5: Wind turbine blades
- IEC 61400-6:2020 Wind energy generation systems - Part 6: Tower and foundation design requirements
- *IEC 61400-1:2019 Ed.4 Wind turbines –. Part 1: Design requirements*
- IEC 61400-11:2012/AMD1:2018 Amendment 1 - Wind turbines - Part 11: Acoustic noise measurement techniques
- *IEC 61400-12-1:2017, Ed.1, Wind Turbine Generator Systems Part 12-1: Power performance measurements of electricity producing wind turbines*
- *IEC 61400-13: 2015 Wind Turbine Generator Systems - Part 13: Measurement of Mechanical Loads*
- *IEC 61400-23 Ed. 1.0 EN :2014 Wind turbines - Part 23: Full-scale structural testing of rotor blades*

- *EN 10025-1:2004, Hot rolled products of structural steels - Part 1: General technical delivery conditions*
- *EN 10025-2:2004, Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels*
- *EN 10025-3:2004, Hot rolled products of structural steels - Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels*
- *EN 10029:2010, Hot rolled steel plates 3 mm thick or above - Tolerances on dimensions, shape and mass*
- *ISO 683-1:2018 Heat-treatable steels, alloy steels and free-cutting steels. Non-alloy steels for quenching and tempering*
- *EN 1563:2018, Founding - Spheroidal graphite cast irons*
- *EN 1993-1-8:2005/AC:2009: Eurocode 3: Design of steel structures Part 1-8: Joints*
- *EN 1999-1-1-2008 Design of aluminum structures – part 1-1: General structural rules*

- *ISO 16281:2008 Rolling bearings - Methods for calculating the modified reference rating life for universally loaded bearings*
- *ISO 16281:2008 / Cor. 1:2009 Rolling bearings - Methods for calculating the modified reference rating life for universally loaded bearings*
- *ISO 281:2007 Rolling bearings - Dynamic load ratings and rating*
- *ISO 76:2006/Amd 1:2017 Rolling bearings – Static load ratings AMENDMENT 1*
- *ISO 898-1:2013, Mechanical 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*
- *VDI 2230 Blatt 1, 2016, Systematic calculation of highly stressed bolted joints - Joints with one cylindrical bolt*
- *ISO 4413:2010 Hydraulic fluid power -- General rules and safety requirements for systems and their components*

- *DIN 51524-3:2017 Pressure fluids - Hydraulic oils - Part 3: HVLP hydraulic oils, Minimum requirements*

- *ISO 16889:2008 + A1:2018 Hydraulic fluid power -- Filters -- Multi-pass method for evaluating filtration performance of a filter element*
- *UNE-EN 14359:2008+A1:2011: Gas-loaded accumulators for fluid power applications.*
- *PED 2014/68/EU Pressure Equipment Directive*

- *DNV-DS-J102:2010 Design and Manufacture of Wind Turbine Blades, Offshore and Onshore Wind Turbines*

- *DIBt - Richtlinie für Windenergieanlagen - Oktober 2012, korrigierte Fassung März 2015*
- *DIBt* – Richtlinie für Windenergieanlagen:2012, Einwirkungen und Standsicherheitsnachweise für Turm und Gründung.

23.2. Gearbox

- *IEC 61400-4:2012 Wind turbines -- Part 4: Design requirements for wind turbine gearboxes*

23.3. Electrical

- *IEC 61400-21-1:2019 Wind energy generation systems - Part 21-1: Measurement and assessment of electrical characteristics - Wind turbines*
-
- *IEC 61400-24:2019 Wind energy generation systems - Part 24: Lightning protection*
-
- *IEC* 60076-16:2018 – Power transformers - Part 16: Transformers for wind turbine applications

- *IEC 60204-1:2016 Safety of machinery - Electrical equipment of machines - Part 1: General requirements*

- IEC 61000-6-2:2016 Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments
- IEC 61000-6-4:2018 Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments
- IEC 61439-1:2020 Low-voltage switchgear and controlgear assemblies – Part 1: General rules
- IEC 61439-2:2020 Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies
- *Low Voltage Directive 2014/35/EU*
- *EMC Directive* 2014/30/EU

23.4. Quality

- ISO 9001:2015 Quality management systems – Requirements

23.5. Personal Safety

- 2006/42/EC Machinery Directive
- EN 50308:2004, Wind turbines – Protective measures – Requirements for design, operation and maintenance.
- OSHA 2005 Requirements for clearances at doorways, hatches, and caged.
  - OSHA's Subpart D Walking-Working Surfaces Section 1910.27v
- ISO12100:2011 Safety of machinery – General principles for design – Risk assessment and risk reduction
- ISO 13849-1:2015 – Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design
- ISO 13849-2:2013 - Safety of machinery – Safety-related parts of control systems – Part 2: Validation

23.6. Corrosion

- *ISO 12944-1:2017, Paints and varnishes - Corrosion protection of steel structures by protective paint systems – Part 1: General introduction (class C3 to C4)*

24. Ice Detection System and Operations with Ice

Siemens Gamesa Renewable Energy's (SGRE) Ice detection and Operation with Ice system offers functionality that extends the range of operation during ice conditions. The main configurable options determine if maximum production or maximum safety is required.

The following options for ice detection sources can be used:

- Low power detection curve (LPDC)
- No cut-in detection
- **Optional extra:** External sensor detection, nacelle- or blade-based.

Once ice has been detected through any of the selected sources the following ice detection response is handled by the Operation with Ice strategy where the following options are available:

- Stop the turbine, either awaiting automatic reset or manual reset
- Stop the turbine, combined with yawing to a specific angle
- Adaptive Operation, continued operation optimizing the power

Figure 1 shows a visualization of the available options and how they are connected.

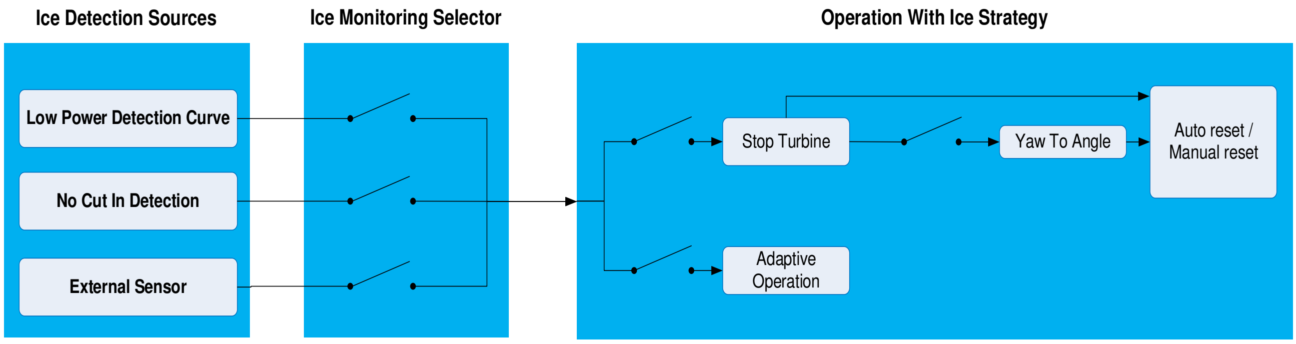

Figure 1: Ice Detection and Operation with Ice Strategy interface for individual turbines

i	Adaptive Operation used as the Operation With Ice strategy requires the Low Power Detection Curve and No Cut In Detection to be used, it is therefore not compatible with the external sensor.

Ice build-up on the turbine can possibly cause damage to objects and people in the vicinity. The ice detection and Operation with Ice system will not protect against ice being thrown from the turbine(s). What the system does is either optimize performance and yield maximum production despite ice on the turbine or stop the turbine to prevent operating with ice. There may be ice on blades upon start and/or stop of the turbine. It is the sole responsibility of the owner of the turbine to ensure that the public is protected from ice being thrown from the turbine. The Owner must always ensure that the operation of the turbine complies with all restrictions applicable to the turbine, irrespective of whether such restrictions follows from permits, legislation or otherwise. SGRE accepts no responsibility for any violation of requirements.

24.1. Ice Detection Sources

24.1.1. Low Power Detection Curve (LPDC)

The LPDC functionality is an integrated part of the turbine controller, thus not requiring additional sensors.

LPDC is a requirement to be active when the *Operation with Ice Strategy: Adaptive* is selected.

LPDC detects ice when power production degrades due to ice build-up on the blades during operation when the turbine produces power in cold weather by comparing the actual power production to the sales power curve shown in Figure 2 when the ambient temperature is below 5° C (configurable). LPDC is based on a percentage of the sales power curve with a minimum separation to the sales power curve.

If production falls below the “LPDC Ice Detection” (Blue) curve shown in Figure 2, the selected Operation with Ice strategy is activated.

If *Operation with Ice Strategy: Adaptive Operation* is selected and the production increases above the “LPDC Ice Detection” curve, Adaptive Operation is deactivated.

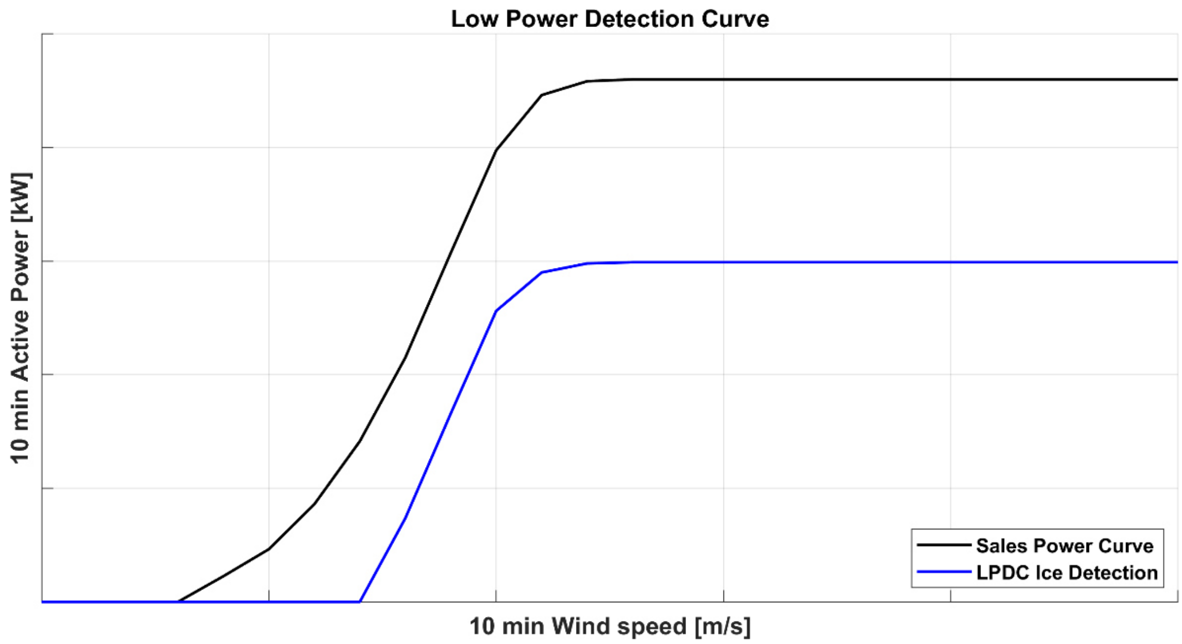

Figure 2: Illustration of Low Power Detection Curve (LPDC)

24.2. No Cut-in

The No Cut-in functionality is an integrated part of the turbine controller, thus not requiring additional sensors. No Cut-in is a requirement to be active when *Operation with Ice Strategy: Adaptive Operation* is configured.

No Cut-in is an ice detection method that indicates when there is enough wind for the wind turbine to produce power, but the turbine is unable to cut-in, connect to the grid, and produce power for a period of time due to severe ice build-up in cold weather.

If Operation with Ice Strategy: Adaptive Operation is selected as the ice detection response strategy, the turbine will cut-in and connect to the grid at an adapted power production level given the conditions. See further below in chapter “Operation with Ice Strategy: Adaptive Operation”.

24.3. External Sensor Options

The external ice detector sensor functionality is an optional extra system that can be used to create a response directly from the sensor on the turbine. Most often the sensor reports data to SCADA which controls the turbines at the site with respect to stopping them. It is intended for installation on wind turbines located in areas where there is a risk that ice can build up on either the turbine nacelle or blades and there are personal safety or legislation concerns that required the turbine to be stopped instantly when ice is detected. Compared to the LPDC and No Cut-in ice detection source options are designed to detect when performance is impacted where ice may already exist on the turbine.

The external sensor is only compatible with Operation with Ice Strategy:

- Stop the turbine
- Stop the turbine, yawing to a specific angle

The external sensor communicates with the Supervisory Control and Data Acquisition (SCADA) system. Typically, only a few external sensors are installed on a given site, and SCADA can be configured to stop the entire site or clusters or individual turbines if deemed necessary.

There are two separate types of use for the external sensor:

- External sensor is selected as the turbines ice detection source (Figure 1) for individual turbines, which allows the individual turbine itself to react to the sensor. Additionally, SCADA can still react to the signal and stop turbine(s) at the site.
- External sensor is not selected as the turbines ice detection source (Figure 1), so the individual turbine itself will not react to the external sensor, but SCADA can still react to the signal and stop turbine(s) at the site.

24.4. External Sensor Types

24.4.1. Nacelle Based Ice Detection Sensor (Optional)

The nacelle ice detection sensor is an optional system intended for installation on wind turbines located in areas where ice can build up on the turbine. The purpose of the ice detector system is to provide the turbine controller information about potential risk for ice on the turbine. The ice detection system can detect in-cloud icing as well as freezing rain. Depending on requirements when ice is detected an ice alarm can initiate a turbine stop.

The system can come with a valid certification from accredited institutes.

24.4.2. Blade-Based Ice Detection Sensor (Optional)

An additional option is to install a blade-based ice detection system. Such system includes a set of sensors (accelerometers) on each blade, plus a central monitoring unit. The ice detection is performed by analysis of blade eigenfrequencies with respect to ice accumulation. Therefore, the system needs a calibration prior to enter service (varying, and up to 3 months depending on the conditions and WTG configuration).

Ice detection is possible at standstill and during operation. No minimum rotation per minute (rpm) is required, however a minimum wind speed of 2 m/s is required to ensure sufficient excitation of blade.

The system can also come with a valid certification from accredited institutes.

24.5. Options and logging in SCADA

Possible options in SCADA to configure the usage of the external sensor on site level (independent of the individual turbine interface):

- Set predefined ice conditions using ice parameters

- Enable or disable automatic stop of individual turbines
- Enable or disable automatic restart of individual turbines
- Group turbines for auto stop and auto restart. SGRE recommends using SCADA to group ice sensor installed turbines along with turbines on which ice sensors are not installed.

Ice parameters are set in the SCADA interface. Depending on requirements, ice parameters can be modified to configure new ice conditions through the SCADA interface. Below is a list of the parameters:

- **Ice Restart Delay:** Turbines that are stopped due to ice are restarted only if ice is not reported from the sensor during the “Ice Stop Delay” in seconds configured by the user.

- **Ice Stop Delay:** Turbines are stopped due to ice only if ice is detected on turbine(s) for more than the ice stop delay in seconds configured by the user.

- **Ambient Temperature Duration:** Duration in seconds for how long the ambient temperature for ice detection should be exceeded to restart the turbines which are stopped due to ice.
  - E.g. above 5°C for 600 seconds

- **Ambient Temperature Threshold:** This parameter defines the temperature which must be exceeded to restart turbines stopped due to ice detection.
  - E.g. above 5°C for 600 seconds

- **Ice Control Start Time** and **Ice Control End Time:** Configured turbines will be stopped due to ice detection when the actual time is between Ice Control Start Time and Ice Control End Time. When the current time falls outside the range specified in Ice Control Start Time and Ice Control End Time, the turbines are restarted.

The alarms are presented in the ‘Alarm log’ of the Web WPS SCADA interface.

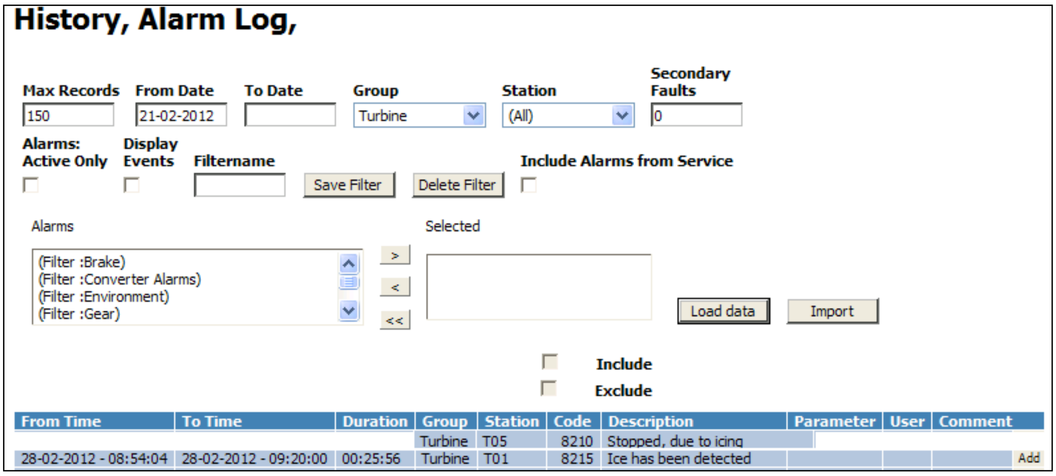

Figure 3 - Presentation of alarms related to the ice detection system in Web WPS SCADA

24.6. Operation with Ice Strategy

24.6.1. Operation with Ice Strategy: Stop Turbine

Stopping the turbine is often used in scenarios where it is not safe to keep running the turbine during icing conditions, e.g. where potential wildlife, people or equipment can be damaged/hurt. Only if using the external sensor can this approach be seen as safe, as the external sensors are often mounted on the nacelle and will detect when ice is forming and not based on production as the “Low Power Curve Detection” and “No Cut In” features do.

Operation with Ice Strategy: Stop Turbine makes sure the turbine is stopped when ice is detected. Additional option is possible in combination with the stop: Yaw to Angle.

Regardless of how *Operation with Ice Strategy: Stop Turbine* is configured, it is possible to determine if the turbine should auto reset or manually reset. The following options exist for auto reset:

- A stopped turbine with an ice detection alarm is reset after X hours
- A stopped turbine with an ice detection alarm requires manual reset
- A stopped turbine with an ice detection alarm that is yawed to a specific angle due to safety constraints is reset after X hours
- A stopped turbine with an ice detection alarm that is yawed to a specific angle due to safety constraints requires manual reset

24.6.2. Operation with Ice Strategy: Adaptive Operation

Operation with Ice Strategy: Adaptive Operation provides customers with a way to optimize the wind turbine so that it continues operation when ice builds up on the blades and ice detection is triggered, thereby limiting shutdown events. By allowing continued operation, ice accumulates more slowly on the blades compared to if it were at a standstill. Therefore, the yield of production with ice buildup will increase due to adaptation/optimization to icing conditions through pitch angle and speed-power modification.

Operation with Ice Strategy: Adaptive Operation offers a limited power production under managed loads and thereby reduces the turbines' shutdown events. *Operation with Ice Strategy: Adaptive Operation* is a wind turbine controller software functionality for optimizing performance, allowing the turbine to maintain operation in ice conditions.

When ice is detected via the LPDC or No Cut-in ice detection sources, *Operation with Ice Strategy: Adaptive Operation* finds the optimal operational setup in order to maximize production by first modifying the speed power curve (as shown in Figure 4). *Operation with Ice Strategy: Adaptive Operation* increases the rotor speed to avoid the blades stalling and the turbine from cutting out. The speed will not exceed nominal speed.

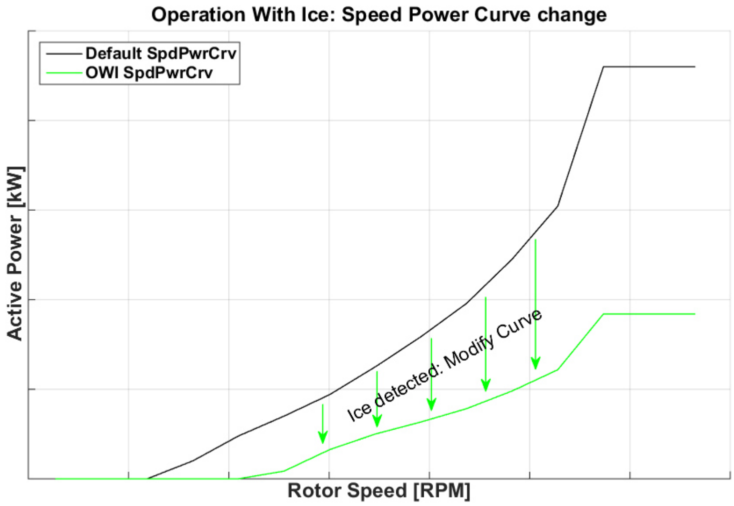

Figure 4: Illustration of OWI Speed-Power curve modification

Use of the *Operation with Ice Strategy: Adaptive Operation* functionality may under certain conditions increase the noise emissions from the turbine, and the noise emissions may exceed the levels indicated in the turbine supply agreement. Any noise levels indicated or warranted in the turbine supply agreement shall not be applicable in the event of operation of the turbine with the *Operation with Ice Strategy: Adaptive Operation* functionality activated.

It is the sole responsibility of the owner of the turbine to ensure that the turbine operating with *Operation with Ice Strategy: Adaptive Operation* functionality activated complies with any noise restriction applicable, irrespective of whether such limits follow from permits, legislation or otherwise. Siemens Gamesa accepts no responsibility for any violation of such limits.