Regione Sardegna
Provincia di Sassari
Comuni di Tergu, Nulvi, Sedini, Chiaramonti, Ploaghe e Codrongianos

**Proposta di ammodernamento complessivo** ("repowering") del "Parco Eolico Nulvi Tergu" esistente da 29,75 MW, con smantellamento degli attuali 35 aerogeneratori e sostituzione in riduzione degli stessi con l'installazione di 15 aerogeneratori, per una potenza totale definitiva di 99 MW

Titolo:

# SCHEDA TECNICA DEGLI AEROGENERATORI SCELTI

Numero documento:

| Commessa | Fase | Tipo doc. | Prog. doc. | Rev. |
|---|---|---|---|---|
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ORDINE DEGLI INGEGNERI DELLA PROVINCIA DI AVELLINO
DOTT. ING.
MASSIMO LO RUSSO
ISCRITTO ALL'ALBO PROFESSIONALE
COL N 1555



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SIEMENS Gamesa
RENEWABLE ENERGY

# Developer Package

# SG 6.6-170

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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 6.6-170 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.

# Table of contents

# 1. Introduction

The SG 6.6-170 is a new variant of the next generation Siemens Gamesa Onshore Geared product platform called Siemens Gamesa 5.X, which builds directly on the SG 6.2-170 variant.

With an updated 83.3 m blade, an upgraded gearbox and an extensive tower portfolio including hub heights ranging from115 m to 165 m, the SG 6.6-170 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

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

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

**Blades**
Siemens Gamesa 5.X blades 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.

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

**Drive train**
The drive train is a 4-points suspension concept: main shaft with two main bearings and the gearbox with two torque arms assembled to the main frame.

The gearbox is in cantilever position; the gearbox planet carrier is assembled to the main shaft by means of a flange bolted joint and supports the gearbox.

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

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

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

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

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

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

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

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

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

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

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

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

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

| Rotor | |
|---|---|
| Type | 3-bladed, horizontal axis |
| Position | Upwind |
| Diameter | 170 m |
| Swept area | 22,698 $m^2$ |
| 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 White, RAL 9018 |

| 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 |

| Mechanical Brake | |
|---|---|
| Type | Hydraulic disc brake |
| Position | Gearbox rear end |

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

| Generator | |
|---|---|
| Type | Asynchronous, DFIG |

| Grid Terminals (LV) | |
|---|---|
| Baseline nominal power | 6.6 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 |

| Type | Tubular steel / Hybrid |
|---|---|
| Hub height | 115m to 185 m and site-specific |
| Corrosion protection | Painted |
| Surface gloss | Semi-gloss, <30 / ISO-2813 Light grey, RAL 7035 or White |
| Color | RAL 9018 |

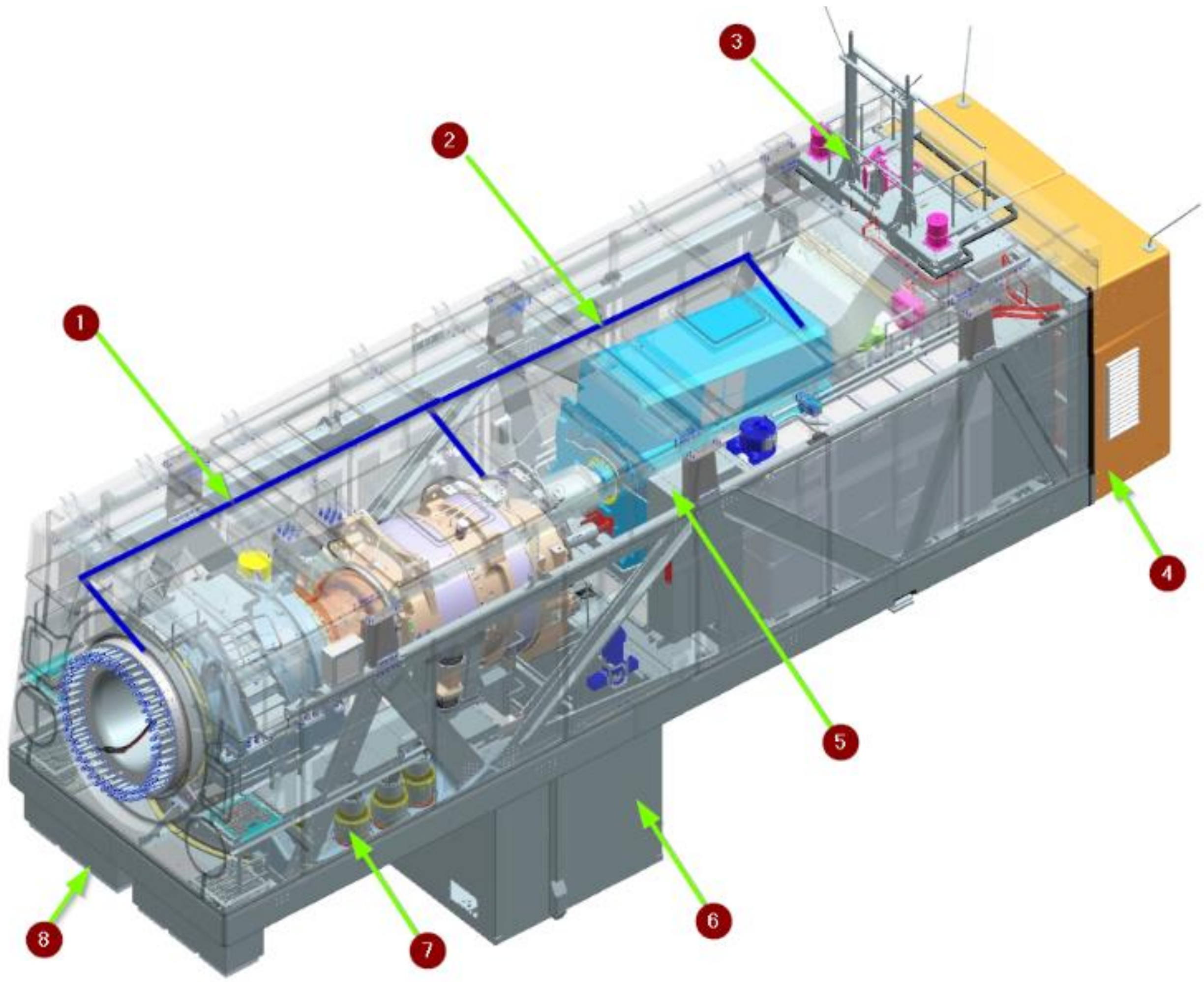
| Operational Data | |
|---|---|
| Cut-in wind speed | 3 m/s |
| Rated wind speed | 11.5 m/s (steady wind without turbulence, as defined by IEC61400-1) |
| Cut-out wind speed | 25 m/s |
| Restart wind speed | 22 m/s |

| Weight | |
|---|---|
| Modular approach | Different modules depending on restriction |

# 4. Nacelle Arrangement

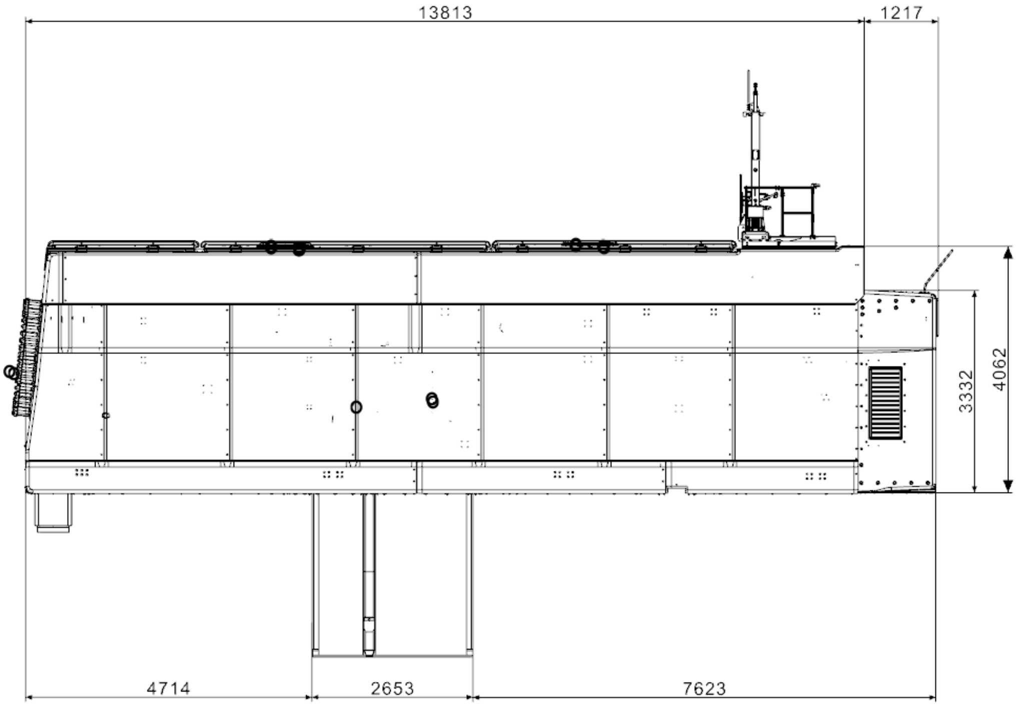
The design and layout of the nacelle are preliminary and may be subject to changes during the development of the product.

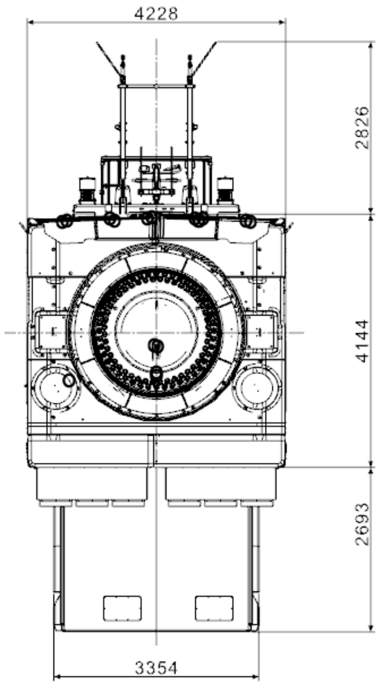
1. LSS area (Main shaft, Bearings, Bearing housing,Spool flange, Gearbox)
2. HSS area ( Couplings, Brake assembly, WTG)
3. External Equipments
4. Cooler room
5. Cabinets
6. TU
7. Bedframe and Yaw motors with ring
8. Air intake filter box



# 5. Nacelle dimensions

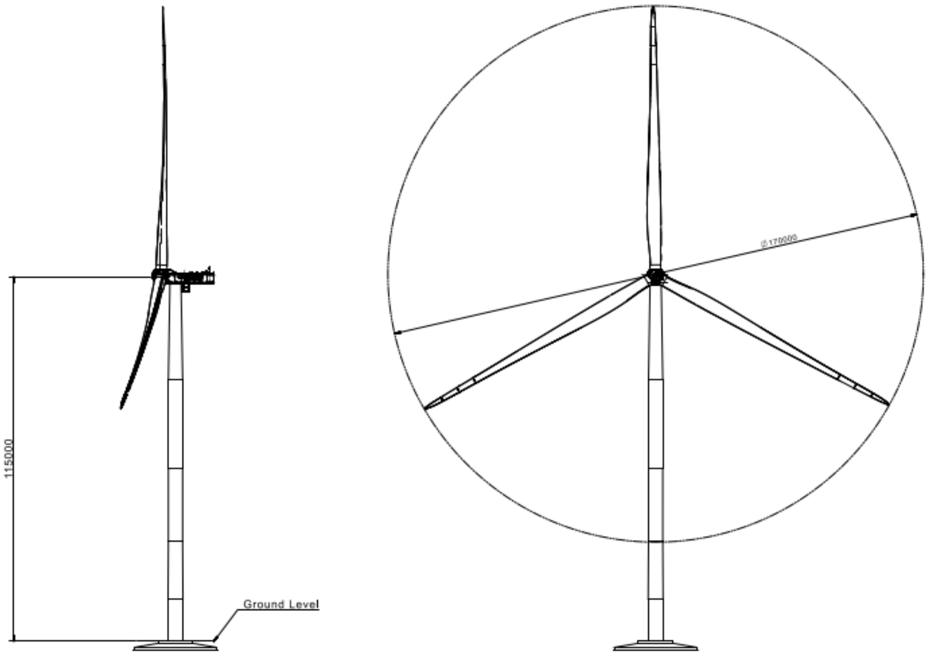
The design and dimensions of the nacelle are preliminary and may be subject to changes during the development phases of the product.



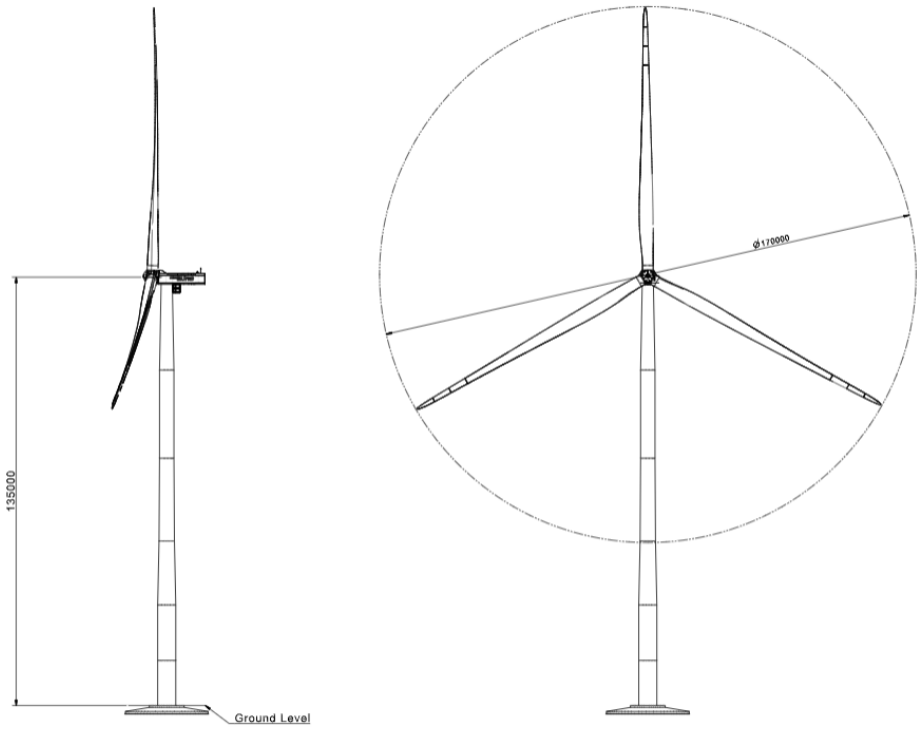



# 6. Elevation Drawing

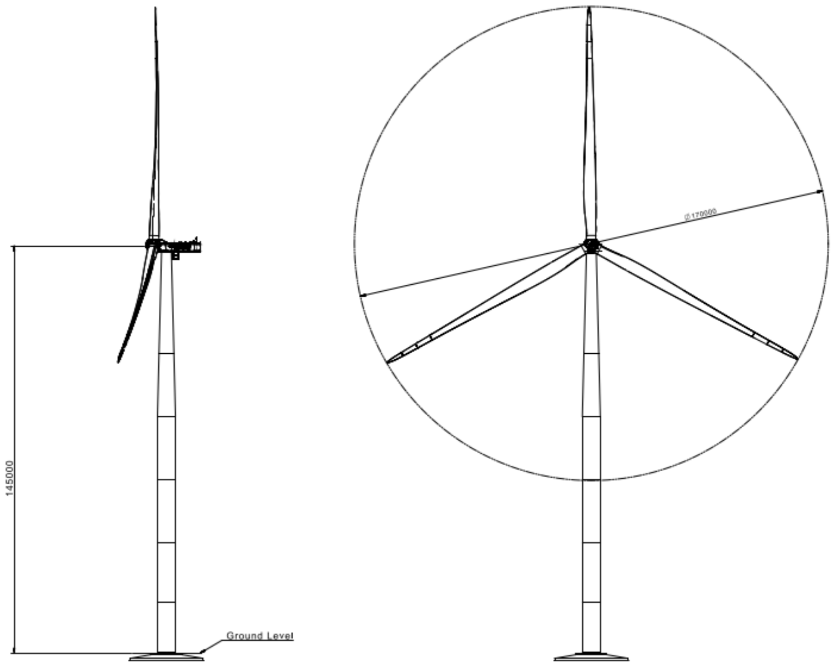
## 6.1. SG 6.6-170 115 m



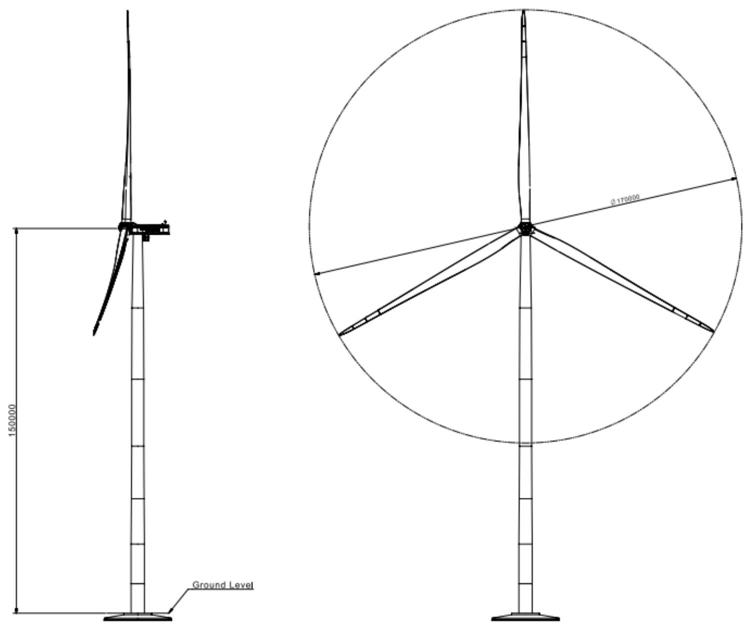

## 6.2. SG 6.6-170 135m



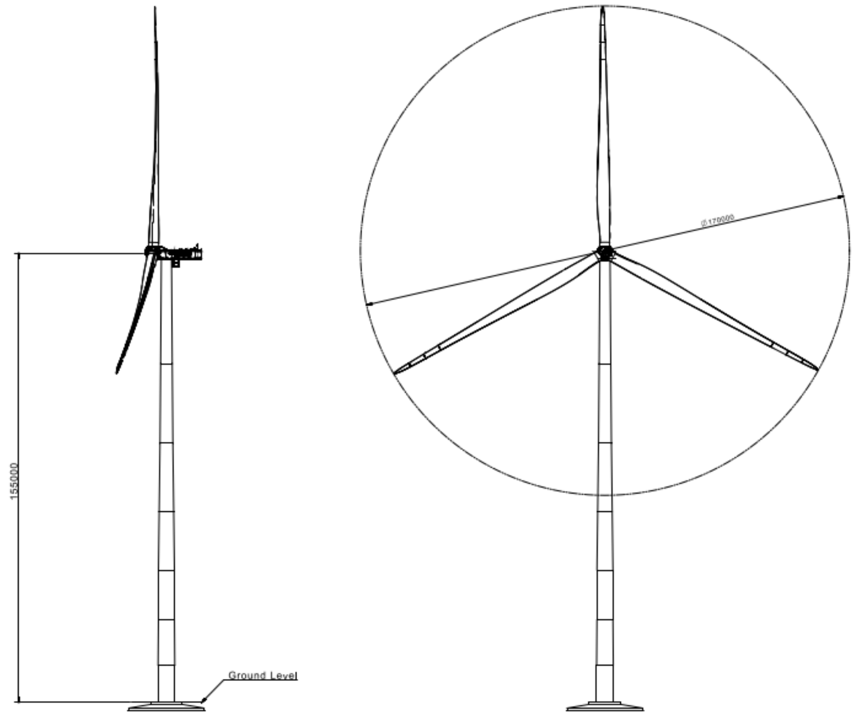
## 6.3. SG 6.6-170 145 m



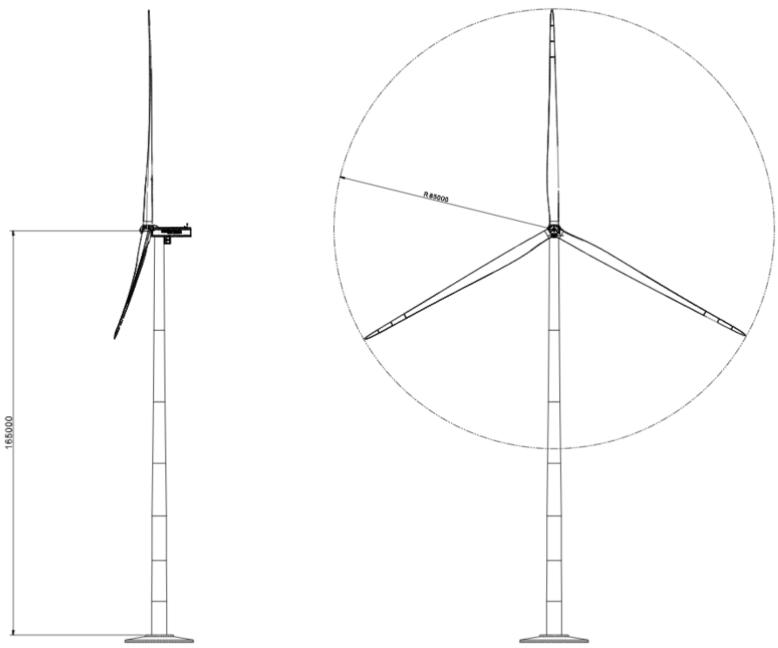

## 6.4. SG 6.6-170 150 m



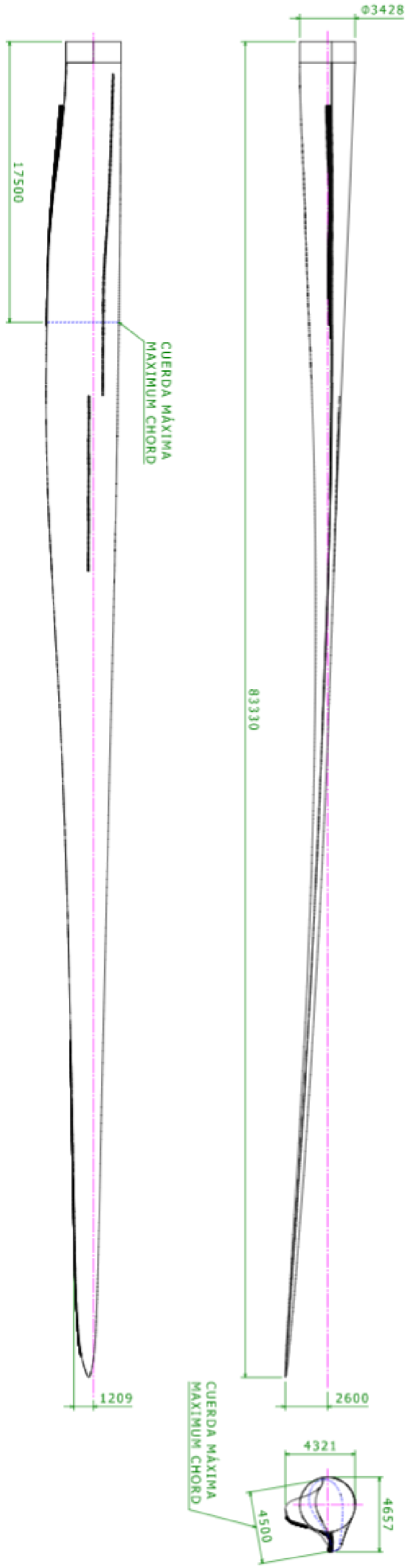
## 6.5. SG 6.6-170 155 m




## 6.6. SG 6.6-170 165 m



# 7. Blade Drawing




Dimensions in millimeter

# 8. Tower Dimensions

SG 6.6-170 is offered with an extensive tower portfolio ranging from 115m-165m. 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. Tapered tubular steel tower

| T100-51B_Rev02b | Section 1 | Section 2 | Section 3 | Section 4 |
|---|---|---|---|---|
| External diameter upper flange (m) | 4,493 | 4,493 | 4,493 | 3,380 |
| External diameter lower flange (m) | 4,700 | 4,493 | 4,493 | 4,493 |
| Section's height (m) | 14,234 | 21,840 | 26,880 | 34,450 |
| Flange type [bottom-top] | T-L | L-L | L-L | L-Top |
| Total weight (kg) | 73788 | 78604 | 73621 | 69651 |
| Total Tower weight (kg) | 295664 | | | |

## 8.2. Tower hub height 110.5m. Tapered tubular steel tower

| T110.5-50A_Rev03a | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 | Section 6 |
|---|---|---|---|---|---|---|
| External diameter upper flange (m) | 4,543 | 4,543 | 4,543 | 4,543 | 4,543 | 3,503 |
| External diameter lower flange (m) | 4,551 | 4,543 | 4,543 | 4,543 | 4,543 | 4,543 |
| Section's height (m) | 9,304 | 14,840 | 17,920 | 20,440 | 22,400 | 23,000 |
| Flange type [bottom-top] | T-T | T-L | L-L | L-L | L-L | L-Top |
| Total weight (kg) | 62.150 | 68.398 | 69.997 | 63.621 | 53.106 | 50.336 |
| Total Tower weight (kg) | 367608 | | | | | |

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

| T115.0-56A_Rev03a | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 |
|---|---|---|---|---|---|
| External diameter upper flange (m) | 4,700 | 4,485 | 4,490 | 4,490 | 3,503 |
| External diameter lower flange (m) | 4,700 | 4,700 | 4,485 | 4,490 | 4,490 |
| Section's height (m) | 13,274 | 18,200 | 22,960 | 28,000 | 29,970 |
| Flange type [bottom-top] | T-T | T-L | L-L | L-L | L-Top |
| Total weight (kg) | 80089 | 78827 | 82122 | 74150 | 66283 |
| Total Tower weight (kg) | 381471 | | | | |

## 8.4. Tower hub height 115m. Tapered tubular steel tower

| T115.0-57A_Rev02a | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 |
|---|---|---|---|---|---|
| External diameter upper flange (m) | 4.500 | 4.393 | 4.385 | 4.020 | 3.503 |
| External diameter lower flange (m) | 4.205 | 4.500 | 4.393 | 4.385 | 4.020 |
| Section's height (m) | 12,292 | 16,520 | 22,400 | 29,120 | 30,082 |
| Flange type [bottom-top] | T-T | T-L | L-L | L-L | L-Top |
| Total weight (kg) | 82.426 | 79.395 | 82.286 | 75.510 | 60.537 |
| Total Tower weight (kg) | 380154 | | | | |

## 8.5. Tower hub height 115m. Tapered tubular steel tower

| T115-58B_Rev01b | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 |
|---|---|---|---|---|---|
| External diameter upper flange (m) | 4.700 | 4.433 | 4.427 | 4.020 | 3.380 |
| External diameter lower flange (m) | 4.700 | 4.700 | 4.433 | 4.427 | 4.020 |
| 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) | 80.055 | 78.241 | 80.502 | 68.289 | 57.145 |
| Total Tower weight (kg) | 364232 | | | | |

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

| T135-52A_Rev03a | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 | Section 6 |
|---|---|---|---|---|---|---|
| External diameter upper flange (m) | 5,683 | 5,680 | 4,832 | 4,524 | 4,518 | 3,503 |
| External diameter lower flange (m) | 6,000 | 5,683 | 5,680 | 4,832 | 4,524 | 4,518 |
| Section's height (m) | 14,160 | 17,360 | 20,160 | 26,040 | 27,720 | 26,974 |
| Flange type [bottom-top] | T-L | L-L | L-L | L-L | L-L | L-Top |
| Total weight (kg) | 87.286 | 83.972 | 83.763 | 86.821 | 68.428 | 56.565 |
| Total Tower weight (kg) | 466.836 | | | | | |

## 8.7. Tower hub height 135m. Tapered tubular steel tower

| T135-54A_Rev08b | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 | Section 6 |
|---|---|---|---|---|---|---|
| External diameter upper flange (m) | 5,137 | 5,200 | 5,195 | 5,189 | 4,900 | 3,503 |
| External diameter lower flange (m) | 5,200 | 5,137 | 5,200 | 5,195 | 5,189 | 4,900 |
| Section's height (m) | 11,574 | 14,840 | 17,640 | 22,400 | 29,960 | 36,000 |
| Flange type [bottom-top] | T-T | T-L | L-L | L-L | L-L | L-Top |
| Total weight (kg) | 84.229 | 82.305 | 81.010 | 82.625 | 82.192 | 72.157 |
| Total Tower weight (kg) | 484.518 | | | | | |

## 8.8. Tower hub height 145m. Tapered tubular steel tower

| T145.0-51A_Rev05a | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 | Section 6 |
|---|---|---|---|---|---|---|
| External diameter upper flange (m) | 6,390 | 6,390 | 6,390 | 6,200 | 4,895 | 3,503 |
| External diameter lower flange (m) | 6,400 | 6,390 | 6,390 | 6,390 | 6,200 | 4,895 |
| Section's height (m) | 17,924 | 21,280 | 22,400 | 22,400 | 22,400 | 36,000 |
| Flange type [bottom-top] | T-L | L-L | L-L | L-L | L-L | L-Top |
| Total weight (kg) | 102614 | 102123 | 94235 | 81970 | 64755 | 84291 |
| Total Tower weight (kg) | 529988 | | | | | |

## 8.9. Tower hub height 150m. Tapered tubular steel tower

| T150-50A_Rev02a | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 | Section 6 | Section 7 |
|---|---|---|---|---|---|---|---|
| External diameter upper flange (m) | 5,200 | 5,200 | 4,934 | 4,730 | 4,724 | 4,518 | 3,503 |
| External diameter lower flange (m) | 5,200 | 5,200 | 5,200 | 4,934 | 4,730 | 4,724 | 4,518 |
| Section's height (m) | 11,486 | 15,400 | 17,640 | 20,440 | 26,040 | 27,720 | 28,688 |
| Flange type [bottom-top] | T-T | T-T | T-L | L-L | L-L | L-L | L-Top |
| Total weight (kg) | 89875 | 87575 | 86506 | 86758 | 87129 | 68463 | 60905 |
| Total Tower weight (kg) | 567212 | | | | | | |

## 8.10. Tower hub height 155m. Tapered tubular steel tower

| T155.0-51A_Rev05a | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 | Section 6 | Section 7 |
|---|---|---|---|---|---|---|---|
| External diameter upper flange (m) | 5,758 | 5,510 | 5,507 | 5,010 | 4,432 | 4,015 | 3,503 |
| External diameter lower flange (m) | 5,800 | 5,758 | 5,510 | 5,507 | 5,010 | 4,432 | 4,015 |
| Section's height (m) | 12,880 | 15,680 | 17,080 | 20,160 | 23,520 | 27,440 | 35,850 |
| Flange type [bottom-top] | T-T | T-L | L-L | L-L | L-L | L-L | L-Top |
| Total weight (kg) | 90081 | 86929 | 85534 | 85621 | 85117 | 77921 | 74076 |
| Total Tower weight (kg) | 585279 | | | | | | |

## 8.11. Tower hub height 155m. Tapered tubular steel tower

| T155-52A_Rev02a | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 | Section 6 | Section 7 |
|---|---|---|---|---|---|---|---|
| External diameter upper flange (m) | 5.738 | 5.510 | 5.507 | 5.010 | 4.432 | 4.015 | 3.380 |
| External diameter lower flange (m) | 5.800 | 5.738 | 5.510 | 5.507 | 5.010 | 4.432 | 4.015 |
| Section's height (m) | 12.880 | 15.680 | 17.080 | 20.160 | 23.520 | 27.440 | 35.850 |
| Flange type [bottom-top] | T-T | T-L | L-L | L-L | L-L | L-L | L-Top |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Total weight (kg)** | 87600 | 85568 | 84341 | 85734 | 84795 | 77295 | 72927 |
| **Total Tower weight (kg)** | 578260 | | | | | | |

## 8.12. Tower hub height 165m. Hybrid concrete tower

| T165-55B-MB_Rev01a | Concrete | Section 1 | Section 2 |
|---|---|---|---|
| **External diameter upper flange (m)** | 4,528 | 4,292 | 3,380 |
| **External diameter lower flange (m)** | 9,148 | 4,301 | 4,292 |
| **Section's height (m)** | 94,69 [1)] | 29,710 | 36,000 |
| **Flange type [bottom-top]** | | L-L | L-Top |
| **Total weight (kg)** | | 81658 | 70750 |
| **Total Tower weight (kg)** | | 152408 | |

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

## 8.13. Tower hub height 165m. Tapered tubular steel tower

| T165.0-57A_Rev02a | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 | Section 6 | Section 7 | Section 8 |
|---|---|---|---|---|---|---|---|---|
| **External diameter upper flange (m)** | 5,800 | 5,799 | 5,795 | 5,791 | 5,256 | 4,668 | 4,079 | 3,503 |
| **External diameter lower flange (m)** | 5,800 | 5,800 | 5,799 | 5,795 | 5,791 | 5,256 | 4,668 | 4,079 |
| **Section's height (m)** | 12,034 | 15,120 | 16,800 | 19,040 | 22,680 | 24,920 | 24,920 | 26,890 |
| **Flange type [bottom-top]** | T-T | T-L | L-L | L-L | L-L | L-L | L-L | L-Top |
| **Total weight (kg)** | 89873 | 90083 | 89627 | 89599 | 89533 | 79877 | 60592 | 54913 |
| **Total Tower weight (kg)** | 644097 | | | | | | | |

## 8.14. Tower hub height 165m. Tapered tubular steel tower

| T165.0-57B_Rev01a | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 | Section 6 | Section 7 | Section 8 |
|---|---|---|---|---|---|---|---|---|
| **External diameter upper flange (m)** | 5,791 | 5,799 | 5,796 | 5,791 | 5,256 | 4,668 | 4,079 | 3,380 |
| **External diameter lower flange (m)** | 5,800 | 5,791 | 5,799 | 5,796 | 5,791 | 5,256 | 4,668 | 4,079 |
| **Section's height (m)** | 12,034 | 15,120 | 16,800 | 19,040 | 22,680 | 24,920 | 24,920 | 26,890 |
| **Flange type [bottom-top]** | T-T | T-L | L-L | L-L | L-L | L-L | L-L | L-Top |
| **Total weight (kg)** | 89573 | 91002 | 90706 | 89641 | 89533 | 79877 | 60690 | 54131 |
| **Total Tower weight (kg)** | 645154 | | | | | | | |

## 8.15. Tower hub height 185m. Hybrid concrete tower

| T185-50A-MB_Rev03a | Concrete | Section 1 | Section 2 |
|---|---|---|---|
| **External diameter upper flange (m)** | 4,528 | 4,293 | 3,380 |
| **External diameter lower flange (m)** | 10,128 | 4,301 | 4,293 |
| **Section's height (m)** | 114,300 [1)] | 30,055 | 36,000 |
| **Flange type [bottom-top]** | | L-L | L-Top |
| **Total weight (kg)** | | 82600 | 74686 |
| **Total Tower weight (kg)** | | 157286 | |

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

# 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 6.6-170.

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

The design climatic conditions in this document are the standard climatic conditions but there are tower configurations which are designed to specific climatic conditions. These conditions are documented as part of the specific tower documentation.

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 | 25 |
| **1. Wind, operation** | 1.1 | Wind definitions | - | IEC 61400-1 |
| | 1.2 | IEC class | - | S |
| | 1.3 | Mean air density, ρ | kg/m$^3$ | 1.25 |
| | 1.4 | Mean wind speed, $V_{ave}$ | m/s | 7.38 |
| | 1.5 | Weibull scale parameter, A | m/s | 8.3 |
| | 1.6 | Weibull shape parameter, k | - | 2.64 |
| | 1.7 | Wind shear exponent, α | - | 0.36 |
| | 1.8 | Reference turbulence intensity at 15 m/s, $I_{ref}$ | - | 0.16[2] |
| | 1.9 | Standard deviation of wind direction | Deg | - |
| | 1.10 | Maximum flow inclination | Deg | 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/m$^3$ | 1.225 |
| | 2.3 | Reference wind speed average over 10 min at hub height, $V_{ref}$ | m/s | 42.5[3] |
| | 2.4 | Maximum 3 s gust in hub height, $V_{e50}$ | m/s | 59.5 |
| | 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 [4,5] |
| | 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 |

[1] All mentioning of IEC 61400-1 refers to to IEC 61400-1:2018 Ed4.
[2] NTM and ETM as per IEC A
[3] EWM as per IEC 2
[4] 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.
[5] 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 |
|---|---|---|---|---|
| | 4.2 | Internal nacelle environment (corrosivity category) | - | C3H (std)<br>≥C3H (high C) |
| | 4.3 | Exterior environment (corrosivity category) | - | C3H (std)<br>≥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[6]** | 12.1 | Annual precipitation | mm/yr | 1100 |

[6] 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 6.6-170 AM0 STD

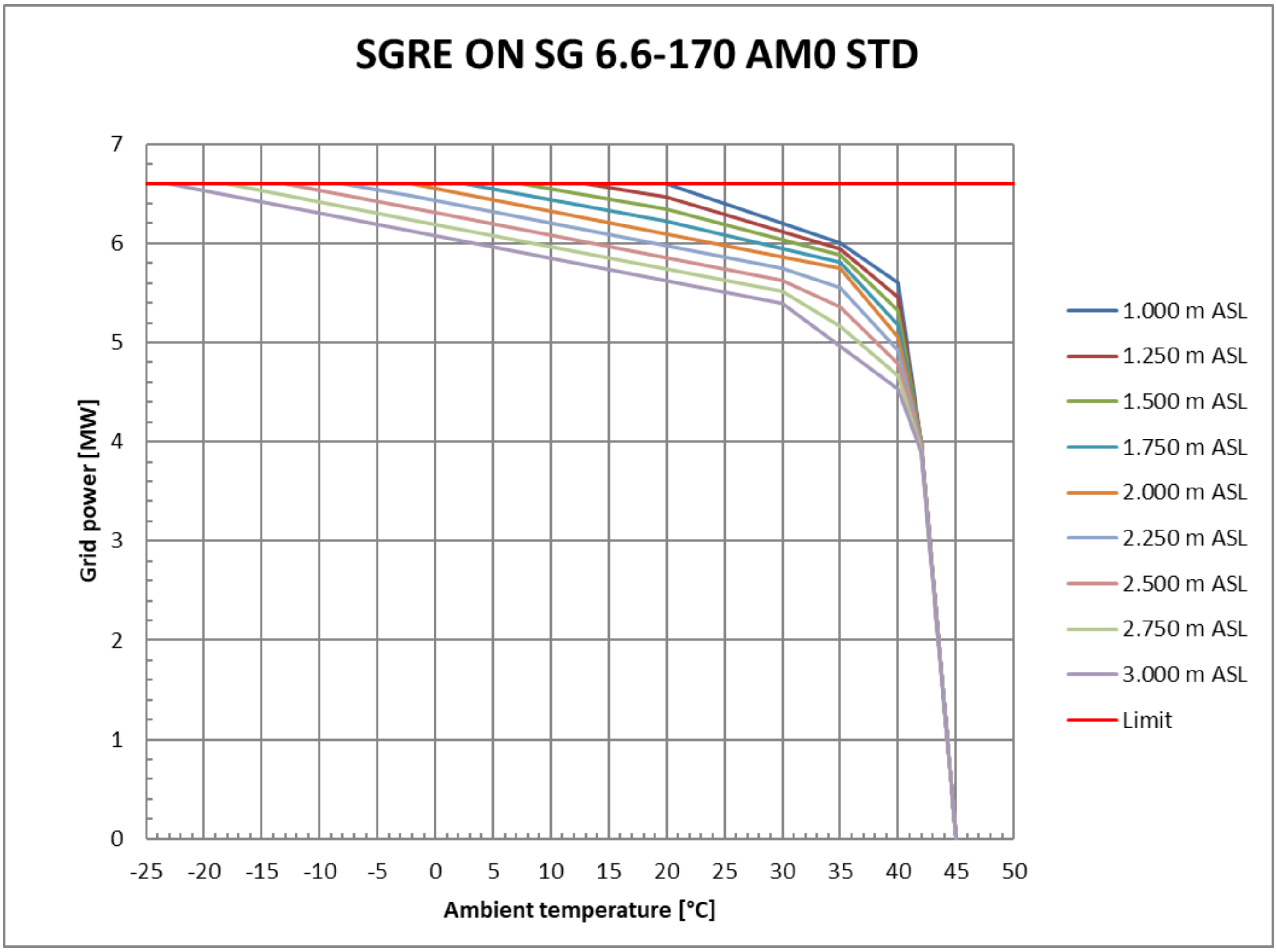



*Figure 1: SG 6.6-170 AM0 STD power derating curves by ambient temperature and altitude*

*Table 1: SG 6.6-170 AM0 STD grid power as function of ambient temperature and altitude*

| SGRE ON SG 6.6-170 AM0 STD | | | | | 6.60 | MW | 8.83 | RPM |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| **Altitude** | | | | | | | **1,000 m ASL** | |
| **Temp.** | **°C** | **20** | **35** | **40** | **42** | **45** | | |
| **Power** | **MW** | **6.6** | **6** | **5.6** | **4** | **0** | | |
| **Load** | **-** | **1** | **0.91** | **0.85** | **0.61** | **0** | | |
| Altitude | | | | | | | 1,250 m ASL | |
| Temp. | °C | 13 | 20 | 35 | 40 | 42 | 45 | |
| Power | MW | 6.6 | 6.47 | 5.94 | 5.46 | 4 | 0 | |
| Load | - | 1 | 0.98 | 0.9 | 0.83 | 0.61 | 0 | |
| Altitude | | | | | | | 1,500 m ASL | |
| Temp. | °C | 7.5 | 20 | 35 | 40 | 42 | 45 | |
| Power | MW | 6.6 | 6.35 | 5.88 | 5.32 | 4 | 0 | |
| Load | - | 1 | 0.96 | 0.89 | 0.81 | 0.61 | 0 | |
| Altitude | | | | | | | 1,750 m ASL | |
| Temp. | °C | 2.5 | 20 | 35 | 40 | 42 | 45 | |
| Power | MW | 6.6 | 6.22 | 5.81 | 5.18 | 4 | 0 | |
| Load | - | 1 | 0.94 | 0.88 | 0.79 | 0.61 | 0 | |
| **Altitude** | | | | | | | **2,000 m ASL** | |
| **Temp.** | **°C** | **-2** | **35** | **40** | **42** | **45** | | |
| **Power** | **MW** | **6.6** | **5.75** | **5.05** | **4** | **0** | | |
| **Load** | **-** | **1** | **0.87** | **0.77** | **0.61** | **0** | | |
| Altitude | | | | | | | 2,250 m ASL | |
| Temp. | °C | -8 | -2 | 30 | 35 | 40 | 42 | 45 |
| Power | MW | 6.6 | 6.48 | 5.75 | 5.55 | 4.92 | 3.97 | 0 |
| Load | - | 1 | 0.98 | 0.87 | 0.84 | 0.74 | 0.6 | 0 |
| Altitude | | | | | | | 2,500 m ASL | |
| Temp. | °C | -13 | -2 | 30 | 35 | 40 | 42 | 45 |
| Power | MW | 6.6 | 6.36 | 5.63 | 5.36 | 4.79 | 3.95 | 0 |
| Load | - | 1 | 0.96 | 0.85 | 0.81 | 0.73 | 0.6 | 0 |
| Altitude | | | | | | | 2,750 m ASL | |
| Temp. | °C | -18 | -2 | 30 | 35 | 40 | 42 | 45 |
| Power | MW | 6.6 | 6.24 | 5.52 | 5.16 | 4.66 | 3.92 | 0 |
| Load | - | 1 | 0.95 | 0.84 | 0.78 | 0.71 | 0.59 | 0 |
| **Altitude** | | | | | | | **3,000 m ASL** | |
| **Temp.** | **°C** | **-23** | **30** | **40** | **42** | **45** | | |
| **Power** | **MW** | **6.6** | **5.4** | **4.53** | **3.9** | **0** | | |
| **Load** | **-** | **1** | **0.82** | **0.69** | **0.59** | **0** | | |

*Table 2: SG 6.6-170 AM0 STD ambient temperature as function of grid power and altitude*

| SGRE ON SG 6.6-170 AM0 STD | | | 6.6 | MW | 8.83 | RPM | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **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)** | | | | | |
| **6.6** | | **-20** | -20 | -20 | -20 | **-20** | -20 | -20 | -20 | **-23** |
| **6.6** | | **20** | 13 | 7.5 | 2.5 | **-2** | -8 | -13 | -18 | **-23** |
| **6.5** | | **22.5** | 18.5 | 12.5 | 7 | **2.5** | -3 | -8.5 | -13.5 | **-18.5** |
| **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** |

## 10.2. SG 6.6-170 AM0 HT

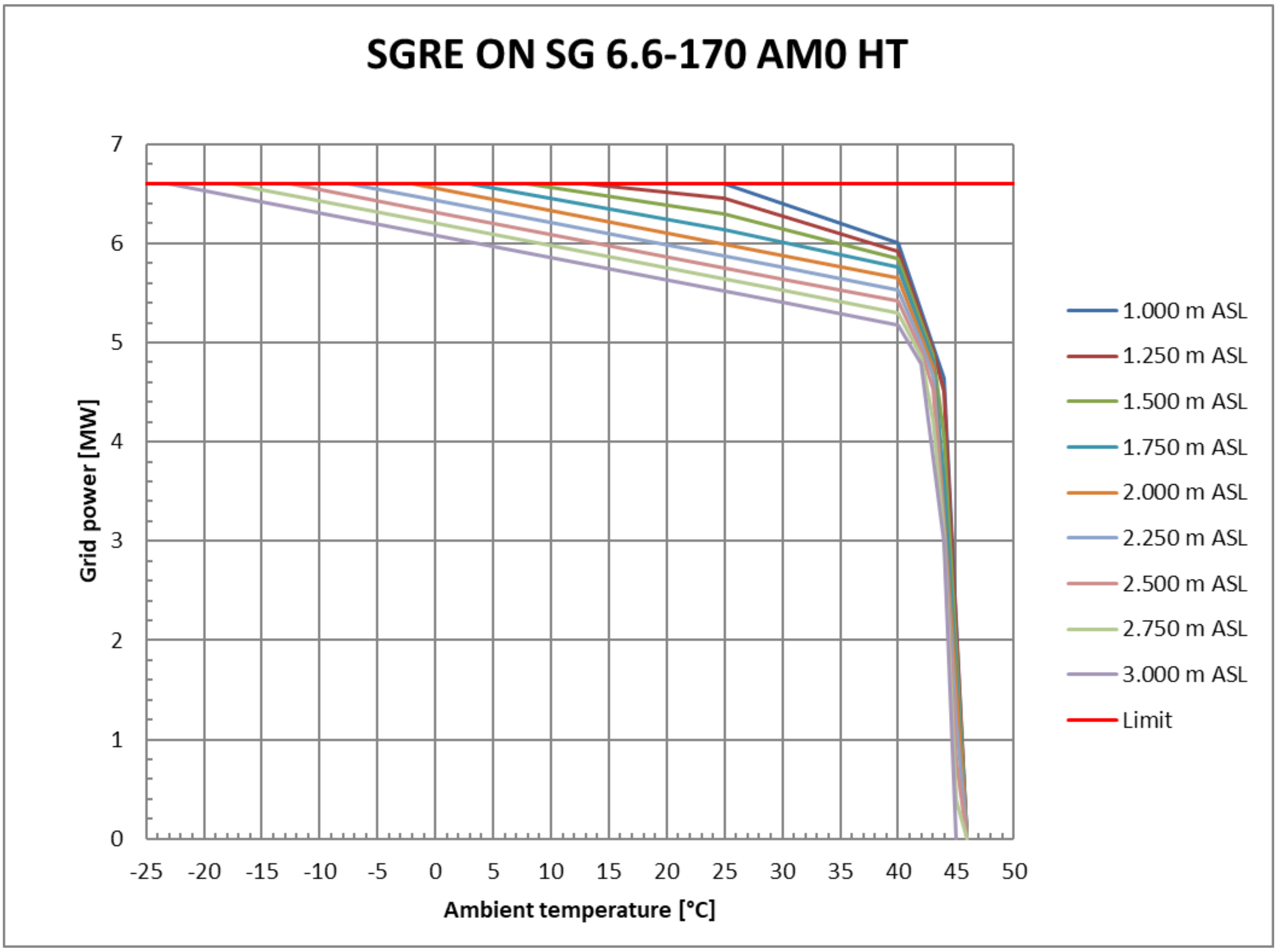



*Figure 2: SG 6.6-170 AM0 HT power derating curves by ambient temperature and altitude*

*Table 3: SG 6.6-170 AM0 HT grid power as function of ambient temperature and altitude*

| **SGRE ON SG 6.6-170 AM0 HT** | | | | | **6.60** | **MW** | **8.83** | **RPM** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Altitude** | | | | | | | **1,000 m ASL** | | | | |
| **Temp.** | **°C** | **25** | **40** | **44** | **46** | | | | | | |
| **Power** | **MW** | **6.6** | **6** | **4.64** | **0** | | | | | | |
| **Load** | **-** | **1** | **0.91** | **0.7** | **0** | | | | | | |
| Altitude | | | | | | | 1,250 m ASL | | | | |
| Temp. | °C | 13 | 25 | 40 | 43 | 44 | 46 | | | | |
| Power | MW | 6.6 | 6.45 | 5.92 | 4.92 | 4.51 | 0 | | | | |
| Load | - | 1 | 0.98 | 0.9 | 0.75 | 0.68 | 0 | | | | |
| Altitude | | | | | | | 1,500 m ASL | | | | |
| Temp. | °C | 8 | 25 | 40 | 43 | 44 | 46 | | | | |
| Power | MW | 6.6 | 6.29 | 5.84 | 4.87 | 4.06 | 0 | | | | |
| Load | - | 1 | 0.95 | 0.89 | 0.74 | 0.61 | 0 | | | | |
| Altitude | | | | | | | 1,750 m ASL | | | | |
| Temp. | °C | 3 | 25 | 40 | 43 | 44 | 46 | | | | |
| Power | MW | 6.6 | 6.14 | 5.76 | 4.81 | 3.61 | 0 | | | | |
| Load | - | 1 | 0.93 | 0.87 | 0.73 | 0.55 | 0 | | | | |
| **Altitude** | | | | | | | **2,000 m ASL** | | | | |
| **Temp.** | **°C** | **-2** | **40** | **43** | **46** | | | | | | |
| **Power** | **MW** | **6.6** | **5.65** | **4.75** | **0** | | | | | | |
| **Load** | **-** | **1** | **0.86** | **0.72** | **0** | | | | | | |
| Altitude | | | | | | | 2,250 m ASL | | | | |
| Temp. | °C | -7.5 | -2 | 30 | 40 | 42 | 43 | 44 | 45 | 46 | |
| Power | MW | 6.6 | 6.48 | 5.76 | 5.53 | 4.99 | 4.66 | 3.12 | 1.19 | 0 | |
| Load | - | 1 | 0.98 | 0.87 | 0.84 | 0.76 | 0.71 | 0.47 | 0.18 | 0 | |
| Altitude | | | | | | | 2,500 m ASL | | | | |
| Temp. | °C | -12.5 | -2 | 30 | 40 | 42 | 43 | 44 | 45 | 46 | |
| Power | MW | 6.6 | 6.36 | 5.64 | 5.42 | 4.92 | 4.53 | 3.08 | 0.79 | 0 | |
| Load | - | 1 | 0.96 | 0.86 | 0.82 | 0.75 | 0.69 | 0.47 | 0.12 | 0 | |
| Altitude | | | | | | | 2,750 m ASL | | | | |
| Temp. | °C | -17.5 | -15 | -2 | 30 | 40 | 42 | 43 | 44 | 45 | 46 |
| Power | MW | 6.6 | 6.54 | 6.25 | 5.53 | 5.3 | 4.86 | 4.21 | 3.04 | 0.39 | 0 |
| Load | - | 1 | 0.99 | 0.95 | 0.84 | 0.8 | 0.74 | 0.64 | 0.46 | 0.06 | 0 |
| **Altitude** | | | | | | | **3,000 m ASL** | | | | |
| **Temp.** | **°C** | **-23** | **-15** | **30** | **40** | **42** | **44** | **45** | | | |
| **Power** | **MW** | **6.6** | **6.42** | **5.41** | **5.18** | **4.79** | **2.99** | **0** | | | |
| **Load** | **-** | **1** | **0.97** | **0.82** | **0.78** | **0.73** | **0.45** | **0** | | | |

*Table 4: SG 6.6-170 AM0 HT ambient temperature as function of grid power and altitude*

| SGRE ON SG 6.6-170 AM0 HT | | | | 6.6 | MW | 8.83 | RPM | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **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)** | | | | | |
| **6.6** | | **-20** | -20 | -20 | -20 | **-20** | -20 | -20 | -20 | **-23** |
| **6.6** | | **25** | 13 | 8 | 3 | **-2** | -7.5 | -12.5 | -17.5 | **-23** |
| **6.5** | | **27.5** | 21 | 13.5 | 7.5 | **2.5** | -3 | -8 | -13.5 | **-18.5** |
| **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 | | |

| SGRE ON SG 6.6-170 AM0 HT | | | | 6.6 | MW | | 8.83 | RPM | | |
|---|---|---|---|---|---|---|---|---|---|---|

| 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) | | | | | |
| **1.8** | | | | | 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** |

# 11. Flexible Rating Specification

The SG 6.6-170 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[7].

## 11.1. 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 6.6-170 can offer increased operation flexibility with modes based on AM 0 with reduced power rating.

## 11.2. Full list of Application Modes SG 6.6-170

| 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[8] |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Cos Phi | Voltage Range | Frequency range | |
| SG 6.6-170 | AM 0 | 6.6 | 106.0 | D2849164 | D4180291 | 0.9 | [0.95,1.12] Un | ±3% Fn | 20ºC |
| SG 6.6-170 | AM-1 | 6.5 | 106.0 | D2861213 | D4180291 | 0.9 | [0.95,1.12] Un | ±3% Fn | 23ºC |
| SG 6.6-170 | AM-2 | 6.4 | 106.0 | D2863704 | D4180291 | 0.9 | [0.95,1.12] Un | ±3% Fn | 25ºC |
| SG 6.6-170 | AM-3 | 6.3 | 106.0 | D2863706 | D4180291 | 0.9 | [0.95,1.12] Un | ±3% Fn | 28ºC |
| SG 6.6-170 | AM-4 | 6.2 | 106.0 | D2863708 | D4180291 | 0.9 | [0.95,1.12] Un | ±3% Fn | 30ºC |
| SG 6.6-170 | AM-5 | 6.1 | 106.0 | D2863710 | D4180291 | 0.9 | [0.95,1.12] Un | ±3% Fn | 33ºC |
| SG 6.6-170 | AM-6 | 6.0 | 106.0 | D2863712 | D4180291 | 0.9 | [0.95,1.12] Un | ±3% Fn | 35ºC |

[7] 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

## 11.3. 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.

## 11.4. List of NRS Modes SG 6.6-170

| Rotor Configuration | NRS Mode | Rating [MW] | Noise [dB(A)] | Power Curve Document | Acoustic Emission Document | Max temperature With Max active power and electrical capabilities[9] |
|---|---|---|---|---|---|---|
| SG 6.6-170 | N1 | 6.40 | 105.5 | D2863684 | D4040973 | 20ºC |
| SG 6.6-170 | N2 | 6.10 | 104.5 | D2863686 | D4041105 | 20ºC |
| SG 6.6-170 | N3 | 5.24 | 103.0 | D2863688 | D4073328 | 30ºC |
| SG 6.6-170 | N4 | 5.12 | 102.0 | D2863690 | D4073330 | 30ºC |
| SG 6.6-170 | N5 | 4.87 | 101.0 | D2863692 | D4041112 | 30ºC |
| SG 6.6-170 | N6 | 4.52 | 100.0 | D2863697 | D4041113 | 30ºC |
| SG 6.6-170 | N7 | 3.60 | 99.0 | D2863699 | D4041114 | 30ºC |

## 11.5. 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.

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

# 12. Standard Ct and Power Curve, Rev 2, Mode AM 0

## 12.1. Standard Power Curve, Application Mode - AM 0

Air density= 1.225 kg/m$^3$

Validity range:

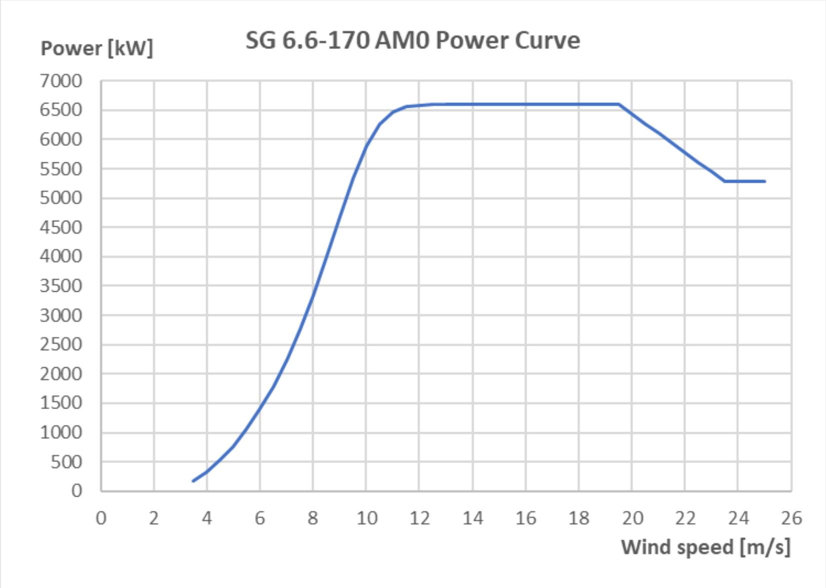
| | |
|---|---|
| **Wind Shear (10min average)** | ≤ 0.3 |
| **Turbulence intensity TI [%] for bin i** | $5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$ |
| **Terrain** | Not complex according to IEC 61400-12-1 |
| **Upflow β [°]** | -2° ≤ β ≤ +2° |
| **Grid frequency [Hz]** | ± 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 6.6-170 Rev. 2, AM 0 | |
|---|---|
| Wind Speed [m/s] | Power [kW] |
| 3.0 | 46 |
| 3.5 | 164 |
| 4.0 | 325 |
| 4.5 | 523 |
| 5.0 | 765 |
| 5.5 | 1052 |
| 6.0 | 1392 |
| 6.5 | 1787 |
| 7.0 | 2245 |
| 7.5 | 2767 |
| 8.0 | 3357 |
| 8.5 | 4006 |
| 9.0 | 4682 |
| 9.5 | 5333 |
| 10.0 | 5881 |
| 10.5 | 6260 |
| 11.0 | 6466 |
| 11.5 | 6555 |
| 12.0 | 6587 |
| 12.5 | 6597 |
| 13.0 | 6599 |
| 13.5 | 6600 |
| 14.0 | 6600 |
| 14.5 | 6600 |
| 15.0 | 6600 |
| 15.5 | 6600 |
| 16.0 | 6600 |
| 16.5 | 6600 |
| 17.0 | 6600 |
| 17.5 | 6600 |
| 18.0 | 6600 |
| 18.5 | 6600 |
| 19.0 | 6600 |
| 19.5 | 6600 |
| 20.0 | 6435 |
| 20.5 | 6270 |
| 21.0 | 6105 |
| 21.5 | 5940 |
| 22.0 | 5775 |
| 22.5 | 5610 |
| 23.0 | 5445 |
| 23.5 | 5280 |
| 24.0 | 5280 |
| 24.5 | 5280 |
| 25.0 | 5280 |



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 | 13050 | 15553 | 17947 | 20187 | 22245 | 24104 | 25756 | 27201 | 28444 | 29494 | 30364 |
| | 2.0 | 11797 | 14775 | 17757 | 20656 | 23409 | 25978 | 28339 | 30477 | 32383 | 34055 | 35492 |
| | 2.5 | 10552 | 13723 | 17050 | 20393 | 23639 | 26711 | 29562 | 32169 | 34525 | 36630 | 38487 |

Annual Production [MWh] SG 6.6-170 Rev.2, 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$^3$

## 12.2. 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** | $5\% \frac{(0.75\mathrm{v_i} + 5.6)}{\mathrm{v_i}} < \mathrm{TI_i} < 12\% \frac{(0.75\mathrm{v_i} + 5.6)}{\mathrm{v_i}}$ |
| **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.

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]

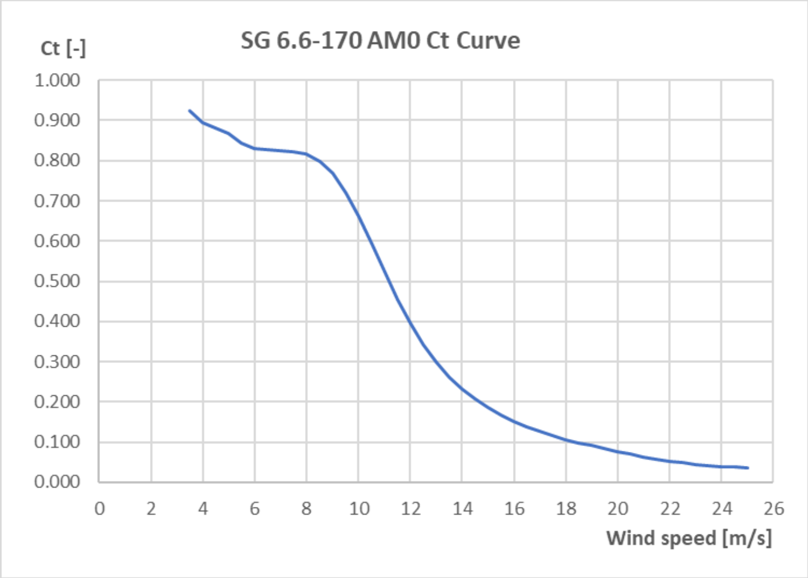
ad = Air density [kg/m$^3$]

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 6.6-170 Rev. 2, AM 0 | |
|---|---|
| Wind Speed [m/s] | Ct [-] |
| 3.0 | 0.977 |
| 3.5 | 0.925 |
| 4.0 | 0.894 |
| 4.5 | 0.881 |
| 5.0 | 0.868 |
| 5.5 | 0.844 |
| 6.0 | 0.830 |
| 6.5 | 0.826 |
| 7.0 | 0.826 |
| 7.5 | 0.823 |
| 8.0 | 0.816 |
| 8.5 | 0.799 |
| 9.0 | 0.767 |
| 9.5 | 0.719 |
| 10.0 | 0.660 |
| 10.5 | 0.594 |
| 11.0 | 0.524 |
| 11.5 | 0.456 |
| 12.0 | 0.394 |
| 12.5 | 0.342 |
| 13.0 | 0.298 |
| 13.5 | 0.262 |
| 14.0 | 0.232 |
| 14.5 | 0.207 |
| 15.0 | 0.185 |
| 15.5 | 0.167 |
| 16.0 | 0.152 |
| 16.5 | 0.138 |
| 17.0 | 0.126 |
| 17.5 | 0.116 |
| 18.0 | 0.107 |
| 18.5 | 0.099 |
| 19.0 | 0.091 |
| 19.5 | 0.085 |
| 20.0 | 0.077 |
| 20.5 | 0.070 |
| 21.0 | 0.064 |
| 21.5 | 0.058 |
| 22.0 | 0.053 |
| 22.5 | 0.049 |
| 23.0 | 0.045 |
| 23.5 | 0.041 |
| 24.0 | 0.039 |
| 24.5 | 0.038 |
| 25.0 | 0.037 |



# 13. Acoustic Emission

**Typical Sound Power Levels**
The sound power levels are presented with reference to the code IEC 61400-11 ed. 3.1 (2018) based on hub height. 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 to 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 |
| AM-1 | 92.0 | 92.0 | 94.5 | 98.4 | 101.8 | 104.7 | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 |
| AM-2 | 92.0 | 92.0 | 94.5 | 98.4 | 101.8 | 104.7 | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 |
| AM-3 | 92.0 | 92.0 | 94.5 | 98.4 | 101.8 | 104.7 | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 |
| AM-4 | 92.0 | 92.0 | 94.5 | 98.4 | 101.8 | 104.7 | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 |
| AM-5 | 92.0 | 92.0 | 94.5 | 98.4 | 101.8 | 104.7 | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 |
| AM-6 | 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 10 kHz)*

**Low Noise Operations**
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 reduction settings can be tailored to time of day as well as wind direction to offer the most suitable solution for a specific location.

Noise control is achieved through the optimization of active power and rotational speed of the wind turbine. This reduction is dependent on the wind speed. The Noise Reduction System controls the noise settings of each turbine to the most appropriate level at all times, in order to keep the noise emissions within the limits allowed.

The NRS Modes may not be applicable to all tower variants. Please contact Siemens Gamesa for further information.

**Typical Sound Power Frequency Distribution**
The information contained in the tables below is contained here for information purpose only. To the extent permitted by law, SGRE does not provide any warranty of any type, either express or implied, with respect to the information provided in this section. In no event will SGRE be liable for damages, including any general, special, incidental or consequential damages, arising out of the information contained in this section.

Typical spectra for $L_{WA}$ in dB(A) re 1 pW for the corresponding centre frequencies are tabulated below for 6, 7, 8, 9, 10, 11 and 12 m/s referenced to hub height.

| Wind speed [m/s] | 1/1 octave band center frequencies | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
| 6 | 80.1 | 86.7 | 88.9 | 89.9 | 93.1 | 92.8 | 88.3 | 76.5 |
| 7 | 83.5 | 90.1 | 92.3 | 93.3 | 96.5 | 96.2 | 91.7 | 79.9 |
| 8 | 86.4 | 93.0 | 95.2 | 96.2 | 99.4 | 99.1 | 94.6 | 82.8 |
| 9 | 87.0 | 94.7 | 97.1 | 96.6 | 100.0 | 100.8 | 96.0 | 84.8 |
| 10 | 87.0 | 94.7 | 97.1 | 96.6 | 100.0 | 100.8 | 96.0 | 84.8 |
| 11 | 87.0 | 93.4 | 96.1 | 97.9 | 101.8 | 99.9 | 93.3 | 83.0 |
| 12 | 87.0 | 93.4 | 96.1 | 97.9 | 101.8 | 99.9 | 93.3 | 83.0 |

*Table 2: Typical 1/1 octave band spectrum for 63 Hz to 8 kHz for AM 0 setting*

# 14. Electrical Specification

**Nominal output and grid conditions**

| | |
|---|---|
| Nominal power ................ | 6600 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 .............. | 6750 kW @20°C ext. ambient |
| Nominal speed................. | 1120 rpm-6p (50Hz)<br>1344 rpm-6p (60Hz) |

**Generator Protection**

| | |
|---|---|
| Insulation class ................ | Stator H/H<br>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).............. | 82kA. |

**Power Consumption from Grid** (approximately)

| | |
|---|---|
| At stand-by,No yawing ...... | 10 kW |
| At stand-by, yawing........... | 23 kW |

**Controller back-up**

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

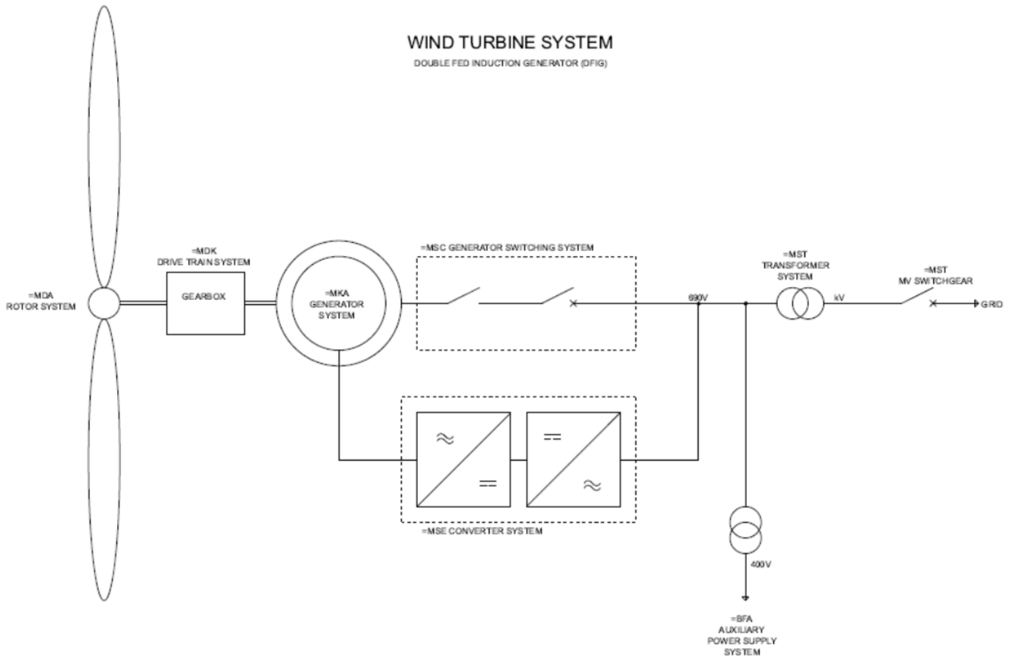
**Transformer Specification**

| | |
|---|---|
| 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 |

# 15. Simplified Single Line Diagram




# 16. Transformer Specifications ECO 30 kV

### Transformer

| | |
|---|---|
| Type ................................. | Liquid filled |
| Max Current...................... | 7.11 kA + harmonics at nominal voltage ± 10 % |
| 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 |
| Vector group .................... | Dyn11 |
| Standard…………………... | IEC 60076<br>ECO Design Directive |

### 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 |

# 17. 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.

## 17.1. 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 / 25 kA/1s |
| Peak withstand current | 50 kA / 62,5 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 / 25 kA/1s |
| Pressure relief | Upwards |
| Standard | IEC 62271 / IEEE-C37 /CSA-C22.2 |
| 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 / 25 kA/1s |
| Short circuit making current | 50 kA / 62,5 kA |
| 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 / 25 kA/1s |
| Short circuit making current | 50 kA / 62,5 kA |
| Short circuit breaking current | 20 kA/1s / 25 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<br>Max 2 feeder cables |
| Cable entry | From bottom |
| Cable clamp size (cable outer diameter) | 26 - 38mm<br>36 - 52mm<br>50 - 75mm |
| Circuit breaker feeder | 630 A bushings type C |
| Cable entry | M16<br>From bottom |
| **Interface to turbine control** | |
| Breaker status | |
| SF6 supervision | 1 NO contact |
| External trip | 1 NO contact |

# 18. Grid Connection Capabilities

This document describes the grid performance of the SG 6.6, 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.

## 18.1. 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.

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 SG 6.6, 50 & 60 Hz wind turbine are presented in Figure 1

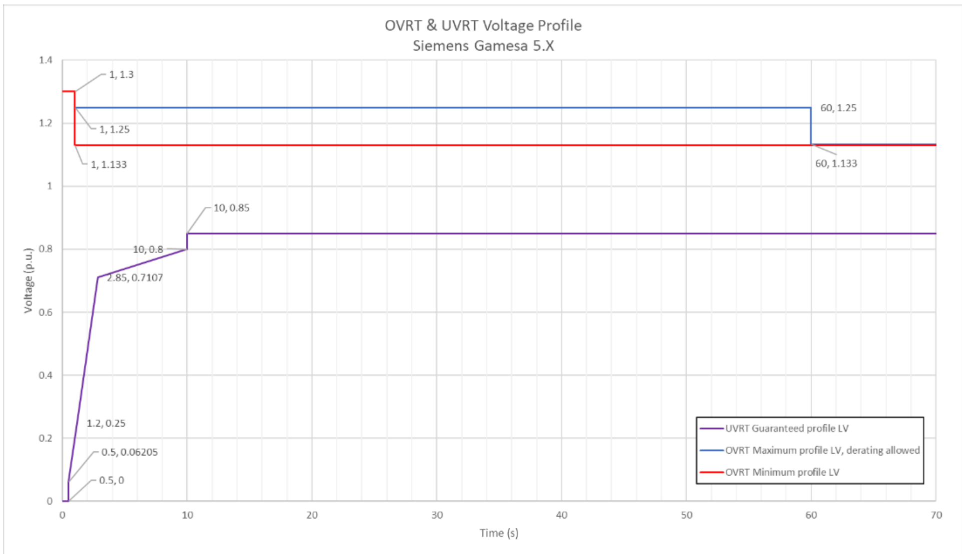



*Figure 3. High and Low voltage limits for SG 6.6, 50 & 60 Hz wind turbine. The nominal voltage is 690 V (i.e. 1 p.u.).*

## 18.2. 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.

## 18.3. Frequency Capability

The wind turbine can operate in the frequency range between 0.92pu and 1.08pu, making a difference between a steady state operation (full simultaneity): ±3%, and transients' events (limited simultaneity): ±8% around 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.

## 18.4. 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 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 be set to execute reactive power control locally, to secure a continuous operation of the wind turbine and maximize the availability, overriding external control and setpoints.

## 18.5. 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.

## 18.6. Reactive Power – Voltage Control

The power plant controller can operate in four different modes:

- Q Control –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 – Reactive power 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 references. Finally, voltage references are distributed to each individual wind turbine. The wind turbine's controller responds to the voltage references from the SCADA system and commands the wind turbine to generate the required reactive power to change the voltage towards the reference.

## 18.7. 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 controller. The wind turbine controllers respond to the references from the SCADA system and commands the wind turbine to generate this active power locally.

## 18.8. 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 LV Terminals | 3.0* | *See Note 1 |
| Maximum ROCOF | 4 Hz/s | |
| Allowable Max Negative Sequence Voltage | 5% | |
| Voltage support after FRT recovery | 3s | Configurable by parameter |
| Active Power recovery after UVRT to 95% of pre-fault value | 1000ms | Standard Configuration.<br>Configurable by parameters adjustment. |
| Voltage support during FRT | Available | Configurable by parameter |
| Active current priority during UVRT | Available | Configurable by parameter |
| Active Power damping after UVRT | ±5% pre-fault level in 2s | Can be affected if active power recovery ramp after UVRT is modified |
| $I_Q$ Injection Curve during FRT | k = 2 | Configurable by parameters. |
| $I_Q$ Response Time (FRT) | 30ms | +20ms considering RMS value calculation |
| $I_Q$ Settling Time (FRT) | 60ms | +20ms considering RMS calculation<br>Within a -10%/+20% settling band |
| Active Power Ramp | + 20% Prated/s | Standard |
| Active Power Ramp - Fast Mode | ± 25% Prated/s | When commanded by SCADA |
| Reactive Power Ramp | ±5000 kVAr/s* | *Configurable by parameter, see Note 2 |

**Note 1.**

For sites with a SCR below 5 or with X/R below 5, SGRE recommends carrying out specific grid impact analysis based on transient simulations that can reflect the response of the wind turbines to a wide range of grid events at different operation levels. SGRE can provide a PSCAD model that might be used for carrying out the mentioned studies.

If operational limits are reached, min SCR could not be guaranteed with standard configuration. Specific reactive power management configuration must be done by means of detailed grid studies, trying to avoid voltage saturation extremes in any case (over and under voltage saturation levels).

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.

**Note 2.**

In weak grids maximum ramp is limited to ±2500 kVar /s and further limitation applied when reaching voltage

# 19. Reactive Power Capability - 50 & 60 Hz

This document describes the programmed reactive power capability of Siemens Gamesa SG5X, 50/60 Hz wind turbines during active power production and no wind operation. SG5X wind turbines are equipped with a back-to-back partial load frequency converter which allows the wind turbine to operate in a wide power factor range.

## 19.1. Programmed Reactive Power Capability. General Considerations

The programmed 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 1** shows the programmed reactive power capability depending on the generated Active Power at rated voltage at the LV terminals (PQV curves).
- **Figure 2** shows the programmed reactive power capability depending on the voltage level (QV curve) at full power operation.
- **Figure 3** includes programmed reactive power capability at no-wind operating conditions.

To achieve the maximum output from the turbine, SGRE recommends the wind power plant to be designed to maintain the voltage at the generator terminal 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 programmed reactive power capability is subjected to a tolerance up to ± 5% of rated power.

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 programmed 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 programmed reactive power capability described is valid while operating the wind turbine within the limits specified in the design climatic conditions.

In case that grid connection studies or reactive capability studies show that a further reactive power capability is needed in some operating points, please contact SGRE for the evaluation of a possible temporary or permanent controlled increase. This might be possible but needs to be analyzed in a project specific basis.

The reactive power produced can be both inductive and capacitive. In this document the inductive reactive power is represented with a negative sign (-) and capacitive reactive power with a positive sign (+).

## 19.2. Reactive Power / Active Power at Normal Operation

The available reactive power for all application modes in kVAr, as a function of active power at the LV terminal of WTG (PQV curves), is presented in **Figure 1**. For the no wind operation mode (Statcom mode, QwP0) capability, see chapter 5.

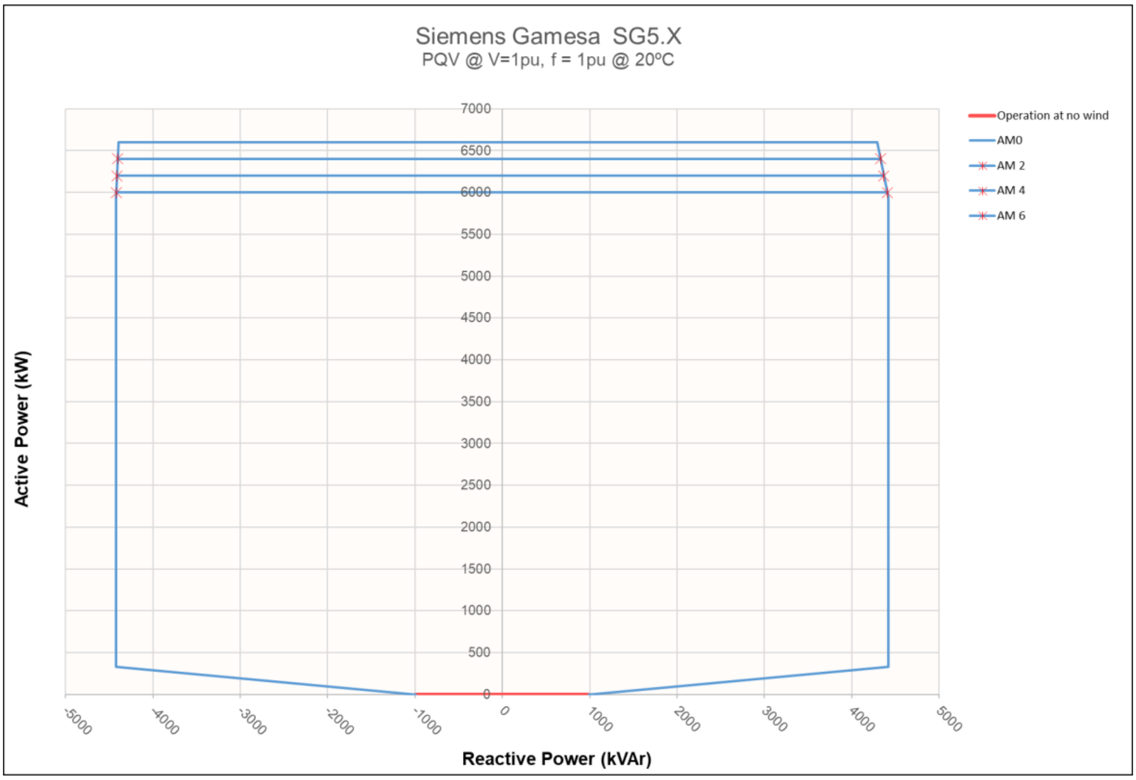



**Figure 4:** Siemens Gamesa 5.X → Programmed reactive power capability curves (PQV), 50/60 Hz WTG, at LV terminals.

| Application mode (AM) | Rating active power (kW) | Rating capacitive reactive power (kVAr) | Rating inductive reactive power (kVAr) | External Nacelle Temperature (ºC) |
|---|---|---|---|---|
| **AM0** | **6600** | **4290** | **-4394** | **20** |
| AM-1 | 6500 | 4310 | -4398 | 23 |
| **AM-2** | **6400** | **4330** | **-4402** | **25** |
| AM-3 | 6300 | 4350 | -4407 | 28 |
| **AM-4** | **6200** | **4370** | **-4411** | **30** |
| AM-5 | 6100 | 4390 | -4415 | 33 |
| **AM-6** | **6000** | **4410** | **-4419** | **35** |

**Table 5:** Siemens Gamesa 5.X → 50/60 Hz WTG Application modes definition.

## 19.3. Reactive Power / Voltage at normal operation

The programmed reactive power capability, provided for all application modes in kVAr, depending on the voltage level (QV curve) at full active power operation at the LV terminals of the wind turbine is depicted in **Figure 2**.

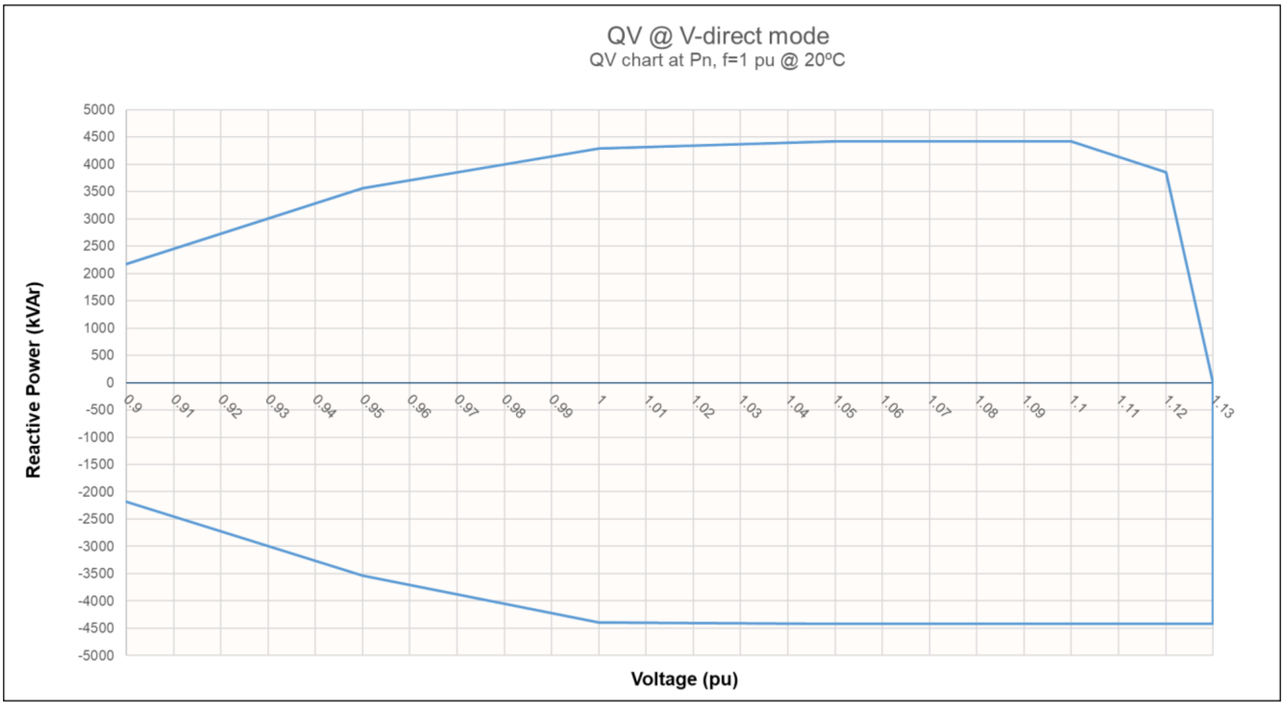



**Figure 5:** Siemens Gamesa 5.X → Programmed reactive power capability curves (QV), 50/60 Hz WTG, at LV terminals, at Full Power operation.

| Capacitive reactive power | | Voltage (pu) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0,9 | 0,95 | 1 | 1,05 | 1,1 | 1,12 | 1,13 |
| Active Power (kW) | 0* | 990 | 990 | 990 | 840 | 476 | 330 | 0 |
| | 330 | 4422 | 4422 | 4422 | 4006 | 2904 | 1386 | 0 |
| | 660 | 4422 | 4422 | 4422 | 4422 | 3788 | 2791 | 0 |
| | 1320 | 4422 | 4422 | 4422 | 4422 | 4422 | 4422 | 0 |
| | 1980 | 4422 | 4422 | 4422 | 4422 | 4422 | 4422 | 0 |
| | 2640 | 4422 | 4422 | 4422 | 4422 | 4422 | 4422 | 0 |
| | 3300 | 4422 | 4422 | 4422 | 4422 | 4422 | 4422 | 0 |
| | 3960 | 4422 | 4422 | 4422 | 4422 | 4422 | 4422 | 0 |
| | 4620 | 4422 | 4422 | 4422 | 4422 | 4422 | 4422 | 0 |
| | 5280 | 4422 | 4422 | 4422 | 4422 | 4422 | 4422 | 0 |
| | 5940 | 3977 | 4422 | 4422 | 4422 | 4422 | 4305 | 0 |
| | 6600 | 2178 | 3564 | 4290 | 4422 | 4422 | 3854 | 0 |

**Table 6:** Siemens Gamesa 5.X → Programmed capacitive reactive power capability values (kVAr), 50/60 Hz WTG, at LV terminals.

* No wind operation capacitive reactive power capability

| Inductive reactive power | | Voltage (pu) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0,9 | 0,95 | 1 | 1,05 | 1,1 | 1,12 | 1,13 |
| Active Power (kW) | 0* | -990 | -990 | -990 | -990 | -990 | -990 | -990 |
| | 330 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 |
| | 660 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 |
| | 1320 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 |
| | 1980 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 |
| | 2640 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 |
| | 3300 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 |
| | 3960 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 |
| | 4620 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 |
| | 5280 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 |
| | 5940 | -4027.8 | -4422 | -4422 | -4422 | -4422 | -4422 | -4422 |
| | 6600 | -2178 | -3534 | -4394 | -4422 | -4422 | -4422 | -4422 |

*Table 7:* Programmed inductive reactive power capability values (kVAr), 50/60 Hz WTG, at LV terminals.

* No wind operation inductive reactive power capability

## 19.4. Reactive Power / Voltage at no-wind conditions

The available reactive power, as a function of voltage at the LV terminals of WTG during no-wind operation, with generator stopped or below the connection speed, (Statcom mode, QwP0), is presented in **Figure *6***. Reactive power is provided in kVAr for all application modes:

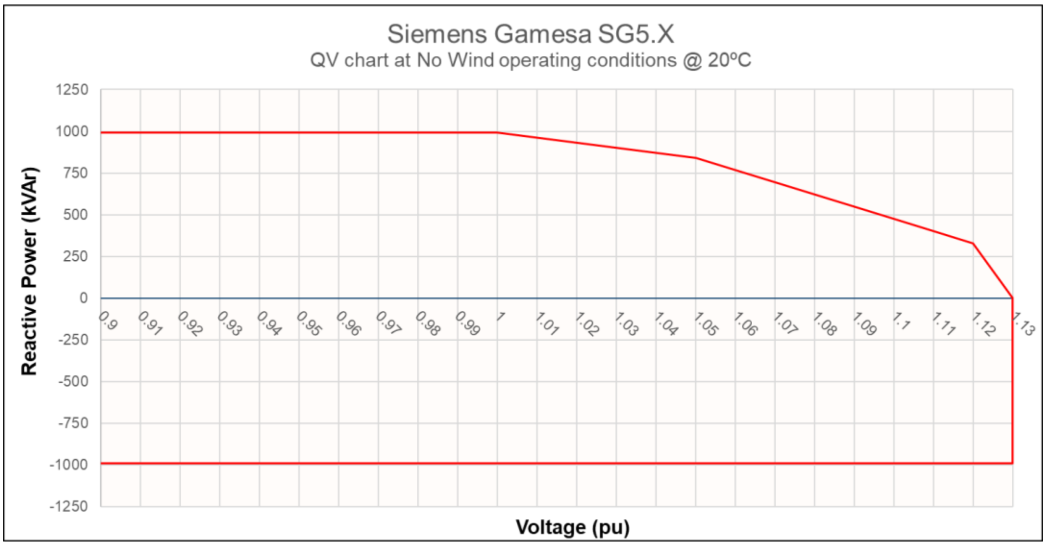



**Figure 6:** QwP0 Siemens Gamesa 5.X → Programmed reactive power capability chart (kVAr) at no wind conditions, at LV terminals, 50/60Hz.

| All AMs @ Statcom mode | | |
|---|---|---|
| V (pu) | Qcap (kVAr) | Qind (kVAr) |
| 0.9 | 990 | -990 |
| 0.95 | 990 | -990 |
| 1 | 990 | -990 |
| 1.05 | 840 | -990 |
| 1.1 | 476 | -990 |
| 1.12 | 330 | -990 |
| 1.13 | 0 | -990 |

**Table 8:** QwP0 Siemens Gamesa 5.X→Reactive power capability values (kVAr) at no wind conditions (QwP0), at LV terminals, 50/60 Hz.

# 20. SCADA System Description

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

## 20.1. 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.
- Turbine 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.

## 20.2. 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.

## 20.3. 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.

## 20.4. 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.

## 20.5. 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.

## 20.6. 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.

## 20.7. 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.

## 20.8. 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.

## 20.9. 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.

# 21. 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.

## 21.1. General

- IEC-RE Operational Document: OD-501 ed.3, 2022 Type and Component Certification Scheme
- IEC 61400-1:2019 Ed.4 Wind turbines – Part; Design requirements
- IEC 61400-11:2012/AMD1:2018 Amendment 1 - Part 1; Acoustic noise measurement techniques
- IEC 61400-12-1:2022-09 ed – Part 1; Power performance measurements of electricity producing wind turbines
- IEC 61400-21-1:2019 - Part 21-1; Measurement and assessment of electrical characteristics - Wind turbines
- IEC 61400-13: 2015/ AMD1:2021 Amendment 1 - Part 13; Measurement of Mechanical Loads
- IEC 61400-24:2019 - Part 24; Lightning protection
- IECRE OD-501-4 Conformity Assessment and Certification of Certification of Loads by RECB
- IECRE OD-501-5 Conformity Assessment and Certification of Certification of control and protection system by RECB
- ISO 12100:2010 Safety of machinery - General principles for design, Risk assessment and risk reduction
- ISO 4413:2010 Hydraulic fluid power - General rules and safety requirements for systems and their components
- ISO 16889:2022 Hydraulic fluid power - Filters - Multi-pass method for evaluating filtration performance of a filter element
- ISO 683-1:2018 Heat-treatable steels, alloy steels and free-cutting steels. Non-alloy steels for quenching and tempering
- DIN ISO 76:2019-04; Static load ratings (ISO 76:2006 + Amd.1:2017)
- ISO 281:2007; Rolling bearings - Dynamic load ratings and rating
- 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
- XP ISO/TS 16281:2008; Rolling bearings - Methods for calculating the modified reference rating life for universally loaded bearings
- EN 1837:2021 Safety of machinery - Integral lighting of machines
- 2014/68/EU Pressure Equipment Directive
- EN 14359:2017 Gas-loaded accumulators for fluid power applications
- EN 10025-1:2004 Hot rolled products of structural steels - Part 1: General technical delivery conditions
- EN 10025-2: 2019, Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels
- EN 10025-3: 2019, 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
- 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
- DIN EN 1999-1-1/NA:2021-03: Design of aluminum structures – part 1-1, General rules
- VDI 2230 Blatt 1, 2016, Systematic calculation of highly stressed bolted joints - Joints with one cylindrical bolt
- DIN 51524-3:2017 Pressure fluids - Hydraulic oils - Part 3: HVLP hydraulic oils, Minimum requirements
- DIN 2413:2020 Seamless steel tubes for oil- and water-hydraulic systems - Calculation rules for pipes and elbows for dynamic loads
- DIN 51524-3:2017 Pressure fluids - Hydraulic oils - Part 3: HVLP hydraulic oils, Minimum requirements
- EN 14359:2017 Gas-loaded accumulators for fluid power applications.
- DIBt - Richtlinie für Windenergieanlagen - Oktober 2012, korrigierte Fassung März 2015
- DIBt – Richtlinie für Windenergieanlagen:2012, Einwirkungen und Standsicherheitsnachweise für Turm und Gründung.

## 21.2. Rotor blade

- IEC 61400-5:2020 Wind energy generation systems - Part 5: Wind turbine blades
- IEC 61400-23 Ed. 1.0 EN :2014 Wind turbines - Part 23: Full-scale structural testing of rotor blades
- IECRE OD-501-1 Conformity Assessment and Certification of Certification of Blade by RECB

## 21.3. Gearbox

- IEC 61400-4:2012 Wind turbines -- Part 4: Design requirements for wind turbine gearboxes
- IECRE OD-501-2 Conformity Assessment and Certification of Wind turbine gearboxes by RECB

## 21.4. Tower

- IEC 61400-6:2020 Wind energy generation systems - Part 6: Tower and foundation design requirements
- IECRE OD-501-3 Conformity Assessment and Certification of Tower by RECB

## 21.5. Electrical

- 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 control gear assemblies – Part 1: General rules
- IEC 61439-2:2020 Low-voltage switchgear and control gear assemblies – Part 2: Power switchgear and control gear assemblies
- Low Voltage Directive 2014/35/EU
- EMC Directive 2014/30/EU
- UL 1741:2021 Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources
- CSA C22.1:2012 Canadian Electrical Code, Part I (25th Edition), Safety Standard for Electrical Installations
- CSA C22.2 NO. 272:2020 Wind turbine electrical systems

## 21.6. Quality

- ISO 9001:2018 Quality management systems – Requirements
- ISO 45001:2018 - Occupational health and safety management systems — Requirements with guidance for use

## 21.7. Personal Safety

- EN ISO 13850:2015 Safety of machinery - Emergency stop function - Principles for design
- IEC 60204-1:2016/AMD1:2021 Safety of machinery - Part 1: General requirements; Amendment 1
- Machinery Directive 2006/42/EC
- IEC 62061:2021 Safety of machinery - Functional safety of safety-related control systems
- ISO 13849-1:2015 – Safety of machinery – Safety-related parts of control systems – Part 1: General principles
- ISO 13849-2:2013 - Safety of machinery – Safety-related parts of control systems – Part 2: Validation
- EU safety, health, and environmental requirements. CE Marking
- UK Conformity Assessed (UKCA) marking.
- ANSI/UL: 2021 Standard for Safety for Wind Turbines Permitting Entry of Personnel
- NFPA 79:2021 Electrical Standard for Industrial Machinery / Approved Soll: 2024 NFPA-FIRE
- UL 489:2016 Molded-case circuit breakers, molded-case switches, and circuit-breaker enclosures

## 21.8. 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)

# 22. 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.

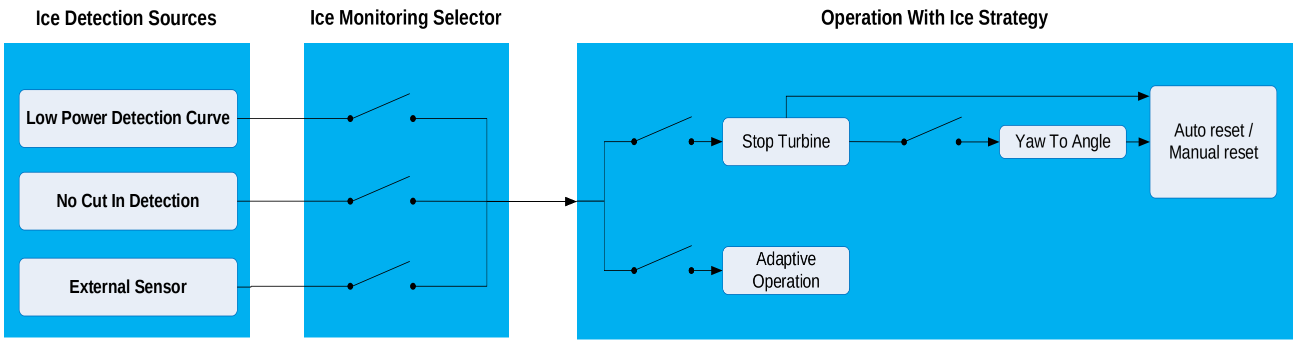



Figure 1: Ice Detection and Operation with Ice Strategy interface for individual turbines

| | |
|---|---|
| *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.

## 22.1. Ice Detection Sources

### 22.1.1. 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.

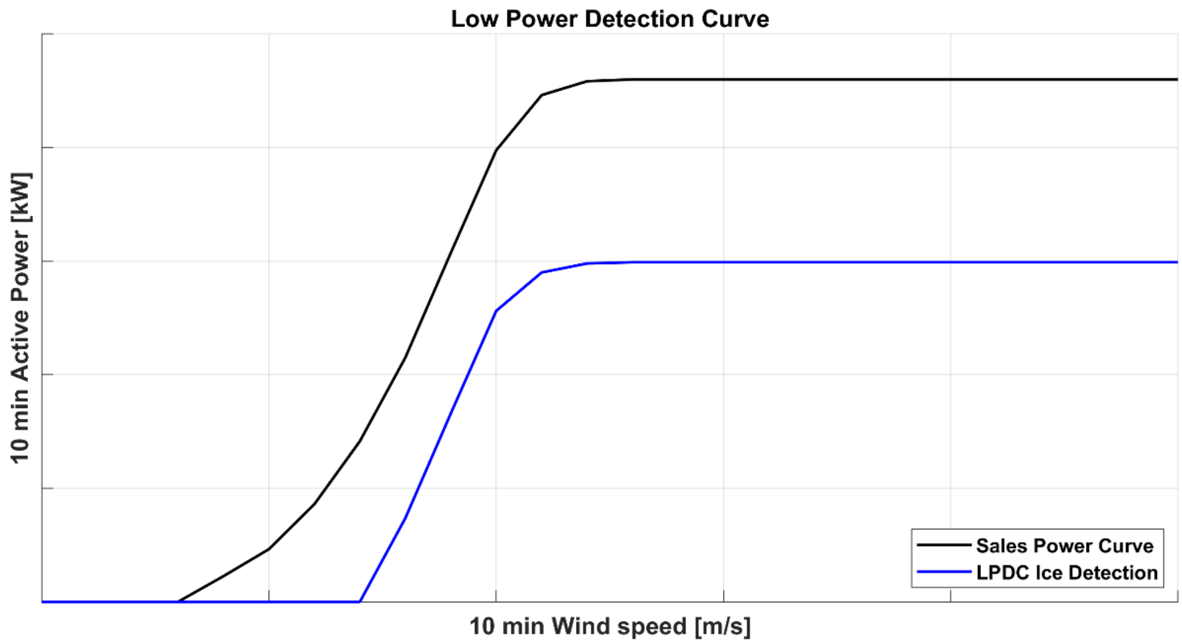



Figure 2: Illustration of Low Power Detection Curve (LPDC)

### 22.1.2. 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”.

### 22.1.3. 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. 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 <u>is</u> 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 <u>is not</u> 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.

### 22.1.4. External Sensor Types

### 22.1.5. 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.

### 22.1.6. 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.

### 22.1.7. 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.

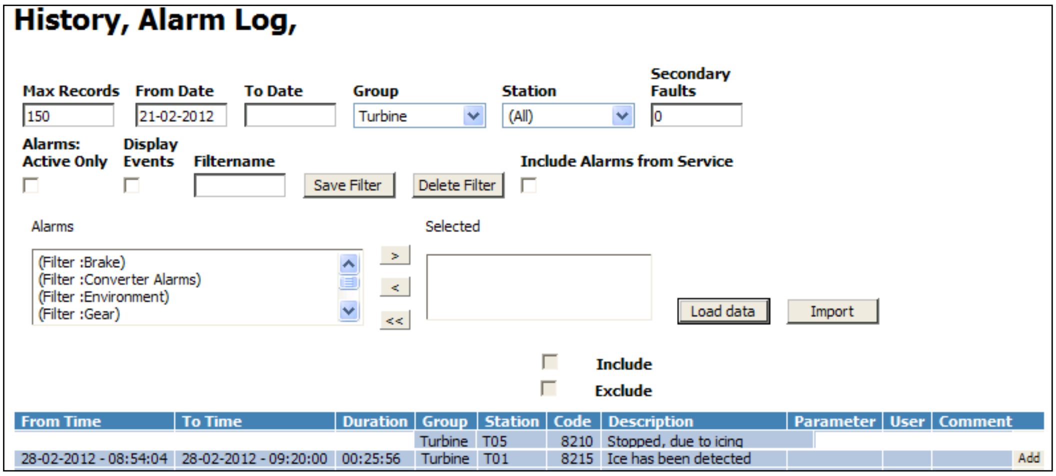



*Figure 3 - Presentation of alarms related to the ice detection system in Web WPS SCADA*

# 22.2. Operation with Ice Strategy

## 22.2.1. 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

## 22.2.2. 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.

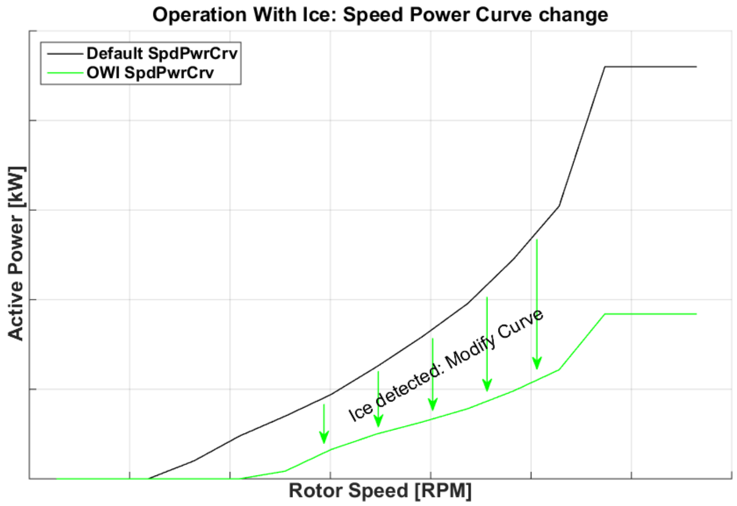



Figure 4: Illustration of OWI Speed-Power curve modification

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.