INTEGRALE RICOSTRUZIONE PARCHI EOLICI
"Faeto-Celle"

ADEGUAMENTO TECNICO IMPIANTO EOLICO MEDIANTE INTERVENTO DI REPOWERING DELLE TORRI ESISTENTI E RIDUZIONE NUMERICA DEGLI AEROGENERATORI

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Opera	**Progetto di Integrale Ricostruzione di n. 1 impianto eolico composto da 14 aerogeneratori da 6,6 MW per una potenza complessiva di 92,4 MW nei Comuni di Faeto e Celle di San Vito e relative opere di connessione alla località "Monte S.Vito - Ciuccia - Crepacore" con smantellamento di n. 60 aerogeneratori di potenza in esercizio pari a 33,75 MW.**

Firmato digitalmente da
DEMAIO ANTONIO
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	Descrizione Elaborato: Piano di gestione e manutenzione	

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Scala:	----	Integrale Ricostruzione Faeto - Celle
Formato:		Codice progetto AU R2P8522

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INDICE FIGURE

A. PARTE GENERALE

A.1 Componenti dell'impianto eolico

L'impianto eolico di progetto presenta i seguenti componenti principali:

- 14 aerogeneratori di grande taglia
- 1 cavidotto interrato di collegamento tra gli aerogeneratori e sottostazione costituito da due o più terne da 30 kV
- 1 cavidotto da 30kV per il collegamento tra la SSEU di trasformazione e la stazione elettrica di TERNA di Celle San Vito (FG)

La gestione e la manutenzione dell'impianto devono contemplare tutti i componenti elencati. Inoltre, per eseguire la corretta manutenzione sull'aerogeneratore, la piazzola deve essere sempre accessibile con i mezzi normalmente necessari (furgoni, cestello, gru,…) e quindi anche le vie di accesso devono essere correttamente manutenute mantenendo il fondo praticabile anche nella stagione avversa e organizzando lo sgombero neve nel caso di precipitazioni di tal tipo.

A.2 Schede Tecniche dei Componenti dell'impianto

AEROGENERATORE

Le macchine proposte hanno le seguenti caratteristiche:

- grande taglia con diametro rotore fino a 155 m;
- altezza mozzo fino a 102,5 m, comunque altezza complessiva, altezza mozzo più pala, non superiore a 180m)

L'aerogeneratore di riferimento è SG. 6.6-155 da 6,6 MW di potenza nominale, con altezza mozzo pari a 102,5 m. Tale turbina descrive e riassume le caratteristiche del gruppo di turbine idonee al sito.

In allegato 1 è riportata la scheda tecnica del Costruttore Siemens-Gamesa con tutte le caratteristiche funzionali principali.

Lo schema costruttivo rimane quello classico, in cui la navicella è progettata con struttura portante saldata. Al suo interno sono alloggiati il sistema di trasmissione con moltiplicatore di giri, il generatore elettrico e i dispositivi ausiliari.

L'avvio della turbina avviene con un vento di 3m/s, a passo massimo.

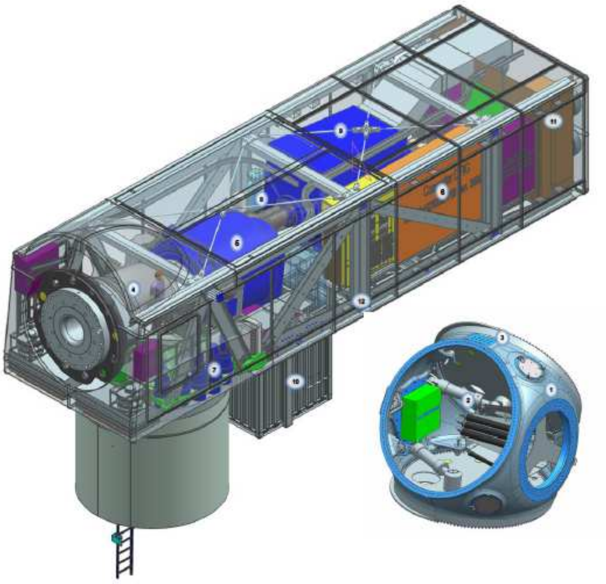

Figura 1 - Navicella SG 6.6-155

Al crescere del vento il rotore può aumentare la sua velocità fino a quella nominale, variando il passo delle pale e regolando il generatore.

A velocità del vento alte, oltre quella di raggiungimento della potenza nominale, il sistema di regolazione del passo e quello del generatore mantengono la potenza al valore prefissato, indipendentemente da variazioni di velocità del vento, di carico, di temperatura o di densità dell'aria.

Quando necessario, l'aerogeneratore frena aerodinamicamente mettendo le pale completamente in bandiera.

Tutte le funzioni dell'aerogeneratore sono monitorate e controllate da diverse unità di controllo basate su microprocessori.

Le pale del rotore, aventi forte influenza sull'output della turbina e sull'emissione sonora, sono di materiale a base epossidica rinforzato da fibre di vetro e di carbonio, quindi caratterizzate da durevolezza, resistenza all'abrasione e alta resistenza ai fattori chimici e alle radiazioni solari. Hanno inoltre un rivestimento di protezione contro i fattori atmosferici.

Il profilo alare si estende fino alla navicella, ottimizzando così l'andamento delle linee di corrente per l'intera lunghezza della pala.

COMPONENTI PRINCIPALI DELLA TURBINA

Pale:

- Numero: 3

- Lunghezza: 82.5 m
- Materiale: materiale composito a matrice epossidica rinforzata con fibra di vetro e carbonio

Rotore:

- Diametro 155 m
- Area spazzata 18,869 mq

Sistema di controllo del passo (pitch control):

- Sistema idraulico
- massima affidabilità grazie al sistema di gestione della turbina
- Manutenzione meccanica e del software

Mozzo:

- design compatto ideale per la trasmissione dei carichi
- integrazione degli azionamenti delle pale

Generatore e convertitore di frequenza:

- generatore asincrono a doppia alimentazione.
- regime di rotazione variabile per un ottimo rendimento
- temperatura contenuta del generatore anche a temperature ambientali molto elevate; le aree a temperatura più elevata sono costantemente monitorate da numerosi sensori

Sistema di imbardata (yaw control):

- azionamento mediante motoriduttori
- grazie allo scarso attrito del cuscinetto e la completa ventilazione dei freni, lo sforzo dei motoriduttori durante la rotazione è ridotto al minimo

CAVI ELETTRICI

I cavi elettrici unipolari a 30 kV di riferimento sono i Prysmian o similari. La relativa scheda tecnica, "Medium Voltage Systems" – Prysmian Cavi e Sistemi Energia Srl.

Tutti i collegamenti elettrici, tra gli aerogeneratori e alla sottostazione, sono realizzati per mezzo di cavidotti interrati: questa soluzione permette di minimizzare l'emissione elettromagnetica ed elimina del tutto il problema della visibilità delle linee aeree e il relativo impatto sull'avifauna.

SOTTOSTAZIONE MT/AT

Lo schema elettrico dell'impianto è descritto dall'unifilare di tav. VIA02_Connessione_Schema elettrico Unifilare unifilare. La connessione del parco eolico, costituito da 14 aerogeneratori, prevede le seguenti opere:

- *Una stazione elettrica di trasformazione 150 kV, esistente nel comune di Celle San Vito (FG)*
- *foglio catastale 16 particella 124.*
- *Un cavidotto interrato in media tensione a 30 kV per il trasferimento dell'energia prodotta dagli aerogeneratori alla Stazione Elettrica (SE) della RTN a 150 kV di Celle San Vito mediante le infrastrutture esistenti di proprietà*

Per la componentistica si veda la VIA02_CPI_RelazioneImpianti.

A.3 Schemi di Funzionamento dell'impianto

I sistemi di controllo per la gestione dell'aerogeneratore sono il *pitch control* e lo *yaw control*.

Il primo, pitch control, di cui è dotata ciascuna pala in modo indipendente, esegue la rotazione delle pale intorno al loro asse principale e permette la riduzione della potenza al suo valore nominale, evitando così l'utilizzo di freni meccanici. Gli angoli aerodinamici e costruttivi sono costantemente monitorati, in modo da permettere veloci regolazioni in funzione del vento. Il vento è misurato in continuo con anemometro di macchina.

Il carico elettrico è costantemente monitorato ed in caso di caduta di rete, ovvero mancanza di carico, si ha un arresto di emergenza del rotore tramite frenatura aerodinamica e stazionamento meccanico. Stessa procedura in caso di grave guasto e incendio.

Il secondo, *yaw control* detto anche imbardata, modifica l'orientamento della navicella, allineando la macchina rispetto alla direzione del vento e garantendo, indipendentemente dalla direzione del vento, la migliore esposizione del rotore ovvero perpendicolare alla direzione del vento in posizione sopravento rispetto alla torre.

La direzione del vento è costantemente monitorata da apposita banderuola di macchina. Per gli schemi di funzionamento dell'impianto far riferimento alle seguenti tavole di progetto VIA02_SEIP_SchemaUnifilare.

B. SISTEMA DI MANUTENZIONE DELL'IMPIANTO

L'aerogeneratore è dotato di un sistema di controllo remoto che permette di monitorarne costantemente lo stato, e in caso di anomalie, opportuni sensori trasmettono gli allarmi relativi consentendo tempestivi interventi anche per manutenzione non programmata.

Relativamente alla manutenzione dell'aerogeneratore la progettazione dello stesso ha raccolto le esigenze degli operatori sviluppando una macchina con le seguenti caratteristiche:

- ✓ accesso alla navicella dall'interno della torre con utilizzo di ascensore;
- ✓ montacarichi esterno
- ✓ notevole disponibilità di spazio nella navicella per interventi facili ed ergonomici

- accesso al mozzo agevole direttamente dalla navicella
- facilità nel raggiungere tutti i componenti
- sicurezza durante la manutenzione grazie alla protezione di tutte le parti rotanti
- in caso di necessità, la macchina consente lo smontaggio di molti componenti

Il programma di manutenzione generale programmata è suddiviso in tre categorie:

- Manutenzione visiva e con rilevamento di rumori anomali;
- Manutenzione meccanica con verifica livelli lubrificanti;
- Manutenzione elettrica.

C. MANUALE D'USO DI TUTTI I COMPONENTI DELL'IMPIANTO

Le turbine eoliche sono macchine nel pieno senso e quindi ricadono nel campo di applicazione della direttiva Macchine UE98/37 con successivi aggiornamenti e norme collegate.

La normativa di riferimento per la progettazione e la sicurezza è la CEI-EN 61400-1 ed.3 "Turbine eoliche – Parte 1: Prescrizioni per la progettazione" del febbraio 2006 (recepimento della IEC 61400-1 ed.3 del novembre 2005 "Wind Turbines – Part 1: Design requirements) e norme collegate.

Le turbine vengono progettate, costruite, collaudate, secondo le normative di cui sopra, e vengono sottoposte nel loro complesso all'esame di enti indipendenti di certificazione, che in caso di esito positivo, emettono differenti certificati. Il più completo, che riassume anche gli altri, è la certificazione di tipo (Type Certificate). Prima di questa vengono verificati il progetto, il sistema e l'organizzazione di costruzione, i materiali.

Per questo motivo il "Manuale d'Uso e Manutenzione" dell'aerogeneratore è un requisito essenziale che raccoglie in dettaglio tutte le operazioni di manutenzione ordinaria e straordinaria di tutti i componenti. La complessità della macchina ed il numero dei vari componenti incorporati rende il documento complessivo così articolato che solo alla consegna del WTG viene fornita la copia specifica per il tipo di macchina.

D. PROGRAMMA DI MANUTENZIONE

Il programma di manutenzione generale programmato prevede scadenze regolari con intervallo variabile a seconda della tipologia di controllo. Gli intervalli previsti sono:

- Manutenzione iniziale – ad 1 mese dall'entrata in funzione;
- Manutenzione semestrale;
- Manutenzione annuale (o secondo multipli di anno);

In tal modo si ottiene un ottimale livello di efficienza dell'impianto, garantendo costantemente adeguati livelli di sicurezza.

In particolare, le principali azioni riguardanti la torre sono:

- verifica della coppia di serraggio dei bulloni (cadenza annuale);

- controllo visivo dello stato delle lamiere (primo controllo dopo tre anni, successivi con cadenza annuale);

- misura dello spessore della vernice in diverse parti della torre (primo controllo dopo cinque anni e successivi dopo due anni).

Risulta evidente che grazie alla presenza di una squadra di manutenzione sulla macchina ogni semestre, vi sia la possibilità di segnalare eventuali anomalie riscontrate.

Per i collegamenti in AT e le sottostazioni AT/AT e AT/AAT si rimanda al progetto relativo alle Infrastrutture richieste da TERNA tramite STMG.

E. ALLEGATI

[1] D2294354_025 SGRE ON SG 6.6-155 Developer Package

Foggia, Dicembre 2023

Il tecnico

Arch. Antonio Demaio

Developer Package

SG 6.6-155

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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 6.6-155 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 6.6-155 is a new wind turbine of the next generation Siemens Gamesa Onshore Geared product platform called Siemens Gamesa 5.X, which builds on the Siemens Gamesa design and operational experience in the wind energy market.

With a new 76m blade and an extensive tower portfolio including hub heights such as 90 m and 165 m, the SG 6.6-155 aims at becoming a new benchmark in the market for efficiency and profitability.

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

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

2. Technical Description

2.1. Rotor-Nacelle

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

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

2.2. Blades

Sieemns Gamesa 5.Xblades are made up of fiberglass infusion & carbon pultruded-molded components. The blade structure uses aerodynamic shells containing embedded spar-caps, bonded to two main epoxy-fiberglass-balsa/foam-core shear webs. The Siemens Gamesa 5.X blades use a blade design based on SGRE proprietary airfoils.

2.3. Rotor Hub

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

2.4. Drive train

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

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

2.5. Main Shaft

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

2.6. Main Bearings

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

2.7. Gearbox

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

2.8. Generator

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

2.9. Mechanical Brake

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

2.10. Yaw System

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

2.11. Nacelle Cover

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

2.12. Tower

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

2.13. Controller

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

2.14. Converter

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

2.15. SCADA

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

2.16. Turbine Condition Monitoring

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

2.17. Operation Systems

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

If high wind derated mode is enabled, the power production is limited once the wind speed exceeds a threshold value defined by design, until cut-out wind speed is reached and the wind turbine stops producing power.

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

3. Technical specifications

Rotor	
Type	3-bladed, horizontal axis
Position	Upwind
Diameter	155 m
Swept area	18,869 m²
Power regulation	Pitch & torque regulation with variable speed
Rotor tilt	6 degrees

Blade	
Type	Self-supporting
Blade length	76 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

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

Generator	
Type	Asynchronous, DFIG

Grid Terminals (LV)	
Baseline nominal power	6.0MW/6.6 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	SGRE SCADA System

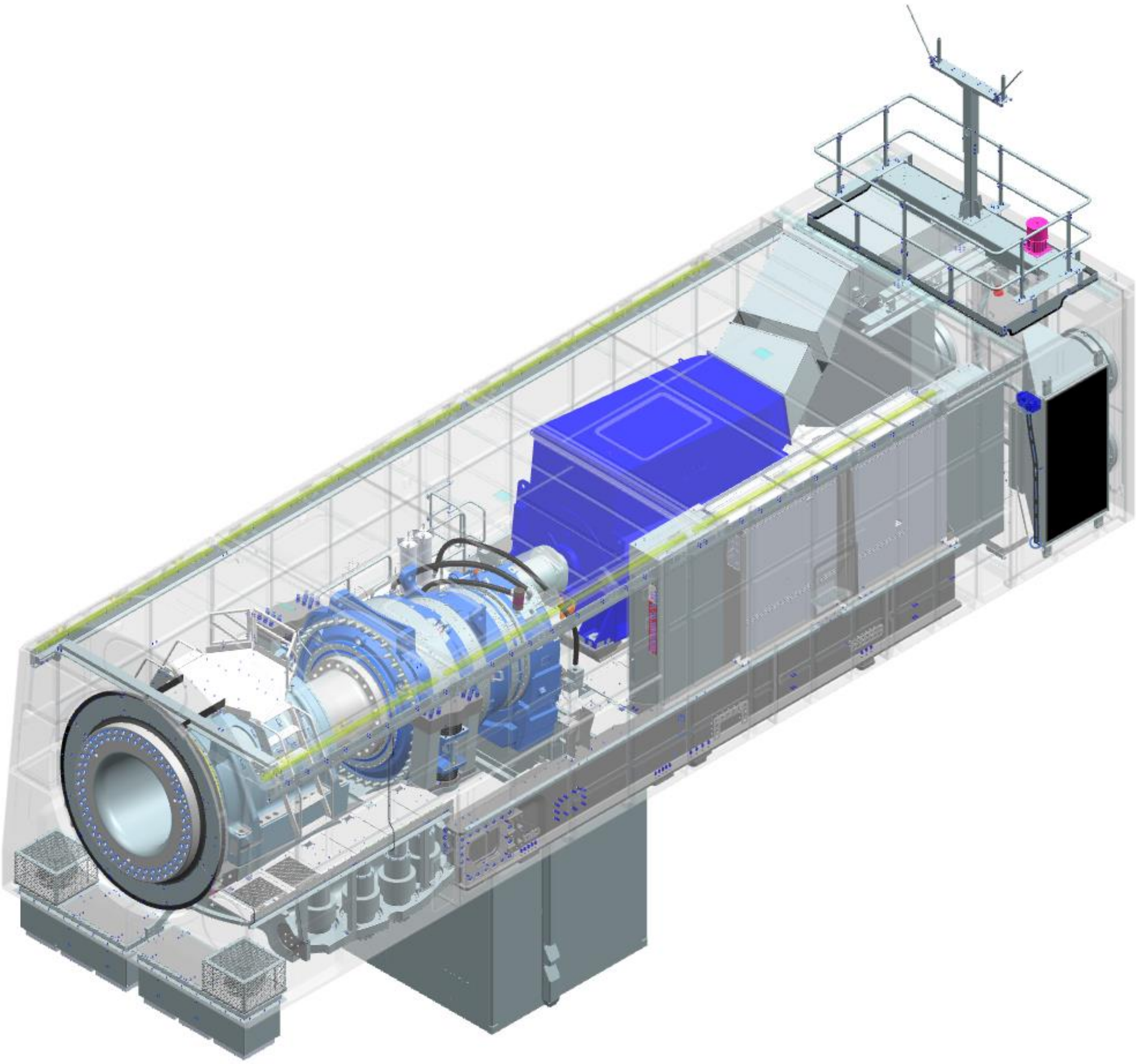
Tower	
Type	Tubular steel / Hybrid
Hub height	90m to 165 m and site-specific
Corrosion protection	
Surface gloss	Painted
Color	Semi-gloss, <30 / ISO-2813 Light grey, RAL 7035 or White, RAL 9018

Operational Data	
Cut-in wind speed	3 m/s
Rated wind speed	11.6 m/s (steady wind without turbulence, as defined by IEC61400-1)
Cut-out wind speed	27 m/s
Restart wind speed	24 m/s

Weight	
Modular approach	Different modules depending on restriction

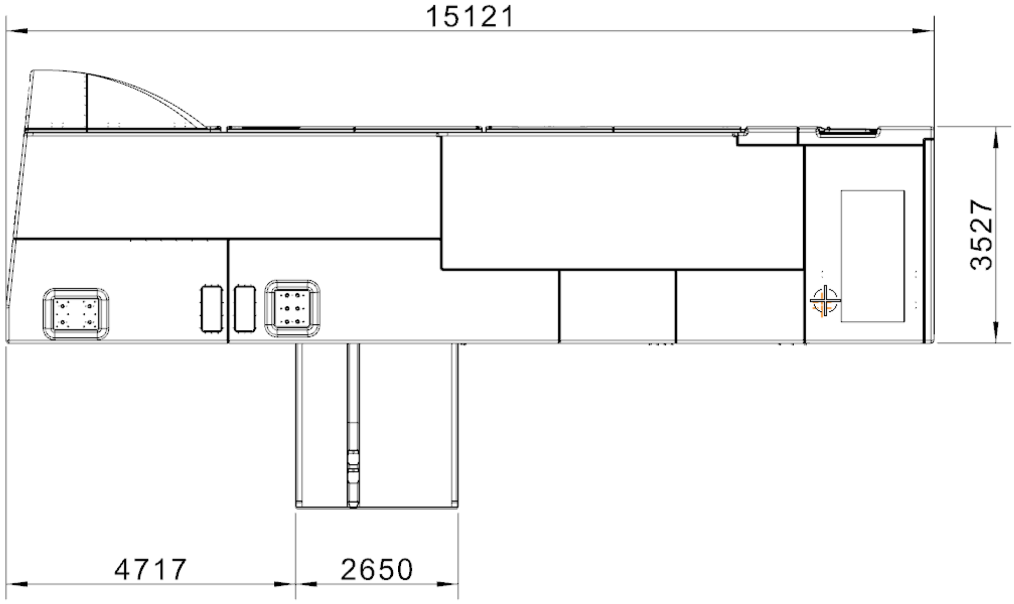
4. Nacelle Arrangement

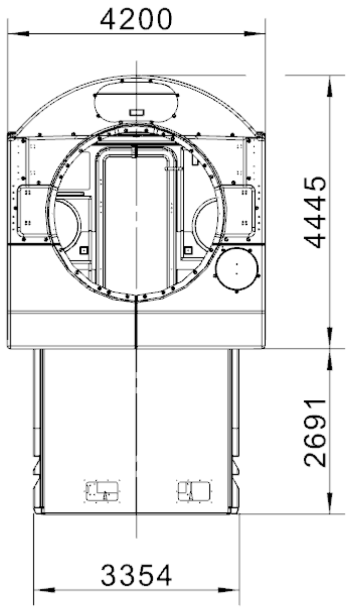
The design and layout of the nacelle are preliminary and may be subject to changes during the development of the product.



5. Nacelle Dimensions

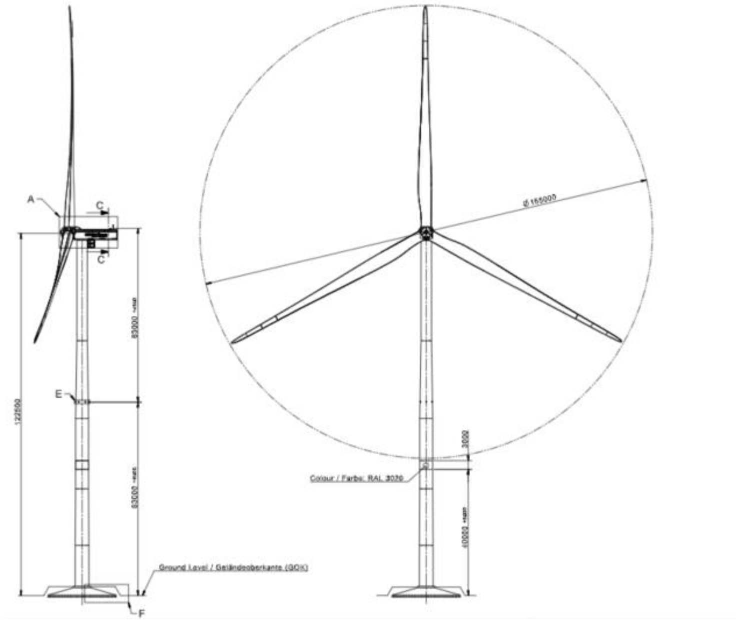
The design and dimensions of the nacelle are preliminary and may be subject to changes during the development phases of the product.



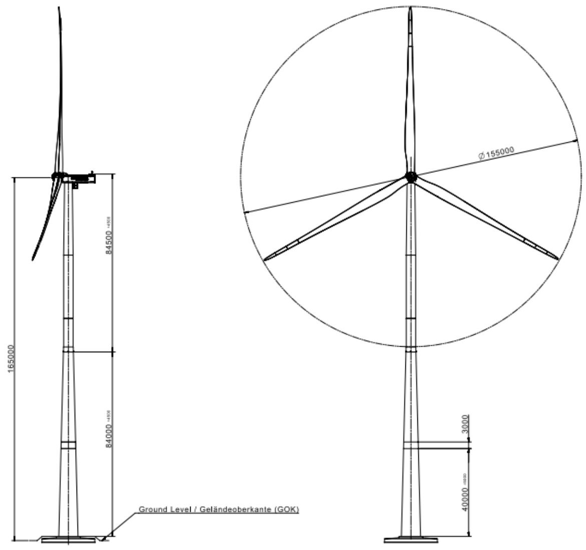


6. Elevation Drawing

6.1. SG 6.6-155 122.5 m



6.2. SG 6.6-155 165 m



7. Blade Drawing

Dimensions in millimeter

8. Tower Dimensions

SG 6.6-155 is offered with an extensive tower portfolio ranging from 90m-165m, including the baseline 122.5m and 165m catalogue towers. All towers are designed in compliance with local logistics requirements. Information about other tower heights and logistic will be available upon request.

8.1. Tower hub height 90m IIA. Tapered tubular steel tower

T90.0-50A	Section 1	Section 2	Section 3	Section 4
External diameter upper flange (m)	4.493	4.493	4.493	3.503
External diameter lower flange (m)	4.700	4.493	4.493	4.493
Section's height (m)	14.860	22.680	24.080	25.770
Total weight (kg)	70417	69557	54286	56143
Total Tower weight (kg)	250404			

8.2. Tower hub height 102.5m IIA. Tapered tubular steel tower

T102.5-50A	Section 1	Section 2	Section 3	Section 4
External diameter upper flange (m)	4,434	4,424	3,599	3,503
External diameter lower flange (m)	4,700	4,434	4,424	3,599
Section's height (m)	16,474	22,680	27,160	33,600
Total weight (kg)	81251	76405	68301	65739
Total Tower weight (kg)	291697			

8.3. Tower hub height 102.5 IIIA. Tapered tubular steel tower

T102.5-51A	Section 1	Section 2	Section 3	Section 4
External diameter upper flange (m)	4.355	4.300	4.300	3.503
External diameter lower flange (m)	4.369	4.355	4.300	4.300
Section's height (m)	13.180	20.720	29.960	35.850
Total weight (kg)	82880	79696	81067	72485
Total Tower weight (kg)	316128			

8.4. Tower hub height 107.5m IIA. Tapered tubular steel tower

T107.5-50A	Section 1	Section 2	Section 3	Section 4	Section 5
External diameter upper flange (m)	4,800	4,800	4,800	4,500	3,503
External diameter lower flange (m)	4,800	4,800	4,800	4,800	4,500
Section's height (m)	15,960	22,400	22,680	22,400	21,290
Total weight (kg)	83260	84100	67250	50480	46960
Total Tower weight (kg)	332050				

8.5. Tower hub height 113.5m IIIA. Tapered tubular steel tower

T113.5-50A	Section 1	Section 2	Section 3	Section 4	Section 5
External diameter upper flange (m)	4.800	4.798	4.792	4.418	3.503
External diameter lower flange (m)	4.800	4.800	4.798	4.792	4.418
Section's height (m)	14.039	19.880	24.360	26.600	26.035
Total weight (kg)	80501	80332	75953	64534	52303
Total Tower weight (kg)	353623				

8.6. Tower hub height 120.5m IIIA. Tapered tubular steel tower

T120.5-50A (T122.5-51A less 2m raised foundation)	Section 1	Section 2	Section 3	Section 4	Section 5
External diameter upper flange (m)	4.500	4.500	4.400	4.400	3.503
External diameter lower flange (m)	4.500	4.500	4.500	4.400	4.400
Section height (m)	13.180	19.040	23.800	29.960	32.210
Total weight (kg)	89293	90738	89933	79262	65219
Total Tower weight (kg)	414446				

8.7. Tower hub height 122.5m IIA. Tapered tubular steel tower

T122.5-50A	Section 1	Section 2	Section 3	Section 4	Section 5
External diameter upper flange (m)	4.800	4.800	4.793	4.099	3.574
External diameter lower flange (m)	4.800	4.800	4.800	4.793	4.099
Section height (m)	14.342	19.368	26.832	29.977	30.000
Total weight (kg)	84513	81457	84754	70462	56744
Total Tower weight (kg)	377930				

8.8. Tower hub height 122.5 IIIA. Tapered tubular steel tower

T122.5-52A	Section 1	Section 2	Section 3	Section 4	Section 5
External diameter upper flange (m)	4.491	4.690	4.691	4.691	3.503
External diameter lower flange (m)	4.700	4.491	4.690	4.691	4.691
Section height (m)	13.180	20.720	26.040	29.960	29.970
Total weight (kg)	83703	89340	88387	73648	63505
Total Tower weight (kg)	398583				

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

T165-50A-MB	Concrete	Section 1	Section 2	Section 3
External diameter upper flange (m)	4,528	4,295	4,017	3,503
External diameter lower flange (m)	8,868	4,300	4,295	4,017
Section height (m)	89,090	21,000	23,500	26,890
Total weight (kg)		62117,7	51425,4	48847,9
Total Tower weight (kg)		162391,0		

9. Design Climatic Conditions

The design climatic conditions are the boundary conditions at which the turbine can be applied without supplementary design review. Applications of the wind turbine in more severe conditions may be possible, depending upon the overall circumstances.

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

Subject	ID	Issue	Unit	Value	
0. Design lifetime	0.0	Design lifetime definition	-	IEC 61400-1[1]	
	0.1	Design lifetime	years	20	25
1. Wind, operation	1.1	Wind definitions	-	IEC 61400-1	
	1.2	IEC class	-	IIA	IIB
	1.3	Mean air density, ρ	kg/m^3	1.225	1.225
	1.4	Mean wind speed, V_{ave}	m/s	8.5	8.5
	1.5	Weibull scale parameter, A	m/s	9.59	9.59
	1.6	Weibull shape parameter, k	-	2	2
	1.7	Wind shear exponent, α	-	0.20	0.20
	1.8	Reference turbulence intensity at 15 m/s, I_{ref}	-	0.16	0.14
	1.9	Standard deviation of wind direction	Deg	7.5	7.5
	1.10	Maximum flow inclination	Deg	8	8
	1.11	Minimum turbine spacing, in rows	D	3	3
	1.12	Minimum turbine spacing, between rows	D	5	5
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	
	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	

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

Subject	ID	Issue	Unit	Value
	3.2	Minimum temperature, stand-still, $T_{min,\ s}$	Deg.C	-30
	3.3	Minimum temperature, operation, $T_{min,\ o}$	Deg.C	-20
	3.4	Maximum temperature, operation, $T_{max,\ o}$	Deg.C	40[2]
	3.5	Maximum temperature, stand-still, $T_{max,\ s}$	Deg.C	50
4. Corrosion	4.1	Atmospheric-corrosivity category definitions	-	ISO 12944-2
	4.2	Internal nacelle environment (corrosivity category)	-	C3-H
	4.3	Exterior environment (corrosivity category)	-	C3-H
5. Lightning	5.1	Lightning definitions	-	IEC 61400-24:2010
	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[3]	12.1	Annual precipitation	mm/yr	1100

[2] Maximum power output may be limited after an extended period of operation with a power output close to nominal power. The limitation depends on air temperature and air density as further described in the High Temperature Ride Through specification.
[3] The specified maximum precipitation considers standard Leading Edge Protection.

10. Power Derating Curves by Ambient Temperature

10.1. SG 6.6-155 AM0 STD

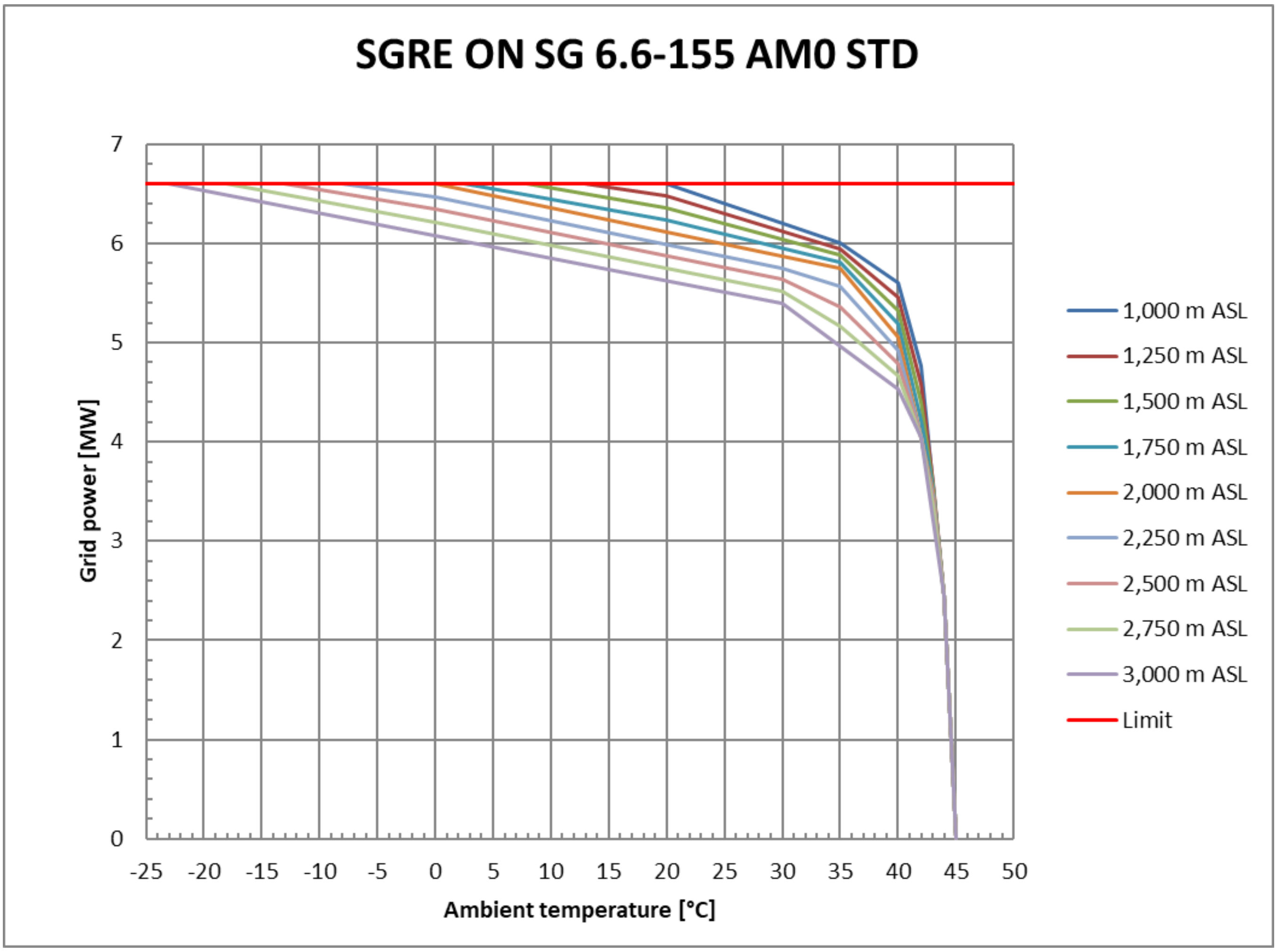


Figure 1: SG 6.6-155 AM0 STD power derating curves by ambient temperature and altitude

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Table 1: SG 6.6-155 AM0 STD grid power as function of ambient temperature and altitude

SGRE ON SG 6.6-155 AM0 STD					6.60	MW	9.31	RPM		
Altitude							**1,000 m ASL**			
Temp.	**°C**	**20**	**35**	**40**	**42**	**44**	**45**			
Power	**MW**	**6.6**	**6**	**5.6**	**4.76**	**2.45**	**0**			
Load	**-**	**1**	**0.91**	**0.85**	**0.72**	**0.37**	**0**			
Altitude							1,250 m ASL			
Temp.	°C	13	20	35	40	42	43	44	45	
Power	MW	6.6	6.48	5.94	5.46	4.58	3.58	2.45	0	
Load	-	1	0.98	0.9	0.83	0.69	0.54	0.37	0	
Altitude							1,500 m ASL			
Temp.	°C	8	20	35	40	42	43	44	45	
Power	MW	6.6	6.36	5.88	5.32	4.4	3.55	2.45	0	
Load	-	1	0.96	0.89	0.81	0.67	0.54	0.37	0	
Altitude							1,750 m ASL			
Temp.	°C	2.5	20	35	40	42	43	44	45	
Power	MW	6.6	6.24	5.81	5.19	4.22	3.53	2.45	0	
Load	-	1	0.94	0.88	0.79	0.64	0.53	0.37	0	
Altitude							**2,000 m ASL**			
Temp.	**°C**	**0**	**35**	**40**	**42**	**43**	**44**	**45**		
Power	**MW**	**6.6**	**5.75**	**5.05**	**4.04**	**3.5**	**2.45**	**0**		
Load	**-**	**1**	**0.87**	**0.77**	**0.61**	**0.53**	**0.37**	**0**		
Altitude							2,250 m ASL			
Temp.	°C	-8	0	30	35	40	42	43	44	45
Power	MW	6.6	6.47	5.75	5.56	4.92	4.04	3.45	2.45	0
Load	-	1	0.98	0.87	0.84	0.74	0.61	0.52	0.37	0
Altitude							2,500 m ASL			
Temp.	°C	-13	0	30	35	40	42	43	44	45
Power	MW	6.6	6.34	5.64	5.36	4.79	4.04	3.4	2.45	0
Load	-	1	0.96	0.85	0.81	0.73	0.61	0.52	0.37	0
Altitude							2,750 m ASL			
Temp.	°C	-18	0	30	35	40	42	43	44	45
Power	MW	6.6	6.21	5.52	5.16	4.66	4.04	3.35	2.45	0
Load	-	1	0.94	0.84	0.78	0.71	0.61	0.51	0.37	0
Altitude							**3,000 m ASL**			
Temp.	**°C**	**-23**	**30**	**40**	**42**	**44**	**45**			
Power	**MW**	**6.6**	**5.4**	**4.53**	**4.04**	**2.45**	**0**			
Load	**-**	**1**	**0.82**	**0.69**	**0.61**	**0.37**	**0**			

Table 2: SG 6.6-155 AM0 STD ambient temperature as function of grid power and altitude

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	8	2.5	**0**	-8	-13	-18	**-23**
6.5	**22.5**	18.5	13	7.5	**4**	-2	-8	-13.5	**-18.5**
6.4	**25**	22	18	12	**8**	3	-3	-9	**-14**
6.3	**27.5**	25	22	17	**12.5**	7	1.5	-4	**-10**
6.2	**30**	27.5	25	21.5	**16.5**	11.5	6	0.5	**-5.5**
6.1	**32.5**	30.5	28	25	**20.5**	15.5	10	5	**-1**
6.0	**35**	33.5	31	28.5	**24.5**	19.5	14.5	9	**3.5**
5.9	**36.5**	35.5	34	32	**29**	24	18.5	13.5	**8**
5.8	**37.5**	36.5	35.5	35	**33**	28	23	18	**12.5**
5.7	**39**	37.5	36.5	36	**35.5**	31.5	27.5	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	30.5	**25.5**
5.4		40	39.5	38.5	**37.5**	36	34.5	31.5	**30**
5.3	**40.5**	40.5	40	39	**38**	37	35.5	33	**31**
5.2			40.5	40	**39**	38	36.5	34.5	**32.5**
5.1	**41**				**39.5**	38.5	37.5	35.5	**33.5**
5.0		41			**40**	39.5	38	36.5	**34.5**
4.9	**41.5**			40.5	**40.5**	40	39	37.5	**35.5**
4.8			41			40.5	40	38.5	**37**
4.7	**42**	41.5		41				39.5	**38**
4.6			41.5					40	**39**
4.5		42			**41**		40.5	40.5	**40**
4.4				41.5		41	41	41	**40.5**
4.3			42						**41**
4.2				42	**41.5**	41.5	41.5		**41.5**
4.1	**42.5**							41.5	**42**
4.0		42.5			**42**	42	42	42	
3.9			42.5						
3.8				42.5					
3.7					**42.5**	42.5	42.5		
3.6	**43**							42.5	**42.5**
3.5		43	43	43	**43**				
3.4						43	43		
3.3								43	
3.2									**43**
3.0	**43.5**	43.5	43.5						
2.9				43.5	**43.5**	43.5	43.5		
2.8								43.5	**43.5**
2.4	**44**	44	44	44	**44**	44	44	44	**44**
1.2	**44.5**	44.5	44.5	44.5	**44.5**	44.5	44.5	44.5	**44.5**
0.0	**45**	45	45	45	**45**	45	45	45	**45**

10.1.1. SG 6.6-155 AM0 HT

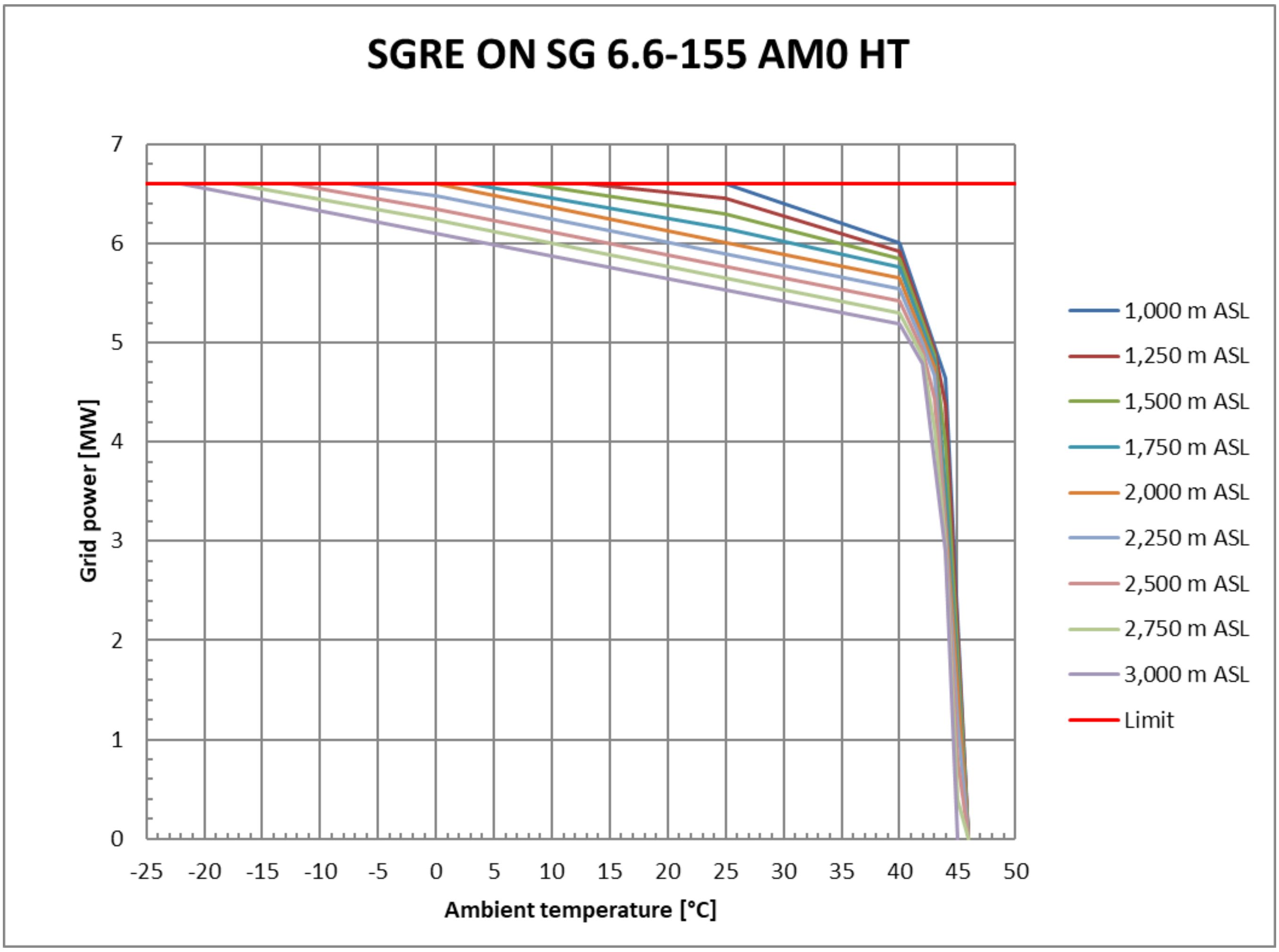


Figure 2: SG 6.6-155 AM0 HT power derating curves by ambient temperature and altitude

Table 3: SG 6.6-155 AM0 HT grid power as function of ambient temperature and altitude

SGRE ON SG 6.6-155 AM0 HT					6.60	MW	9.31	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	4.37	0		
Load	-	1	0.98	0.9	0.75	0.66	0		
Altitude							1,500 m ASL		
Temp.	°C	8	25	40	43	44	46		
Power	MW	6.6	6.3	5.84	4.87	3.97	0		
Load	-	1	0.96	0.89	0.74	0.6	0		
Altitude							1,750 m ASL		
Temp.	°C	3	25	40	43	44	46		
Power	MW	6.6	6.15	5.76	4.81	3.52	0		
Load	-	1	0.93	0.87	0.73	0.53	0		
Altitude							**2,000 m ASL**		
Temp.	**°C**	**0**	**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	0	40	42	43	44	45	46
Power	MW	6.6	6.48	5.54	4.99	4.67	3.1	1.19	0
Load	-	1	0.98	0.84	0.76	0.71	0.47	0.18	0
Altitude							2,500 m ASL		
Temp.	°C	-12.5	0	40	42	43	44	45	46
Power	MW	6.6	6.35	5.42	4.92	4.43	3.04	0.79	0
Load	-	1	0.96	0.82	0.75	0.67	0.46	0.12	0
Altitude							2,750 m ASL		
Temp.	°C	-17.5	0	40	42	43	44	45	46
Power	MW	6.6	6.23	5.3	4.86	4.13	2.96	0.39	0
Load	-	1	0.94	0.8	0.74	0.63	0.45	0.06	0
Altitude							**3,000 m ASL**		
Temp.	**°C**	**-22**	**40**	**42**	**44**	**45**			
Power	**MW**	**6.6**	**5.19**	**4.79**	**2.89**	**0**			
Load	**-**	**1**	**0.79**	**0.73**	**0.44**	**0**			

Table 4: SG 6.6-155 AM0 HT ambient temperature as function of grid power and altitude

SGRE ON SG 6.6-155 AM0 HT				6.6	MW	9.31	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	**-22**
6.6		**25**	13	8	3	**0**	-7.5	-12.5	-17.5	**-22**
6.5		**27.5**	21	13.5	8	**4**	-1.5	-7.5	-13	**-17.5**
6.4		**30**	26.5	19.5	13	**8.5**	3	-2.5	-8	**-13**
6.3		**32.5**	29.5	25	18	**12.5**	7.5	2	-3.5	**-9**
6.2		**35**	32	28.5	22.5	**17**	11.5	6.5	1	**-4.5**
6.1		**37.5**	35	31.5	27	**21**	16	11	5.5	**0**
6.0		**40**	38	35	31	**25.5**	20	15	10	**4.5**
5.9		**40.5**	40	38	34.5	**29.5**	24.5	19.5	14	**9**
5.8			40.5	40	38.5	**33.5**	28.5	23.5	18.5	**13**
5.7				40.5	40	**38**	33	28	23	**17.5**
5.6		**41**			40.5	**40**	37	32.5	27	**22**
5.5			41	41	41	**40.5**	40	36.5	31.5	**26.5**
5.4		**41.5**	41.5			**41**	40.5	40	36	**31**
5.3		**42**		41.5			41	40.5	40	**35**
5.2			42		41.5	**41.5**		41	40.5	**39.5**
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**				
4.6		**44**	43.5				43	42.5		
4.4				43.5				43	42.5	
4.3			44							**42.5**
4.1					43.5				43	
3.9				44		**43.5**				
3.8							43.5			**43**
3.7								43.5		
3.5					44				43.5	
3.4		**44.5**								
3.3										**43.5**
3.2			44.5							
3.1						**44**	44			
3.0								44		
2.9				44.5					44	
2.8										**44**
2.6					44.5					
2.3		**45**				**44.5**				
2.1			45				44.5			
1.9				45				44.5		

SGRE ON SG 6.6-155 AM0 HT				6.6	MW	9.31	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)**					
1.7					45					
1.6									44.5	
1.5						**45**				
1.4										**44.5**
1.1		**45.5**					45			
1.0			45.5							
0.9				45.5						
0.8					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 Specifications ®

The SG 6.6-155 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[4].

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. The SG 6.6-155 can offer increased operation flexibility with modes based on AM 0 with reduced power rating. These new modes are created with same noise performance of the corresponding Application Mode 0 but with decreased power rating and improved temperature de-rating than the corresponding Application Mode 0.
In addition, the turbine's electrical performance is constant for the full set of application modes, as shown on the table below. The SG 6.6-155 is designed with a base wind class, applicable to AM 0, of IEC IIA for 20 year lifetime as well as IEC IIB for 25 year lifetime. All other Application Modes may be analysed for more demanding site conditions.

11.2. List of Application Modes

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[5]
						Cos Phi	Voltage Range	Frequency range	
SG 6.6-155	AM 0	6.6	105.0	D2075721	D2311677	0.9	[0.95,1.12] Un	±3% Fn	20ºC
SG 6.6-155	AM-1	6.5	105.0	D2354395	D2359800	0.9	[0.95,1.12] Un	±3% Fn	23ºC
SG 6.6-155	AM-2	6.4	105.0	D2354431	D2359800	0.9	[0.95,1.12] Un	±3% Fn	25ºC
SG 6.6-155	AM-3	6.3	105.0	D2354439	D2359800	0.9	[0.95,1.12] Un	±3% Fn	28ºC
SG 6.6-155	AM-4	6.2	105.0	D2354491	D2359800	0.9	[0.95,1.12] Un	±3% Fn	30ºC
SG 6.6-155	AM-5	6.1	105.0	D2354488	D2359800	0.9	[0.95,1.12] Un	±3% Fn	33ºC
SG 6.6-155	AM-6	6.0	105.0	D2075725	D2359800	0.9	[0.95,1.12] Un	±3% Fn	35ºC
SG 6.6-155	AM-7	5.8	105.0	D2354517	D2359800	0.9	[0.95,1.12] Un	±3% Fn	38ºC
SG 6.6-155	AM-8	5.6	105.0	D2356422	D2359800	0.9	[0.95,1.12] Un	±3% Fn	40ºC

[4] 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 Ride Through and Reactive Power Capability Document for more information

[5] Please Refer to "High Temperature Ride Through" for more details'

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 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. Sound Power Levels correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade.

The activation of NRS modes depend on the tower type selection. This information can be provided upon request.

11.4. List of NRS Modes

Rotor Configuration	NRS Mode	Rating [MW]	Noise [dB(A)]	Power Curve Document	Acoustic Emission Document	Max temperature With Max active power and electrical capabilities[6]
SG 6.6-155	N1	6.30	104.0	D2314777	D2359800	20ºC
SG 6.6-155	N2	6.10	103.5	D2314778	D2359800	20ºC
SG 6.6-155	N3	5.24	102.0	D2314779	D2359800	20ºC
SG 6.6-155	N4	5.12	101.0	D2314780	D2359800	20ºC
SG 6.6-155	N5	4.87	100	D2314781	D2359800	20 ºC
SG 6.6-155	N6	4.52	99.0	D2314783	D2359800	20 ºC
SG 6.6-155	N7	3.50	98.0	D2373456	D2379747	20 ºC
SG 6.6-155	N8	2.97	97.0	D2373458	D2379748	20 ºC

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.

[6] Please Refer to High Temperature Ride ThroughSpecification" for more details'

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

Air density= 1.225 kg/m^3

Validity range:

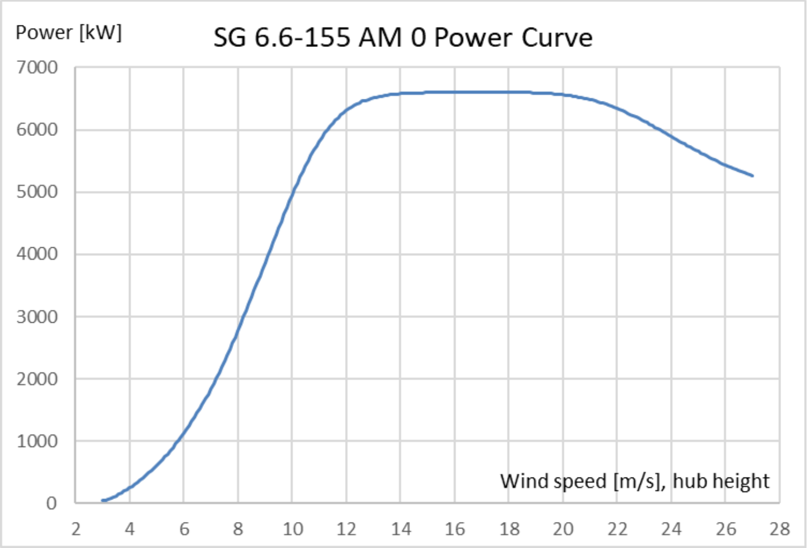
Wind Shear (10min average)	≤ 0.3
Turbulence intensity TI [%] for bin i	$5\%\frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\%\frac{(0.75v_i + 5.6)}{v_i}$
Terrain	Not complex according to IEC 61400-12-1
Upflow β [°]	-2° ≤ β ≤ +2°
Grid frequency [Hz]	± 0.5 Hz

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 (D2315786).

SG 6.6-155 Rev. 0, AM 0	
Wind Speed [m/s]	Power [kW]
3.0	47
3.5	126
4.0	252
4.5	415
5.0	613
5.5	848
6.0	1128
6.5	1457
7.0	1840
7.5	2281
8.0	2775
8.5	3312
9.0	3868
9.5	4421
10.0	4948
10.5	5421
11.0	5812
11.5	6106
12.0	6309
12.5	6438
13.0	6513
13.5	6555
14.0	6578
14.5	6589
15.0	6595
15.5	6597
16.0	6599
16.5	6599
17.0	6600
17.5	6600
18.0	6599
18.5	6597
19.0	6592
19.5	6581
20.0	6562
20.5	6531
21.0	6486
21.5	6423
22.0	6342
22.5	6246
23.0	6137
23.5	6018
24.0	5894
24.5	5770
25.0	5652
25.5	5537
26.0	5434
26.5	5342
27.0	5262



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	11262	13601	15888	18077	20135	22040	23778	25342	26731	27947	28996
	2.0	9838	12499	15234	17956	20603	23129	25503	27707	29729	31559	33194
	2.5	8624	11355	14296	17337	20376	23333	26150	28789	31232	33468	35497

Annual Production [MWh] SG 6.6-155 Rev 0, Mode AM 0 wind turbine for the standard version, as a function of the annual mean wind speed at hub height, and for different Weibull parameters. Air density 1.225 kg/m^3

13. 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	$5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$
Terrain	Not complex according to IEC 61400-12-1
Upflow β [°]	-2° ≤ β ≤ +2°
Grid frequency [Hz]	± 0.5 Hz

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

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

Ct is defined by the following expression:

Ct = F / (0.5 * ad * w^2 * A)

where

F = Rotor force [N]

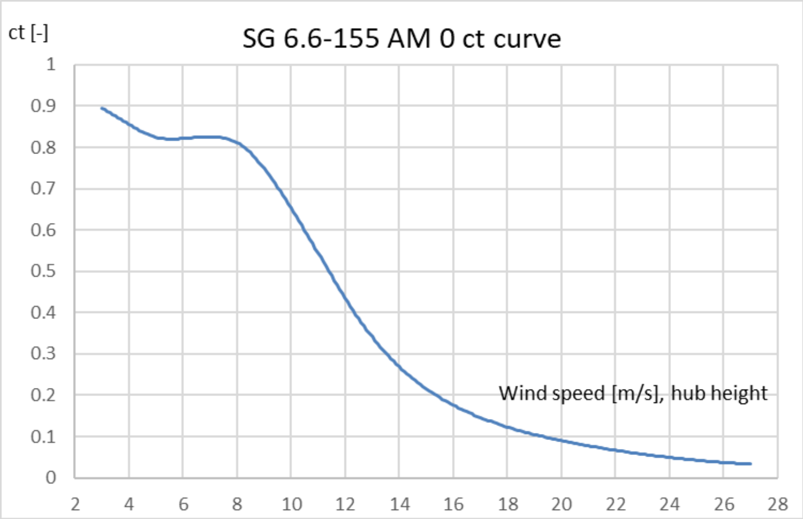
ad = Air density [kg/m^3]

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 (D2315786).

SG 6.6-155 Rev. 0, AM 0	
Wind Speed [m/s]	ct [-]
3.0	0.894
3.5	0.876
4.0	0.856
4.5	0.838
5.0	0.825
5.5	0.820
6.0	0.821
6.5	0.824
7.0	0.825
7.5	0.823
8.0	0.812
8.5	0.787
9.0	0.750
9.5	0.704
10.0	0.653
10.5	0.600
11.0	0.545
11.5	0.489
12.0	0.436
12.5	0.386
13.0	0.342
13.5	0.303
14.0	0.269
14.5	0.240
15.0	0.216
15.5	0.195
16.0	0.176
16.5	0.161
17.0	0.147
17.5	0.134
18.0	0.123
18.5	0.114
19.0	0.105
19.5	0.097
20.0	0.090
20.5	0.084
21.0	0.078
21.5	0.072
22.0	0.067
22.5	0.062
23.0	0.058
23.5	0.053
24.0	0.049
24.5	0.046
25.0	0.043
25.5	0.040
26.0	0.037
26.5	0.035
27.0	0.033



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

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

Validity range:

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

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

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

For a detailed description of Application Mode – AM 0, please refer to latest version of Flexible Rating Specification (D2315786).

SG 6.6-155 Mode AM 0 Power curves [kW]									
Ws hub [m/s]	Air density [kg/m³]								
	1.225	1.06	1.09	1.12	1.15	1.18	1.21	1.24	1.27
3.0	47	34	37	39	41	43	45	48	50
3.5	126	99	104	109	114	118	123	129	134
4.0	252	206	214	222	231	239	248	256	265
4.5	415	346	358	371	383	396	408	421	434
5.0	613	517	534	552	569	586	604	621	639
5.5	848	721	744	767	790	814	837	860	883
6.0	1128	963	993	1023	1053	1083	1113	1142	1172
6.5	1457	1248	1286	1324	1362	1400	1438	1476	1514
7.0	1840	1580	1627	1675	1722	1769	1817	1864	1911
7.5	2281	1962	2020	2078	2136	2194	2252	2310	2368
8.0	2775	2391	2461	2531	2601	2671	2741	2810	2880
8.5	3312	2856	2939	3022	3105	3188	3270	3353	3435
9.0	3868	3341	3437	3533	3629	3725	3820	3915	4010
9.5	4421	3826	3936	4045	4153	4261	4368	4474	4579
10.0	4948	4302	4423	4543	4662	4779	4893	5003	5111
10.5	5421	4759	4889	5015	5137	5255	5367	5473	5573
11.0	5812	5187	5317	5441	5558	5666	5765	5856	5939
11.5	6106	5569	5690	5800	5901	5991	6071	6140	6202
12.0	6309	5887	5990	6080	6159	6227	6284	6333	6375
12.5	6438	6134	6213	6281	6337	6384	6422	6453	6479
13.0	6513	6311	6367	6413	6451	6480	6504	6522	6537
13.5	6555	6428	6466	6495	6518	6536	6550	6560	6569
14.0	6578	6502	6526	6543	6557	6567	6575	6580	6585
14.5	6589	6546	6560	6570	6578	6583	6587	6590	6593
15.0	6595	6571	6579	6585	6589	6592	6594	6595	6597
15.5	6597	6585	6589	6592	6594	6596	6597	6598	6598
16.0	6599	6592	6594	6596	6597	6598	6599	6599	6599
16.5	6599	6596	6597	6598	6599	6599	6599	6600	6600
17.0	6600	6598	6599	6599	6599	6600	6600	6600	6600
17.5	6600	6599	6599	6599	6599	6600	6600	6600	6600
18.0	6599	6598	6599	6599	6599	6599	6599	6599	6599
18.5	6597	6597	6597	6597	6597	6597	6597	6597	6597
19.0	6592	6592	6592	6592	6592	6592	6592	6592	6592
19.5	6581	6581	6581	6581	6581	6581	6581	6581	6581
20.0	6562	6562	6562	6562	6562	6562	6562	6562	6562
20.5	6531	6531	6531	6531	6531	6531	6531	6531	6531
21.0	6486	6486	6486	6486	6486	6486	6486	6486	6486
21.5	6423	6423	6423	6423	6423	6423	6423	6423	6423
22.0	6342	6342	6342	6342	6342	6342	6342	6342	6342
22.5	6246	6246	6246	6246	6246	6246	6246	6246	6246
23.0	6137	6137	6137	6137	6137	6137	6137	6137	6137
23.5	6018	6018	6018	6018	6018	6018	6018	6018	6018
24.0	5894	5894	5894	5894	5894	5894	5894	5894	5894
24.5	5770	5770	5770	5770	5770	5770	5770	5770	5770
25.0	5652	5652	5652	5652	5652	5652	5652	5652	5652
25.5	5537	5537	5537	5537	5537	5537	5537	5537	5537
26.0	5434	5434	5434	5434	5434	5434	5434	5434	5434
26.5	5342	5342	5342	5342	5342	5342	5342	5342	5342
27.0	5262	5262	5262	5262	5262	5262	5262	5262	5262

The annual energy production data for different annual mean wind speeds in hub height are calculated from the above power curve assuming a Weibull wind speed distribution with a K-factor of 2.0, 100 percent availability, and no reductions due to array losses, grid losses, or other external factors affecting the production.

AEP [MWh]		Annual Average Wind Speed [m/s] at Hub Height										
		5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10
Density [kg/m³]	1.225	9838	12499	15234	17956	20603	23129	25503	27707	29729	31559	33194
	1.06	8546	10956	13476	16030	18555	21001	23334	25527	27562	29424	31106
	1.09	8787	11247	13811	16401	18952	21418	23762	25960	27994	29853	31527
	1.12	9025	11533	14139	16762	19339	21821	24174	26376	28409	30262	31928
	1.15	9261	11815	14460	17115	19714	22211	24572	26776	28807	30654	32312
	1.18	9494	12092	14775	17458	20078	22588	24955	27160	29187	31028	32677
	1.21	9724	12365	15082	17792	20431	22951	25324	27529	29552	31386	33026
	1.24	9951	12633	15383	18118	20773	23303	25680	27883	29902	31729	33359
	1.27	10176	12896	15678	18436	21107	23645	26024	28226	30240	32059	33680

Annual Production [MWh] SG 6.6-155 Rev 0, Mode AM 0 wind turbine for the standard version, as a function of the annual mean wind speed at hub height, and for Weibull parameter k=0.

15. Standard Ct Curve, Application Mode - AM 0

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

Validity range:

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

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

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

Ct is defined by the following expression:

Ct = F / (0.5 * ad * w2 * A)

where

F = Rotor force [N]

ad = Air density [kg/m3]

w = Wind speed [m/s]

A = Swept area of rotor [m^2]

For a detailed description of Application Mode - AM 0, please refer to latest version of Flexible Rating Specification (D2315786).

SG 6.6-155 Mode AM 0 ct curves [-]									
Ws hub [m/s]	Air density [kg/m^3]								
	1.225	1.06	1.09	1.12	1.15	1.18	1.21	1.24	1.27
3.0	0.894	0.894	0.894	0.894	0.894	0.894	0.894	0.894	0.894
3.5	0.876	0.876	0.876	0.876	0.876	0.876	0.876	0.876	0.876
4.0	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856
4.5	0.838	0.838	0.838	0.838	0.838	0.838	0.838	0.838	0.838
5.0	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825
5.5	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
6.0	0.821	0.821	0.821	0.821	0.821	0.821	0.821	0.821	0.821
6.5	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824
7.0	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825
7.5	0.823	0.823	0.823	0.823	0.823	0.823	0.823	0.823	0.823
8.0	0.812	0.812	0.812	0.812	0.812	0.812	0.812	0.812	0.812
8.5	0.787	0.787	0.787	0.787	0.787	0.787	0.787	0.787	0.787
9.0	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750
9.5	0.704	0.705	0.705	0.704	0.704	0.704	0.704	0.704	0.703
10.0	0.653	0.656	0.656	0.656	0.656	0.655	0.654	0.652	0.651
10.5	0.600	0.609	0.608	0.607	0.606	0.604	0.601	0.598	0.595
11.0	0.545	0.562	0.561	0.558	0.555	0.552	0.547	0.542	0.537
11.5	0.489	0.517	0.514	0.510	0.505	0.499	0.493	0.486	0.479
12.0	0.436	0.472	0.467	0.461	0.455	0.447	0.440	0.432	0.424
12.5	0.386	0.428	0.422	0.414	0.407	0.398	0.390	0.382	0.374
13.0	0.342	0.386	0.378	0.370	0.362	0.354	0.346	0.337	0.330
13.5	0.303	0.347	0.339	0.330	0.322	0.314	0.306	0.299	0.292
14.0	0.269	0.311	0.303	0.295	0.287	0.280	0.273	0.266	0.259
14.5	0.240	0.279	0.271	0.264	0.257	0.250	0.244	0.237	0.232
15.0	0.216	0.250	0.243	0.237	0.230	0.224	0.219	0.213	0.208
15.5	0.195	0.226	0.22	0.213	0.208	0.202	0.197	0.192	0.188
16.0	0.176	0.204	0.199	0.193	0.188	0.183	0.179	0.174	0.170
16.5	0.161	0.186	0.181	0.176	0.171	0.167	0.162	0.159	0.155
17.0	0.147	0.169	0.165	0.160	0.156	0.152	0.148	0.145	0.141
17.5	0.134	0.155	0.151	0.147	0.143	0.139	0.136	0.133	0.130
18.0	0.123	0.142	0.138	0.135	0.131	0.128	0.125	0.122	0.119
18.5	0.114	0.131	0.127	0.124	0.121	0.118	0.115	0.113	0.110
19.0	0.105	0.121	0.118	0.115	0.112	0.109	0.106	0.104	0.102
19.5	0.097	0.112	0.109	0.106	0.103	0.101	0.099	0.096	0.094
20.0	0.090	0.104	0.101	0.098	0.096	0.094	0.091	0.089	0.087
20.5	0.084	0.096	0.093	0.091	0.089	0.087	0.085	0.083	0.081
21.0	0.078	0.089	0.087	0.085	0.082	0.081	0.079	0.077	0.075
21.5	0.072	0.083	0.08	0.078	0.077	0.075	0.073	0.071	0.070
22.0	0.067	0.076	0.074	0.073	0.071	0.069	0.068	0.066	0.065
22.5	0.062	0.071	0.069	0.067	0.066	0.064	0.063	0.061	0.060
23.0	0.058	0.065	0.064	0.062	0.061	0.059	0.058	0.057	0.056
23.5	0.053	0.061	0.059	0.058	0.056	0.055	0.054	0.053	0.052
24.0	0.049	0.056	0.055	0.053	0.052	0.051	0.050	0.049	0.048
24.5	0.046	0.052	0.051	0.050	0.048	0.047	0.046	0.045	0.044
25.0	0.043	0.048	0.047	0.046	0.045	0.044	0.043	0.042	0.041
25.5	0.040	0.045	0.044	0.043	0.042	0.041	0.040	0.039	0.039
26.0	0.037	0.042	0.041	0.040	0.039	0.038	0.038	0.037	0.036
26.5	0.035	0.040	0.039	0.038	0.037	0.036	0.035	0.035	0.034
27.0	0.033	0.037	0.036	0.036	0.035	0.034	0.033	0.033	0.032

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

Typical Sound Power Levels

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

Wind speed [m/s]	3	4	5	6	7	8	9	10	11	12	Up tp cut-out
AM 0	92.0	92.0	94.8	98.8	102.1	105.0	105.0	105.0	105.0	105.0	105.0

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

Wind speed [m/s]	6	8
AM 0	88.6	92.8

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

Low Noise Operations

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

For a detailed description of Application Mode – AM 0, please refer to Flexible Rating Specification (D2315786).

17. Electrical Specifications

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) 1344 rpm-6p (60Hz)

Generator Protection

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

Generator Cooling

Cooling system	Air cooling
Internal ventilation	Air
Control parameter............	Winding, Air, Bearings temperatures

Frequency Converter

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

Main Circuit Protection

Short circuit protection......	Circuit breaker
Surge arrester..................	varistors

Peak Power Levels

10 min average................	Limited to nominal

Grid Capabilities Specification

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

Power Consumption from Grid (approximately)

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

Controller back-up

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

Transformer Specification

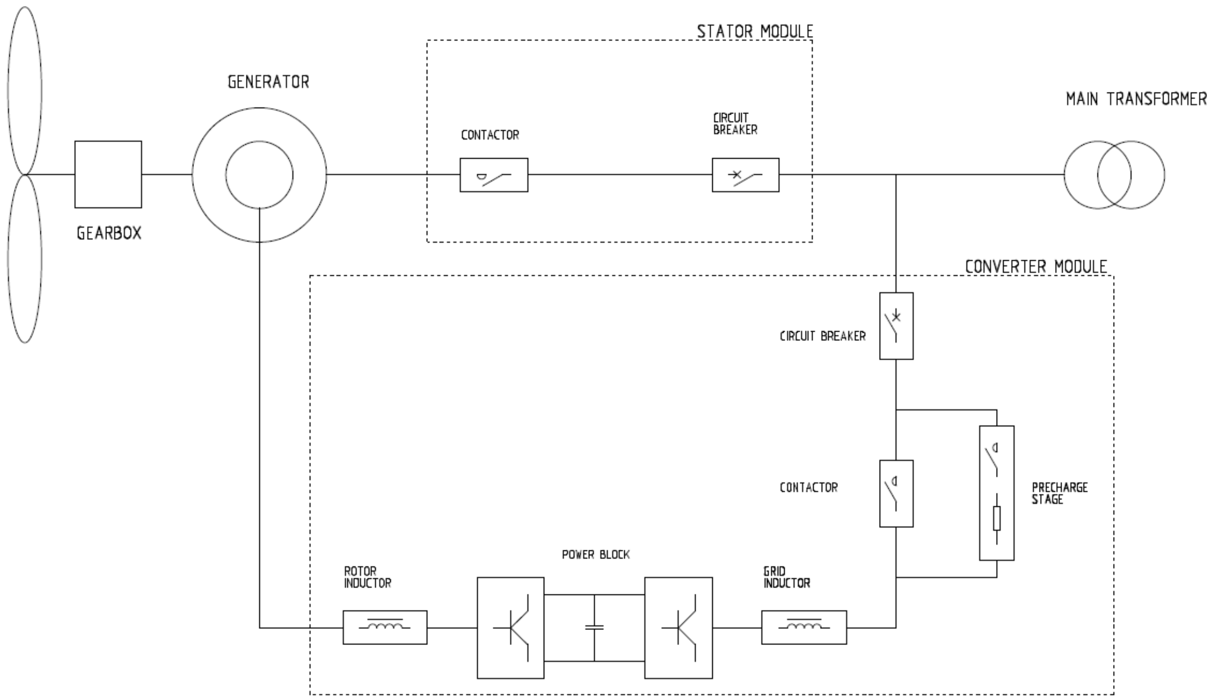
Transformer impedance requirement.......................	8.5 % - 10.5%
Secondary voltage	690 V
Vector group	Dyn 11 or Dyn 1 (star point earthed)

Earthing Specification

Earthing system	Acc. to IEC62305-3 ED 1.0:2010
Foundation reinforcement..	Must be connected to earth electrodes
Foundation terminals	Acc. to SGRE Standard
HV connection	HV cable shield shall be connected to earthing system

Simplified Single Line Diagram

18. Simplified Single Line Diagram



19. Transformer Specifications ECO 30 kV

Transformer

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

Transformer Cooling

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

Transformer Monitoring

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

Transformer Earthing

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

20. 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.

21. Technical Data for Switchgear

Switchgear	
Make	Siemens / Ormazabal
Type	8DJH, 8DJH 36 / cgmcosmos, cgm.3
Rated voltage	20-40,5(Um) kV
Operating voltage	20-40,5(Um) kV
Rated current	630 A
Short time withstand current	20 kA/1s
Peak withstand current	50 kA
Power frequency withstand voltage	70 kV
Lightning withstand voltage	170 kV
Insulating medium	SF_6
Switching medium	Vacuum
Consist of	2/3/4 panels
Grid cable feeder	Cable riser or line cubicle
Circuit breaker feeder	Circuit breaker
Degree of protection, vessel	IP65
Internal arc classification IAC:	A FLR 20 kA 1s
Pressure relief	Upwards
Standard	IEC 62271
Temperature range	-25°C to +45°C
Grid cable feeder (line cubicle)	
Rated current, Cubicle	630 A
Rated current, load breaker	630 A
Short time withstand current	20 kA/1s
Short circuit making current	50 kA/1s
Three position switch	Closed, open, earthed
Switch mechanism	Spring operated
Control	Local
Voltage detection system	Capacitive

Circuit breaker feeder	
Rated current, Cubicle	630 A
Rated current circuit breaker	630 A
Short time withstand current	20 kA/1s
Short circuit making current	50 kA/1s
Short circuit breaking current	20 kA/1s
Three position switch	Closed, open, earthed
Switch mechanism	Spring operated
Tripping mechanism	Stored energy
Control	Local
Coil for external trip	230V AC
Voltage detection system	Capacitive
Protection	
Over-current relay	Self-powered
Functions	50/51 50N/51N
Power supply	Integrated CT supply
Interface- MV/HV Cables	630 A bushings type C
Grid cable feeder	M16
	Max 2 feeder cables
Cable entry	From bottom
Cable clamp size (cable outer diameter) *	26 - 38mm 36 - 52mm 50 - 75mm
Circuit breaker feeder	630 A bushings type C
Cable entry	M16
	From bottom
Interface to turbine control	
Breaker status	
SF6 supervision	1 NO contact
External trip	1 NO contact

*Cable clamps are not part of switchgear delivery.

22. Grid Performance Specifications – 50 Hz

22.1. General

This document describes the grid performance of the Siemens Gamesa 5.X, 50 Hz wind turbine. Siemens Gamesa Renewable Energy (SGRE) will provide wind turbine technical data for the developer to use in the design of the wind power plant and the evaluation of requirements compliance. The developer will be responsible for the evaluation and ensuring that the requirements are met for the wind power plant.

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

22.2. Fault Ride Through (FRT) Capability

The wind turbine is capable of operating when voltage transient events occur on the interconnecting transmission system above and below the standard voltage lower limits and time slot according to Figure 1 and Figure 2.

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

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

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

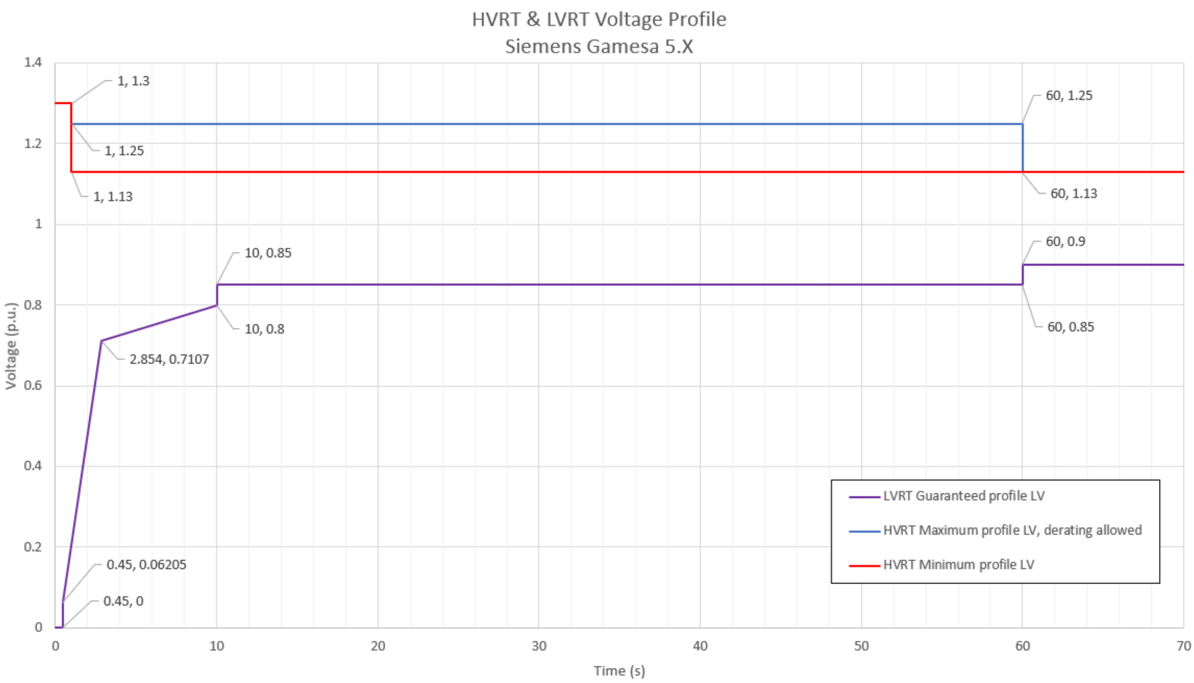


Figure 1. High and Low voltage limits for Siemens Gamesa 5.X, 50 Hz wind turbine in the range of 0-70 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).

22.3. Power Factor

The wind turbine can operate in a power factor range of 0.9 leading to 0.9 lagging at the low voltage side of the wind turbine transformer, considering a voltage level equal or higher of 0.95pu. Depending on the voltage behaviour (higher or lower, inside maximum permissible margins), the Reactive Power maximum capability is modified accordingly.

The control mode for the wind turbine is with reactive power set-points or Local Voltage Control mode (external set-points of voltage).

22.4. 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.

22.5. Frequency Capability

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

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

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

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

22.6. Voltage Capability

The voltage operation range for the wind turbine is between 85% and 113% of nominal voltage at the low voltage side of the wind turbine transformer. The voltage can be up to 130% for 1s, see Figure 1. The wind turbine's target voltage shall stay between 95% and 105% to support the best possible performance by staying within the operation limits.

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

22.7. Flicker and Harmonics

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

22.8. Reactive Power – Voltage Control

The power plant controller can operate in four different modes:

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

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

22.9. Frequency Control

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

22.10. Summary of Grid Connection Capabilities

Characteristic	Value	Comments
Rated Voltage	690V	
Maximum Voltage Range	+13% -15%	Q & P deratings due to V-f Simultaneities could apply
Rated Frequency	50 / 60 Hz	
Maximum Frequency Range	± 8%	Q & P deratings due to V-f Simultaneities could apply
Rated Power Factor	0.9 Under & Over excited	Rated point reachable at Full Power, V = 0.95, f = ±3% Applicable to any AM and turbine variant
Minimum SCR at WTG MV Terminals	V-Direct: ≥ 2.0* Q-Direct: ≥ 3.0**	See note 1.
Minimum X/R at WTG MV Terminals	3.0	
Max. Frequency gradient (ROCOF)	≤ 4 Hz/s	
Allowable Max Negative Sequence Voltage	≤ 5%	
Voltage support after FRT recovery	3s	Configurable by parameter
Power recovery to 95% of Pre- Fault value	< 1000ms	Standard Configuration. Configurable by parameters adjustment.
Voltage support during FRT	Available	Configurable by parameter
Active current priority during Voltage Dip	Available	Configurable by parameter
Active Power damping after Dip	±5% pre-fault level in <2s	Can be affected if Power Recovery Ramps after Voltage Dip is modified
I_Q Injection Curve during FRT	k = [2 – 6]	Configurable by parameters. See note 2.
I_Q Response Time (FRT)	≤ 30ms	+20ms for 1 cycle RMS calculation
I_Q Settling Time (FRT)	≤ 60ms	+20ms for 1 cycle RMS calculation -10% +20% required step
Active Power Ramp	± 6% Prated / s	Standard
Active Power Ramps - Fast Mode	+12,5% Prated/s -25% Prated/s	When commanded by SCADA
Reactive Power Ramp	±5000 kVAr/s	Configurable by parameter

Note 1.

* SCR ratio can be reduced further if Active Power recovery ramps are limited to a certain value, that secures stable operation, after voltage dip events.

** SCR ratio can be reduced further if Reactive Power Management configuration is done correctly by means of detailed grid studies, trying to avoid voltage saturation extremes in any case (over and under voltage saturation levels).

Note 2.

In weak grids with low SCR value, the maximum configurable k value could be limited to <6 due to grid stability. Specific grid studies shall be executed for determining the optimum and maximum values.

All data are subject to tolerances in accordance with IEC.

23. Grid Performance Specifications – 60 Hz

This document describes the grid performance of the Siemens Gamesa 5.X, 60 Hz wind turbine. Siemens Gamesa Renewable Energy (SGRE) will provide wind turbine technical data for the developer to use in the design of the wind power plant and the evaluation of requirements compliance. The developer will be responsible for the evaluation and ensuring that the requirements are met for the wind power plant.

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

23.1. 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 and Figure 2.

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

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

The standard voltage limits for the Siemens Gamesa 5.X, 60 Hz wind turbine are presented in Figure 1 between 0 - 70 seconds.

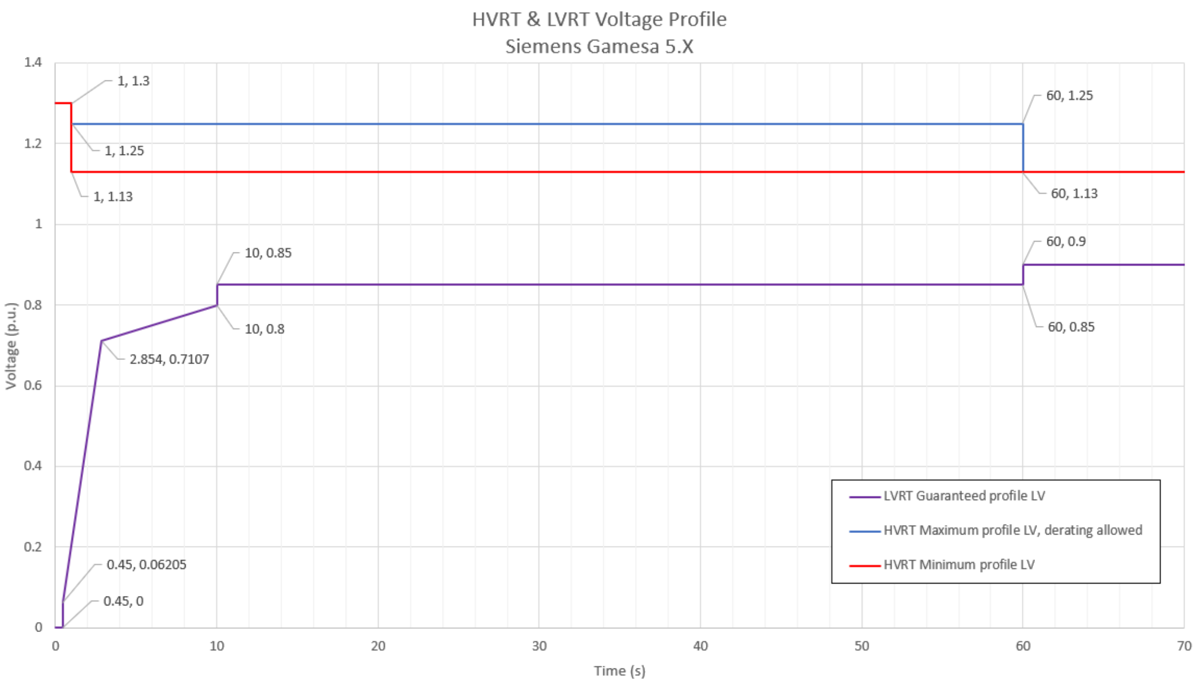


Figure 1. High and Low voltage limits for Siemens Gamesa 5.X, 60 Hz wind turbine in the range of 0-70 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).

23.2. Power Factor

The wind turbine can operate in a power factor range of 0.9 leading to 0.9 lagging at the low voltage side of the wind turbine transformer, considering a voltage level equal or higher of 0.95pu. Depending on the voltage behavior (higher or lower, inside maximum permissible margins), the Reactive Power maximum capability is modified accordingly.

The control mode for the wind turbine is with reactive power set-points or Local Voltage Control mode (external set-points of voltage).

23.3. Supervisory Control and Data Acquisition (SCADA) Capability

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

23.4. Frequency Capability

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

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

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

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

23.5. Voltage Capability

The voltage operation range for the wind turbine is between 85% and 113% of nominal voltage at the low voltage side of the wind turbine transformer. The voltage can be up to 130% for 1s, see Figure 1. The wind turbine's target voltage shall stay between 95% and 105% to support the best possible performance by staying within the operation limits.

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

23.6. 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.

23.7. Reactive Power – Voltage Control

The power plant controller can operate in four different modes:

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

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

23.8. Frequency Control

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

23.9. 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
Rated Power Factor	0.9 Under & Over excited	Rated point reachable at Full Power, V = 0.95, f = ±3% Applicable to any AM and turbine variant
Minimum SCR at WTG MV Terminals	V-Direct: ≥ 2.0* Q-Direct: ≥ 3.0**	See note 1.
Minimum X/R at WTG MV Terminals	3.0	
Max. Frequency gradient (ROCOF)	≤ 4 Hz/s	
Allowable Max Negative Sequence Voltage	≤ 5%	
Voltage support after FRT recovery	3s	Configurable by parameter
Power recovery to 95% of Pre- Fault value	< 1000ms	Standard Configuration. Configurable by parameters adjustment.
Voltage support during FRT	Available	Configurable by parameter
Active current priority during Voltage Dip	Available	Configurable by parameter
Active Power damping after Dip	±5% pre-fault level in <2s	Can be affected if Power Recovery Ramps after Voltage Dip is modified
I_Q Injection Curve during FRT	k = [2 – 6]	Configurable by parameters. See note 2.
I_Q Response Time (FRT)	≤ 30ms	+20ms for 1 cycle RMS calculation
I_Q Settling Time (FRT)	≤ 60ms	+20ms for 1 cycle RMS calculation -10% +20% required step
Active Power Ramp	± 6% Prated / s	Standard
Active Power Ramps - Fast Mode	+12,5% Prated/s -25% Prated/s	When commanded by SCADA
Reactive Power Ramp	±5000 kVAr/s	Configurable by parameter

Note 1.

* SCR ratio can be reduced further if Active Power recovery ramps are limited to a certain value, that secures stable operation, after voltage dip events.

** SCR ratio can be reduced further if Reactive Power Management configuration is done correctly by means of detailed grid studies, trying to avoid voltage saturation extremes in any case (over and under voltage saturation levels).

Note 2.

In weak grids with low SCR value, the maximum configurable k value could be limited to <6 due to grid stability. Specific grid studies shall be executed for determining the optimum and maximum values.

All data are subject to tolerances in accordance with IEC.

24. Reactive Power Capability

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

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

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

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

24.1. Reactive Power Capability. Generalities.

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

Figure 3 shows the reactive power capability depending on the generated Active Power at various voltages at the LV terminals, starting by 91% of rated voltage (PQV curves).

Figure 4 shows the reactive power capability depending on the voltage level (QV curve) at full power operation.

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

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

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

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

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

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

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

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

24.2. Operation below 90% of rated voltage

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

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

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

24.3. Reactive Power / Voltage limiting function

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

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

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

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

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

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

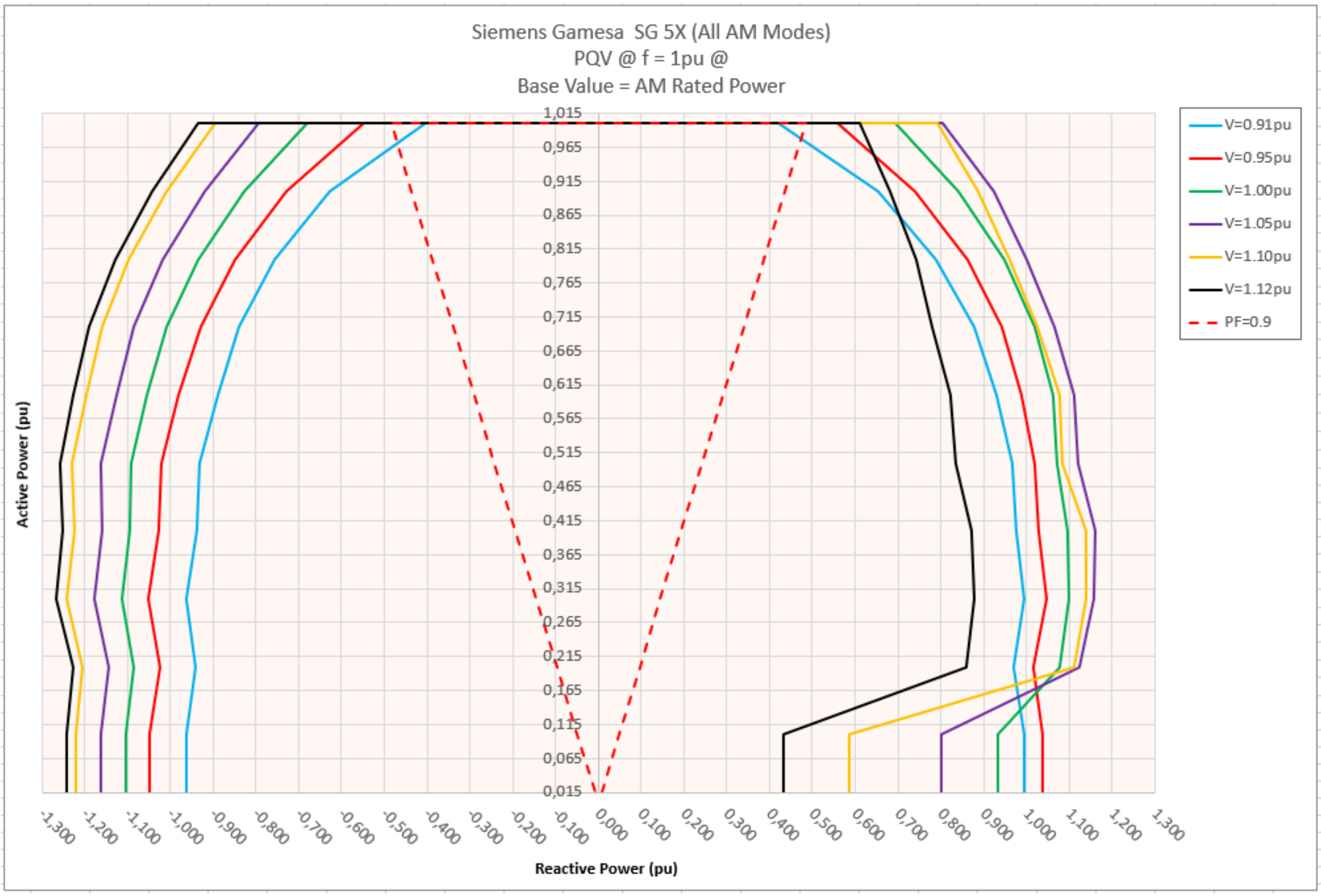


Figure 3: Siemens Gamesa 5.XReactive power capability curves (PQV), 50/60 Hz Wind Turbine, at LV terminals.

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

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

Table 5: Application modes definition.

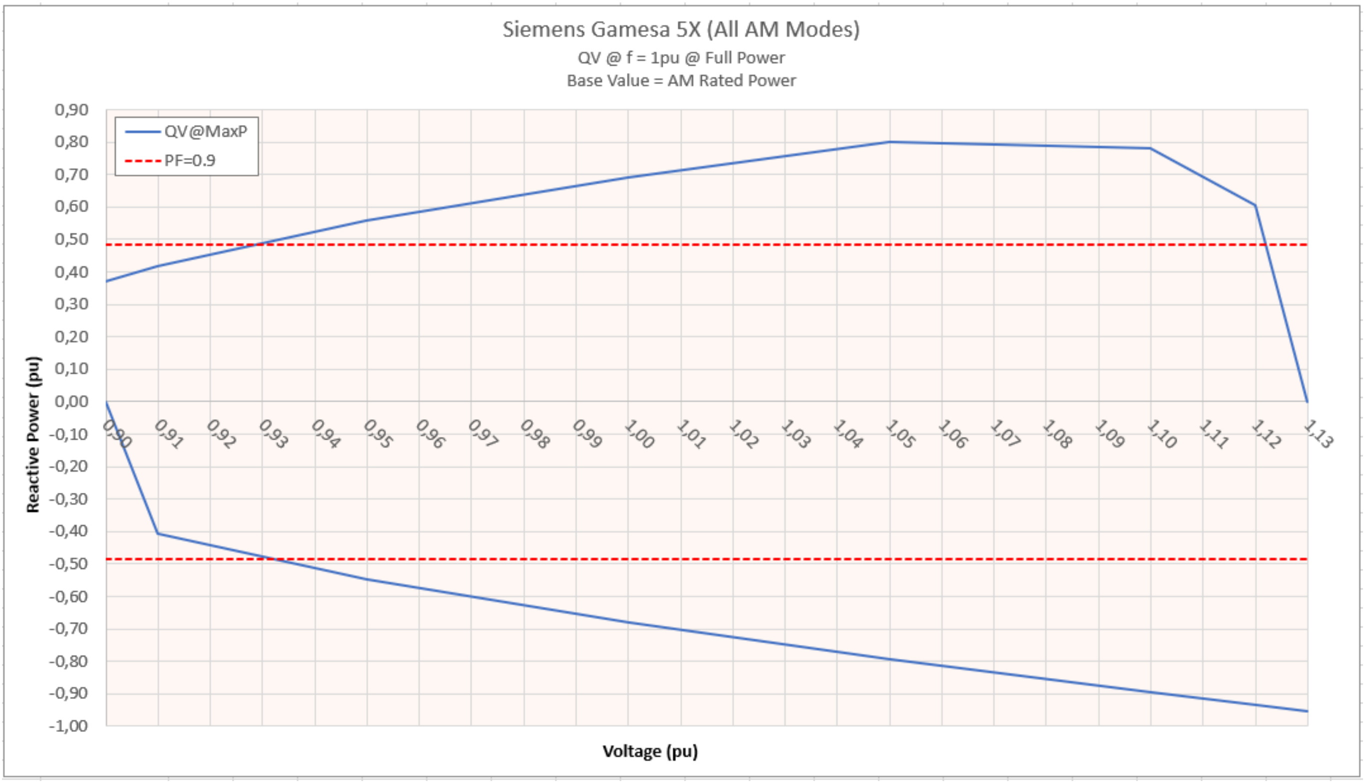


Figure 4: Siemens Gamesa 5.X→ Reactive power capability curves (QV), 50/60 Hz Wind Turbine, at LV terminals, at Full Power operation.

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

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

Table 6: Siemens Gamesa 5.XReactive power capability values (pu), 50/60 Hz Wind Turbine, at LV terminals.

Capacitive / Over-excited operation.

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

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

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

Table 7: Siemens Gamesa 5.X→ Reactive power capability values (pu), 50/60 Hz Wind Turbine, at LV terminals.

Inductive / Under-excited operation.

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

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

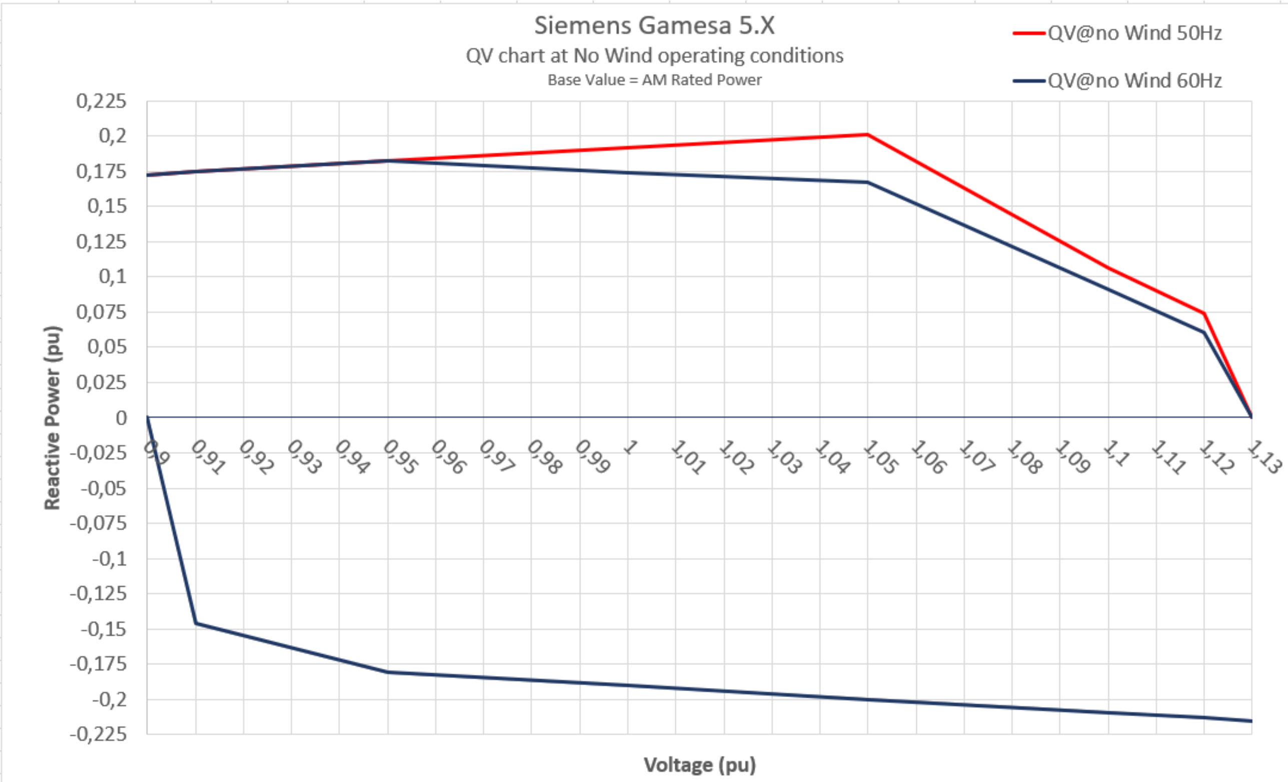


Figure 5: Reactive Power Capability chart (pu) at no wind conditions, at LV terminals, 50/60Hz.

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

Siemens Gamesa 5.X50Hz Base Value = AM Rated Power		
Voltage (pu)	**Q+ (pu)**	**Q- (pu)**
0,90	0,173	0,00
0,91	0,174	-0,146
0,95	0,182	-0,181
1,00	0,192	-0,190
1,05	0,201	-0,200
1,10	0,107	-0,209
1,12	0,074	-0,213
1,13	0,000	-0,215

Siemens Gamesa 5.X60Hz Base Value = AM Rated Power		
Voltage (pu)	**Q+ (pu)**	**Q- (pu)**
0,90	0,173	0,000
0,91	0,174	-0,146
0,95	0,182	-0,181
1,00	0,174	-0,190
1,05	0,167	-0,200
1,10	0,091	-0,209
1,12	0,061	-0,213
1,13	0,000	-0,215

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

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

25. SCADA System Description

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

25.1. 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.
- Local storage of data at wind turbines if communication is interrupted and transferred to historical database when possible.
- System access from anywhere using a standard web browser. No special client software or licenses are required.
- Users are assigned individual usernames and passwords, and the administrator can assign a user level to each username for added security.
- Email function can be configured for fast alarm response for both turbine and substation alarms. 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 and control.
- 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, bat/wildlife and ice.
- Capabilities for monitoring hybrid power plant equipment such as Battery Energy Storage Systems (BESS) and Photo Voltaic (PV) systems. Control of such equipment is achieved via the SGRE power plant controller.
- Power curve plots and efficiency calculations with pressure and temperature correction (pressure and temperature correction available only if SGRE MET system supplied).
- Condition monitoring integrated with the turbine controller using designated server.
- Ethernet-based system with secure compatible interfaces (OPC UA / IEC 60870-5-104) for online data access.
- Legacy protocols like OPC-(XML)-DA or Modbus TCP can be supported on request
- Access to historical - scientific and optional high resolution data via Restfull API.
- Virus Protection Solution.
- Back-up & restore.

25.2. Wind turbine hardware

Components within the wind turbine are monitored and controlled by the individual local wind turbine controller (SICS). The SICS 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.

25.3. 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.

25.4. SCADA server panel

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

- The server is configured with standard disk redundancy (RAID) to ensure continuous operation in case of disk failure. Network equipment. This includes all necessary switches and media converters.
- UPS back up to ensure safe shut down of servers in case of power outage.

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

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

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

25.5. Grid measuring station and Wind Farm Controller

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

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 configuration.

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.

25.6. 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 panel. For communication with third party equipment OPC UA and IEC 60870-5-104 are supported. Legacy protocols like OPC-(XML)-DA or Modbus TCP can be supported on request

25.7. SGRE SCADA software

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

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

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

25.8. Virus protection solution

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

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

25.9. Back-up & restore

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

26. 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.

26.1. GENERAL

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

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

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

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

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

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

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

26.2. GEARBOX

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

26.3. ELECTRICAL

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

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

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

26.4. QUALITY

- ISO 9001:2015 Quality management systems – Requirements

26.5. PERSONAL SAFETY

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

26.6. CORROSION

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

27. Ice Detection System

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.

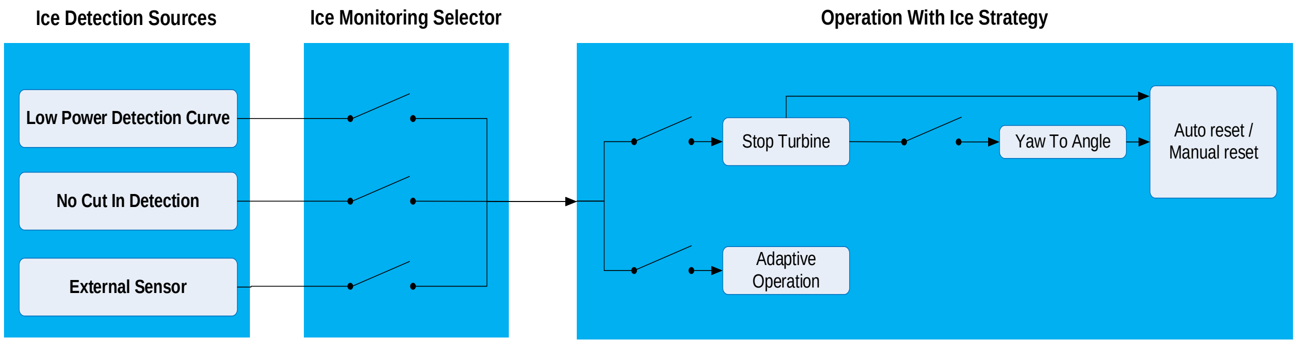


Figure 1: Ice Detection and Operation with Ice Strategy interface for individual turbines

> 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.

27.1. Ice Detection Sources

27.2. 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.

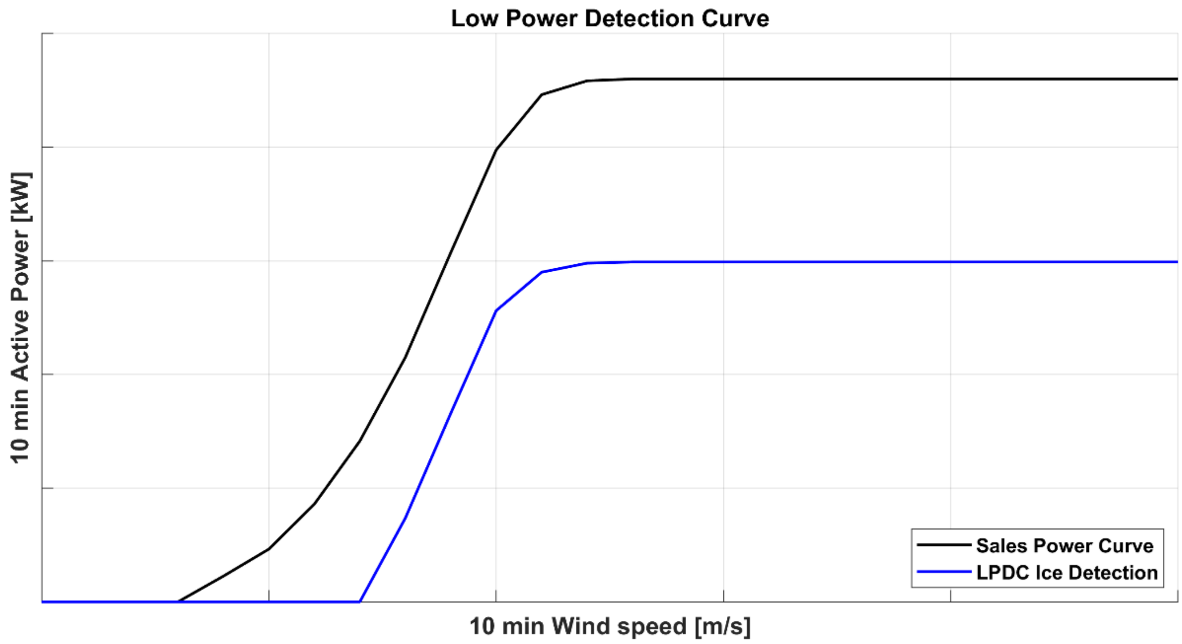


Figure 2: Illustration of Low Power Detection Curve (LPDC)

27.3. 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".

27.4. External Sensor Options

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

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

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

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

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

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

27.5. External Sensor Types

27.5.1. Nacelle Based Ice Detection Sensor (Optional)

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

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

27.5.2. Blade-Based Ice Detection Sensor (Optional)

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

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

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

27.5.3. 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.

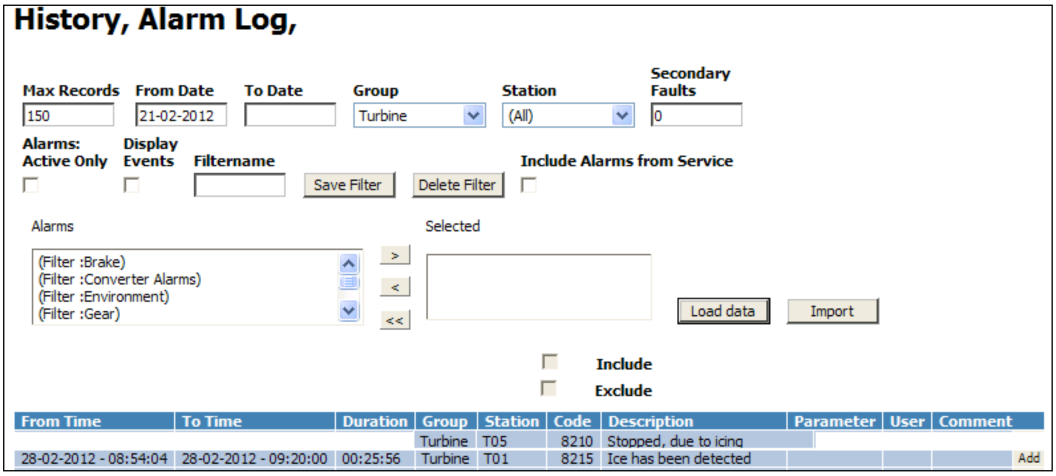


Figure 3 - Presentation of alarms related to the ice detection system in Web WPS SCADA

27.6. Operation with Ice Strategy

27.6.1. Operation with Ice Strategy: Stop Turbine

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

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

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

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

27.7. 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.

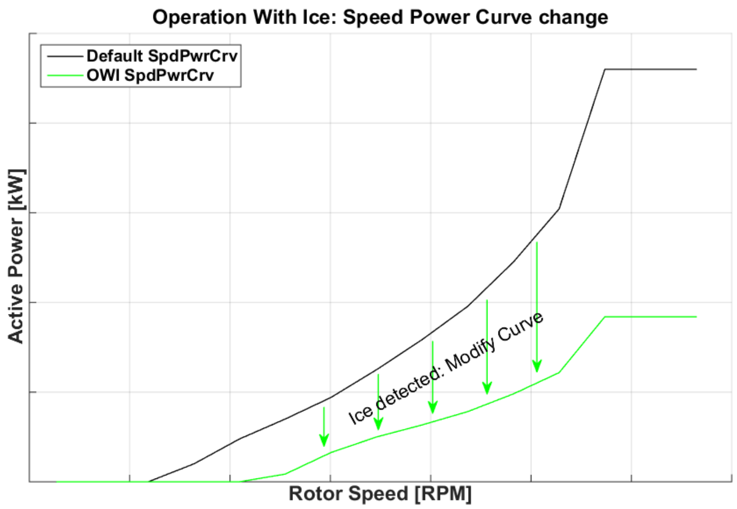


Figure 4: Illustration of OWI Speed-Power curve modification

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.