



**REGIONE AUTONOMA DELLA SARDEGNA**  
CITTA' METROPOLITANA DI CAGLIARI E PROVINCIA DEL MEDIO CAMPIDANO



COMUNE DI SELEGAS



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**PROGETTO PER LA REALIZZAZIONE  
DEL PARCO EOLICO  
"TREXENTA"**

Potenza complessiva 43.4 MW

**PROGETTO DEFINITIVO  
DELL'IMPIANTO, DELLE OPERE CONNESSE E DELLE  
INFRASTRUTTURE INDISPENSABILI**

PA-R.2

**ELEMENTI TECNICI AEROGENERATORE DI  
RIFERIMENTO**

COMMITTENTE

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ENERGY  
SARDEGNA 2**  
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## 1 INTRODUZIONE

Il tipo di aerogeneratore previsto per l'impianto in oggetto (aerogeneratore di progetto) è un aerogeneratore ad asse orizzontale con rotore tripala e una potenza massima di 6,2 MW, le cui caratteristiche principali sono di seguito riportate:

- rotore tripala a passo variabile, di diametro massimo pari a 170 m, posto sopravvento alla torre di sostegno, costituito da 3 pale generalmente in resina epossidica rinforzata con fibra di vetro e da mozzo rigido in acciaio;
- navicella in carpenteria metallica con carenatura in vetroresina e lamiera, in cui sono collocati il generatore elettrico, il moltiplicatore di giri, il trasformatore BT/MT e le apparecchiature idrauliche ed elettriche di comando e controllo;
- torre di sostegno tubolare troncoconica in acciaio, avente altezza fino all'asse del rotore pari a massimi 119 m;
- altezza complessiva massima fuori terra dell'aerogeneratore pari a 200,0 m;
- diametro massimo alla base del sostegno tubolare: 4,7 m;
- area spazzata massima: 22.698 m<sup>2</sup>.

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## 2 DATI CARATTERISTICI AEROGENERATORE DI PROGETTO


Posizione rotore:	sopravento
Regolazione di potenza:	a passo variabile
Diametro rotore:	max 170 m
Area spazzata:	max 22.698 m <sup>2</sup>
Direzione di rotazione:	senso orario
Temperatura di esercizio:	-20°C / +40°C
Velocità del vento all'avviamento:	min 3 m/s
Arresto per eccesso di velocità del vento:	25 m/s
Freni aerodinamici:	messa in bandiera totale
Numero di pale:	3

Modalità di trasporto di tutti i componenti da porto navale a sito: mezzi di trasporto eccezionale standard/speciali aventi uno snodo ed il componente fissato al rimorchio in senso orizzontale.

Modalità trasporto singola pala da area di trasbordo al sito di installazione: mezzo speciale "blade lifter" per il sollevamento della pala fino ad un'inclinazione di 60° rispetto al suolo.

Curva di potenza (alla densità atmosferica del livello del mare):

Wind speed [m/s]	Power [kW]
3.0	34
4.0	292
5.0	676
6.0	1229
7.0	2000
8.0	3017
9.0	4284
10.0	5483
11.0	6114
12.0	6197

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Wind speed [m/s]	Power [kW]
13.0	6200
14.0	6200
15.0	6200
16.0	6200
17.0	6186
18.0	5853
19.0	5348
20.0	4825
21.0	4251
22.0	3664
23.0	3064
24.0	2451

Ai fini degli approfondimenti progettuali e dei relativi studi specialistici, si sono individuati alcuni specifici modelli commerciali di aerogeneratore ad oggi esistenti sul mercato, idonei ad essere conformi all'aerogeneratore di progetto.

Le caratteristiche di dettaglio dei modelli commerciali sono state utilizzate, in particolare, ai fini di redigere:

- lo studio di impatto acustico;
- le verifiche strutturali preliminari;
- la progettazione trasportistica (componenti più pesanti e più ingombranti dei differenti modelli) calcolo preliminare per il dimensionamento del plinto di fondazione (modello commerciale peggiorativo)

Per tutti gli altri aspetti progettuali sono state utilizzate le caratteristiche generali sopra riportate, sufficienti in particolare a svolgere la progettazione civile, la progettazione elettrica, lo studio anemologico, lo studio di impatto paesaggistico, la relazione vegetazionale, la relazione faunistica, lo studio di impatto elettro-magnetico, ecc.

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Nello specifico i modelli di aerogeneratore considerati, dei quali a seguire si allega la documentazione tecnica di dettaglio, risultano i seguenti:

- 1) Vestas V162-119 m HH-6.2 MW
- 2) Siemens-Gamesa SG170-115 m HH-6.2 MW

Ai fini dell'espletamento della procedura di VIA la scelta di un singolo modello commerciale è da considerarsi antieconomica ed inopportuna dal punto di vista progettuale e tecnologico. Infatti, vincolare il progetto ad uno specifico modello commerciale potrebbe comportare le seguenti conseguenze:

- al momento del rilascio dell'autorizzazione alla costruzione dell'intervento, il modello commerciale scelto potrebbe risultare superato da altri modelli più recenti in ragione della rapida evoluzione tecnologica in atto. Si potrebbe disporre, per esempio, di modelli analoghi in grado di garantire la stessa performance energetica con migliori prestazioni ambientali;
- il venditore dello specifico modello commerciale potrebbe indebitamente avvantaggiarsi di una sorta di condizione di monopolio e quindi fissare il prezzo fuori dal mercato, obbligando il proponente a realizzare un progetto non sostenibile economicamente.

# Developer Package

## SG 6.2-170



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## Application of the Developer Package

The Developer Package serves the purpose of informing customers about the latest planned product development from Siemens Gamesa Renewable Energy A/S and its affiliates in the Siemens Gamesa group including Siemens Gamesa Renewable Energy S.A. and its subsidiaries (hereinafter “SGRE”). By sharing information about coming developments, SGRE can ensure that customers are provided with necessary information to make decisions.

Furthermore, the Developer Package can assist in guiding prospective customers with the indicated technical footprint of the SG 6.2-170 and the different product variants in cases where financial institutes, governing bodies, or permitting entities require product specific information in their decision processes.

All technical data contained in the Developer Package is subject to change owing to ongoing technical developments of the wind turbine. Consequently, SGRE and its affiliates reserve the right to change the below specifications without prior notice. Information contained within the Developer Package may not be treated separately or out of the context of the Developer Package.

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# 1. Introduction

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

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

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

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

## 2. Technical Description

### 2.1. Rotor-Nacelle

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

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

### 2.2. Blades

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

### 2.3. Rotor Hub

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

### 2.4. Drive train

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

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

### 2.5. Main Shaft

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

### 2.6. Main Bearings

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

### 2.7. Gearbox

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

### 2.8. Generator

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

### 2.9. Mechanical Brake

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

## 2.10. Yaw System

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

## 2.11. Nacelle Cover

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

## 2.12. Tower

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

## 2.13. Controller

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

## 2.14. Converter

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

## 2.15. SCADA

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

## 2.16. Turbine Condition Monitoring

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

## 2.17. Operation Systems

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

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

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

### 3. Technical Specifications

Rotor	
Type	3-bladed, horizontal axis
Position	Upwind
Diameter	170 m
Swept area	22,698 m <sup>2</sup>
Power regulation	Pitch & torque regulation with variable speed
Rotor tilt	6 degrees

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

Aerodynamic Brake	
Type	Full span pitching
Activation	Active, hydraulic

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

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

Generator	
Type	Asynchronous, DFIG

Grid Terminals (LV)	
Baseline nominal power	6.0MW/6.2 MW
Voltage	690 V
Frequency	50 Hz or 60 Hz

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

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

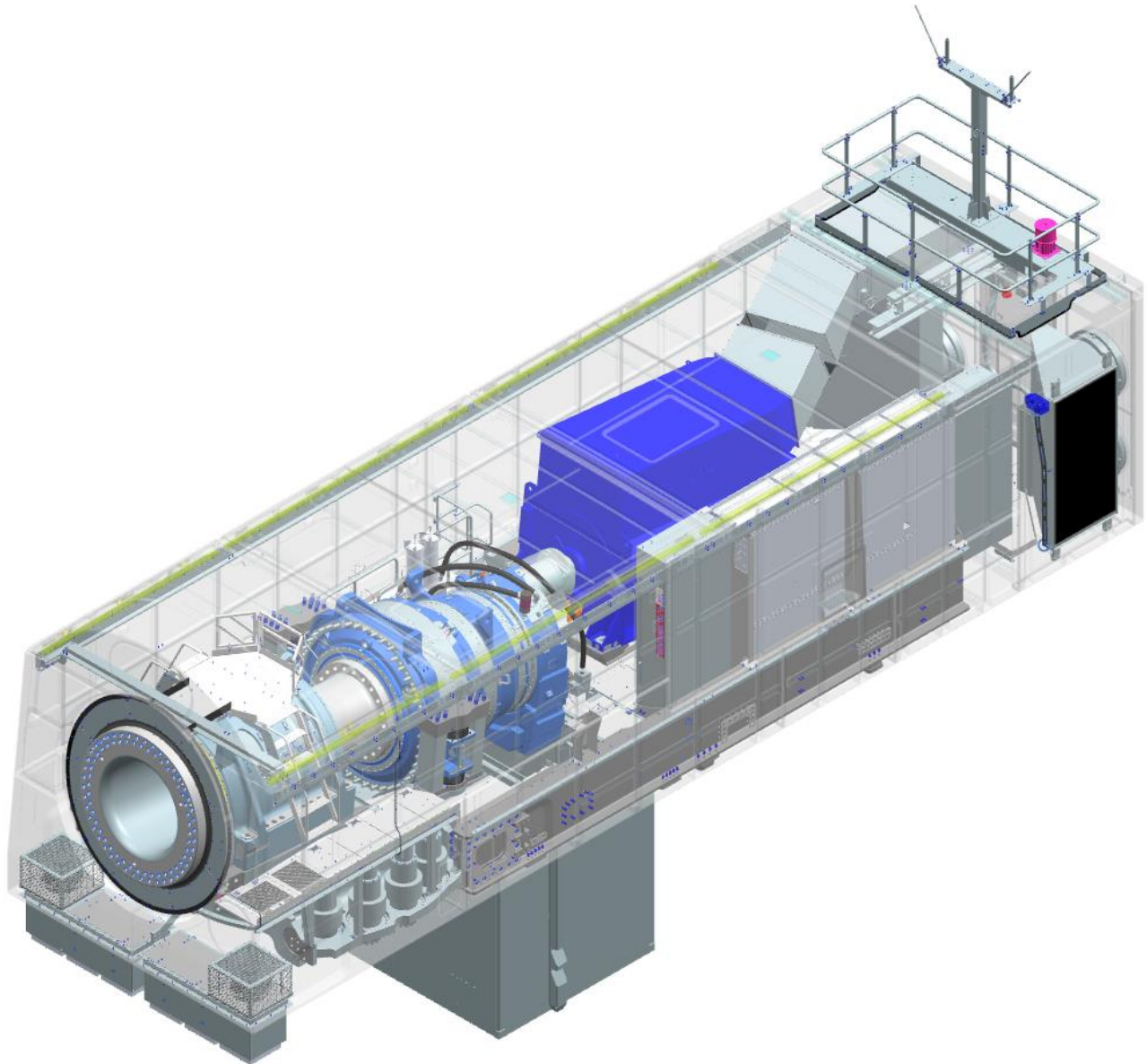
Tower	
Type	Tubular steel / Hybrid
Hub height	100m to 165 m and site-specific
Corrosion protection	
Surface gloss	Painted
Color	Semi-gloss, <30 / ISO-2813 Light grey, RAL 7035 or White, RAL 9018

Operational Data	
Cut-in wind speed	3 m/s
Rated wind speed	11.0 m/s (steady wind without turbulence, as defined by IEC61400-1)
Cut-out wind speed	25 m/s
Restart wind speed	22 m/s

Weight	
Modular approach	Different modules depending on restriction

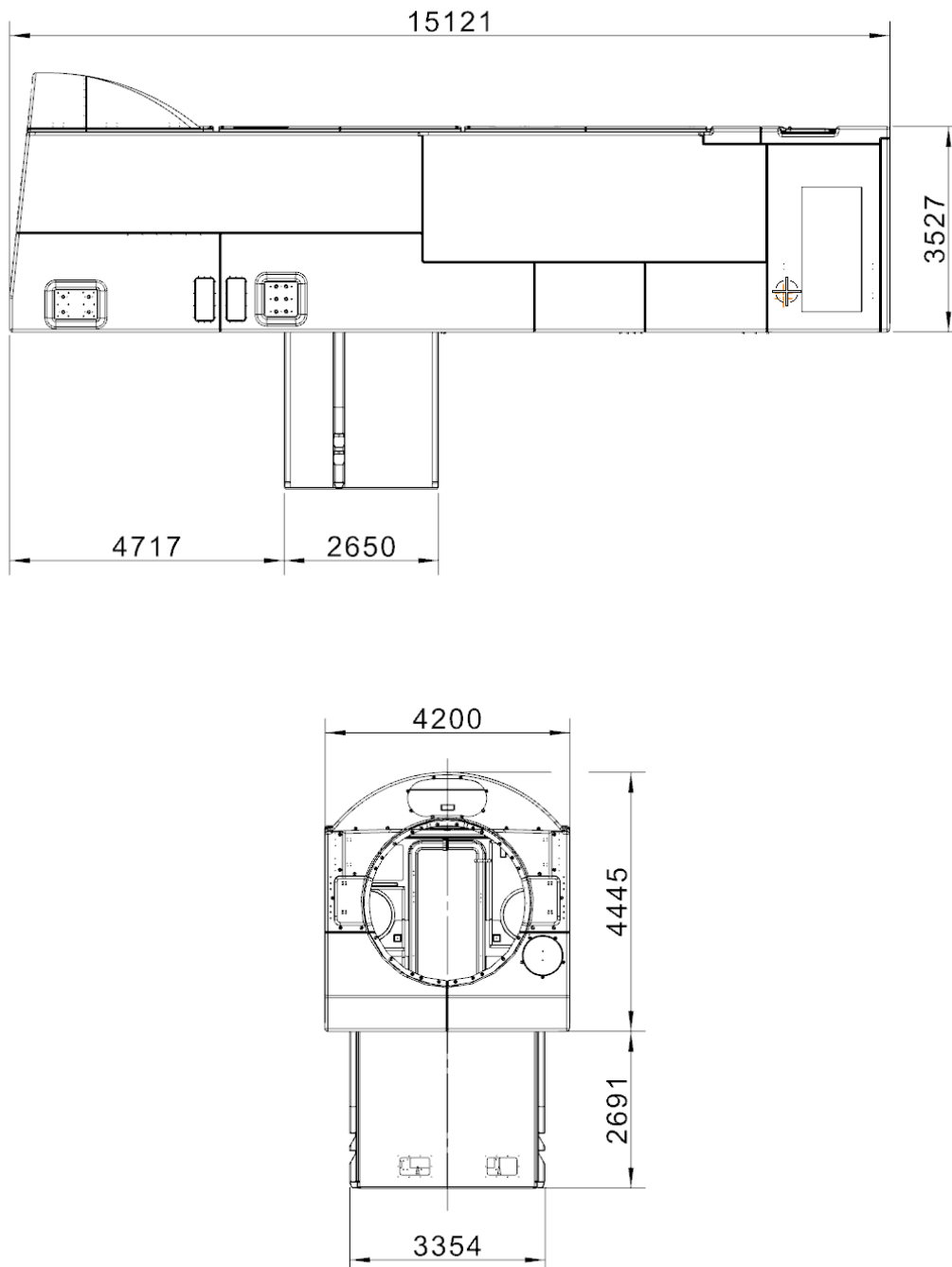
## 4. Nacelle Arrangement

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



## 5. Nacelle dimensions

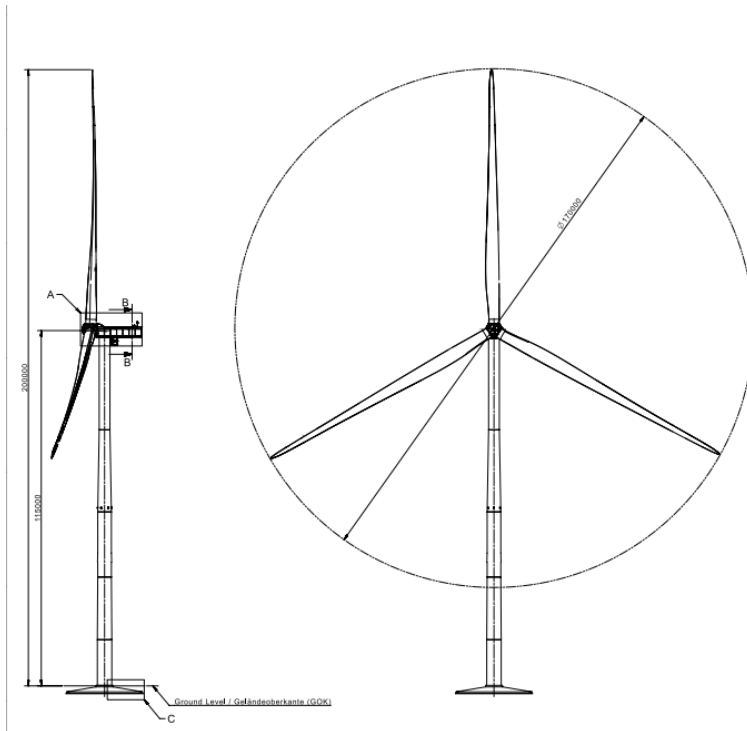
The design and dimensions of the nacelle are preliminary and may be subject to changes during the development phases of the product.



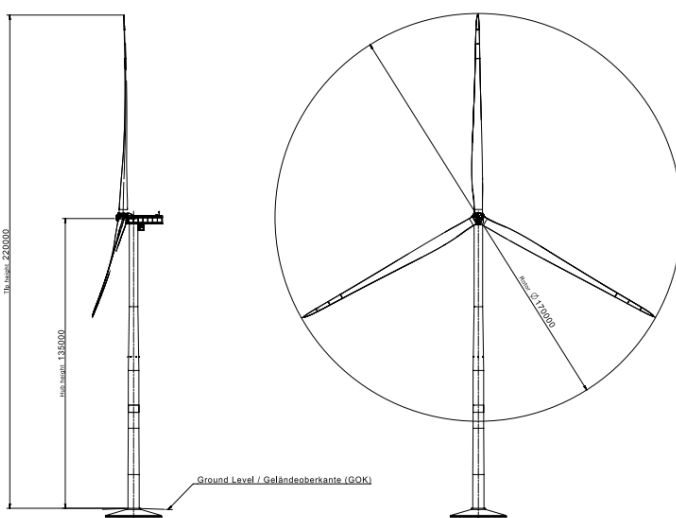


## 6. Elevation Drawing

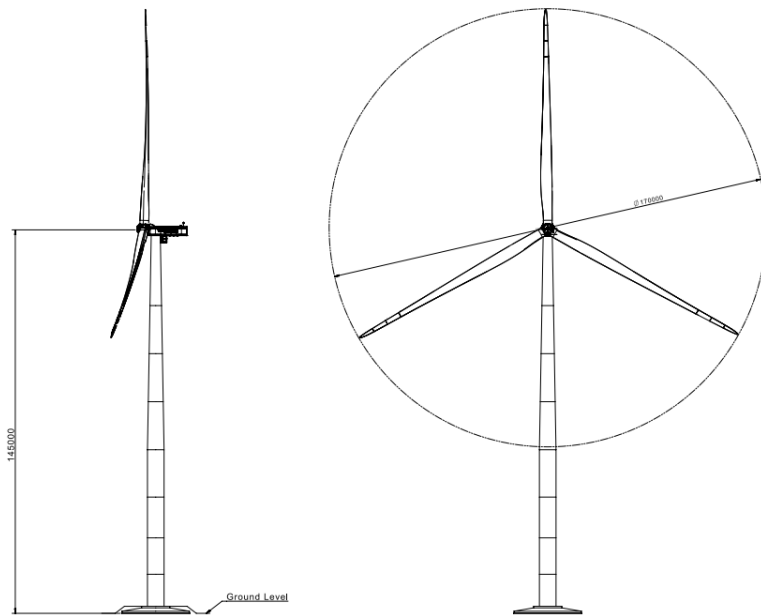
### 6.1. SG 6.2-170 115 m



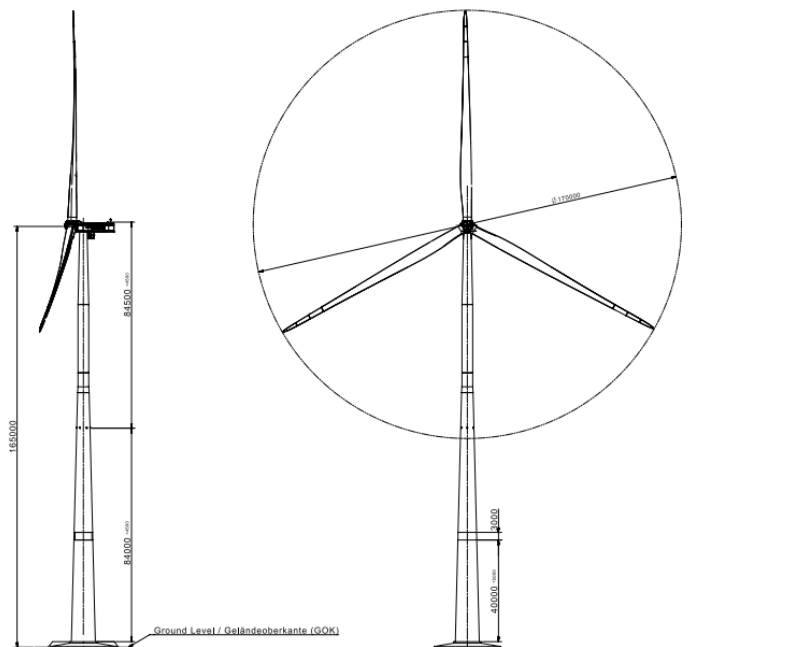
### 6.2. SG 6.6-170 135 m



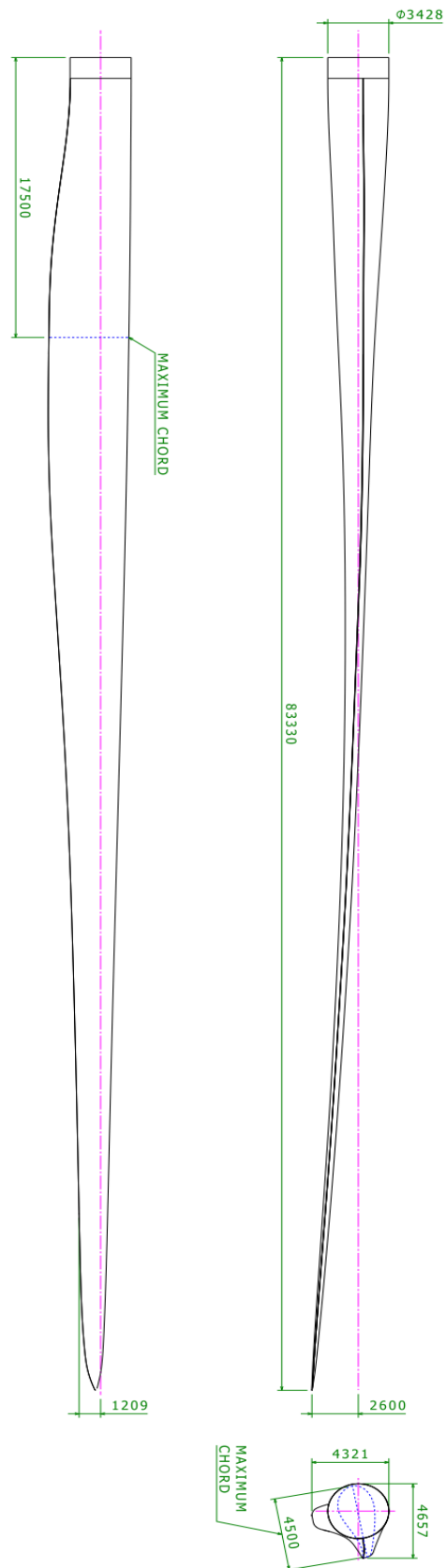
### 6.3. SG 6.2-170 145 m



### 6.4. SG 6.2-170 165 m



## 7. Blade Drawing



Dimensions in millimeter

## 8. Tower Dimensions

SG 6.2-170 is offered with an extensive tower portfolio ranging from 100m-165m, including the baseline 115m and 165m catalogue towers. All towers are designed in compliance with local logistics requirements. Information about other tower heights and logistic will be available upon request.

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

T100-51A	Section 1	Section 2	Section 3	Section 4
External diameter upper flange (m)	4.700	4.493	4.493	3.503
External diameter lower flange (m)	4.700	4.700	4.493	4.493
Section's height (m)	14.300	21.560	26.880	34.450
Total weight (kg)	84033	79746	76060	75793
Total Tower weight (kg)	315632			

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

T101.5-50A	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
External diameter upper flange (m)	4.297	4.500	4.495	4.495	4.100	3.503
External diameter lower flange (m)	4.500	4.296	4.500	4.495	4.495	4.100
Section's height (m)	8.464	14.840	15.120	17.640	21.000	21.850
Total weight (kg)	61269	69797	57635	53454	48049	49717
Total Tower weight (kg)	339922					

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

T115.0-50A	Section 1	Section 2	Section 3	Section 4	Section 5
External diameter upper flange (m)	4,700	4,436	4,427	4,021	3,503
External diameter lower flange (m)	4,700	4,700	4,436	4,427	4,021
Section's height (m)	13,284	18,200	23,800	27,160	29,970
Total weight (kg)	85636	85143	85408	73226	64918
Total Tower weight (kg)	394329				

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

T115-51A	Section 1	Section 2	Section 3	Section 4	Section 5
External diameter upper flange (m)	4.800	4.793	4.793	4.793	3.503
External diameter lower flange (m)	4.800	4.800	4.793	4.793	4.793
Section's height (m)	11.780	17.920	21.840	28.000	32.770
Total weight (kg)	86804	84644	81556	77286	72512
Total Tower weight (kg)	402801				

### 8.5. Tower hub height 135m IIIA. Tapered tubular steel tower

T135-50A	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
External diameter upper flange (m)	5,682	5,679	4,829	4,426	4,419	3,503
External diameter lower flange (m)	6,000	5,682	5,679	4,829	4,426	4,419
Section's height (m)	15,000	17,640	20,720	24,920	27,440	26,694
Total weight (kg)	90710	83941	85048	84470	69785	56934
Total Tower weight (kg)	470888					

## 8.6. Tower hub height 145m IIIA. Tapered tubular steel tower

T145-50A	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8
External diameter upper flange (m)	6.400	6.400	6.400	6.400	5.750	5.100	4.450	3.503
External diameter lower flange (m)	6.400	6.400	6.400	6.400	6.400	5.750	5.100	4.450
Section's height (m)	12.320	14.000	15.680	18.200	18.480	18.480	18.480	26.890
Total weight (kg)	83350	82480	83110	83910	73260	62220	50400	64480
Total Tower weight (kg)	583210							

## 8.7. Tower hub height 155m IIIA. Tapered tubular steel tower

T155-50A	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8
External diameter upper flange (m)	6.575	6.575	6.575	6.575	6.575	5.376	4.44	3.503
External diameter lower flange (m)	6.6	6.575	6.575	6.575	6.575	5.975	5.376	4.44
Section's height (m)	12.32	13.44	14.56	16.24	18.48	18.48	28.84	29.97
Total weight (kg)	83980	82320	82350	82980	80910	70170	83270	70760
Total Tower weight (kg)	636740							

## 8.8. Tower hub height 165m IIIA. Hybrid

T165-53A-MB	Concrete	Section 1	Section 2
External diameter upper flange (m)	4,528	4,292	3,503
External diameter lower flange (m)	9,148	4,300	4,292
Section's height (m)	96,990	29,710	36,000
Total weight (kg)		81021	69827
Total Tower weight (kg)		150848	

## 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	
<b>0. Design lifetime</b>	0.0	Design lifetime definition	-	IEC 61400-1 <sup>1</sup>	
	0.1	Design lifetime	years	20	25
<b>1. Wind, operation</b>	1.1	Wind definitions	-	IEC 61400-1	
	1.2	IEC class	-	IIIA	IIIB
	1.3	Mean air density, $\rho$	kg/m <sup>3</sup>	1.225	1.225
	1.4	Mean wind speed, $V_{ave}$	m/s	7.5	7.5
	1.5	Weibull scale parameter, A	m/s	8.46	8.46
	1.6	Weibull shape parameter, k	-	2	2
	1.7	Wind shear exponent, $\alpha$	-	0.20	0.20
	1.8	Reference turbulence intensity at 15 m/s, $I_{ref}$	-	0.16	0.14
	1.9	Standard deviation of wind direction	Deg	-	-
	1.10	Maximum flow inclination	Deg	8	8
	1.11	Minimum turbine spacing, in rows	D	-	-
	1.12	Minimum turbine spacing, between rows	D	-	-
<b>2. Wind, extreme</b>	2.1	Wind definitions	-	IEC 61400-1	
	2.2	Air density, $\rho$	kg/m <sup>3</sup>	1.225	
	2.3	Reference wind speed average over 10 min at hub height, $V_{ref}$	m/s	37.5	
	2.4	Maximum 3 s gust in hub height, $V_{e50}$	m/s	52.5	
	2.5	Maximum hub height power law index, $\alpha$	-	0.11	
	2.6	Storm turbulence	-	N/A	
<b>3. Temperature</b>	3.1	Temperature definitions	-	IEC 61400-1	
	3.2	Minimum temperature at 2 m, stand-still, $T_{min, s}$	Deg.C	-30	
	3.3	Minimum temperature at 2 m, operation, $T_{min, o}$	Deg.C	-20	
	3.4	Maximum temperature at 2 m, operation, $T_{max, o}$	Deg.C	40 <sup>2</sup>	
	3.5	Maximum temperature at 2 m, stand-still, $T_{max, s}$	Deg.C	50	
<b>4. Corrosion</b>	4.1	Atmospheric-corrosivity category definitions	-	ISO 12944-2	
	4.2	Internal nacelle environment (corrosivity category)	-	C3H (std) ≥C3H (high C)	
	4.3	Exterior environment (corrosivity category)	-	C3H (std) ≥C3H (high C)	
<b>5. Lightning</b>	5.1	Lightning definitions	-	IEC61400-24:2010	
	5.2	Lightning protection level (LPL)	-	LPL 1	
<b>6. Dust</b>	6.1	Dust definitions	-	IEC 60721-3-4:1995	

<sup>1</sup> All mentioning of IEC 61400-1 refers to IEC 61400-1:2018 Ed4.

<sup>2</sup> 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.

Subject	ID	Issue	Unit	Value
	6.2	Working environmental conditions	mg/m <sup>3</sup>	Average Dust Concentration (95% time) → 0.05 mg/m <sup>3</sup>
	6.3	Concentration of particles	mg/m <sup>3</sup>	Peak Dust Concentration (95% time) → 0.5 mg/M <sup>3</sup>
<b>7. Hail</b>	7.1	Maximum hail diameter	mm	20
	7.2	Maximum hail falling speed	m/s	20
<b>8. Ice</b>	8.1	Ice definitions	-	-
	8.2	Ice conditions	Days/yr	7
<b>9. Solar radiation</b>	9.1	Solar radiation definitions	-	IEC 61400-1
	9.2	Solar radiation intensity	W/m <sup>2</sup>	1000
<b>10. Humidity</b>	10.1	Humidity definition	-	IEC 61400-1
	10.2	Relative humidity	%	Up to 95
<b>11. Obstacles</b>	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.		
<b>12. Precipitation<sup>3</sup></b>	12.1	Annual precipitation	mm/yr	1100

<sup>3</sup> The specified maximum precipitation considers standard liquid Leading Edge Protection. For sites with higher annual precipitation and/or longer lifetime, it is recommended to consider optional reinforced Leading Edge Protection.

## 10. Power Derating Curves by Ambient Temperature

### 10.1. SG 6.2-170 AM0 STD

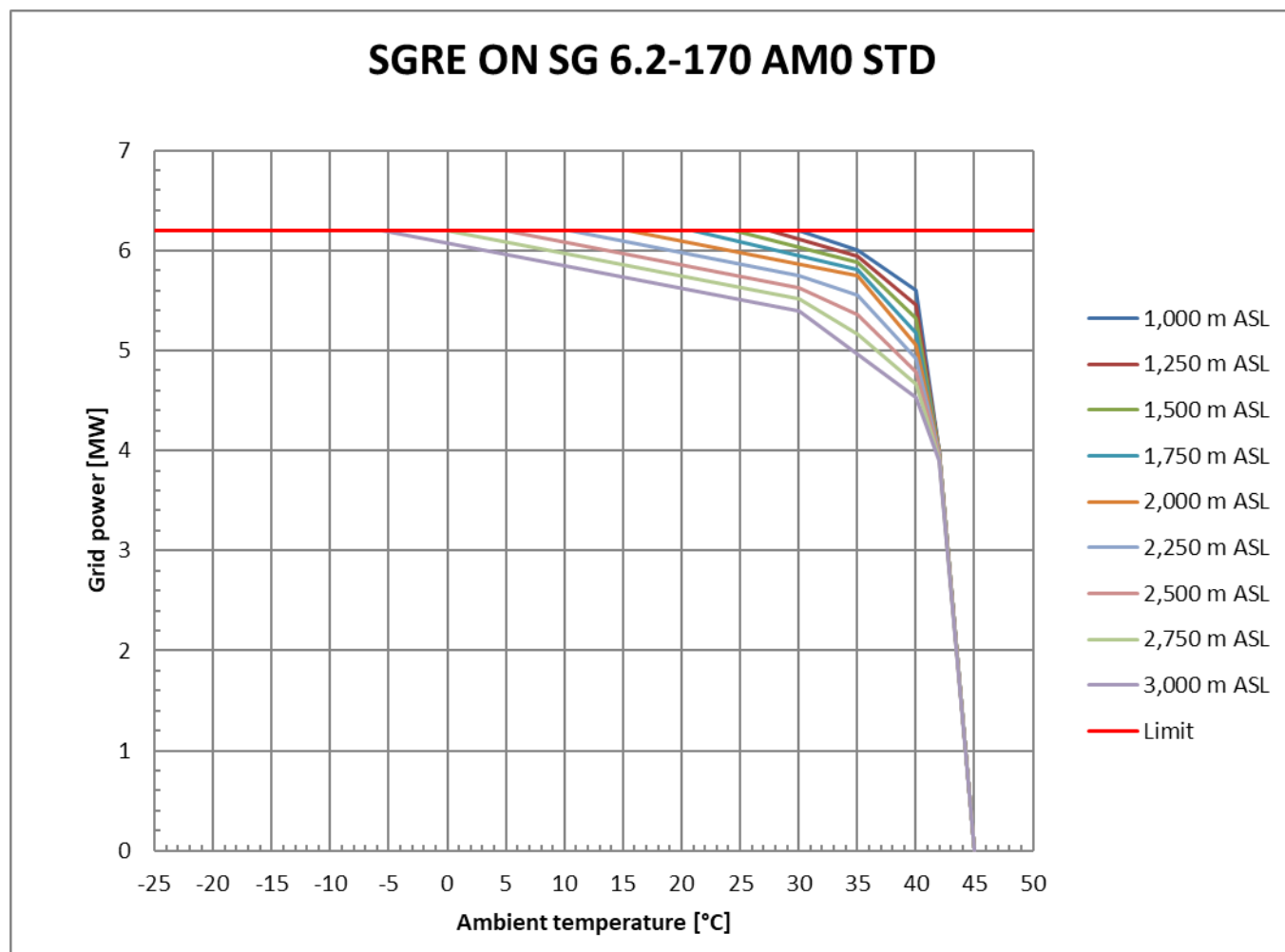


Figure 1: SG 6.2-170 AM0 STD power derating curves by ambient temperature and altitude



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

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

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

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

10.1.1. SG 6.2-170 AM0 HT

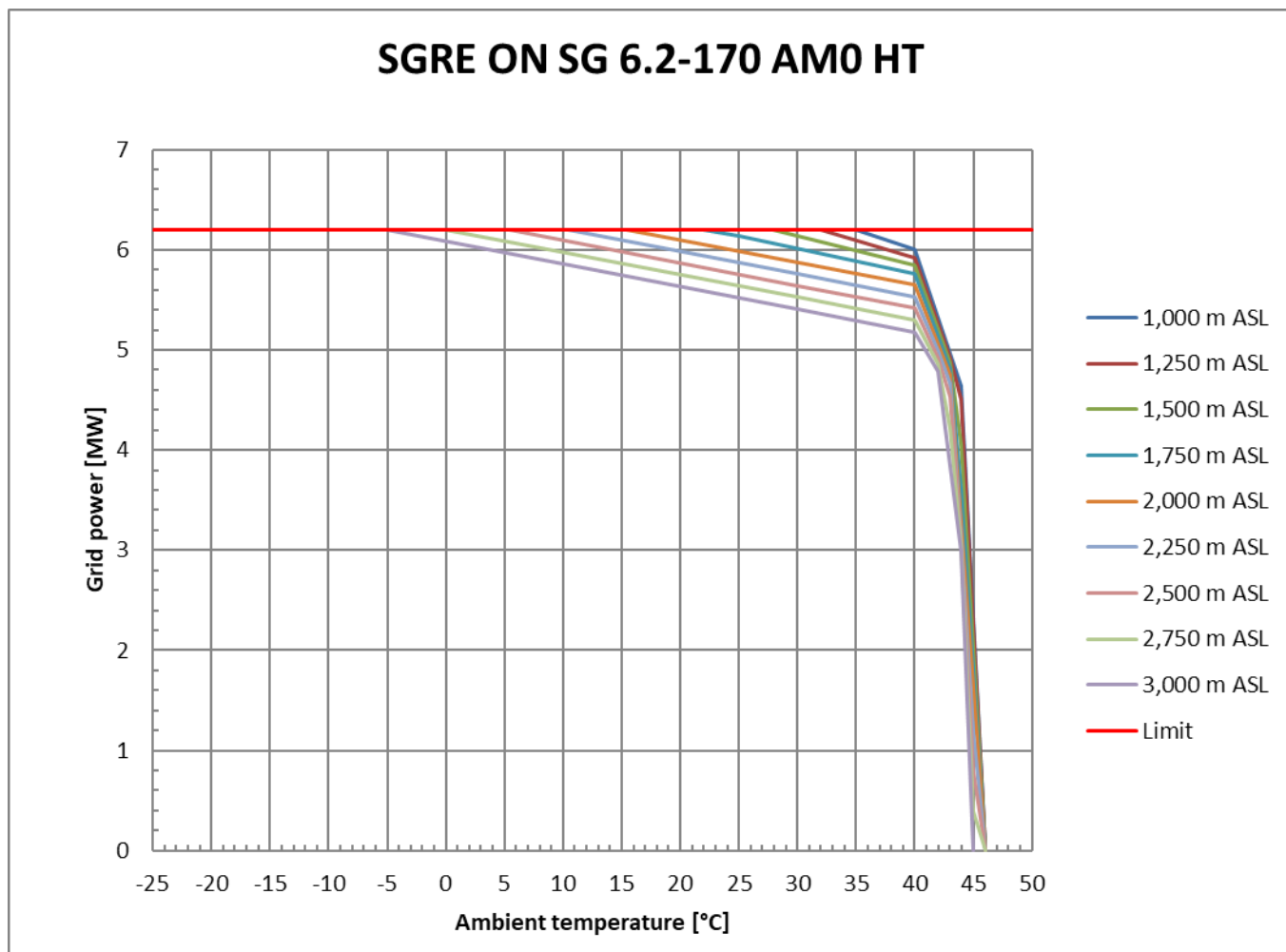


Figure 2: SG 6.2-170 AM0 HT power derating curves by ambient temperature and altitude

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

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

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

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

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

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

## 11. Flexible Rating Specifications ®

The SG 6.2-170 is offered with various operational modes that are achieved through the flexible operating capacity of the product, enabling the configuration of an optimal power rating that is best suited for each wind farm. The operating modes are broadly divided into two categories: Application Modes and Noise Reduction System Modes<sup>4</sup>.

### 11.1. Application Modes

Application Modes ensure optimal turbine performance with maximum power rating allowed by the structural and electrical systems of the turbine. There are multiple Application Modes, offering flexibility of different power ratings. All Application Modes are part of the turbine Certificate.

SG 6.2-170 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 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 6.2-170 is designed with a base wind class, applicable to AM 0, of IEC IIIA for 20 year lifetime as well as IEC IIIB for 25 year lifetime. All other Application Modes may be analyzed for more demanding site conditions.

### 11.2. Full 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 <sup>5</sup>
						Cos Phi	Voltage Range	Frequency range	
SG 6.2-170	AM 0	6.2	106	D2075729	D2359593	0.9	[0.95,1.1 2] Un	±3% Fn	30°C
SG 6.2-170	AM-1	6.1	106	D2356499	D2359593	0.9	[0.95,1.1 2] Un	±3% Fn	33°C
SG 6.2-170	AM-2	6.0	106	D2356509	D2359593	0.9	[0.95,1.1 2] Un	±3% Fn	35°C
SG 6.2-170	AM-3	5.9	106	D2356523	D2359593	0.9	[0.95,1.1 2] Un	±3% Fn	37°C
SG 6.2-170	AM-4	5.8	106	D2356539	D2359593	0.9	[0.95,1.1 2] Un	±3% Fn	38°C
SG 6.2-170	AM-5	5.7	106	D2356376	D2359593	0.9	[0.95,1.1 2] Un	±3% Fn	39°C
SG 6.2-170	AM-6	5.6	106	D2356368	D2359593	0.9	[0.95,1.1 2] Un	±3% Fn	40°C

<sup>4</sup> It should be noted that the definition of various modes as described in this chapter is applicable in combination with standard temperature limits and grid capabilities of the turbine. Please refer to High Temperature Power De-rating Specification and Reactive Power Capability Document for more information

<sup>5</sup> Please Refer to "High Temperature Power De-rating Specification" 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.

#### 11.3.1. 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 <sup>6</sup>
SG 6.2-170	N1	6.00	105.5	D2323420	D2359593	30°C
SG 6.2-170	N2	5.80	104.5	D2314784	D2359593	30°C
SG 6.2-170	N3	5.24	103.0	D2314785	D2359593	30°C
SG 6.2-170	N4	5.12	102.0	D2314786	D2359593	30°C
SG 6.2-170	N5	4.87	101.0	D2314787	D2359593	30°C
SG 6.2-170	N6	4.52	100.0	D2314788	D2359593	30°C
SG 6.2-170	N7	3.60	99.0	D2314789	D2359593	30°C
SG 6.2-170	N8	2.60	98.0	D2460509	D2460507	30°C

### 11.4. Control Strategy

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

<sup>6</sup> Please refer to "High Temperature Ride Through" for more details'.



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

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

Air density= 1.225 kg/m<sup>3</sup>

Validity range:

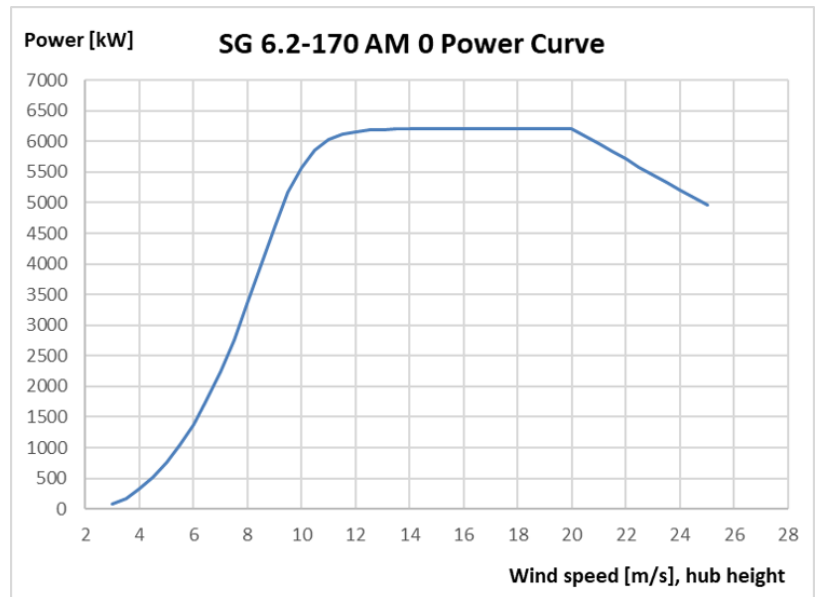
<b>Wind Shear (10min average)</b>	$\leq 0.3$
<b>Turbulence intensity TI [%] for bin i</b>	$5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$
<b>Terrain</b>	Not complex according to IEC 61400-12-1
<b>Upflow <math>\beta</math> [°]</b>	$-2^\circ \leq \beta \leq +2^\circ$
<b>Grid frequency [Hz]</b>	$\pm 0.5$ 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<sup>3</sup>. The power curve does not include losses in the transformer and high voltage cables.

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

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



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

AEP [MWh]		Annual Average Wind Speed [m/s] at Hub Height										
		5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
Weibull K	1.5	12624	15003	17272	19392	21337	23092	24653	26018	27192	28185	29009
	2.0	11514	14363	17198	19937	22528	24939	27150	29151	30937	32503	33853
	2.5	10370	13438	16625	19798	22856	25732	28389	30811	32995	34946	36669

Annual Production [MWh] SG 6.2-170 Rev 0, AM 0 wind turbine for the standard version, as a function of the annual mean wind speed at hub height, and for different Weibull parameters. Air density 1.225 kg/m<sup>3</sup>

## 12.2. Standard Ct Curve, Application Mode - AM 0

Air density= 1.225 kg/m<sup>3</sup>

Validity range:

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

$$C_t = F / (0.5 * \rho * w^2 * A)$$

where

F = Rotor force [N]

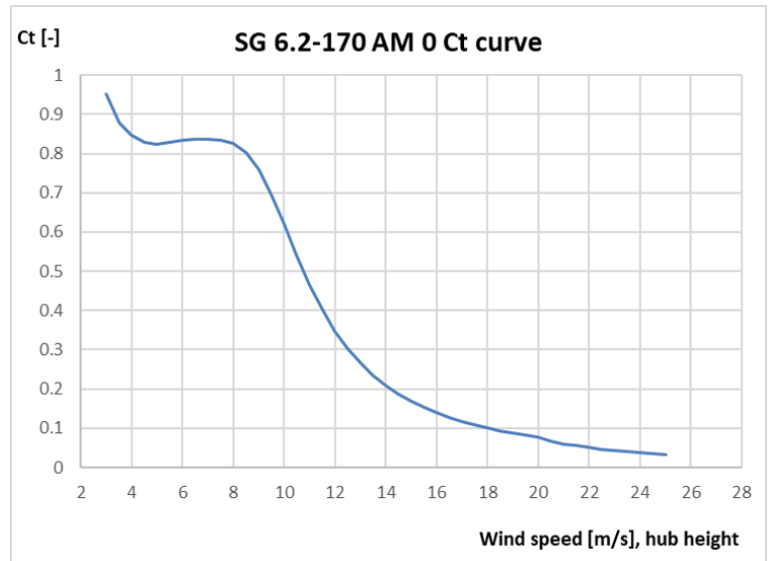
ρ = Air density [kg/m<sup>3</sup>]

w = Wind speed [m/s]

A = Swept area of rotor [m<sup>2</sup>]

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

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



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

### 13.1. Standard Power Curve, Application Mode – AM 0

Air density= [1.06, 1.27] kg/m<sup>3</sup>

Validity range:

<b>Wind Shear (10min average)</b>	$\leq 0.3$
<b>Turbulence intensity TI [%] for bin i</b>	$5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$
<b>Terrain</b>	Not complex according to IEC 61400-12-1
<b>Upflow <math>\beta</math> [°]</b>	$-2^\circ \leq \beta \leq +2^\circ$
<b>Grid frequency [Hz]</b>	$\pm 0.5$ 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<sup>3</sup>. The power curve does not include losses in the transformer and high voltage cables.

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

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

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

AEP [MWh]		Annual Average Wind Speed [m/s] at Hub Height										
		5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10
Density [kg/m <sup>3</sup> ]	1.225	11514	14363	17198	19937	22528	24939	27150	29151	30937	32503	33853
	1.06	10152	12804	15493	18136	20675	23069	25292	27325	29156	30780	32191
	1.09	10413	13107	15829	18495	21049	23449	25673	27702	29526	31139	32540
	1.12	10667	13401	16151	18838	21403	23808	26030	28054	29871	31474	32862
	1.15	10916	13685	16463	19167	21741	24149	26369	28387	30195	31788	33165
	1.18	11159	13962	16763	19483	22065	24475	26692	28704	30503	32085	33451
	1.21	11397	14231	17055	19788	22376	24787	27000	29005	30795	32367	33722
	1.24	11630	14493	17338	20083	22676	25086	27295	29293	31074	32635	33979
1.27	11859	14750	17613	20368	22966	25375	27580	29570	31341	32893	34225	

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



## 13.2. Standard Ct Curve, Application Mode - AM 0

Air density= [1.06, 1.27] kg/m<sup>3</sup>

Validity range:

<b>Wind Shear (10min average)</b>	$\leq 0.3$
<b>Turbulence intensity TI [%] for bin i</b>	$5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$
<b>Terrain</b>	Not complex according to IEC 61400-12-1
<b>Upflow <math>\beta</math> [°]</b>	$-2^\circ \leq \beta \leq +2^\circ$
<b>Grid frequency [Hz]</b>	$\pm 0.5$ 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:

$$C_t = F / (0.5 * \rho * w^2 * A)$$

where

F = Rotor force [N]

$\rho$  = Air density [kg/m<sup>3</sup>]

w = Wind speed [m/s]

A = Swept area of rotor [m<sup>2</sup>]

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

SG 6.2-170 Mode AM 0 ct curves [-]									
Ws hub [m/s]	Air density [kg/m <sup>3</sup> ]								
	1.225	1.06	1.09	1.12	1.15	1.18	1.21	1.24	1.27
3.0	0.953	0.953	0.953	0.953	0.953	0.953	0.953	0.953	0.953
3.5	0.880	0.880	0.880	0.880	0.880	0.880	0.880	0.880	0.880
4.0	0.847	0.847	0.847	0.847	0.847	0.847	0.847	0.847	0.847
4.5	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828
5.0	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824
5.5	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828
6.0	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833
6.5	0.836	0.836	0.836	0.836	0.836	0.836	0.836	0.836	0.836
7.0	0.837	0.837	0.837	0.837	0.837	0.837	0.837	0.837	0.837
7.5	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835
8.0	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825
8.5	0.802	0.804	0.804	0.804	0.803	0.803	0.802	0.801	0.800
9.0	0.759	0.767	0.767	0.766	0.765	0.763	0.761	0.757	0.753
9.5	0.696	0.716	0.715	0.712	0.709	0.705	0.699	0.693	0.686
10.0	0.620	0.654	0.651	0.646	0.640	0.633	0.625	0.615	0.605
10.5	0.541	0.588	0.582	0.575	0.566	0.556	0.546	0.535	0.524
11.0	0.466	0.521	0.513	0.503	0.493	0.483	0.472	0.461	0.450
11.5	0.402	0.458	0.448	0.438	0.428	0.417	0.407	0.396	0.386
12.0	0.347	0.401	0.391	0.381	0.371	0.361	0.352	0.343	0.334
12.5	0.303	0.351	0.342	0.333	0.324	0.315	0.307	0.299	0.291
13.0	0.266	0.309	0.300	0.292	0.284	0.276	0.269	0.262	0.256
13.5	0.235	0.273	0.265	0.258	0.251	0.244	0.238	0.232	0.226
14.0	0.209	0.243	0.236	0.229	0.223	0.217	0.212	0.207	0.202
14.5	0.187	0.217	0.211	0.205	0.200	0.195	0.190	0.185	0.181
15.0	0.169	0.195	0.190	0.185	0.180	0.175	0.171	0.167	0.163
15.5	0.153	0.176	0.171	0.167	0.163	0.158	0.155	0.151	0.147
16.0	0.139	0.160	0.156	0.152	0.148	0.144	0.141	0.137	0.134
16.5	0.127	0.146	0.142	0.138	0.135	0.132	0.128	0.125	0.123
17.0	0.117	0.134	0.130	0.127	0.124	0.121	0.118	0.115	0.113
17.5	0.108	0.124	0.120	0.117	0.114	0.112	0.109	0.106	0.104
18.0	0.100	0.115	0.112	0.109	0.106	0.104	0.101	0.099	0.097
18.5	0.093	0.107	0.104	0.101	0.099	0.096	0.094	0.092	0.090
19.0	0.087	0.100	0.097	0.095	0.093	0.090	0.088	0.086	0.084
19.5	0.082	0.094	0.091	0.089	0.087	0.085	0.083	0.081	0.079
20.0	0.077	0.088	0.086	0.084	0.082	0.080	0.078	0.076	0.075
20.5	0.066	0.075	0.073	0.071	0.069	0.068	0.066	0.065	0.064
21.0	0.060	0.068	0.067	0.065	0.064	0.062	0.061	0.060	0.058
21.5	0.055	0.063	0.061	0.060	0.058	0.057	0.056	0.055	0.054
22.0	0.051	0.058	0.056	0.055	0.054	0.053	0.051	0.050	0.049
22.5	0.047	0.053	0.052	0.051	0.050	0.048	0.047	0.046	0.046
23.0	0.043	0.049	0.048	0.047	0.046	0.045	0.044	0.043	0.042
23.5	0.040	0.045	0.044	0.043	0.042	0.041	0.040	0.040	0.039
24.0	0.037	0.042	0.041	0.040	0.039	0.038	0.037	0.037	0.036
24.5	0.034	0.039	0.038	0.037	0.036	0.035	0.035	0.034	0.033
25.0	0.032	0.036	0.035	0.034	0.034	0.033	0.032	0.032	0.031

## 14. Standard Acoustic Emission, Rev. 0. Mode AM 0

### Typical Sound Power Levels

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

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

Table 1: Acoustic emission,  $L_{WA}[dB(A) \text{ re } 1 \mu W](10 \text{ Hz to } 10kHz)$

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

Table 2: Acoustic emission,  $L_{WA}[dB(A) \text{ re } 1 \mu W](10 \text{ Hz to } 160 \text{ Hz})$

### Low Noise Operations

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

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

## 15. Electrical Specifications

### Nominal output and grid conditions

Nominal power .....	6200 kW
Nominal voltage.....	690 V
Power factor correction.....	Frequency converter control
Power factor range .....	0.9 capacitive to 0.9 inductive at nominal balanced voltage

### Generator

Type.....	DFIG Asynchronous
Maximum power .....	6350 kW @30°C ext. ambient

Nominal speed.....	1120 rpm-6p (50Hz) 1344 rpm-6p (60Hz)
--------------------	--

### Generator Protection

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

### Generator Cooling

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

### Frequency Converter

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

### Main Circuit Protection

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

### Peak Power Levels

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

### Grid Capabilities Specification

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

### Power Consumption from Grid (approximately)

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

### Controller back-up

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

### Transformer Specification

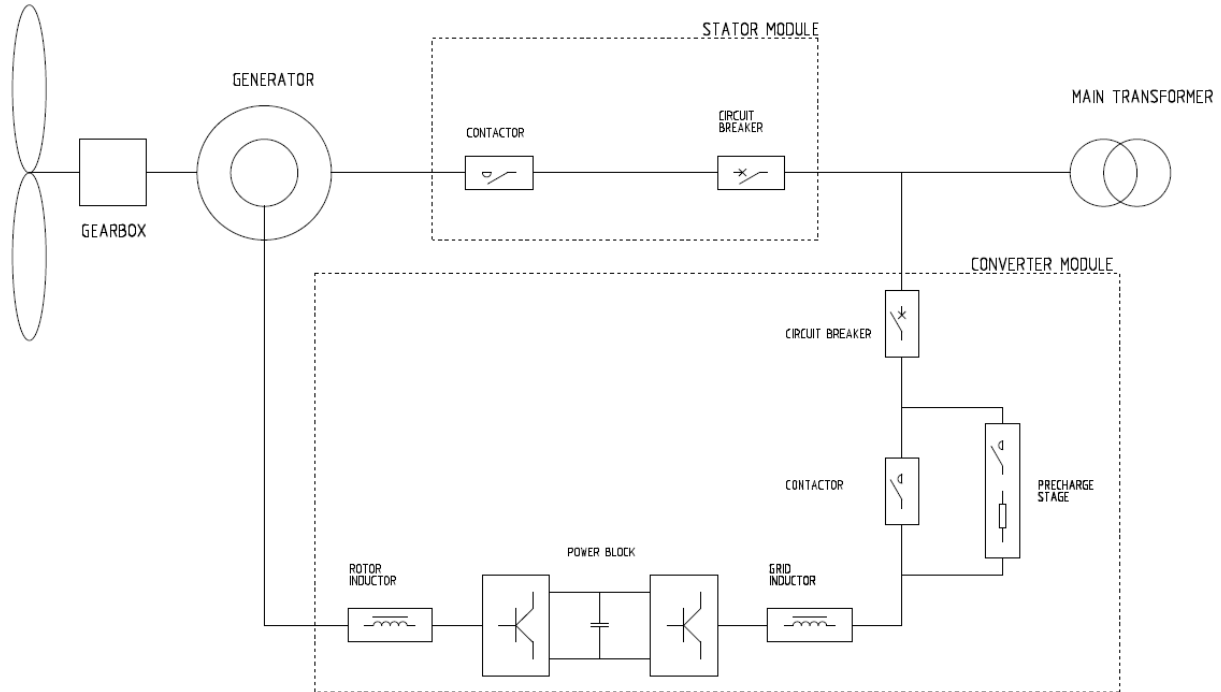
Transformer impedance requirement.....	8.5 % - 10.5%
Secondary voltage .....	690 V
Vector group .....	Dyn 11 or Dyn 1 (star point earthed)

### Earthing Specification

Earthing system .....	Acc. to IEC62305-3 ED 1.0:2010
Foundation reinforcement..	Must be connected to earth electrodes
Foundation terminals .....	Acc. to SGRE Standard

HV connection .....	HV cable shield shall be connected to earthing system
---------------------	---

## 16. Simplified Single Line Diagram



## 17. 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
Cold Climate Package	EN50708 – ECO Tier 2 (optional)

### Transformer Monitoring

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

### Transformer Cooling

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

### Transformer Earthing

Star point	The star point of the transformer is connected to earth
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## 18. 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 (SF<sub>6</sub>) 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 disconnecter open and close position, earth switch open and close position, and circuit breaker open position, to prevent improper operation of the equipment.

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

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

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

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

\* Up to four feeders.

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

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

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

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

## 19. 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 <sub>6</sub>
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

Grid cable feeder	630 A bushings type C 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 M16
Cable entry	From bottom

### Interface to turbine control

Breaker status	
SF6 supervision	1 NO contact
External trip	1 NO contact

\*Cable clamps are not part of switchgear delivery.

## 20. Grid Performance Specifications – 50 Hz

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.

### 20.1. 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 ( $S_k/S_n$ ) 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.

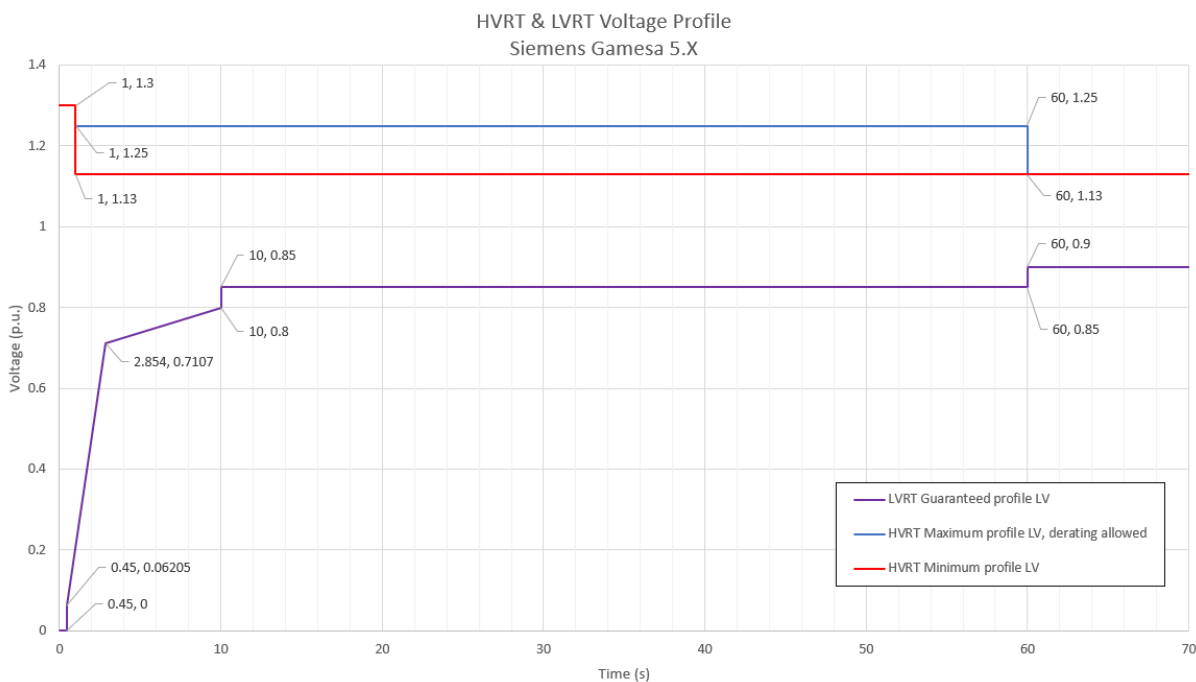


Figure 1. High and Low voltage limits for Siemens Gamesa 5.X, 50 Hz wind turbine in the range of 0-70 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).



## 20.2. 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 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).

## 20.3. Supervisory Control and Data Acquisition (SCADA) Capability

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

## 20.4. Frequency Capability

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):  $\pm 3\%$ , and transients' events (limited simultaneity):  $\pm 8\%$ , over rated frequency.

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

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

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

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

## 20.6. 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.

## 20.7. 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.

## 20.8. 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.

## 20.9. 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, $V = 0.95$ , $f = \pm 3\%$ Applicable to any AM and turbine variant
Minimum SCR at WTG MV Terminals	V-Direct: $\geq 2.0^*$ Q-Direct: $\geq 3.0^{**}$	See note 1.
Minimum X/R at WTG MV Terminals	3.0	
Max. Frequency gradient (ROCOF)	$\leq 4$ Hz/s	
Allowable Max Negative Sequence Voltage	$\leq 5\%$	
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	$\pm 5\%$ 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)	$\leq 30$ ms	+20ms for 1 cycle RMS calculation
$I_q$ Settling Time (FRT)	$\leq 60$ ms	+20ms for 1 cycle RMS calculation -10% +20% required step
Active Power Ramp	$\pm 6\%$ Prated / s	Standard
Active Power Ramps - Fast Mode	+12,5% Prated/s -25% Prated/s	When commanded by SCADA
Reactive Power Ramp	$\pm 5000$ 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.

## 21. 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.

### 21.1. 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.

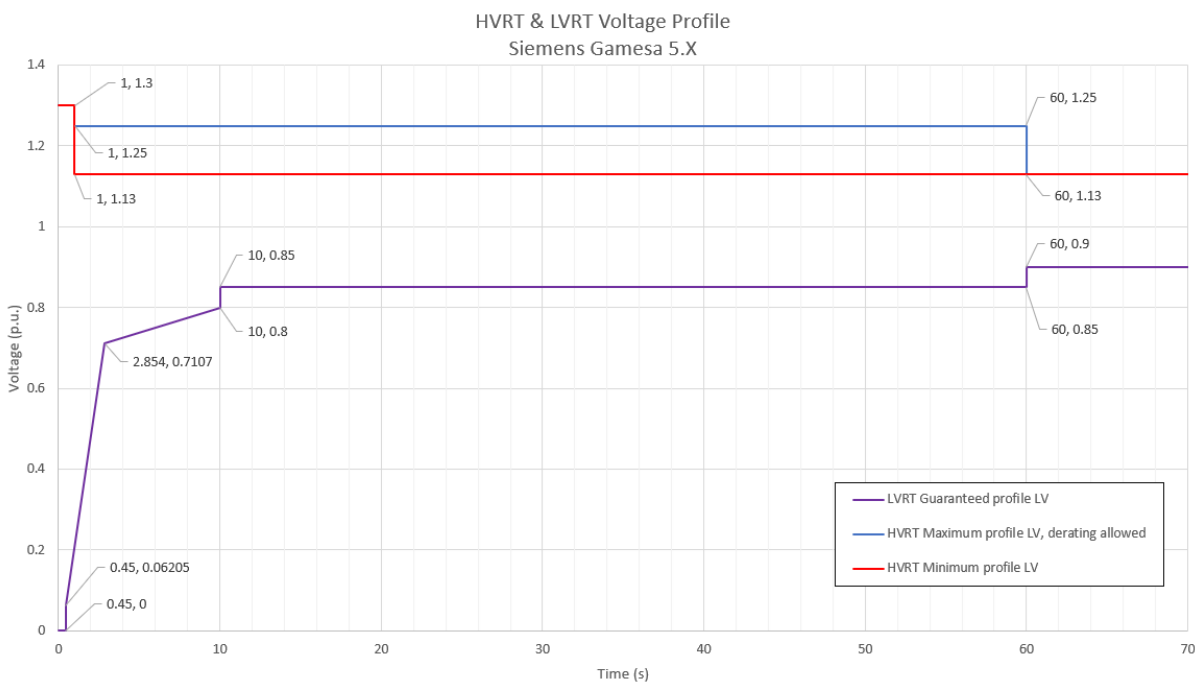


Figure 1. High and Low voltage limits for Siemens Gamesa 5.X, 60 Hz wind turbine in the range of 0-70 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).

## 21.2. 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).

## 21.3. 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.

## 21.4. 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):  $\pm 3\%$ , and transients' events (limited simultaneity):  $\pm 8\%$ , 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.

## 21.5. 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  $\pm 10\%$  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.

## 21.6. 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.

## 21.7. 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.

## 21.8. 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.

## 22. 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 <sub>q</sub> Injection Curve during FRT	k = [2 – 6]	Configurable by parameters. See note 2.
I <sub>q</sub> Response Time (FRT)	≤ 30ms	+20ms for 1 cycle RMS calculation
I <sub>q</sub> 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.

## 23. Reactive Power Capability - 50 & 60 Hz

This document describes the reactive power capability of Siemens Gamesa 5X, 50/60 Hz wind turbines during active power production. Siemens Gamesa 5Xwind 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.

### 23.1. 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,  $\leq 5\%$ ) 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  $\pm 10\%$ .

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.

## 23.2. 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 UVRT 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.

## 23.3. 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.

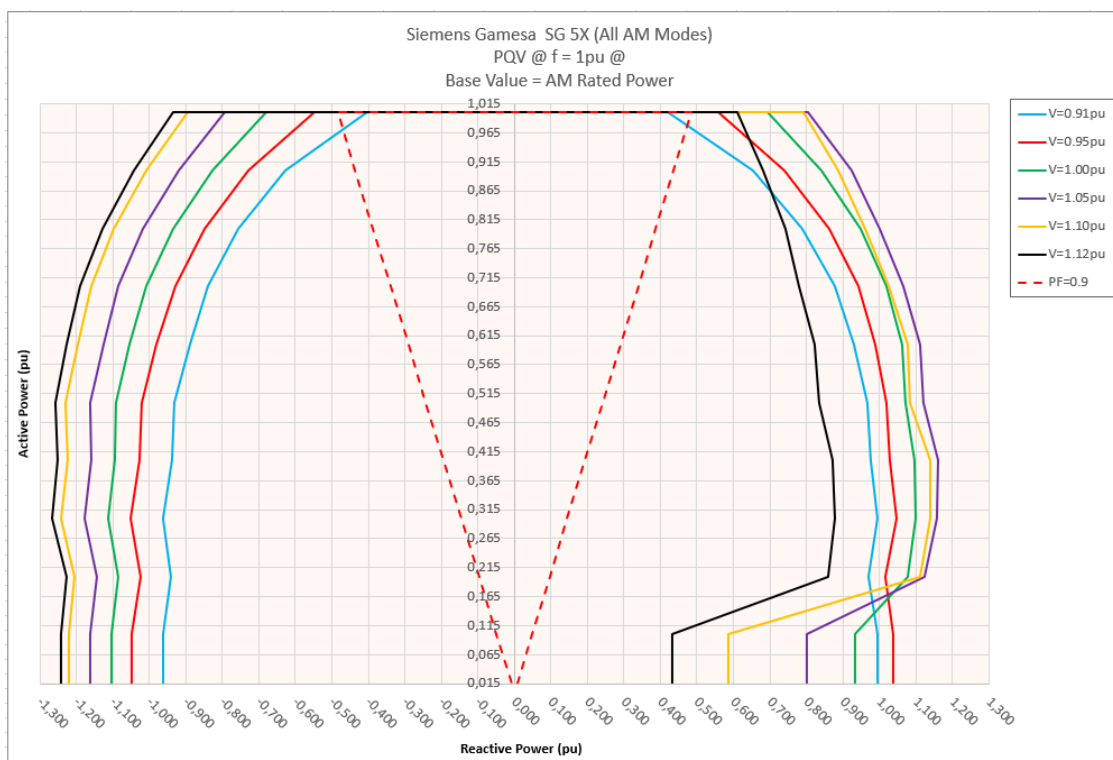
In the maximum configurable values of the voltage protection parameters (permanent operation, 85% and 113%):

- 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.

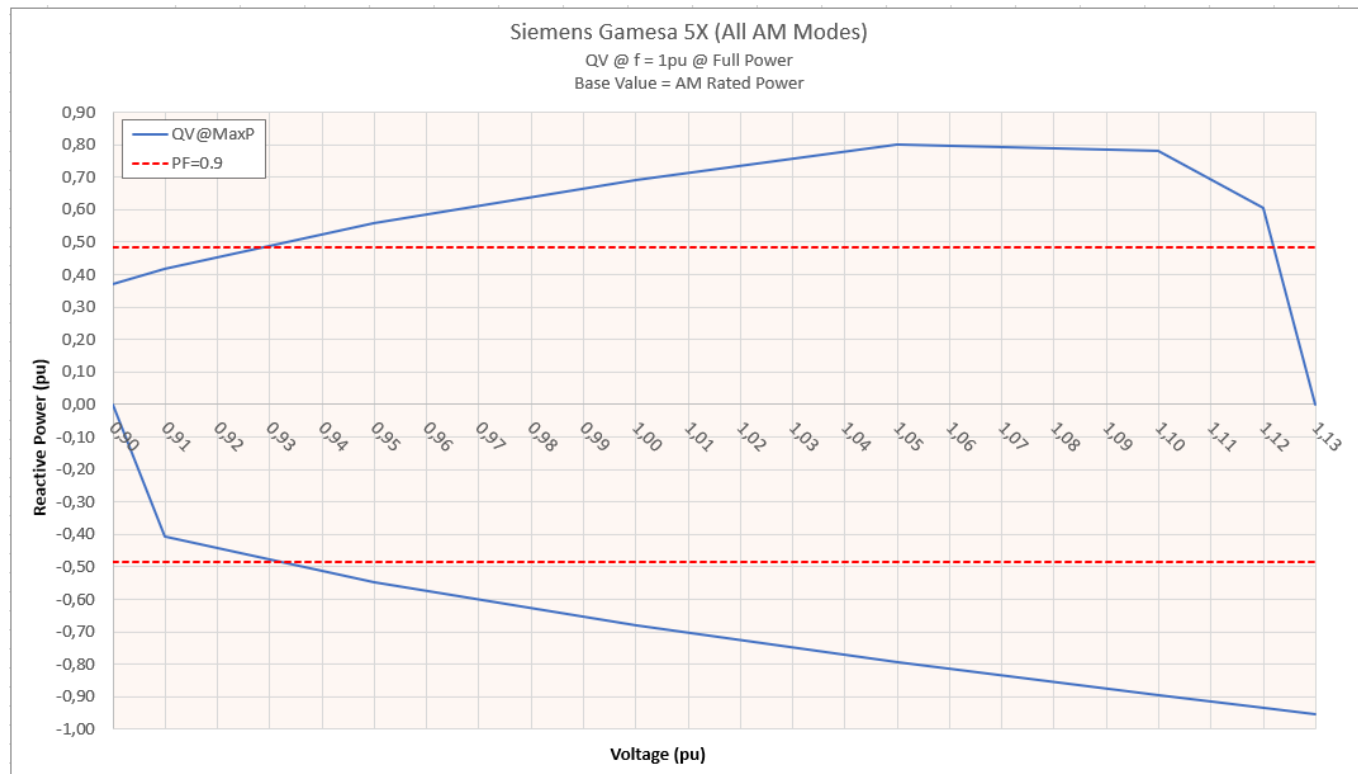


**Figure 3:** Siemens Gamesa 5.X Reactive power capability curves (PQR), 50/60 Hz Wind Turbine, at LV terminals.

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

Application mode (AM)	Rating	External Nacelle Temperature
	Kw	°C
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)	<b>0,015*</b>	0,985	0,997	1,038	0,933	0,803	0,586	0,433	0
	<b>0,10</b>	0,985	0,997	1,038	0,933	0,803	0,586	0,433	0
	<b>0,20</b>	0,957	0,969	1,018	1,077	1,124	1,112	0,860	0
	<b>0,30</b>	0,982	0,995	1,047	1,098	1,157	1,140	0,877	0
	<b>0,40</b>	0,962	0,975	1,029	1,095	1,160	1,139	0,873	0
	<b>0,50</b>	0,955	0,968	1,018	1,073	1,121	1,085	0,834	0
	<b>0,60</b>	0,914	0,929	0,990	1,063	1,112	1,076	0,823	0
	<b>0,70</b>	0,861	0,877	0,942	1,019	1,065	1,026	0,781	0
	<b>0,80</b>	0,770	0,789	0,862	0,949	1,001	0,962	0,742	0
	<b>0,90</b>	0,629	0,652	0,741	0,842	0,923	0,888	0,682	0
<b>1,00</b>	0,373	0,419	0,559	0,693	0,803	0,791	0,611	0	

**Table 6:** Siemens Gamesa 5.X Reactive 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.

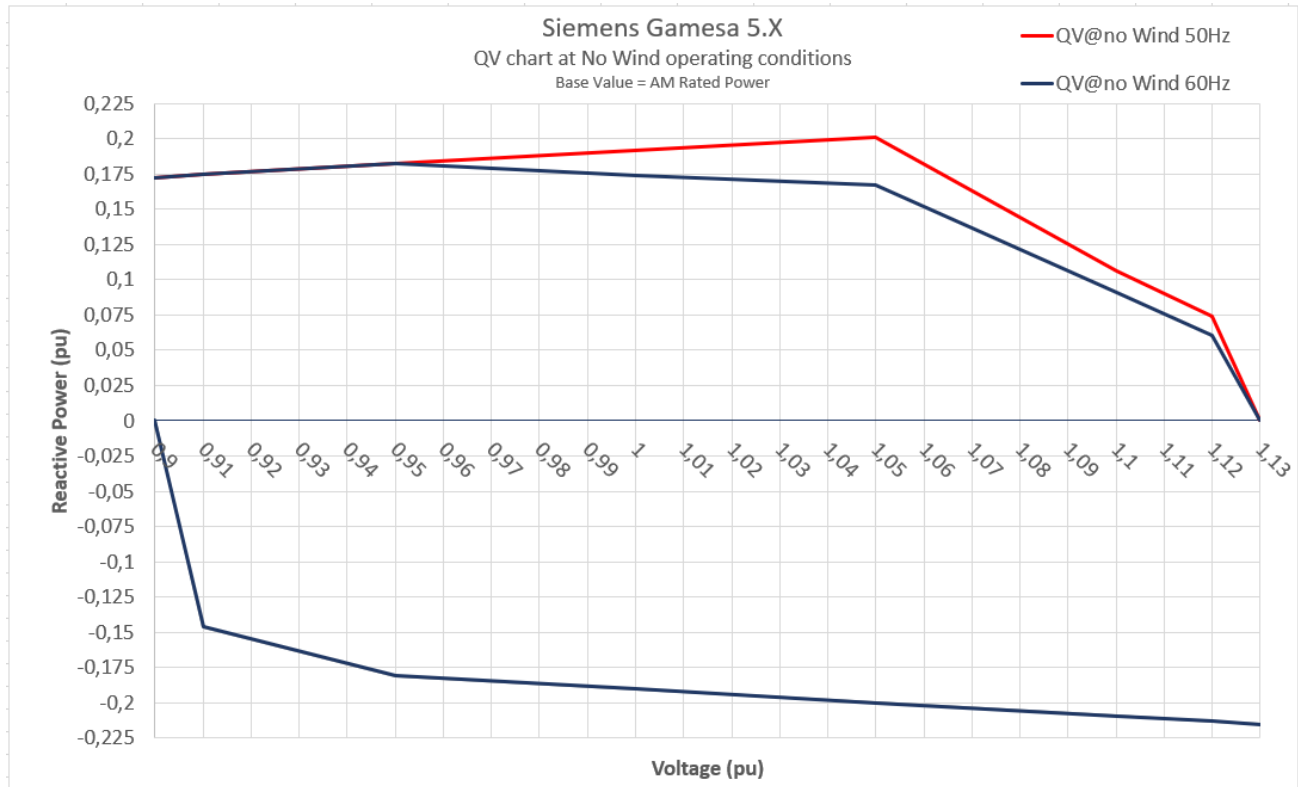
Base Value = AM Rated Power		Voltage (pu)							
		0,9	0,91	0,95	1	1,05	1,1	1,12	1,13
Active Power (pu)	0,015*	0	-0,963	-1,048	-1,105	-1,162	-1,220	-1,242	-1,253
	0,10	0	-0,963	-1,048	-1,105	-1,162	-1,220	-1,242	-1,253
	0,20	0	-0,941	-1,024	-1,085	-1,144	-1,204	-1,228	-1,241
	0,30	0	-0,962	-1,050	-1,114	-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			Siemens Gamesa 5.X60Hz Base Value = AM Rated Power		
Voltage (pu)	Q+ (pu)	Q- (pu)	Voltage (pu)	Q+ (pu)	Q- (pu)
0,90	0,173	0,00	0,90	0,173	0,000
0,91	0,174	-0,146	0,91	0,174	-0,146
0,95	0,182	-0,181	0,95	0,182	-0,181
1,00	0,192	-0,190	1,00	0,174	-0,190
1,05	0,201	-0,200	1,05	0,167	-0,200
1,10	0,107	-0,209	1,10	0,091	-0,209
1,12	0,074	-0,213	1,12	0,061	-0,213
1,13	0,000	-0,215	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.

## 24. SCADA System Description

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

### 24.1. 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.

### 24.2. 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.

### 24.3. 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.



## 24.4. 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.

## 24.5. 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.

## 24.6. 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

## 24.7. 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.

## 24.8. 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.

## 24.9. 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.

## 25. 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.

### 25.1. 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.*

## 25.2. GEARBOX

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

## 25.3. 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*

## 25.4. QUALITY

- *ISO 9001:2015 Quality management systems – Requirements*

## 25.5. 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*

## 25.6. 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)*

## 26. Ice Detection System and Operations with Ice

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

The following options for ice detection sources can be used:

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

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

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

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

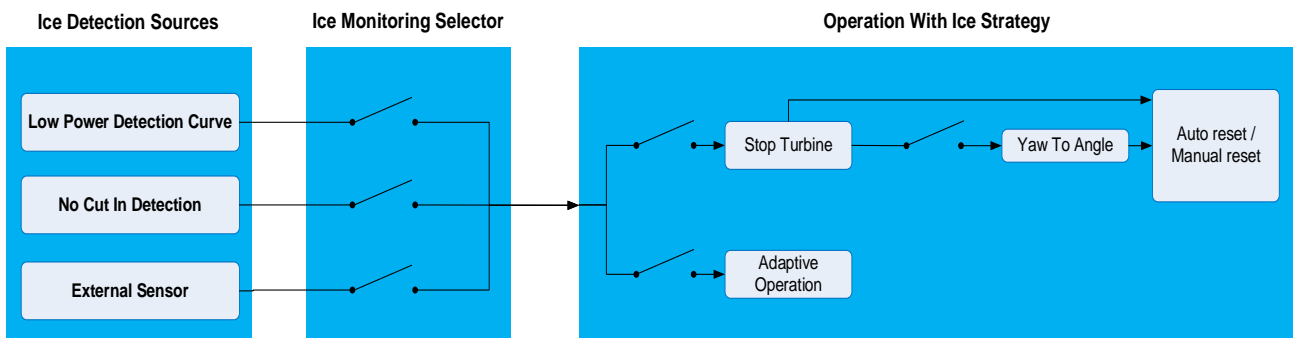


Figure 1: Ice Detection and Operation with Ice Strategy interface for individual turbines



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.

## 26.1. Ice Detection Sources

### 26.1.1. Low Power Detection Curve (LPDC)

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

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

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

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

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

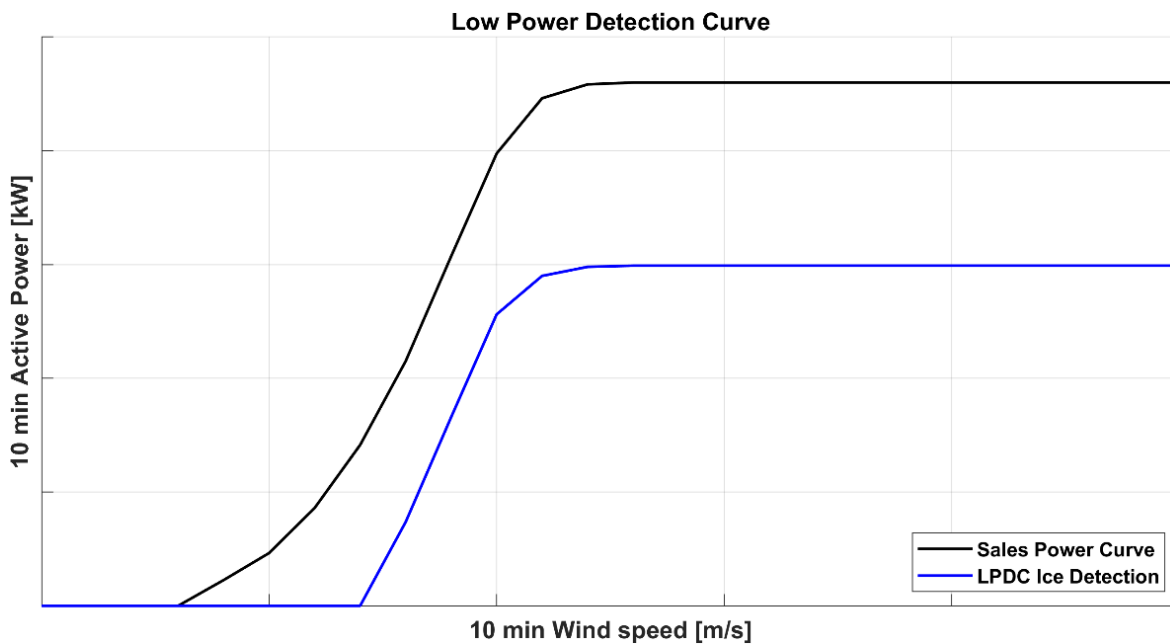


Figure 2: Illustration of Low Power Detection Curve (LPDC)

## 26.2. No Cut-in

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

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

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

## 26.3. External Sensor Options

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

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

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

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

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

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

## 26.4. External Sensor Types

### 26.4.1. Nacelle Based Ice Detection Sensor (Optional)

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

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

### 26.4.2. Blade-Based Ice Detection Sensor (Optional)

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

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

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

## 26.5. Options and logging in SCADA

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

- Set predefined ice conditions using ice parameters
- Enable or disable automatic stop of individual turbines

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

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

- **Ice Restart Delay:** Turbines that are stopped due to ice are restarted only if ice is not reported from the sensor during the “Ice Stop Delay” in seconds configured by the user.
- **Ice Stop Delay:** Turbines are stopped due to ice only if ice is detected on turbine(s) for more than the ice stop delay in seconds configured by the user.
- **Ambient Temperature Duration:** Duration in seconds for how long the ambient temperature for ice detection should be exceeded to restart the turbines which are stopped due to ice.
  - E.g. above 5°C for 600 seconds
- **Ambient Temperature Threshold:** This parameter defines the temperature which must be exceeded to restart turbines stopped due to ice detection.
  - E.g. above 5°C for 600 seconds
- **Ice Control Start Time and Ice Control End Time:** Configured turbines will be stopped due to ice detection when the actual time is between Ice Control Start Time and Ice Control End Time. When the current time falls outside the range specified in Ice Control Start Time and Ice Control End Time, the turbines are restarted.

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

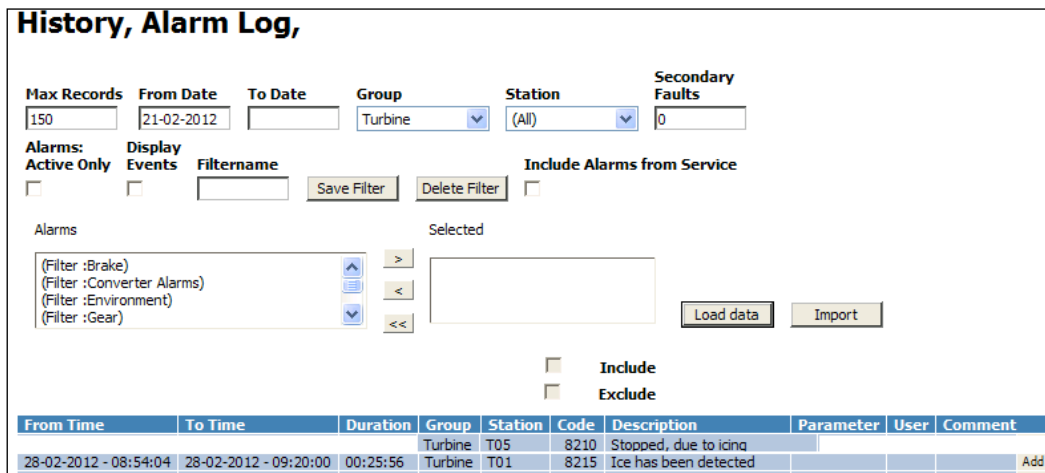


Figure 3 - Presentation of alarms related to the ice detection system in Web WPS SCADA

## 26.6. Operation with Ice Strategy

### 26.6.1. 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

### 26.6.2. Operation with Ice Strategy: Adaptive Operation

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

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

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

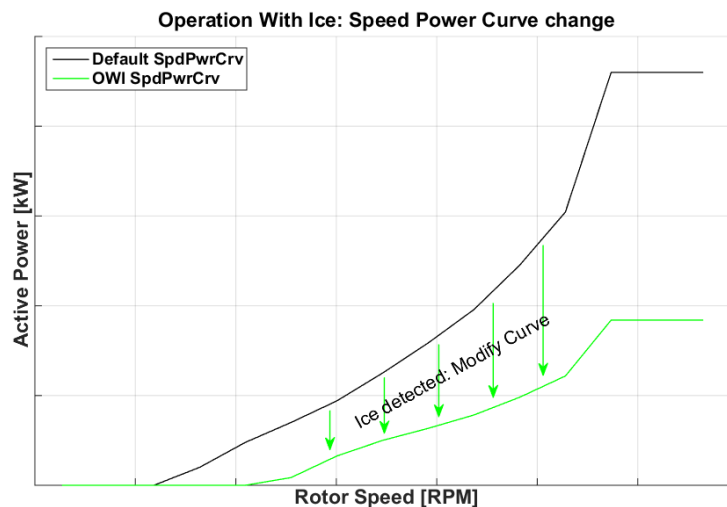


Figure 4: Illustration of OWI Speed-Power curve modification

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

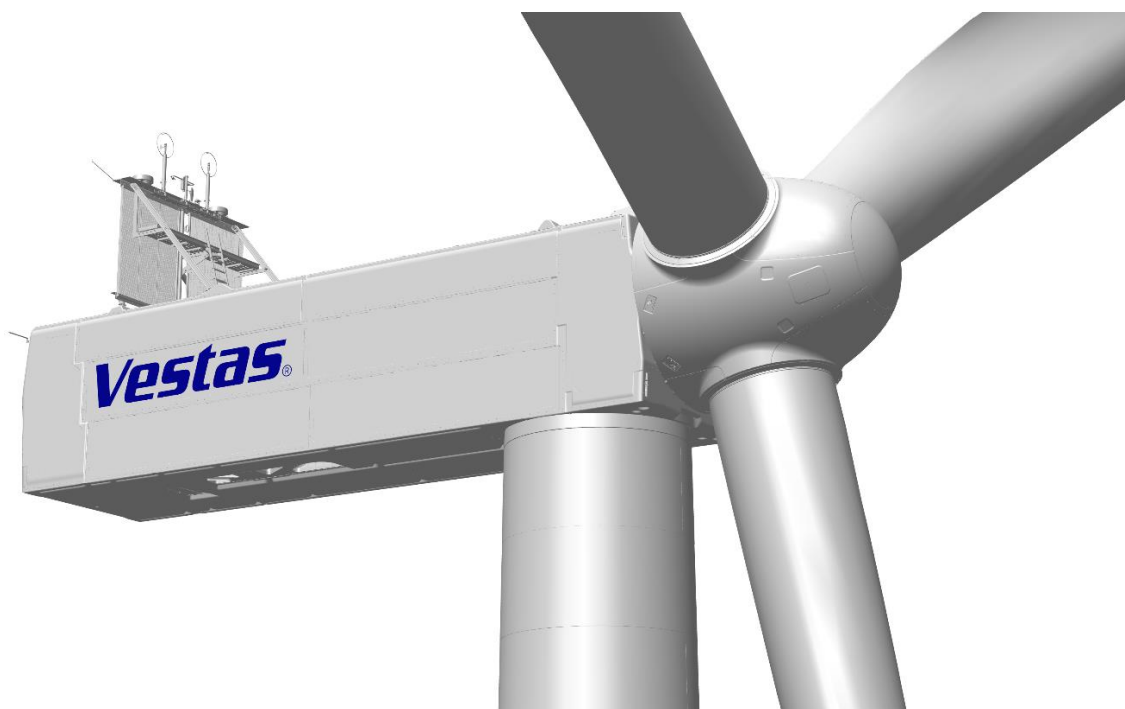
It is the sole responsibility of the owner of the turbine to ensure that the turbine operating with *Operation with Ice Strategy: Adaptive Operation* functionality activated complies with any noise restriction applicable, irrespective of whether such limits follow from permits, legislation or otherwise.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

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# Performance Specification

## EnVentus™

### V162-6.2 MW 50/60 Hz



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**See general reservations, notes and disclaimers (including, Section 5, p. 15) to this Performance Specification.**



## 1 General Description

The Vestas V162-6.2 MW is a wind turbine variant within the EnVentus™ turbine range. It is a pitch regulated upwind turbine with active yaw and a three-blade rotor. The V162-6.2 MW turbine has a rotor diameter of 162 m and a rated power of 6.2 MW.

For more details, please refer to the General Description of the EnVentus™ turbine range (General Description EnVentus™ - 0081-5017).

## 2 Type Approvals and Available Hub Heights

The standard turbine is type certified according to the certification standards and available hub heights listed below:

Certification	Wind Class	Hub Height
IECRE OD-501	IEC S	119 / 125 / 166 m
DIBt 2012	DIBt S	119 / 166 / 169 m



### 3 Operational Envelope and Performance Guidelines

Actual climate and site conditions have many variables and should be considered in evaluating actual turbine performance. The design and operating parameters set forth in this section do not constitute warranties, guarantees, or representations as to turbine performance at actual sites.

#### 3.1 Climate and Site Conditions

The standard turbine is designed for the wind climate conditions listed below. Values refer to hub height.

Wind Climate	IEC S	IEC S	IEC S
Power Rating	6.2 MW	6.2 MW	6.2 MW
Hub Height	119 m	125 m	166 m
Wind Speed (10 min average), $V_{ave}$	6.9 m/s	8.0 m/s	7.4 m/s
Weibull Scale Factor, $C$	8.3 m/s	9.6 m/s	8.9 m/s
Weibull Shape Factor, $k$	2.48	2.3	2.48
$I_{ref}$ acc. to IEC 61400-1	0.15	0.14	0.15
Turbulence Intensity acc. to IEC 61400-1, Including Wind Farm Turbulence (@15 m/s) $I_{90}$ (90% quantile)	16.9%	15.7%	16.9 %
Wind Shear, $\alpha$	0.30	0.20	0.30
Inflow Angle (vertical)	8°	8°	8°
<b>Extreme design parameters – IEC</b>			
Extr. Wind Speed (10 min average), $V_{50}$	37.1 m/s	37.5 m/s	39.5 m/s
Survival Wind Speed (3 s gust), $V_{e50}$	51.9 m/s	52.5 m/s	55.3 m/s
Turbulence Intensity, $I_{V50}$	11%	11 %	11 %

Wind Class	DIBt S	DIBt S
Hub Height	119 m	CHT* 166/169 m
Power Rating	6.2 MW	6.2 MW
<b>Average design parameters – DIBt</b>		
Wind Speed (10 min average), $V_{ave}$	6.6 m/s	7.0 m/s
Weibull Scale Factor, $C$	8.0 m/s	8.5 m/s
Weibull Shape Factor, $k$	2.22	2.22
$I_{ref}$ acc. to IEC 61400-1	S	S
Turbulence Intensity, $I_{90}$ (90% quant.)	S	S
<b>Extreme design parameters – DIBt</b>		
Extr Wind Speed (10 min average), $V_{50}$	39.4 m/s	37.6 m/s
Survival Wind Speed (3 s gust), $V_{e50}$	55.2 m/s	52.6 m/s
Turbulence intensity, $I_{V(z)}$	11.3%	11.1%
Wind Shear, $\alpha$	0.25	0.27
Inflow Angle	8°	8°

\*CHT is Concrete Hybrid Tower

**NOTE** The turbine is intended for low to medium wind speed sites and is classified as IEC S. Please contact Vestas Wind Systems A/S for further information if needed.

Climatic conditions for turbines with the optional Vestas Anti-icing System (VAS), may vary from above. Please contact Vestas Wind Systems A/S for further information.

### 3.1.1 Wind Power Plant Layout

Turbine spacing is to be evaluated site-specifically. Spacing below two rotor diameters (2D) may require sector-wise curtailment.

**NOTE** As evaluation of climate and site conditions is complex, consult Vestas for every project. If conditions exceed the above parameters, Vestas must be consulted.



### 3.2 Operational Envelope – Wind

Values refer to hub height and are determined by the sensors and control system of the turbine.

Wind Climate	IEC S / DIBt S	
	PO6200	SO2, SO3, SO4, SO5, SO6
Cut-In, $V_{in}$	3 m/s	3 m/s
Cut-Out (10 min exponential avg.), $V_{out}$	24 m/s	20 m/s
Re-Cut In (10 min exponential avg.)	22 m/s	18 m/s



### 3.3 Operational Envelope – Temperature and Altitude

Values below refer to hub height and are determined by the sensors and control system of the turbine.

Operational Envelope – Temperature	
Ambient Temperature Interval	-20° to +45°C
Ambient Temperature Interval (Low Temperature operation)	-30° to +45°C

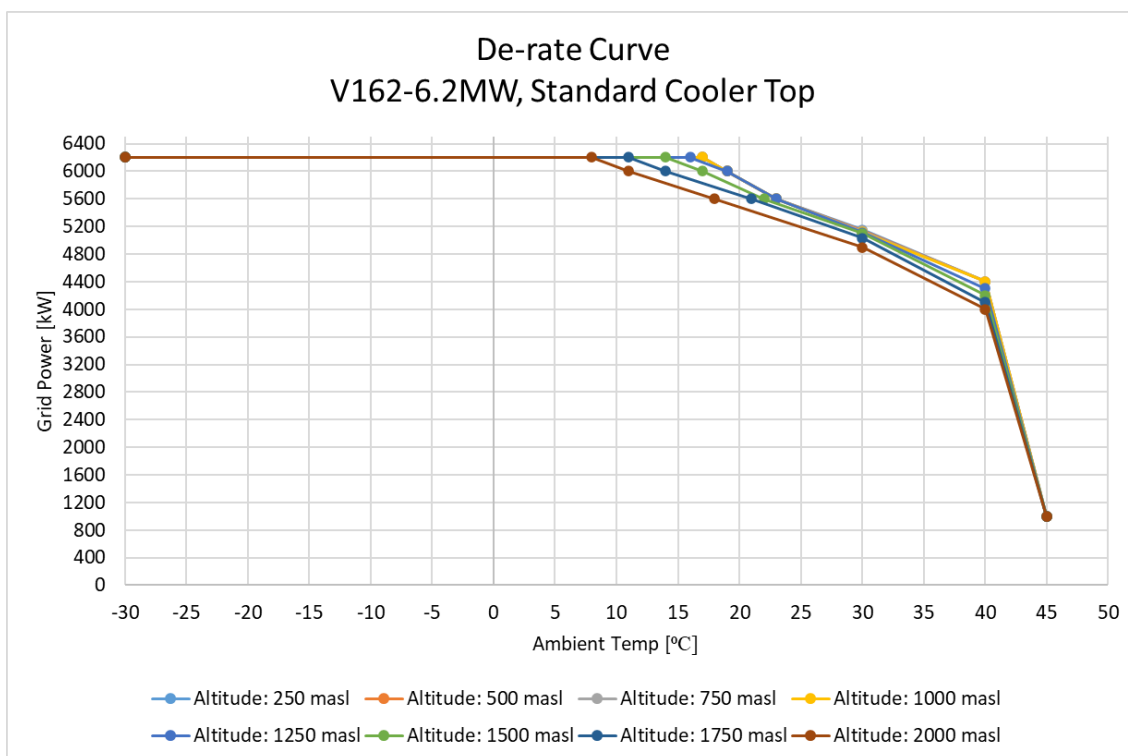
**NOTE**

The wind turbine will stop producing power at ambient temperatures above 45°C. For the low temperature operation of the wind turbine please consult Vestas.

The turbine is designed for use at altitudes up to 1000 m above sea level as standard and optional up to 2000 m above sea level.

#### 3.3.1 Temperature dependent operation

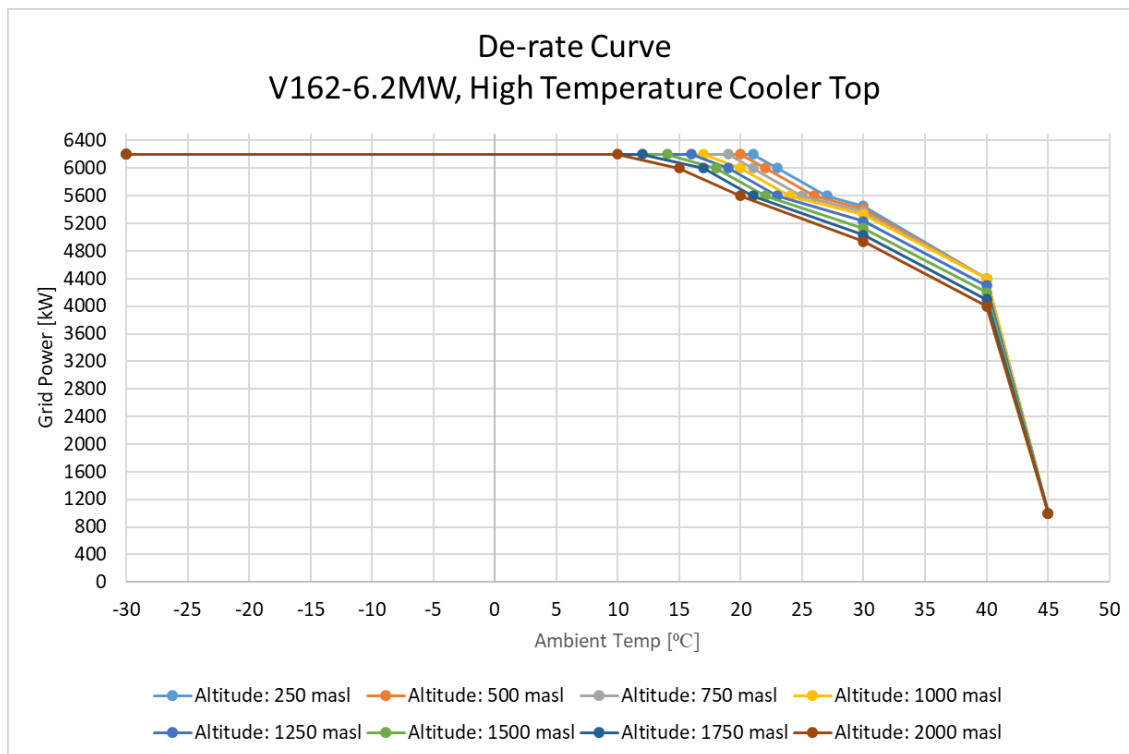
Values below refer to hub height and are determined by the sensors and control system of the turbine. At ambient temperatures above the thresholds shown for each operating mode, the turbine will maintain derated production.



Altitude [masl]	[°C]	[kW]	[°C]	[kW]	[°C]	[kW]	[°C]	[kW]	[°C]	[kW]	[°C]	[kW]
250	17	6200	19	6000	23	5600	30	5150	40	4400	45	1000
500	17	6200	19	6000	23	5600	30	5140	40	4400	45	1000
750	17	6200	19	6000	23	5600	30	5130	40	4400	45	1000
1000	17	6200	19	6000	23	5600	30	5120	40	4400	45	1000
1250	16	6200	19	6000	23	5600	30	5110	40	4300	45	1000
1500	14	6200	17	6000	22	5600	30	5100	40	4200	45	1000
1750	11	6200	14	6000	21	5600	30	5033	40	4100	45	1000
2000	8	6200	11	6000	18	5600	30	4900	40	4000	45	1000

Figure 3-1: Temperature dependant derated operation – Standard cooler top





Altitude [masl]	[°C]	[kW]	[°C]	[kW]	[°C]	[kW]	[°C]	[kW]	[°C]	[kW]	[°C]	[kW]
250	21	6200	23	6000	27	5600	30	5450	40	4400	45	1000
500	20	6200	22	6000	26	5600	30	5410	40	4400	45	1000
750	19	6200	21	6000	25	5600	30	5370	40	4400	45	1000
1000	17	6200	20	6000	24	5600	30	5330	40	4400	45	1000
1250	16	6200	19	6000	23	5600	30	5233	40	4300	45	1000
1500	14	6200	18	6000	22	5600	30	5133	40	4200	45	1000
1750	12	6200	17	6000	21	5600	30	5033	40	4100	45	1000
2000	10	6200	15	6000	20	5600	30	4933	40	4000	45	1000

Figure 3-2: Temperature dependant derated operation – Optional high temperature cooler top



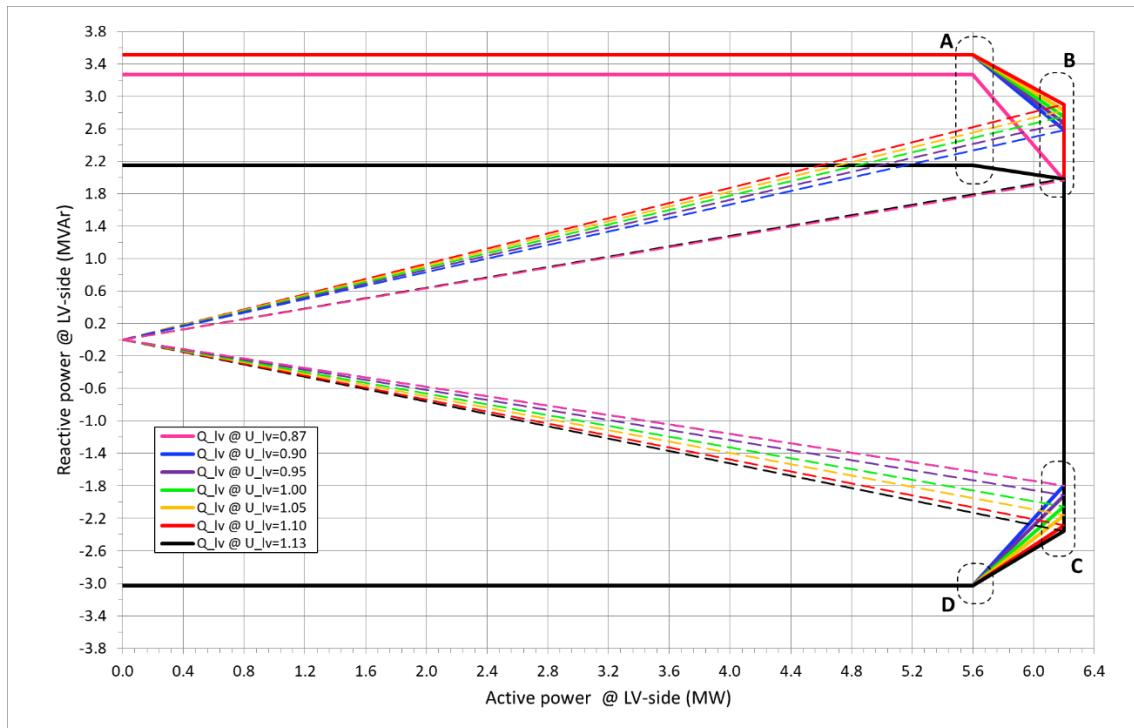
### 3.4 Operational Envelope – Conditions for Power Curve and $C_t$ Values (at Hub Height)

Please consult section 6 and subsequent, for power curves and  $C_t$  values.

Conditions for Power Curve and $C_t$ Values (at Hub Height)	
Wind Shear, $\alpha$	0.00-0.30 (10-minute average)
Turbulence Intensity, $I$	6-12% (10-minute average)
Blades	Clean
Rain	No
Ice/Snow on Blades	No
Leading Edge	No damage
Terrain	IEC 61400-12-1
Inflow Angle (Vertical)	$0 \pm 2^\circ$
Grid Voltage	Nominal Voltage $\pm 2.5\%$
Grid Frequency	Nominal Frequency $\pm 0.5$ Hz
Grid Active Power (LV-side)	Per tabulated values in Section 6 and following sections
Grid Reactive Power (LV-side)	Power Factor 1.0

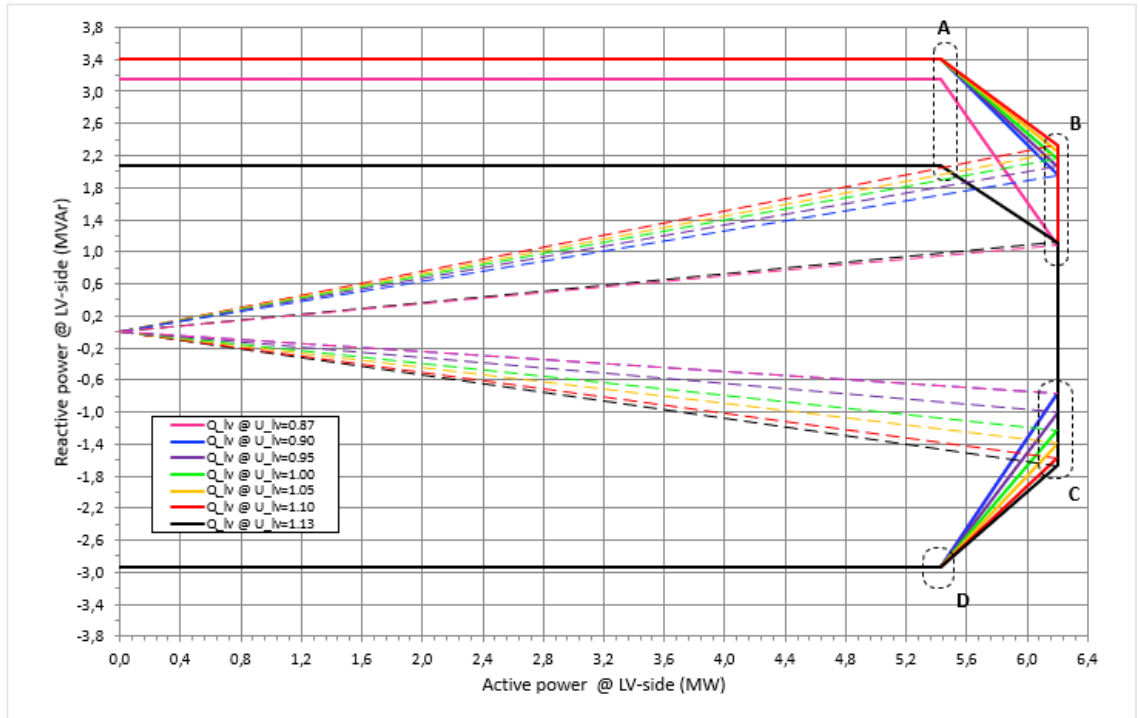
### 3.5 Operational Envelope – Reactive Power Capability

The turbine has a reactive power capability on the low voltage side of the HV transformer as illustrated in Figure 3-3 and Figure 3-4:



Point:	Coordinates								Power factor	
	A		B		C		D		B (Capacitive)	C (Inductive)
	x (P)	y (Q)	x (P)	y (Q)	x (P)	y (Q)	x (P)	y (Q)		
Reactive power [kVAr] @ LV side @ U <sub>lv</sub> = 0.87 p.u. voltage	5.600	3.265	6.200	1.963	6.200	-1.797	5.600	-3.031	0.953	0.960
Reactive power [kVAr] @ LV side @ U <sub>lv</sub> = 0.90 p.u. voltage	5.600	3.513	6.200	2.586	6.200	-1.797	5.600	-3.031	0.923	0.960
Reactive power [kVAr] @ LV side @ U <sub>lv</sub> = 0.95 p.u. voltage	5.600	3.513	6.200	2.670	6.200	-1.918	5.600	-3.031	0.918	0.955
Reactive power [kVAr] @ LV side @ U <sub>lv</sub> = 1.00 p.u. voltage	5.600	3.513	6.200	2.753	6.200	-2.053	5.600	-3.031	0.914	0.949
Reactive power [kVAr] @ LV side @ U <sub>lv</sub> = 1.05 p.u. voltage	5.600	3.513	6.200	2.827	6.200	-2.163	5.600	-3.031	0.910	0.944
Reactive power [kVAr] @ LV side @ U <sub>lv</sub> = 1.10 p.u. voltage	5.600	3.513	6.200	2.900	6.200	-2.287	5.600	-3.031	0.906	0.938
Reactive power [kVAr] @ LV side @ U <sub>lv</sub> = 1.13 p.u. voltage	5.600	2.149	6.200	1.983	6.200	-2.359	5.600	-3.031	0.952	0.935

Figure 3-3: Reactive power capability (7500 kVA transformer variant).



	Point:	Coordinates								Power factor	
		A		B		C		D		B (Capacitive)	C (Inductive)
		x (P)	y (Q)	x (P)	y (Q)	x (P)	y (Q)	x (P)	y (Q)		
Reactive power [kVAr] @ LV side @ U <sub>lv</sub> = 0.87 p.u. voltage		5,430	3,160	6,200	1,082	6,200	-0,764	5,430	-2,933	0,985	0,992
Reactive power [kVAr] @ LV side @ U <sub>lv</sub> = 0.90 p.u. voltage		5,430	3,400	6,200	1,956	6,200	-0,764	5,430	-2,933	0,954	0,992
Reactive power [kVAr] @ LV side @ U <sub>lv</sub> = 0.95 p.u. voltage		5,430	3,400	6,200	2,058	6,200	-1,002	5,430	-2,933	0,949	0,987
Reactive power [kVAr] @ LV side @ U <sub>lv</sub> = 1.00 p.u. voltage		5,430	3,400	6,200	2,158	6,200	-1,228	5,430	-2,933	0,944	0,981
Reactive power [kVAr] @ LV side @ U <sub>lv</sub> = 1.05 p.u. voltage		5,430	3,400	6,200	2,246	6,200	-1,393	5,430	-2,933	0,940	0,976
Reactive power [kVAr] @ LV side @ U <sub>lv</sub> = 1.10 p.u. voltage		5,430	3,400	6,200	2,332	6,200	-1,568	5,430	-2,933	0,936	0,969
Reactive power [kVAr] @ LV side @ U <sub>lv</sub> = 1.13 p.u. voltage		5,430	2,080	6,200	1,115	6,200	-1,665	5,430	-2,933	0,984	0,966

Figure 3-4: Reactive power capability (Optional 7300 kVA transformer variant).

The turbine is able to maintain the reactive power capability at low wind with no active power production.

### 3.6 Sound Modes

The sound modes listed below are available for the turbine.

Sound modes			
Mode No.	Maximum Sound Level	Serrated trailing edges	Available hub heights
<b>PO6200</b>	104.8 dBA	Yes (standard)	119 / 125 / 166 / 169 m
<b>PO6200-0S</b>	107.6 dBA	No (option)	119 / 125 / 166 / 169 m

In addition, Sound Optimized (SO) modes as listed below are available as options for the turbine.

Sound Optimized (SO) modes			
Mode No.	Maximum Sound Level	Serrated trailing edges	Available hub heights
<b>SO2</b>	102 dBA	Yes (standard)	119 / 125 / 166 / 169 m
<b>SO3</b>	101 dBA	Yes (standard)	119 / 125 / 166 / 169 m
<b>SO4</b>	100 dBA	Yes (standard)	119 / 125 / 166 / 169 m
<b>SO5</b>	99 dBA	Yes (standard)	119 / 125 / 166 / 169 m
<b>SO6</b>	98 dBA	Yes (standard)	Site specific

**NOTE** Sound Optimized (SO) modes are only available with serrated trailing edges on the blades. For further details on sound performance and in case of specific requests, please contact Vestas Wind Systems A/S.

## 4 Drawings

Overview drawings describing the wind turbines, tower and foundation are shown in these documents.

V162 HH119 – 0075-8518  
V162 HH125 – 0079-6651  
V162 HH166 – 0075-8514  
V162 HH166 (CHT) – 0089-4873  
V162 HH169 (CHT) – 0089-4874

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**NOTE** For detailed drawings, please contact Vestas Wind Systems A/S.

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### 4.1 Turbine visual impression – side view



## 5 General Reservations, Notes and Disclaimers

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- The performance specifications described in this document apply to the current version of the V162-6.2 MW wind turbine. Updated versions of the V162-6.2 MW wind turbine, which may be manufactured in the future, may differ from these performance specifications. In the event that Vestas supplies an updated version of the V162-6.2 MW wind turbine, Vestas will provide an updated performance specification applicable to the updated version.
- All listed start/stop parameters (e.g. wind speeds) are equipped with hysteresis control. This can, in certain borderline situations, result in turbine stops even though the ambient conditions are within the listed operation parameters.
- This document, Performance Specification, is not an offer for sale, and does not contain any guarantee, warranty and/or verification of the power curve and sound (including, without limitation, the power curve and sound verification method). Any guarantee, warranty and/or verification of the power curve and sound (including, without limitation, the power curve and sound verification method) must be agreed to separately in writing.



**6 Power Curves, Ct Values and Sound Curves, Mode PO6200/PO6200-0S**

**6.1 Power Curves, Mode PO6200/PO6200-0S**

Wind speed [m/s]	Air density [kg/m <sup>3</sup> ]													
	1.225	0.950	0.975	1.000	1.025	1.050	1.075	1.100	1.125	1.150	1.175	1.200	1.250	1.275
3.0	34	11	13	15	16	18	20	22	24	26	29	31	36	39
3.5	150	96	101	106	111	116	121	126	131	136	140	145	155	160
4.0	292	208	216	223	231	239	246	254	262	269	277	285	300	308
4.5	467	344	355	367	378	389	400	411	422	434	445	456	478	489
5.0	676	507	523	538	553	569	584	599	615	630	645	660	691	706
5.5	927	701	722	742	763	783	804	824	845	866	886	907	948	968
6.0	1229	934	961	988	1015	1042	1068	1095	1122	1149	1176	1202	1256	1282
6.5	1584	1211	1245	1279	1313	1347	1381	1415	1449	1483	1517	1551	1618	1652
7.0	2000	1536	1578	1620	1663	1705	1748	1790	1832	1874	1916	1958	2042	2084
7.5	2476	1907	1959	2011	2063	2115	2166	2218	2270	2321	2373	2424	2527	2579
8.0	3017	2330	2393	2456	2518	2581	2644	2706	2769	2831	2893	2955	3079	3141
8.5	3626	2808	2883	2958	3032	3107	3182	3256	3330	3405	3478	3552	3699	3772
9.0	4284	3340	3428	3515	3603	3691	3776	3862	3948	4034	4117	4200	4365	4446
9.5	4917	3903	4000	4096	4193	4289	4381	4473	4564	4656	4743	4830	4999	5081
10.0	5483	4465	4567	4669	4771	4873	4966	5059	5152	5245	5325	5404	5551	5619
10.5	5882	5001	5102	5202	5303	5403	5481	5559	5636	5714	5770	5826	5923	5965
11.0	6114	5493	5578	5663	5748	5834	5884	5935	5986	6036	6062	6088	6128	6143
11.5	6176	5865	5916	5968	6019	6071	6091	6111	6131	6151	6159	6168	6181	6187
12.0	6197	6077	6097	6118	6138	6159	6166	6174	6181	6189	6191	6194	6198	6199
12.5	6200	6157	6165	6174	6182	6190	6192	6195	6197	6199	6199	6200	6200	6200
13.0	6200	6188	6191	6194	6196	6199	6199	6199	6200	6200	6200	6200	6200	6200
13.5	6200	6198	6198	6199	6199	6200	6200	6200	6200	6200	6200	6200	6200	6200
14.0	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200
14.5	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200
15.0	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200
15.5	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200
16.0	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200
16.5	6200	6197	6198	6198	6198	6199	6199	6199	6200	6200	6200	6200	6200	6200
17.0	6186	6147	6151	6155	6160	6164	6167	6171	6174	6178	6180	6183	6187	6189
17.5	6077	5974	5983	5992	6001	6010	6020	6030	6039	6049	6058	6068	6086	6095
18.0	5853	5719	5730	5741	5752	5763	5775	5788	5800	5813	5826	5840	5867	5880
18.5	5590	5472	5481	5491	5500	5509	5520	5531	5542	5554	5566	5578	5603	5616
19.0	5348	5236	5245	5254	5263	5272	5283	5293	5303	5313	5325	5336	5359	5371
19.5	5095	4983	4993	5002	5012	5021	5031	5041	5051	5062	5073	5084	5107	5119
20.0	4825	4711	4720	4730	4739	4748	4759	4769	4780	4790	4802	4813	4837	4849
20.5	4538	4428	4436	4445	4454	4463	4473	4483	4493	4504	4515	4526	4549	4559
21.0	4251	4148	4156	4165	4173	4182	4192	4201	4211	4221	4231	4241	4261	4271
21.5	3954	3861	3869	3877	3885	3892	3901	3910	3919	3928	3936	3945	3964	3973
22.0	3664	3575	3582	3590	3597	3605	3614	3623	3633	3642	3649	3657	3673	3683
22.5	3367	3281	3289	3297	3304	3312	3320	3329	3337	3345	3353	3360	3375	3383
23.0	3064	2989	2995	3001	3008	3014	3021	3028	3034	3041	3049	3056	3072	3080
23.5	2763	2687	2695	2703	2711	2719	2725	2731	2737	2743	2749	2756	2771	2779
24.0	2451	2375	2383	2392	2400	2408	2414	2419	2425	2431	2437	2444	2460	2469

Original Instruction: T05 0107-3707 VER 00

T05 0107-3707 Ver 00 - Approved- Exported from DMS: 2021-07-08 by FRPIC



**6.2 Ct Values, Mode PO6200/PO6200-0S**

Air density kg/m <sup>3</sup>														
Wind speed [m/s]	1.225	0.950	0.975	1.000	1.025	1.050	1.075	1.100	1.125	1.150	1.175	1.200	1.250	1.275
3.0	0.908	0.911	0.911	0.912	0.912	0.912	0.911	0.911	0.910	0.910	0.909	0.909	0.907	0.906
3.5	0.882	0.889	0.888	0.887	0.887	0.886	0.886	0.885	0.884	0.884	0.883	0.883	0.881	0.881
4.0	0.853	0.859	0.859	0.858	0.857	0.856	0.856	0.856	0.855	0.855	0.854	0.853	0.852	0.852
4.5	0.837	0.839	0.839	0.839	0.838	0.838	0.838	0.838	0.837	0.837	0.837	0.837	0.836	0.836
5.0	0.819	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.819	0.819	0.819	0.819	0.819
5.5	0.813	0.814	0.814	0.814	0.814	0.814	0.814	0.814	0.814	0.814	0.814	0.814	0.813	0.813
6.0	0.812	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.812	0.812	0.812	0.812	0.811
6.5	0.810	0.813	0.812	0.812	0.812	0.812	0.812	0.811	0.811	0.811	0.810	0.810	0.809	0.809
7.0	0.807	0.812	0.811	0.811	0.810	0.810	0.810	0.809	0.809	0.808	0.808	0.808	0.807	0.806
7.5	0.804	0.810	0.809	0.809	0.808	0.808	0.807	0.807	0.806	0.806	0.805	0.804	0.803	0.802
8.0	0.799	0.807	0.807	0.806	0.805	0.805	0.804	0.803	0.803	0.802	0.801	0.800	0.799	0.798
8.5	0.794	0.804	0.803	0.802	0.802	0.801	0.800	0.799	0.798	0.797	0.796	0.795	0.792	0.791
9.0	0.775	0.801	0.800	0.798	0.796	0.795	0.792	0.790	0.787	0.785	0.781	0.778	0.771	0.767
9.5	0.722	0.778	0.774	0.769	0.764	0.760	0.754	0.749	0.744	0.739	0.733	0.727	0.716	0.710
10.0	0.657	0.731	0.725	0.719	0.712	0.706	0.700	0.693	0.686	0.680	0.672	0.665	0.649	0.641
10.5	0.582	0.676	0.669	0.662	0.654	0.647	0.638	0.629	0.620	0.611	0.601	0.592	0.571	0.561
11.0	0.504	0.622	0.612	0.603	0.593	0.584	0.573	0.561	0.550	0.539	0.527	0.516	0.493	0.482
11.5	0.430	0.561	0.548	0.536	0.524	0.512	0.499	0.487	0.475	0.462	0.452	0.441	0.421	0.411
12.0	0.370	0.494	0.481	0.468	0.455	0.442	0.431	0.420	0.409	0.398	0.389	0.380	0.362	0.354
12.5	0.322	0.429	0.417	0.406	0.394	0.383	0.373	0.364	0.354	0.345	0.337	0.330	0.315	0.308
13.0	0.283	0.374	0.364	0.354	0.344	0.334	0.326	0.318	0.310	0.302	0.296	0.289	0.277	0.271
13.5	0.250	0.329	0.320	0.311	0.303	0.294	0.287	0.281	0.274	0.267	0.261	0.256	0.245	0.240
14.0	0.223	0.290	0.283	0.276	0.268	0.261	0.255	0.249	0.243	0.238	0.233	0.228	0.219	0.214
14.5	0.200	0.259	0.252	0.246	0.240	0.233	0.228	0.223	0.218	0.213	0.208	0.204	0.196	0.192
15.0	0.180	0.232	0.226	0.221	0.215	0.209	0.205	0.200	0.196	0.192	0.188	0.184	0.177	0.173
15.5	0.163	0.209	0.204	0.199	0.194	0.189	0.185	0.181	0.177	0.173	0.170	0.167	0.160	0.157
16.0	0.148	0.189	0.185	0.181	0.176	0.172	0.168	0.165	0.161	0.157	0.154	0.151	0.146	0.143
16.5	0.135	0.172	0.168	0.164	0.160	0.156	0.153	0.150	0.147	0.144	0.141	0.138	0.133	0.131
17.0	0.124	0.156	0.153	0.149	0.146	0.142	0.140	0.137	0.134	0.131	0.129	0.126	0.122	0.120
17.5	0.113	0.140	0.137	0.134	0.131	0.128	0.126	0.123	0.121	0.119	0.117	0.115	0.111	0.109
18.0	0.100	0.123	0.121	0.118	0.116	0.113	0.111	0.109	0.107	0.105	0.104	0.102	0.099	0.097
18.5	0.089	0.109	0.107	0.105	0.102	0.100	0.098	0.097	0.095	0.093	0.092	0.090	0.087	0.086
19.0	0.078	0.096	0.094	0.092	0.090	0.088	0.087	0.085	0.084	0.082	0.081	0.080	0.077	0.076
19.5	0.070	0.085	0.083	0.082	0.080	0.078	0.077	0.076	0.074	0.073	0.072	0.071	0.069	0.068
20.0	0.062	0.075	0.074	0.072	0.071	0.069	0.068	0.067	0.066	0.065	0.064	0.063	0.061	0.060
20.5	0.054	0.066	0.065	0.063	0.062	0.061	0.060	0.059	0.058	0.057	0.056	0.055	0.054	0.053
21.0	0.048	0.058	0.057	0.056	0.055	0.054	0.053	0.052	0.051	0.050	0.050	0.049	0.047	0.047
21.5	0.042	0.051	0.050	0.049	0.048	0.047	0.047	0.046	0.045	0.044	0.044	0.043	0.042	0.041
22.0	0.037	0.045	0.044	0.043	0.042	0.041	0.041	0.040	0.040	0.039	0.038	0.038	0.037	0.036
22.5	0.033	0.039	0.038	0.038	0.037	0.036	0.036	0.035	0.035	0.034	0.034	0.033	0.032	0.032
23.0	0.029	0.034	0.033	0.033	0.032	0.032	0.031	0.031	0.030	0.030	0.029	0.029	0.028	0.028
23.5	0.025	0.029	0.029	0.028	0.028	0.028	0.027	0.027	0.026	0.026	0.026	0.025	0.025	0.024
24.0	0.022	0.025	0.025	0.024	0.024	0.024	0.023	0.023	0.023	0.022	0.022	0.022	0.022	0.021

Original Instruction: T05 0107-3707 VER 00

T05 0107-3707 Ver 00 - Approved- Exported from DMS: 2021-07-08 by FRPIC



### 6.3 Sound Curves, Mode PO6200/PO6200-0S

Sound Power Level at Hub Height		
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>	
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Mode PO6200 (Blades with serrated trailing edge)	Sound Power Level at Hub Height [dBA] Mode PO6200-0S (Blades without serrated trailing edge)
3	93.9	96.7
4	94.1	96.9
5	94.3	97.1
6	96.2	99.0
7	99.2	102.0
8	102.0	104.8
9	104.3	107.1
10	104.8	107.6
11	104.8	107.6
12	104.8	107.6
13	104.8	107.6
14	104.8	107.6
15	104.8	107.6
16	104.8	107.6
17	104.8	107.6
18	104.8	107.6
19	104.8	107.6
20	104.8	107.6



## 7 Power Curves, Ct Values and Sound Curves, Sound Optimized Modes

### 7.1 Power Curves, Sound Optimized Mode SO2

Wind speed [m/s]	Air density [kg/m <sup>3</sup> ]													
	1.225	0.950	0.975	1.000	1.025	1.050	1.075	1.100	1.125	1.150	1.175	1.200	1.250	1.275
3.0	27	9	10	12	13	14	16	18	20	21	23	25	29	32
3.5	144	91	95	100	105	110	115	120	125	129	134	139	149	153
4.0	289	205	212	220	228	235	243	251	258	266	274	281	297	304
4.5	464	341	352	363	375	386	397	408	419	430	441	452	475	486
5.0	669	502	517	532	547	563	578	593	608	624	639	654	685	700
5.5	919	693	714	734	755	775	796	816	837	857	878	898	939	960
6.0	1219	925	952	979	1005	1032	1059	1086	1113	1140	1166	1193	1246	1272
6.5	1574	1201	1235	1269	1303	1337	1371	1405	1439	1473	1507	1540	1608	1642
7.0	1991	1525	1568	1610	1653	1695	1737	1780	1822	1864	1906	1948	2033	2075
7.5	2461	1892	1944	1995	2047	2099	2151	2203	2255	2306	2358	2410	2513	2564
8.0	2983	2299	2362	2424	2486	2549	2611	2673	2735	2797	2859	2921	3044	3106
8.5	3530	2729	2802	2876	2949	3022	3095	3168	3241	3314	3386	3458	3601	3672
9.0	4079	3173	3257	3342	3426	3511	3594	3677	3760	3843	3922	4001	4153	4226
9.5	4500	3611	3706	3800	3895	3989	4071	4152	4234	4316	4377	4438	4546	4592
10.0	4745	4028	4120	4212	4304	4396	4457	4518	4579	4640	4675	4710	4766	4787
10.5	4860	4381	4453	4526	4599	4672	4707	4743	4779	4815	4830	4845	4869	4877
11.0	4928	4650	4700	4750	4800	4851	4866	4881	4896	4911	4917	4923	4931	4934
11.5	4972	4824	4851	4878	4905	4932	4940	4947	4955	4963	4966	4969	4973	4974
12.0	5009	4928	4942	4957	4972	4986	4991	4996	5001	5006	5007	5008	5009	5008
12.5	5038	4987	4997	5006	5016	5026	5029	5032	5034	5037	5037	5037	5037	5037
13.0	5052	5016	5024	5031	5038	5045	5047	5049	5051	5052	5052	5052	5052	5052
13.5	5057	5028	5035	5041	5047	5053	5054	5055	5056	5057	5057	5057	5057	5057
14.0	5057	5033	5038	5043	5048	5053	5054	5055	5056	5057	5057	5057	5057	5057
14.5	5052	5029	5034	5038	5043	5048	5048	5049	5050	5051	5051	5051	5052	5052
15.0	5037	5012	5017	5022	5027	5032	5032	5033	5034	5035	5036	5036	5037	5038
15.5	5015	4992	4996	5000	5005	5009	5010	5011	5012	5013	5014	5014	5016	5016
16.0	4990	4968	4972	4976	4980	4984	4986	4986	4988	4988	4989	4990	4991	4992
16.5	4964	4942	4946	4950	4954	4958	4959	4960	4961	4962	4963	4964	4965	4966
17.0	4938	4916	4920	4924	4927	4931	4932	4933	4935	4936	4936	4937	4938	4939
17.5	4912	4888	4893	4897	4901	4905	4906	4907	4909	4910	4910	4911	4912	4913
18.0	4885	4864	4867	4871	4875	4879	4880	4881	4882	4882	4883	4884	4886	4886
18.5	4859	4841	4844	4847	4850	4853	4854	4855	4856	4857	4857	4858	4860	4860
19.0	4836	4818	4821	4824	4826	4829	4831	4832	4833	4834	4835	4836	4837	4837
19.5	4813	4789	4793	4796	4800	4803	4805	4806	4808	4810	4811	4812	4814	4815
20.0	4736	4690	4695	4701	4706	4711	4714	4718	4722	4726	4729	4732	4740	4744



## 7.2 Ct Values, Sound Optimized Mode SO2

Air density kg/m <sup>3</sup>														
Wind speed [m/s]	1.225	0.950	0.975	1.000	1.025	1.050	1.075	1.100	1.125	1.150	1.175	1.200	1.250	1.275
3.0	0.914	0.912	0.913	0.913	0.914	0.915	0.915	0.915	0.915	0.915	0.915	0.914	0.913	0.913
3.5	0.888	0.894	0.893	0.893	0.893	0.892	0.892	0.891	0.891	0.891	0.890	0.889	0.888	0.887
4.0	0.851	0.857	0.856	0.856	0.855	0.854	0.854	0.853	0.853	0.852	0.852	0.852	0.851	0.850
4.5	0.822	0.823	0.823	0.823	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822
5.0	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801
5.5	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797
6.0	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797
6.5	0.798	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.798	0.798	0.798	0.798	0.798
7.0	0.801	0.804	0.804	0.803	0.803	0.803	0.803	0.803	0.802	0.802	0.802	0.802	0.801	0.801
7.5	0.796	0.798	0.798	0.798	0.798	0.798	0.797	0.797	0.797	0.797	0.796	0.796	0.795	0.795
8.0	0.784	0.787	0.787	0.786	0.786	0.786	0.786	0.785	0.785	0.785	0.784	0.784	0.783	0.783
8.5	0.747	0.751	0.750	0.750	0.750	0.749	0.749	0.749	0.748	0.748	0.748	0.747	0.746	0.745
9.0	0.707	0.717	0.717	0.717	0.716	0.716	0.715	0.715	0.714	0.713	0.711	0.709	0.703	0.699
9.5	0.634	0.683	0.682	0.681	0.680	0.679	0.675	0.670	0.665	0.660	0.651	0.643	0.624	0.613
10.0	0.541	0.631	0.627	0.623	0.619	0.615	0.606	0.597	0.588	0.578	0.566	0.554	0.528	0.516
10.5	0.455	0.566	0.559	0.552	0.544	0.537	0.525	0.513	0.502	0.490	0.478	0.466	0.444	0.433
11.0	0.385	0.500	0.490	0.481	0.471	0.461	0.450	0.438	0.427	0.415	0.405	0.395	0.376	0.368
11.5	0.332	0.437	0.427	0.416	0.406	0.395	0.386	0.376	0.366	0.357	0.348	0.340	0.325	0.317
12.0	0.289	0.382	0.372	0.363	0.353	0.343	0.335	0.327	0.319	0.311	0.303	0.296	0.283	0.277
12.5	0.254	0.335	0.326	0.318	0.309	0.301	0.294	0.287	0.280	0.273	0.267	0.261	0.249	0.244
13.0	0.225	0.294	0.287	0.280	0.272	0.265	0.259	0.253	0.247	0.241	0.235	0.230	0.220	0.216
13.5	0.200	0.260	0.254	0.248	0.241	0.235	0.230	0.224	0.219	0.214	0.209	0.205	0.196	0.192
14.0	0.179	0.232	0.226	0.220	0.215	0.209	0.205	0.200	0.195	0.191	0.187	0.183	0.175	0.172
14.5	0.160	0.207	0.202	0.197	0.192	0.187	0.183	0.179	0.175	0.171	0.167	0.164	0.157	0.154
15.0	0.144	0.185	0.181	0.177	0.172	0.168	0.164	0.161	0.157	0.153	0.150	0.147	0.142	0.139
15.5	0.130	0.167	0.163	0.159	0.155	0.151	0.148	0.145	0.142	0.138	0.136	0.133	0.128	0.125
16.0	0.118	0.151	0.147	0.144	0.140	0.137	0.134	0.131	0.128	0.125	0.123	0.120	0.116	0.114
16.5	0.107	0.136	0.133	0.130	0.127	0.124	0.122	0.119	0.116	0.114	0.112	0.109	0.105	0.103
17.0	0.098	0.124	0.121	0.119	0.116	0.113	0.111	0.108	0.106	0.104	0.102	0.100	0.096	0.094
17.5	0.090	0.114	0.111	0.109	0.106	0.104	0.102	0.100	0.097	0.095	0.094	0.092	0.088	0.087
18.0	0.083	0.104	0.102	0.100	0.097	0.095	0.093	0.091	0.089	0.087	0.086	0.084	0.081	0.080
18.5	0.076	0.096	0.094	0.092	0.090	0.087	0.086	0.084	0.082	0.080	0.079	0.078	0.075	0.073
19.0	0.070	0.088	0.086	0.084	0.082	0.080	0.079	0.077	0.075	0.074	0.073	0.071	0.069	0.067
19.5	0.065	0.081	0.079	0.078	0.076	0.074	0.073	0.071	0.070	0.068	0.067	0.066	0.064	0.063
20.0	0.060	0.074	0.072	0.071	0.069	0.068	0.067	0.066	0.064	0.063	0.062	0.061	0.059	0.058



### 7.3 Sound Curves, Sound Optimized Mode SO2

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO2 (Blades with serrated trailing edge)
3	93.5
4	93.7
5	94.3
6	97.3
7	100.2
8	102.0
9	102.0
10	102.0
11	102.0
12	102.0
13	102.0
14	102.0
15	102.0
16	102.0
17	102.0
18	102.0
19	102.0
20	102.0



### 7.4 Power Curves, Sound Optimized Mode SO3

Air density [kg/m <sup>3</sup> ]														
Wind speed [m/s]	1.225	0.950	0.975	1.000	1.025	1.050	1.075	1.100	1.125	1.150	1.175	1.200	1.250	1.275
3.0	27	9	10	12	13	14	16	18	20	21	23	25	29	32
3.5	144	91	95	100	105	110	115	120	125	129	134	139	149	153
4.0	289	205	212	220	228	235	243	251	258	266	274	281	297	304
4.5	464	341	352	363	375	386	397	408	419	430	441	452	475	486
5.0	669	502	517	532	547	563	578	593	608	624	639	654	685	700
5.5	919	693	714	734	755	775	796	816	837	857	878	898	939	960
6.0	1219	925	952	979	1005	1032	1059	1086	1113	1140	1166	1193	1246	1272
6.5	1574	1201	1235	1269	1303	1337	1371	1405	1439	1473	1507	1540	1608	1642
7.0	1990	1525	1567	1610	1652	1694	1737	1779	1821	1864	1906	1948	2032	2074
7.5	2453	1886	1937	1989	2041	2092	2144	2196	2247	2299	2350	2402	2504	2556
8.0	2953	2277	2339	2400	2462	2524	2585	2647	2708	2770	2831	2892	3014	3076
8.5	3458	2674	2745	2817	2889	2960	3032	3103	3174	3246	3317	3387	3528	3598
9.0	3940	3059	3140	3222	3303	3385	3465	3546	3626	3706	3784	3862	4012	4083
9.5	4306	3423	3514	3604	3694	3784	3866	3948	4031	4113	4177	4242	4353	4400
10.0	4532	3760	3853	3945	4037	4130	4199	4268	4337	4406	4448	4490	4557	4582
10.5	4659	4070	4154	4237	4320	4403	4451	4498	4545	4592	4615	4637	4671	4683
11.0	4742	4331	4398	4466	4534	4602	4629	4657	4685	4713	4723	4733	4748	4754
11.5	4800	4532	4580	4628	4676	4723	4738	4753	4768	4782	4788	4794	4803	4806
12.0	4829	4647	4680	4714	4747	4780	4789	4799	4809	4818	4822	4826	4830	4832
12.5	4839	4698	4725	4751	4777	4803	4810	4817	4824	4831	4834	4836	4840	4840
13.0	4841	4724	4745	4767	4789	4811	4817	4823	4829	4835	4837	4839	4842	4842
13.5	4841	4731	4752	4774	4795	4817	4822	4827	4833	4838	4839	4840	4842	4842
14.0	4840	4746	4765	4783	4801	4820	4824	4828	4833	4837	4838	4839	4840	4841
14.5	4834	4754	4770	4786	4801	4817	4820	4824	4828	4831	4832	4833	4835	4835
15.0	4819	4744	4758	4773	4787	4801	4805	4808	4812	4816	4817	4818	4820	4820
15.5	4798	4728	4741	4754	4767	4781	4784	4788	4791	4794	4796	4797	4798	4799
16.0	4773	4707	4719	4732	4744	4756	4759	4763	4766	4770	4771	4772	4774	4774
16.5	4746	4685	4696	4708	4719	4730	4734	4737	4740	4743	4744	4745	4747	4748
17.0	4720	4664	4674	4684	4695	4705	4708	4710	4713	4716	4717	4718	4720	4720
17.5	4693	4637	4648	4658	4668	4679	4681	4684	4687	4690	4691	4692	4694	4694
18.0	4666	4620	4629	4637	4646	4654	4656	4659	4661	4664	4664	4665	4667	4668
18.5	4640	4604	4611	4617	4623	4630	4632	4634	4636	4638	4638	4639	4640	4641
19.0	4617	4584	4589	4595	4600	4606	4608	4610	4612	4614	4615	4616	4618	4618
19.5	4598	4574	4578	4582	4586	4590	4592	4593	4595	4596	4597	4597	4598	4599
20.0	4575	4548	4552	4555	4559	4563	4565	4567	4569	4571	4572	4573	4576	4577

Original Instruction: T05 0107-3707 VER 00

T05 0107-3707 Ver 00 - Approved- Exported from DMS: 2021-07-08 by FRPIC



### 7.5 Ct Values, Sound Optimized Mode SO3

Air density kg/m <sup>3</sup>														
Wind speed [m/s]	1.225	0.950	0.975	1.000	1.025	1.050	1.075	1.100	1.125	1.150	1.175	1.200	1.250	1.275
3.0	0.914	0.912	0.913	0.913	0.914	0.915	0.915	0.915	0.915	0.915	0.915	0.914	0.913	0.913
3.5	0.888	0.894	0.893	0.893	0.893	0.892	0.892	0.891	0.891	0.891	0.890	0.889	0.888	0.887
4.0	0.851	0.857	0.856	0.856	0.855	0.854	0.854	0.853	0.853	0.852	0.852	0.852	0.851	0.850
4.5	0.822	0.823	0.823	0.823	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822
5.0	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801
5.5	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797
6.0	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797
6.5	0.798	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.798	0.798	0.798	0.798	0.798	0.798
7.0	0.801	0.803	0.803	0.803	0.803	0.802	0.802	0.802	0.802	0.802	0.801	0.801	0.801	0.800
7.5	0.792	0.794	0.794	0.794	0.794	0.794	0.793	0.793	0.793	0.793	0.792	0.792	0.792	0.791
8.0	0.769	0.772	0.771	0.771	0.771	0.771	0.770	0.770	0.770	0.770	0.769	0.769	0.768	0.768
8.5	0.720	0.723	0.723	0.722	0.722	0.722	0.722	0.721	0.721	0.721	0.720	0.720	0.719	0.718
9.0	0.670	0.676	0.676	0.676	0.676	0.675	0.675	0.675	0.674	0.674	0.672	0.671	0.667	0.663
9.5	0.594	0.622	0.621	0.621	0.621	0.620	0.618	0.616	0.613	0.611	0.605	0.600	0.585	0.576
10.0	0.508	0.562	0.560	0.559	0.557	0.556	0.551	0.545	0.540	0.535	0.526	0.517	0.497	0.487
10.5	0.431	0.506	0.502	0.499	0.495	0.491	0.483	0.476	0.468	0.460	0.450	0.440	0.421	0.412
11.0	0.368	0.454	0.448	0.442	0.436	0.431	0.422	0.413	0.404	0.395	0.386	0.377	0.360	0.352
11.5	0.319	0.405	0.397	0.390	0.383	0.376	0.367	0.359	0.350	0.342	0.334	0.327	0.312	0.305
12.0	0.278	0.357	0.349	0.342	0.335	0.328	0.320	0.313	0.305	0.298	0.291	0.285	0.272	0.266
12.5	0.244	0.313	0.306	0.300	0.293	0.286	0.280	0.274	0.267	0.261	0.255	0.249	0.239	0.234
13.0	0.215	0.276	0.270	0.264	0.258	0.252	0.246	0.241	0.235	0.230	0.225	0.220	0.211	0.206
13.5	0.191	0.244	0.239	0.234	0.229	0.223	0.219	0.214	0.209	0.204	0.200	0.195	0.187	0.183
14.0	0.171	0.218	0.213	0.208	0.204	0.199	0.195	0.191	0.186	0.182	0.178	0.174	0.167	0.164
14.5	0.153	0.195	0.191	0.187	0.183	0.178	0.175	0.171	0.167	0.163	0.160	0.156	0.150	0.147
15.0	0.138	0.175	0.171	0.168	0.164	0.160	0.157	0.153	0.150	0.147	0.144	0.141	0.135	0.133
15.5	0.124	0.158	0.154	0.151	0.148	0.144	0.141	0.138	0.135	0.132	0.130	0.127	0.122	0.120
16.0	0.113	0.143	0.140	0.137	0.134	0.130	0.128	0.125	0.122	0.120	0.117	0.115	0.111	0.109
16.5	0.102	0.129	0.127	0.124	0.121	0.118	0.116	0.114	0.111	0.109	0.107	0.105	0.101	0.099
17.0	0.093	0.118	0.115	0.113	0.110	0.108	0.106	0.103	0.101	0.099	0.097	0.095	0.092	0.090
17.5	0.086	0.108	0.106	0.104	0.101	0.099	0.097	0.095	0.093	0.091	0.089	0.088	0.084	0.083
18.0	0.079	0.099	0.097	0.095	0.093	0.091	0.089	0.087	0.085	0.084	0.082	0.080	0.077	0.076
18.5	0.073	0.091	0.089	0.087	0.085	0.084	0.082	0.080	0.079	0.077	0.075	0.074	0.071	0.070
19.0	0.067	0.084	0.082	0.080	0.078	0.077	0.075	0.074	0.072	0.071	0.069	0.068	0.066	0.064
19.5	0.062	0.078	0.076	0.074	0.073	0.071	0.070	0.068	0.067	0.065	0.064	0.063	0.061	0.060
20.0	0.057	0.072	0.070	0.069	0.067	0.066	0.064	0.063	0.062	0.061	0.060	0.058	0.056	0.055





## 7.6 Sound Curves, Sound Optimized Mode SO3

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO3 (Blades with serrated trailing edge)
3	93.5
4	93.7
5	94.3
6	97.3
7	100.2
8	101.0
9	101.0
10	101.0
11	101.0
12	101.0
13	101.0
14	101.0
15	101.0
16	101.0
17	101.0
18	101.0
19	101.0
20	101.0



## 7.7 Power Curves, Sound Optimized Mode SO4

Air density [kg/m <sup>3</sup> ]														
Wind speed [m/s]	1.225	0.950	0.975	1.000	1.025	1.050	1.075	1.100	1.125	1.150	1.175	1.200	1.250	1.275
3.0	27	9	10	12	13	14	16	18	20	21	23	25	29	32
3.5	144	91	95	100	105	110	115	120	125	129	134	139	149	153
4.0	289	205	212	220	228	235	243	251	258	266	274	281	297	304
4.5	464	341	352	363	375	386	397	408	419	430	441	452	475	486
5.0	669	502	517	532	547	563	578	593	608	624	639	654	685	700
5.5	919	693	714	734	755	775	796	816	837	857	878	898	940	960
6.0	1220	926	953	979	1006	1033	1060	1087	1114	1140	1167	1194	1247	1274
6.5	1575	1201	1235	1269	1303	1337	1371	1405	1439	1473	1507	1541	1608	1642
7.0	1986	1522	1564	1606	1649	1691	1733	1776	1818	1860	1902	1944	2028	2070
7.5	2437	1874	1925	1977	2028	2079	2131	2182	2233	2284	2335	2386	2488	2539
8.0	2909	2243	2304	2365	2426	2486	2547	2607	2668	2728	2789	2849	2970	3030
8.5	3367	2602	2672	2742	2811	2881	2951	3020	3090	3160	3229	3298	3435	3504
9.0	3783	2932	3011	3089	3167	3246	3323	3401	3478	3556	3632	3708	3854	3924
9.5	4086	3219	3304	3390	3475	3560	3641	3722	3803	3884	3951	4019	4138	4190
10.0	4294	3496	3586	3675	3764	3854	3927	4001	4074	4147	4196	4245	4327	4359
10.5	4434	3770	3855	3941	4027	4113	4171	4228	4286	4344	4374	4404	4451	4469
11.0	4519	3996	4072	4148	4224	4299	4342	4384	4427	4469	4486	4502	4527	4536
11.5	4548	4117	4185	4254	4322	4390	4421	4453	4484	4515	4526	4537	4554	4559
12.0	4556	4182	4244	4306	4368	4430	4455	4480	4505	4530	4539	4548	4560	4564
12.5	4559	4228	4285	4341	4398	4454	4475	4496	4517	4538	4545	4552	4563	4566
13.0	4562	4274	4324	4375	4425	4476	4492	4509	4526	4543	4549	4555	4565	4568
13.5	4566	4308	4352	4396	4440	4484	4501	4517	4534	4550	4555	4560	4568	4570
14.0	4566	4347	4385	4423	4461	4500	4513	4526	4540	4553	4558	4562	4568	4570
14.5	4561	4372	4405	4438	4471	4504	4516	4528	4539	4551	4554	4558	4563	4564
15.0	4547	4374	4404	4434	4464	4494	4504	4515	4526	4536	4540	4544	4549	4550
15.5	4526	4368	4396	4423	4450	4477	4487	4497	4506	4516	4519	4523	4527	4529
16.0	4502	4360	4384	4409	4433	4458	4466	4475	4484	4492	4496	4498	4503	4504
16.5	4475	4352	4373	4394	4415	4436	4444	4452	4460	4467	4470	4473	4476	4478
17.0	4449	4347	4364	4382	4399	4417	4423	4430	4436	4442	4445	4447	4450	4452
17.5	4424	4322	4340	4358	4377	4395	4400	4406	4412	4418	4420	4422	4425	4426
18.0	4397	4319	4333	4347	4361	4375	4379	4384	4388	4392	4394	4396	4398	4399
18.5	4371	4314	4324	4334	4344	4354	4358	4361	4364	4367	4368	4370	4371	4372
19.0	4348	4303	4310	4318	4326	4333	4336	4339	4341	4344	4345	4346	4348	4349
19.5	4329	4298	4304	4309	4314	4320	4321	4323	4325	4327	4328	4328	4330	4330
20.0	4316	4296	4299	4303	4307	4310	4312	4313	4314	4315	4316	4316	4317	4317



### 7.8 Ct Values, Sound Optimized Mode SO4

Air density kg/m <sup>3</sup>														
Wind speed [m/s]	1.225	0.950	0.975	1.000	1.025	1.050	1.075	1.100	1.125	1.150	1.175	1.200	1.250	1.275
3.0	<b>0.914</b>	0.912	0.913	0.913	0.914	0.915	0.915	0.915	0.915	0.915	0.915	0.914	0.913	0.913
3.5	<b>0.888</b>	0.894	0.893	0.893	0.893	0.892	0.892	0.891	0.891	0.891	0.890	0.889	0.888	0.887
4.0	<b>0.851</b>	0.857	0.856	0.856	0.855	0.854	0.854	0.853	0.853	0.852	0.852	0.852	0.851	0.850
4.5	<b>0.822</b>	0.823	0.823	0.823	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822
5.0	<b>0.801</b>	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801
5.5	<b>0.798</b>	0.797	0.797	0.797	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798
6.0	<b>0.803</b>	0.804	0.804	0.804	0.804	0.804	0.804	0.804	0.804	0.804	0.803	0.803	0.803	0.803
6.5	<b>0.802</b>	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.802	0.802	0.802	0.802	0.802
7.0	<b>0.798</b>	0.800	0.800	0.800	0.800	0.800	0.800	0.799	0.799	0.799	0.799	0.799	0.798	0.798
7.5	<b>0.784</b>	0.786	0.786	0.786	0.786	0.786	0.785	0.785	0.785	0.785	0.785	0.784	0.784	0.784
8.0	<b>0.749</b>	0.751	0.751	0.751	0.751	0.750	0.750	0.750	0.750	0.749	0.749	0.749	0.748	0.748
8.5	<b>0.692</b>	0.694	0.694	0.694	0.694	0.693	0.693	0.693	0.693	0.692	0.692	0.692	0.691	0.691
9.0	<b>0.630</b>	0.633	0.633	0.633	0.633	0.632	0.632	0.632	0.632	0.631	0.631	0.630	0.628	0.626
9.5	<b>0.549</b>	0.563	0.563	0.563	0.563	0.563	0.562	0.561	0.560	0.559	0.555	0.552	0.543	0.537
10.0	<b>0.472</b>	0.504	0.504	0.503	0.503	0.502	0.499	0.496	0.493	0.490	0.484	0.478	0.464	0.456
10.5	<b>0.405</b>	0.456	0.454	0.452	0.450	0.448	0.443	0.438	0.433	0.428	0.420	0.413	0.397	0.389
11.0	<b>0.349</b>	0.410	0.407	0.403	0.400	0.396	0.390	0.384	0.378	0.371	0.364	0.356	0.341	0.334
11.5	<b>0.301</b>	0.361	0.357	0.353	0.349	0.346	0.339	0.333	0.327	0.321	0.314	0.308	0.295	0.288
12.0	<b>0.262</b>	0.316	0.312	0.309	0.305	0.301	0.296	0.290	0.284	0.279	0.273	0.267	0.256	0.251
12.5	<b>0.229</b>	0.278	0.275	0.271	0.268	0.264	0.259	0.254	0.249	0.244	0.239	0.234	0.225	0.220
13.0	<b>0.202</b>	0.247	0.244	0.240	0.237	0.233	0.229	0.224	0.220	0.215	0.211	0.207	0.198	0.194
13.5	<b>0.180</b>	0.221	0.218	0.214	0.211	0.207	0.203	0.200	0.196	0.192	0.188	0.184	0.177	0.173
14.0	<b>0.161</b>	0.199	0.195	0.192	0.189	0.186	0.182	0.178	0.175	0.171	0.168	0.164	0.158	0.155
14.5	<b>0.145</b>	0.179	0.176	0.173	0.170	0.167	0.164	0.160	0.157	0.154	0.151	0.148	0.142	0.139
15.0	<b>0.130</b>	0.161	0.159	0.156	0.153	0.150	0.147	0.144	0.141	0.138	0.136	0.133	0.128	0.125
15.5	<b>0.118</b>	0.146	0.143	0.141	0.138	0.135	0.133	0.130	0.127	0.125	0.122	0.120	0.115	0.113
16.0	<b>0.106</b>	0.132	0.130	0.127	0.125	0.122	0.120	0.118	0.115	0.113	0.111	0.109	0.104	0.102
16.5	<b>0.097</b>	0.120	0.118	0.116	0.114	0.111	0.109	0.107	0.105	0.103	0.101	0.099	0.095	0.093
17.0	<b>0.088</b>	0.110	0.108	0.106	0.104	0.102	0.100	0.098	0.096	0.094	0.092	0.090	0.087	0.085
17.5	<b>0.081</b>	0.101	0.099	0.097	0.095	0.093	0.092	0.090	0.088	0.086	0.084	0.083	0.080	0.078
18.0	<b>0.075</b>	0.093	0.091	0.089	0.088	0.086	0.084	0.082	0.081	0.079	0.077	0.076	0.073	0.072
18.5	<b>0.069</b>	0.086	0.084	0.082	0.081	0.079	0.077	0.076	0.074	0.073	0.071	0.070	0.067	0.066
19.0	<b>0.063</b>	0.079	0.077	0.076	0.074	0.072	0.071	0.070	0.068	0.067	0.065	0.064	0.062	0.061
19.5	<b>0.058</b>	0.073	0.072	0.070	0.069	0.067	0.066	0.064	0.063	0.062	0.061	0.060	0.057	0.056
20.0	<b>0.054</b>	0.068	0.067	0.065	0.064	0.062	0.061	0.060	0.059	0.057	0.056	0.055	0.053	0.052



### 7.9 Sound Curves, Sound Optimized Mode SO4

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO4 (Blades with serrated trailing edge)
3	93.5
4	93.7
5	94.3
6	97.3
7	99.7
8	100.0
9	100.0
10	100.0
11	100.0
12	100.0
13	100.0
14	100.0
15	100.0
16	100.0
17	100.0
18	100.0
19	100.0
20	100.0

Original Instruction: T05 0107-3707 VER 00

T05 0107-3707 Ver 00 - Approved- Exported from DMS: 2021-07-08 by FRPIC



### 7.10 Power Curves, Sound Optimized Mode S05

Wind speed [m/s]	Air density [kg/m <sup>3</sup> ]													
	1.225	0.950	0.975	1.000	1.025	1.050	1.075	1.100	1.125	1.150	1.175	1.200	1.250	1.275
3.0	27	9	10	12	13	14	16	18	20	21	23	25	29	32
3.5	144	91	95	100	105	110	115	120	125	129	134	139	149	153
4.0	289	205	212	220	228	235	243	251	258	266	274	281	297	304
4.5	464	341	352	363	375	386	397	408	419	430	441	452	475	486
5.0	669	502	517	532	547	563	578	593	608	624	639	654	685	700
5.5	919	693	714	734	755	775	796	816	837	857	878	899	940	960
6.0	1220	926	952	979	1006	1032	1059	1086	1113	1140	1166	1193	1247	1274
6.5	1570	1198	1232	1266	1299	1333	1367	1401	1435	1469	1502	1536	1603	1637
7.0	1968	1509	1551	1593	1635	1677	1718	1760	1802	1844	1885	1927	2010	2051
7.5	2386	1835	1886	1936	1986	2036	2086	2136	2186	2236	2286	2336	2436	2486
8.0	2788	2147	2205	2264	2322	2380	2439	2497	2555	2613	2671	2730	2846	2904
8.5	3160	2438	2503	2569	2635	2701	2767	2833	2898	2964	3029	3095	3225	3290
9.0	3480	2693	2765	2837	2909	2980	3052	3124	3195	3267	3338	3409	3550	3620
9.5	3719	2891	2968	3044	3121	3198	3274	3350	3425	3501	3574	3646	3783	3848
10.0	3888	3047	3127	3208	3288	3369	3447	3525	3603	3681	3750	3819	3943	3998
10.5	3984	3155	3238	3320	3403	3486	3564	3642	3720	3798	3860	3922	4030	4075
11.0	4029	3234	3319	3404	3488	3573	3646	3719	3792	3864	3919	3974	4071	4112
11.5	4069	3302	3386	3471	3556	3641	3710	3779	3848	3917	3968	4018	4105	4141
12.0	4106	3375	3458	3542	3625	3708	3773	3838	3903	3968	4014	4060	4135	4164
12.5	4138	3455	3536	3617	3698	3779	3839	3899	3959	4019	4059	4099	4161	4184
13.0	4162	3531	3608	3686	3764	3841	3896	3952	4007	4063	4096	4129	4180	4198
13.5	4171	3594	3666	3738	3810	3882	3932	3983	4034	4084	4113	4142	4188	4205
14.0	4185	3652	3720	3789	3857	3926	3972	4019	4065	4111	4136	4161	4200	4214
14.5	4199	3713	3778	3842	3907	3972	4013	4054	4096	4137	4158	4178	4211	4223
15.0	4209	3773	3834	3896	3957	4018	4053	4088	4124	4159	4176	4192	4218	4228
15.5	4219	3839	3895	3951	4007	4063	4092	4121	4150	4180	4193	4206	4227	4234
16.0	4228	3909	3958	4007	4056	4105	4128	4152	4175	4198	4208	4218	4234	4240
16.5	4237	3978	4019	4060	4102	4143	4161	4178	4196	4213	4221	4229	4241	4246
17.0	4244	4041	4074	4107	4140	4174	4187	4200	4213	4226	4232	4238	4246	4249
17.5	4246	4074	4102	4130	4157	4185	4197	4209	4221	4233	4237	4242	4249	4251
18.0	4251	4122	4144	4166	4188	4209	4218	4226	4234	4242	4245	4248	4252	4253
18.5	4253	4164	4179	4195	4211	4226	4232	4237	4242	4248	4250	4251	4254	4254
19.0	4253	4189	4200	4211	4222	4234	4237	4241	4245	4248	4250	4251	4253	4254
19.5	4254	4212	4220	4227	4234	4242	4244	4247	4249	4252	4253	4253	4254	4255
20.0	4255	4228	4232	4237	4242	4247	4249	4250	4252	4254	4254	4255	4255	4255



**7.11 Ct Values, Sound Optimized Mode SO5**

Air density kg/m <sup>3</sup>														
Wind speed [m/s]	1.225	0.950	0.975	1.000	1.025	1.050	1.075	1.100	1.125	1.150	1.175	1.200	1.250	1.275
3.0	<b>0.914</b>	0.912	0.913	0.913	0.914	0.915	0.915	0.915	0.915	0.915	0.915	0.914	0.913	0.913
3.5	<b>0.888</b>	0.894	0.893	0.893	0.893	0.892	0.892	0.891	0.891	0.891	0.890	0.889	0.888	0.887
4.0	<b>0.851</b>	0.857	0.856	0.856	0.855	0.854	0.854	0.853	0.853	0.852	0.852	0.852	0.851	0.850
4.5	<b>0.822</b>	0.823	0.823	0.823	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822
5.0	<b>0.801</b>	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801
5.5	<b>0.799</b>	0.798	0.798	0.798	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799
6.0	<b>0.803</b>	0.803	0.803	0.804	0.804	0.804	0.804	0.803	0.803	0.803	0.803	0.803	0.803	0.803
6.5	<b>0.797</b>	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.797	0.797	0.797	0.797	0.797
7.0	<b>0.786</b>	0.788	0.788	0.787	0.787	0.787	0.787	0.787	0.787	0.787	0.787	0.786	0.786	0.786
7.5	<b>0.754</b>	0.756	0.756	0.756	0.756	0.756	0.756	0.755	0.755	0.755	0.755	0.755	0.754	0.754
8.0	<b>0.703</b>	0.705	0.705	0.705	0.704	0.704	0.704	0.704	0.704	0.704	0.703	0.703	0.703	0.703
8.5	<b>0.633</b>	0.635	0.635	0.635	0.634	0.634	0.634	0.634	0.634	0.633	0.633	0.633	0.633	0.633
9.0	<b>0.554</b>	0.555	0.555	0.555	0.555	0.555	0.554	0.554	0.554	0.554	0.554	0.554	0.553	0.553
9.5	<b>0.481</b>	0.484	0.484	0.484	0.483	0.483	0.483	0.483	0.483	0.483	0.482	0.481	0.479	0.477
10.0	<b>0.416</b>	0.422	0.422	0.422	0.422	0.422	0.421	0.421	0.420	0.420	0.419	0.417	0.413	0.409
10.5	<b>0.358</b>	0.367	0.367	0.367	0.367	0.367	0.366	0.365	0.365	0.364	0.362	0.360	0.354	0.350
11.0	<b>0.307</b>	0.320	0.320	0.320	0.320	0.319	0.318	0.317	0.316	0.315	0.312	0.310	0.304	0.301
11.5	<b>0.267</b>	0.281	0.281	0.281	0.280	0.280	0.279	0.277	0.276	0.275	0.272	0.270	0.264	0.261
12.0	<b>0.235</b>	0.250	0.249	0.249	0.249	0.248	0.247	0.245	0.244	0.242	0.240	0.237	0.232	0.228
12.5	<b>0.208</b>	0.224	0.224	0.223	0.222	0.222	0.220	0.219	0.217	0.215	0.213	0.210	0.205	0.202
13.0	<b>0.185</b>	0.203	0.202	0.201	0.200	0.199	0.198	0.196	0.194	0.192	0.190	0.187	0.182	0.179
13.5	<b>0.165</b>	0.183	0.182	0.181	0.180	0.179	0.177	0.175	0.174	0.172	0.170	0.167	0.162	0.160
14.0	<b>0.148</b>	0.166	0.165	0.164	0.163	0.162	0.160	0.158	0.157	0.155	0.153	0.150	0.146	0.143
14.5	<b>0.133</b>	0.152	0.151	0.150	0.148	0.147	0.145	0.144	0.142	0.140	0.138	0.136	0.131	0.129
15.0	<b>0.121</b>	0.139	0.138	0.137	0.136	0.134	0.133	0.131	0.129	0.127	0.125	0.123	0.119	0.117
15.5	<b>0.110</b>	0.128	0.127	0.126	0.124	0.123	0.121	0.119	0.118	0.116	0.114	0.112	0.108	0.106
16.0	<b>0.100</b>	0.119	0.117	0.116	0.115	0.113	0.111	0.110	0.108	0.106	0.104	0.102	0.099	0.097
16.5	<b>0.092</b>	0.110	0.109	0.107	0.106	0.104	0.102	0.101	0.099	0.097	0.095	0.094	0.090	0.089
17.0	<b>0.084</b>	0.103	0.101	0.099	0.098	0.096	0.094	0.093	0.091	0.089	0.088	0.086	0.083	0.081
17.5	<b>0.078</b>	0.096	0.094	0.092	0.091	0.089	0.088	0.086	0.084	0.083	0.081	0.080	0.077	0.075
18.0	<b>0.072</b>	0.089	0.088	0.086	0.084	0.083	0.081	0.080	0.078	0.076	0.075	0.074	0.071	0.070
18.5	<b>0.067</b>	0.083	0.082	0.080	0.078	0.077	0.075	0.074	0.072	0.071	0.069	0.068	0.066	0.064
19.0	<b>0.062</b>	0.077	0.076	0.074	0.072	0.071	0.069	0.068	0.067	0.065	0.064	0.063	0.061	0.060
19.5	<b>0.057</b>	0.072	0.070	0.069	0.067	0.066	0.065	0.063	0.062	0.061	0.060	0.059	0.056	0.055
20.0	<b>0.054</b>	0.067	0.066	0.064	0.063	0.061	0.060	0.059	0.058	0.057	0.056	0.055	0.053	0.052

Original Instruction: T05 0107-3707 VER 00

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**7.12 Sound Curves, Sound Optimized Mode SO5**

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO5 (Blades with serrated trailing edge)
3	93.5
4	93.7
5	94.3
6	97.2
7	99.0
8	99.0
9	99.0
10	99.0
11	99.0
12	99.0
13	99.0
14	99.0
15	99.0
16	99.0
17	99.0
18	99.0
19	99.0
20	99.0

Original Instruction: T05 0107-3707 VER 00

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**7.13 Power Curves, Sound Optimized Mode SO6**

Air density [kg/m <sup>3</sup> ]														
Wind speed [m/s]	1.225	0.950	0.975	1.000	1.025	1.050	1.075	1.100	1.125	1.150	1.175	1.200	1.250	1.275
3.0	27	9	10	12	13	14	16	18	20	21	23	25	29	32
3.5	144	91	95	100	105	110	115	120	125	129	134	139	149	153
4.0	289	205	212	220	228	235	243	251	258	266	274	281	297	304
4.5	464	341	352	363	375	386	397	408	419	430	441	452	475	486
5.0	669	502	517	532	547	563	578	593	608	624	639	654	685	700
5.5	919	693	714	734	755	775	796	817	837	858	878	899	940	960
6.0	1219	925	952	978	1005	1032	1059	1085	1112	1139	1165	1192	1245	1272
6.5	1559	1190	1224	1257	1291	1325	1358	1392	1425	1459	1492	1526	1592	1626
7.0	1928	1479	1520	1561	1602	1642	1683	1724	1765	1806	1847	1887	1969	2010
7.5	2278	1751	1799	1847	1895	1943	1991	2039	2087	2134	2182	2230	2326	2374
8.0	2603	2004	2058	2113	2168	2222	2277	2331	2386	2440	2495	2549	2658	2712
8.5	2881	2225	2285	2345	2404	2464	2524	2583	2643	2702	2762	2821	2939	2998
9.0	3097	2398	2462	2526	2590	2654	2717	2781	2845	2909	2972	3034	3157	3217
9.5	3237	2522	2588	2656	2722	2790	2856	2922	2988	3054	3115	3176	3290	3342
10.0	3324	2608	2676	2745	2814	2883	2950	3017	3083	3150	3208	3266	3369	3414
10.5	3379	2675	2745	2816	2886	2956	3023	3089	3155	3222	3274	3326	3419	3459
11.0	3412	2737	2809	2881	2952	3024	3086	3147	3209	3270	3318	3365	3449	3485
11.5	3454	2808	2879	2951	3022	3094	3152	3209	3267	3325	3368	3411	3486	3517
12.0	3492	2880	2950	3020	3090	3160	3214	3268	3322	3376	3414	3453	3517	3541
12.5	3519	2947	3014	3082	3150	3218	3268	3318	3368	3418	3451	3485	3538	3557
13.0	3538	3008	3072	3137	3201	3266	3312	3359	3406	3453	3481	3510	3554	3569
13.5	3546	3065	3124	3184	3244	3303	3346	3388	3431	3473	3498	3522	3561	3575
14.0	3561	3125	3181	3238	3294	3351	3389	3426	3464	3502	3522	3541	3573	3586
14.5	3575	3188	3240	3293	3346	3398	3431	3463	3495	3527	3543	3559	3585	3595
15.0	3588	3256	3304	3352	3400	3449	3475	3501	3527	3553	3565	3576	3595	3602
15.5	3599	3327	3369	3410	3452	3493	3513	3533	3553	3572	3581	3590	3604	3609
16.0	3607	3394	3428	3462	3496	3530	3545	3559	3573	3587	3594	3600	3610	3614
16.5	3613	3453	3479	3505	3532	3558	3568	3578	3588	3598	3603	3608	3615	3617
17.0	3617	3504	3523	3541	3560	3579	3586	3593	3601	3608	3611	3614	3618	3620
17.5	3619	3528	3543	3559	3575	3590	3596	3602	3608	3613	3615	3617	3620	3621
18.0	3621	3560	3571	3582	3593	3604	3607	3611	3614	3618	3619	3620	3622	3622
18.5	3622	3584	3592	3599	3606	3613	3615	3617	3619	3620	3621	3621	3622	3622
19.0	3622	3595	3600	3605	3610	3614	3616	3617	3619	3620	3621	3621	3622	3622
19.5	3622	3606	3609	3612	3615	3618	3619	3620	3621	3622	3622	3622	3622	3622
20.0	3622	3613	3615	3617	3618	3620	3621	3621	3622	3622	3622	3622	3622	3622

Original Instruction: T05 0107-3707 VER 00

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**7.14 Ct Values, Sound Optimized Mode SO6**

Air density kg/m <sup>3</sup>														
Wind speed [m/s]	1.225	0.950	0.975	1.000	1.025	1.050	1.075	1.100	1.125	1.150	1.175	1.200	1.250	1.275
3.0	0.914	0.912	0.913	0.913	0.914	0.915	0.915	0.915	0.915	0.915	0.915	0.914	0.913	0.913
3.5	0.888	0.894	0.893	0.893	0.893	0.892	0.892	0.891	0.891	0.890	0.890	0.889	0.888	0.887
4.0	0.851	0.857	0.856	0.856	0.855	0.854	0.854	0.853	0.853	0.852	0.852	0.852	0.851	0.850
4.5	0.822	0.823	0.823	0.823	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822
5.0	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801
5.5	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800
6.0	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802
6.5	0.789	0.789	0.789	0.789	0.789	0.789	0.789	0.789	0.789	0.789	0.789	0.789	0.788	0.788
7.0	0.757	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.757	0.757	0.757	0.757
7.5	0.702	0.704	0.704	0.703	0.703	0.703	0.703	0.703	0.703	0.703	0.703	0.703	0.702	0.702
8.0	0.627	0.629	0.629	0.628	0.628	0.628	0.628	0.628	0.627	0.627	0.627	0.627	0.626	0.626
8.5	0.542	0.544	0.544	0.544	0.544	0.544	0.543	0.543	0.543	0.543	0.543	0.543	0.542	0.542
9.0	0.468	0.469	0.469	0.469	0.469	0.469	0.469	0.468	0.468	0.468	0.468	0.468	0.467	0.466
9.5	0.402	0.406	0.406	0.406	0.405	0.405	0.405	0.405	0.405	0.404	0.404	0.403	0.400	0.398
10.0	0.344	0.350	0.350	0.350	0.350	0.350	0.349	0.349	0.349	0.348	0.347	0.346	0.342	0.339
10.5	0.296	0.304	0.304	0.304	0.304	0.303	0.303	0.302	0.302	0.301	0.300	0.298	0.293	0.290
11.0	0.256	0.266	0.266	0.266	0.266	0.266	0.265	0.264	0.263	0.262	0.260	0.258	0.253	0.250
11.5	0.224	0.236	0.236	0.236	0.235	0.235	0.234	0.233	0.231	0.230	0.228	0.226	0.222	0.219
12.0	0.198	0.212	0.211	0.211	0.210	0.210	0.208	0.207	0.206	0.204	0.202	0.200	0.195	0.193
12.5	0.176	0.190	0.190	0.189	0.188	0.188	0.186	0.185	0.183	0.182	0.180	0.178	0.173	0.170
13.0	0.157	0.172	0.171	0.170	0.170	0.169	0.167	0.166	0.164	0.163	0.161	0.159	0.154	0.152
13.5	0.140	0.156	0.155	0.154	0.153	0.152	0.150	0.149	0.147	0.146	0.144	0.142	0.138	0.135
14.0	0.126	0.142	0.141	0.140	0.139	0.138	0.137	0.135	0.133	0.132	0.130	0.128	0.124	0.122
14.5	0.114	0.131	0.129	0.128	0.127	0.126	0.124	0.123	0.121	0.120	0.118	0.116	0.112	0.110
15.0	0.103	0.120	0.119	0.118	0.117	0.116	0.114	0.112	0.110	0.109	0.107	0.105	0.102	0.100
15.5	0.094	0.112	0.110	0.109	0.108	0.106	0.104	0.103	0.101	0.099	0.098	0.096	0.092	0.091
16.0	0.086	0.104	0.102	0.101	0.099	0.098	0.096	0.094	0.093	0.091	0.089	0.088	0.084	0.083
16.5	0.079	0.096	0.095	0.093	0.092	0.090	0.088	0.087	0.085	0.083	0.082	0.080	0.077	0.076
17.0	0.072	0.090	0.088	0.086	0.085	0.083	0.081	0.080	0.078	0.077	0.075	0.074	0.071	0.070
17.5	0.067	0.083	0.082	0.080	0.079	0.077	0.076	0.074	0.073	0.071	0.070	0.068	0.066	0.065
18.0	0.062	0.078	0.076	0.074	0.073	0.071	0.070	0.068	0.067	0.066	0.064	0.063	0.061	0.060
18.5	0.057	0.072	0.071	0.069	0.068	0.066	0.065	0.063	0.062	0.061	0.060	0.059	0.056	0.055
19.0	0.053	0.067	0.065	0.064	0.062	0.061	0.060	0.059	0.057	0.056	0.055	0.054	0.052	0.051
19.5	0.049	0.062	0.061	0.059	0.058	0.057	0.056	0.055	0.053	0.052	0.051	0.050	0.049	0.048
20.0	0.046	0.058	0.057	0.055	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.045	0.045



**7.15 Sound Curves, Sound Optimized Mode SO6**

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO6 (Blades with serrated trailing edge)
3	93.5
4	93.7
5	94.3
6	97.1
7	98.0
8	98.0
9	98.0
10	98.0
11	98.0
12	98.0
13	98.0
14	98.0
15	98.0
16	98.0
17	98.0
18	98.0
19	98.0
20	98.0

Original Instruction: T05 0107-3707 VER 00

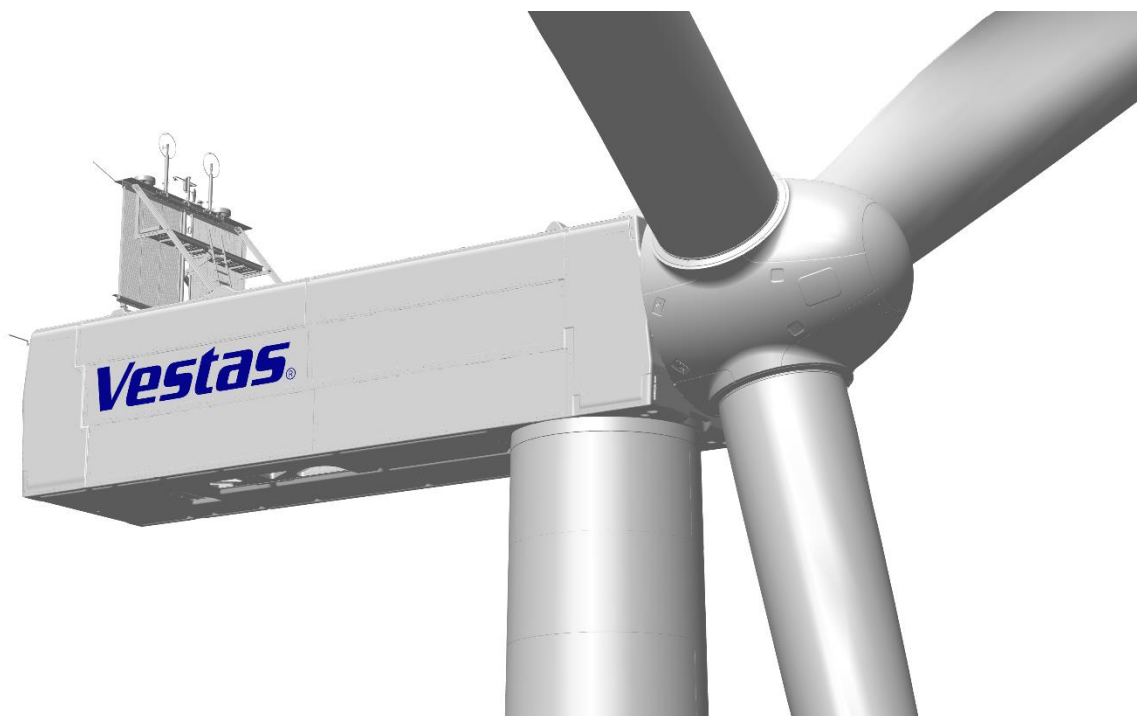
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# General Description

## EnVentus™



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## 1 Introduction

This *General Description* contains data and general descriptions of the EnVentus™ wind turbine range. The EnVentus™ turbine range consists of various turbine variants, with different rotors and ratings.

For turbine variant specific information related to wind class definitions and performance details, please refer to the accompanying Performance Specification document.

## 2 General Description

A wind turbine within the EnVentus™ turbine range is a pitch regulated upwind turbine with active yaw and a three-blade rotor.

The wind turbine utilises the OptiTip® concept and a power system based on a permanent magnet generator and full-scale converter. With these features, the wind turbines are able to operate the rotor at variable speed and thereby maintain the power output at or near rated power even in high wind speed. At low wind speed, the OptiTip® concept and the power system work together to maximise the power output by operating at the optimal rotor speed and pitch angle.

### 3 Mechanical Design

#### 3.1 Rotor

The wind turbine is equipped with a rotor consisting of three blades and a hub. The blades are controlled by the microprocessor pitch control system OptiTip®. Based on the prevailing wind conditions, the blades are continuously positioned to optimise the pitch angle.

Rotor	V150	V162
Diameter	150 m	162 m
Swept Area	17671 m <sup>2</sup>	20612 m <sup>2</sup>
Speed, Dynamic Operation Range	4.9 - 12.6 rpm	4.3 -12.1 rpm
Rotational Direction	Clockwise (front view)	
Orientation	Upwind	
Tilt	6°	
Hub Coning	6°	
No. of Blades	3	
Aerodynamic Brakes	Full feathering	

Table 3-1: Rotor data

#### 3.2 Blades

The blades are made of carbon and fibreglass and consist of two airfoil shells with embedded structure.

Blades	V150	V162
Blade Length	73.65 m	79.35 m
Maximum Chord	4.2 m	4.3 m
Chord at 90% blade radius	1.4 m	1.68 m
Type Description	Structural airfoil shell	
Material	Fibreglass reinforced epoxy, carbon fibres and Solid Metal Tip (SMT)	
Blade Connection	Steel roots inserted	
Airfoils	High-lift profile	

Table 3-2: Blades data

#### 3.3 Blade Bearing

The blade bearings allow the blades to operate at varying pitch angles.

Blade Bearing	
Blade bearing type	High-capacity slewing bearing
Lubrication	Manual grease lubrication

Table 3-3: Blade bearing data



### 3.4 Pitch System

The turbine is equipped with a hydraulic, individual pitch system for each blade. Each pitch system is connected to the hydraulic rotating transfer unit in the nacelle by means of distributed hydraulic hoses and pipes. The hydraulic power unit is positioned in the nacelle.

Each pitch system consists of a hydraulic cylinder mounted to the hub and a piston rod mounted to the blade bearing. Valves facilitating operation of the pitch cylinder are installed on a pitch block bolted directly onto the cylinder.

Pitch System	
Type	Hydraulic
Number	1 cylinder per blade
Range	-5° to 95°

Table 3-4: Pitch system data

Hydraulic System	
Main Pump	Redundant internal-gear oil pumps
Pressure	Max. 260 bar
Filtration	3 µm (absolute) 40 µm in line

Table 3-5: Hydraulic system data.

### 3.5 Hub

The hub supports the three blades and transfers the reaction loads and the torque to the Main Shaft. The hub structure also supports blade bearings and pitch cylinders.

Hub	
Type	Ball shell hub
Material	Cast iron

Table 3-6: Hub data

### 3.6 Main Shaft

The main shaft transfers the reaction forces to the main bearing and the torque to the gearbox.

Main Shaft	
Type Description	Hollow shaft
Material	Cast iron

Table 3-7: Main shaft data

### 3.7 Main Bearing Housing

The main bearing housing carries the main bearings and is the connection point for the drive train system to the nacelle structure.

Main Bearing Housing	
Material	Cast iron

Table 3-8: Main bearing housing data

### 3.8 Main Bearing

The main bearings constitute the main load transfer path for the rotor and drivetrain to the nacelle structure.

Main Bearing	
Type	Rolling bearings
Lubrication	Oil circulation

Table 3-9: Main bearing data

### 3.9 Gearbox

The main gear converts the rotation of the rotor to generator rotation.

Gearbox	
Type	2 Planetary stages
Gear House Material	Cast
Lubrication System	Pressure oil lubrication
Total Gear Oil Volume	800-1000 L
Oil Cleanliness Codes	ISO 4406-/15/12

Table 3-10: Gearbox data

### 3.10 Generator Bearings

Generator bearings ensures a constant airgap between the generator rotor and stator. The bearings are arranged in an assembly that allows for up-tower service.

Generator Bearing	
Type	Rolling bearings
Lubrication	Oil circulation

Table 3-11: Generator bearing data

### 3.11 Yaw System

The yaw system is an active system based on a pre-tensioned plain bearing.

Yaw System	
Type	Plain bearing system
Material	Forged yaw ring heat-treated. Plain bearings PETP
Yaw gear type	Multiple stages planetary gear
Yawing Speed (50 Hz)	Approx. 0.4°/sec.
Yawing Speed (60 Hz)	Approx. 0.5°/sec.

Table 3-12: Yaw system data

### 3.12 Crane

The nacelle is equipped with an internal service crane (single system hoist).

Crane	
Lifting Capacity	HH<149 m max 500 kg HH>149 m max 800 kg

Table 3-13: Crane data

### 3.13 Towers

Tubular Steel Towers and Concrete Hybrid Towers (CHT) are available as standard for several WTG configuration and hub height options.

Tubular steel towers consist of flange joined steel sections.

Concrete Hybrid Towers consists of a concrete bottom part with a transition piece towards a tubular steel top. The concrete part is made of precast high strength concrete rings, and the tubular steel top is made of flange joined steel sections.

Towers includes modular internals, which are certified to relevant type approvals.

Available hub heights are listed in the Performance Specification for each turbine variant. Designated hub heights include a distance from tower top flange to centre of the hub of approximately 2.5m. For steel towers the designated hub height also includes a distance from the foundation section to the ground level of approximately 0.2 m depending on the thickness of the bottom flange.

For steel towers, raised foundations of up to 3 m can be made available on a site-specific basis subject to soil and project conditions which raises the hub height also by up to 3m.

Further WTG configuration and hub height options are developed as non-standard products on site-specific basis.

Towers	
Type	Tubular steel towers Larger diameter steel towers Concrete Hybrid Towers

Table 3-14: Tower structure data

### 3.14 Nacelle Structure and Cover

The nacelle structure is in two parts and consists of a cast iron front part, the base frame, and a girder structure rear part, the rear structure. The base frame is the foundation for the drive train and transmits forces from the rotor to the tower through the yaw system. The bottom surface is machined and connected to the yaw bearing and the yaw gears are bolted to the base frame.

The crane girders are attached to the rear structure.

The nacelle cover is attached to the nacelle structure. The nacelle cover is made of fibreglass. Hatches are positioned in the floor for lowering or hoisting equipment to the nacelle and evacuation of personnel. The roof section is equipped with skylights.

The skylights can be opened from inside the nacelle to access the roof and from outside to access the nacelle. Access from the tower to the nacelle is through the base frame.

Type Description	Material
Nacelle Cover	GRP
Base frame	Cast iron
Rear structure	Girder structure

Table 3-15: Nacelle structure and cover data

### 3.15 Thermal Conditioning System

The thermal conditioning system consists of:

- A Liquid Cooling System
- The Vestas Cooler Top®
- Air cooling of the nacelle internal, and
- Air cooling of the converter including a filter function

#### 3.15.1 Liquid Cooling

The liquid cooling system removes the heat losses from the gearbox, generator, hydraulic power unit, converter and the HV transformer.

The liquid cooling system pump unit includes a set of dynamic flow valves securing the right flow to the different systems. The pump unit also includes a heater for pre-heating the liquid in cold start-up situations, an electrical controlled valve for controlling the liquid temperature and a bypass filter for removal of particles in the cooling liquid.

#### 3.15.2 Cooler Top®

The Vestas Cooler Top® located on top of the rear end of the nacelle. The Cooler Top® is a free flow cooler, thus ensuring that there are no electrical components in the thermal conditioning system located outside the nacelle. The Cooler Top® serves as base for the wind sensors, ice detection sensor, aviation lights and visibility sensor.

### 3.15.3 Nacelle Conditioning

Hot air generated by mechanical and electrical equipment is dissipated from the nacelle by a fan system located in the nacelle. The nacelle conditioning is taking ambient air into the nacelle and exhaust the hot air in the end of the nacelle.

### 3.15.4 Converter Air Cooling

The converter is both liquid and air cooled. The converter air cooling system comprises an air to air heat exchanger, which separates ambient air from converter internal air. The ambient air flow is provided by fan units delivering ambient air to the air to air heat exchanger through a filter. Fans on the internal side of the air to air exchanger provides the converter internal air circulation.

## 4 Electrical Design

### 4.1 Generator

The generator is a three-phase permanent magnet generator connected to the grid through a full-scale converter. The generator housing allows the circulation of cooling air within the stator and rotor.

The heat generated by the losses is removed by an air-to-water heat exchanger.

<i>Generator</i>	
<b>Type</b>	Permanent Magnet Synchronous generator
<b>Rated Power [P<sub>N</sub>]</b>	Up to 6250 kW (depending on turbine variant)
<b>Frequency range [f<sub>N</sub>]</b>	0-138 Hz
<b>Voltage, Stator [U<sub>NS</sub>]</b>	3 x 800 V (at rated speed)
<b>Number of Poles</b>	36
<b>Winding Type</b>	Form with Vacuum Pressurized Impregnation
<b>Winding Connection</b>	Star
<b>Operational speed range</b>	0-460 rpm
<b>Overspeed Limit (2 minutes)</b>	720 rpm
<b>Temperature Sensors, Stator</b>	PT100 sensors placed in the stator hot spots.
<b>Insulation Class</b>	H
<b>Enclosure</b>	IP54

Table 4-1: Generator data

## 4.2 Converter

The converter is a full-scale converter system controlling both the generator and the power delivered to the grid. The converter consists of 4 machine-side converter units and 4 line-side converter units operating in parallel with a common controller.

The converter controls conversion of variable frequency AC power from the generator into fixed frequency AC power with desired active and reactive power levels (and other grid connection parameters) suitable for the grid.

The converter is located in the nacelle and has a grid side voltage rating of 720 V. The generator side voltage rating is nominally 800 V but depends on generator speed.

Converter	
Rated Apparent Power [ $S_N$ ] @ 1.0 p.u. voltage	6550 kVA
Rated Grid Voltage	3 x 720 V
Rated Generator Voltage	3 x 800 V
Rated Grid Current @ 1.0 p.u. voltage	5250 A
Enclosure	IP54

Table 4-2: Converter data

## 4.3 HV Transformer

The transformer is a three-phase, three limb, two-winding, liquid immersed transformer. The transformer is equipped with an external water-cooling circuit. The insulation liquid used is environmentally friendly and low flammable.

The HV transformer is located in a separate locked room in the back of the nacelle. The transformer is designed according to IEC standards and is available in the following version:

- Eco-design complying to Tier 2 of European Ecodesign regulation No 548/2014 and No 2019/1783 set by the European Commission. Refer to Table 4-3.

### 4.3.1 General transformer data

Transformer		
Type description	Eco-design liquid immersed transformer.	
Basic layout	3 phase, 2 winding transformer	
Applied standards	IEC 60076-1, IEC 60076-16, IEC 61936-1 Commission Regulation No 548/2014 Commission Regulation No 2019/1783	
Cooling method	KF/WF	
Rated power	7000 kVA	7300kVA
Expansion system	Open breathing	Sealed
No-load reactive power	~35 kVAr <sup>1</sup>	~40 kVAr <sup>1</sup>
Full load reactive power	~700 kVAr <sup>1</sup>	~770 kVAr <sup>1</sup>
No-load current	~ 0.5 % <sup>1</sup>	~ 0.5 % <sup>1</sup>
Positive sequence short-circuit impedance @ rated power, 95°C	9.9 % <sup>1,2</sup>	10.3 % <sup>1,2</sup>

<b>Transformer</b>	
<b>Positive sequence short-circuit resistance@ rated power, 95°C</b>	~1.0 % <sup>1</sup>
<b>Zero sequence short-circuit impedance@ rated power, 95°C</b>	~9.0 – 10 % <sup>1</sup>
<b>Zero sequence short-circuit resistance@ rated power, 95°C</b>	~1.0 % <sup>1</sup>
<b>Rated voltage, turbine side</b>	
<b>U<sub>m</sub> 1.1kV</b>	0.720 kV
<b>Rated voltage, grid side</b>	
<b>U<sub>m</sub> 24.0kV</b>	19.1-22.0 kV
<b>U<sub>m</sub> 36.0kV</b>	22.1-33.0 kV
<b>U<sub>m</sub> 40.5kV</b>	33.1-36.0 kV
<b>Insulation level AC / LI / LIC</b>	
<b>U<sub>m</sub> 1.1kV</b>	3 / - / - kV
<b>U<sub>m</sub> 24.0kV</b>	50 / 125 / 138 kV
<b>U<sub>m</sub> 36.0kV</b>	70 / 170 / 187 kV
<b>U<sub>m</sub> 40.5kV</b>	80 / 200 / 220 kV
<b>Off-circuit tap changer</b>	None
<b>Frequency</b>	50 Hz / 60 Hz
<b>Vector group</b>	Dyn11
<b>Inrush peak current</b>	5-8 x I <sub>n</sub> <sup>1</sup>
<b>Half crest time</b>	~ 0.6 - 1 s <sup>1</sup>
<b>Sound power level</b>	≤ 80 dB(A) <sup>1</sup>
<b>Average winding temperature rise</b>	Class 120 (E) ≤65 K <sup>1</sup> Class 130 (B) ≤75 K <sup>1</sup>
<b>Max altitude</b>	2000 m <sup>1</sup>
<b>Insulation system</b>	Hybrid insulation system. Winding insulation: 120 (E), Thermally Upgrader Paper 130 (B), High temperature insulation Other materials can have different class.
<b>Insulation liquid, Type/Fire point</b>	Natural/Synthetic ester, biodegradable/ K-class (>300°C)
<b>Insulation liquid, Amount</b>	≤ 3000 kg <sup>1</sup>
<b>Corrosion class</b>	C3 <sup>1</sup>
<b>Weight</b>	≤11200 kg <sup>1</sup>
<b>Overvoltage protection</b>	Plug-in surge arresters on HV bushings <sup>1</sup>
<b>High voltage bushings</b>	Outer cone, interface C1 <sup>1</sup>

Table 4-3: General transformer data.

### 4.3.2 Eco-design – IEC 50 Hz/60 Hz version

The transformer loss limits are given at rated power as combination of load loss and no-load loss which shall fulfil the Peak Efficiency Index (PEI) of the Eco-design requirement.

The maximum losses are described by the PEI limit section of Figure 4-1 and Figure 4-2 and stretch over a range between Loss variant 1 and Loss variant 2. The loss variant values are selected based on energy loss optimization with the turbine user profile, hence the energy loss of transformers between Loss variant 1 and Loss variant 2 are comparable.

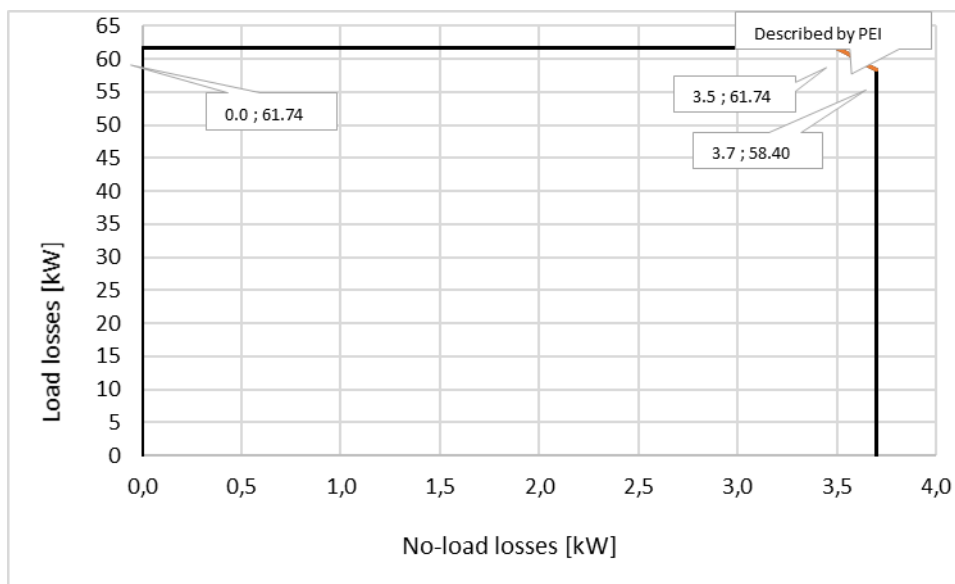


Figure 4-1: Transformer losses allowable area for 7000kVA variant

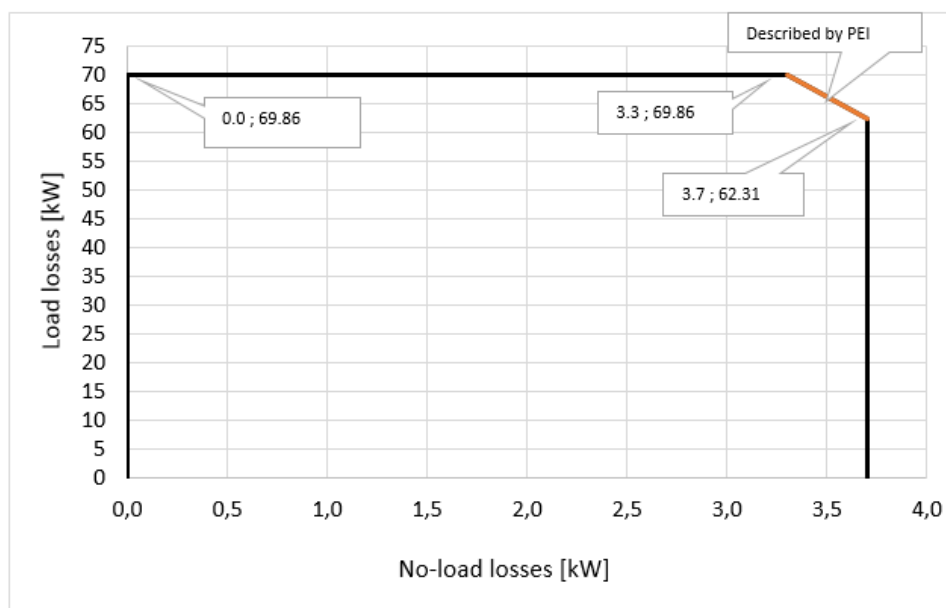


Figure 4-2: Transformer losses allowable area for 7300kVA variant



The actual load losses vary depending on the operational mode of the turbine, hence in *Table 4-4* and *Table 4-5*, the load losses are provided at different operational modes for the two loss variants. For further recalculation of load losses at different operation modes, refer to Figure 4-3.

<b>Transformer losses (rated power 7000kVA)</b>				
<b>Applied standards</b>	Commission Regulation No 2019/1783			
<b>Peak Efficiency Index (PEI)</b>	≥ 99.580			
<b>Loss variant 1</b>				
<b>No-load loss</b>	3.50 kW			
<b>Load loss @ power, 95°C</b>	<b>@7000kVA</b>	<b>@5600kVA</b>	<b>@5400kVA</b>	<b>@5000kVA</b>
	≤61.74kW	≤39.51kW <sup>3</sup>	≤36.74kW <sup>3</sup>	≤31.50kW <sup>3</sup>
<b>Loss variant 2</b>				
<b>No-load loss</b>	3.70 kW			
<b>Load loss @ power, 95°C</b>	<b>@7000kVA</b>	<b>@5600kVA</b>	<b>@5400kVA</b>	<b>@5000kVA</b>
	≤58.40kW	≤37.38kW <sup>3</sup>	≤34.75kW <sup>3</sup>	≤29.80kW <sup>3</sup>

*Table 4-4: Transformer losses for 7000kVA version*

<b>Transformer losses (rated power 7300kVA)</b>			
<b>Applied standards</b>	Commission Regulation No 2019/1783		
<b>Peak Efficiency Index (PEI)</b>	≥ 99.584		
<b>Loss variant 1</b>			
<b>No-load loss</b>	3.30 kW		
<b>Load loss @ power, 95°C</b>	<b>@7300kVA</b>	<b>@6000kVA</b>	<b>@5600kVA</b>
	≤69.86kW	≤47.19kW <sup>3</sup>	≤41.11kW <sup>3</sup>
<b>Loss variant 2</b>			
<b>No-load loss</b>	3.70 kW		
<b>Load loss @ power, 95°C</b>	<b>@7300kVA</b>	<b>@6000kVA</b>	<b>@5600kVA</b>
	≤62.31kW	≤42.09kW <sup>3</sup>	≤36.67kW <sup>3</sup>

*Table 4-5: Transformer losses for 7300kVA version*



Figure 4-3: Transformer load losses scaling

- NOTE**
- <sup>1</sup> Values are preliminary and could be subjected for change.
  - <sup>2</sup> Subjected to standard IEC tolerances.
  - <sup>3</sup> Informative non-binding values based on operation mode.

#### 4.4 HV Cables

The high-voltage cable runs from the transformer in the nacelle down the tower to the HV switchgear located at the bottom of the tower. The high-voltage cable can be of two different constructions:

- A three-core, rubber-insulated, halogen-free, high-voltage cable with a three-core split earth conductor.
- A four-core, rubber-insulated, halogen-free, high-voltage cable.

HV Cables	
<b>High-Voltage Cable Insulation Compound</b>	Improved ethylene-propylene (EP) based material-EPR or high modulus or hard grade ethylene-propylene rubber-HEPR
<b>Pre-terminated</b>	T-Connector Type-C in transformer end. T-Connector Type-C in switchgear end.
<b>Maximum Voltage</b>	24 kV for 19.1-22.0 kV rated voltage 42 kV for 22.1-36.0 kV rated voltage
<b>Conductor Cross Sections</b>	3x70 + 70 mm <sup>2</sup> (Single PE core) 3x70 + 3x70/3 mm <sup>2</sup> (Split PE core)

Table 4-6: HV cables data

#### 4.5 HV Switchgear

A gas insulated switchgear is installed in the bottom of the tower as an integrated part of the turbine. Its controls are integrated with the turbine safety system, which monitors the condition of the switchgear and high voltage safety related devices in the turbine. This system is named 'Ready to Protect' and ensures all protection

devices are operational, whenever high voltage components in the turbine are energised. To ensure that the switchgear is always ready to trip, it is equipped with redundant trip circuits consisting of an active trip coil and an undervoltage trip coil.

In case of grid outage the circuit breaker will disconnect the turbine from the grid after an adjustable time.

When grid returns, all relevant protection devices will automatically be powered up via UPS.

When all the protection devices are operational, the circuit breaker will re-close after an adjustable time. The re-close functionality can furthermore be used to implement a sequential energization of a wind park, in order to avoid simultaneous inrush currents from all turbines once grid returns after an outage.

In case the circuit breaker has tripped due to a fault detection, the circuit breaker will be blocked for re-connection until a manual reset is performed.

In order to avoid unauthorized access to the transformer room during live condition, the earthing switch of the circuit breaker, contains a trapped-key interlock system with its counterpart installed on the access door to the transformer room.

The switchgear is available in three variants with increasing features, see Table 4-7. Beside the increase in features, the switchgear can be configured depending on the number of grid cables planned to enter the individual turbine. The design of the switchgear solution is optimized such grid cables can be connected to the switchgear even before the tower is installed and still maintain its protection toward weather conditions and internal condensation due to a gas tight packing.

The switchgear is available in an IEC version and in an IEEE version. The IEEE version is however only available in the highest voltage class. The electrical parameters of the switchgear are seen in Table 4-8 for the IEC version and in Table 4-9 for the IEEE version.

<b>HV Switchgear</b>			
<b>Variant</b>	<b>Basic</b>	<b>Streamline</b>	<b>Standard</b>
IEC standards	○	⊙	⊙
IEEE standards	⊙	○	⊙
Vacuum circuit breaker panel	⊙	⊙	⊙
Overcurrent, short-circuit and earth fault protection	⊙	⊙	⊙
Disconnecter / earthing switch in circuit breaker panel	⊙	⊙	⊙
Voltage Presence Indicator System for circuit breaker	⊙	⊙	⊙
Voltage Presence Indicator System for grid cables	⊙	⊙	⊙
Double grid cable connection	⊙	⊙	⊙
Triple grid cable connection	⊙	○	○
Preconfigured relay settings	⊙	⊙	⊙
Turbine safety system integration	⊙	⊙	⊙
Redundant trip coil circuits	⊙	⊙	⊙

<b>HV Switchgear</b>			
<b>Variant</b>	<b>Basic</b>	<b>Streamline</b>	<b>Standard</b>
Trip coil supervision	⊙	⊙	⊙
Pendant remote control from outside of tower	⊙	⊙	⊙
Sequential energization	⊙	⊙	⊙
Reclose blocking function	⊙	⊙	⊙
Heating elements	⊙	⊙	⊙
Trapped-key interlock system for circuit breaker panel	⊙	⊙	⊙
Motor operation of circuit breaker	⊙	⊙	⊙
Cable panel for grid cables (configurable)	○	⊙	⊙
Switch disconnecter panels for grid cables – max three panels (configurable)	○	⊙	⊙
Earthing switch for grid cables	○	⊙	⊙
Internal arc classification	○	⊙	⊙
Supervision on MCB's	○	⊙	⊙
Motor operation of switch disconnecter	○	○	⊙
SCADA operation and feedback of circuit breaker	○	○	⊙
SCADA operation and feedback of switch disconnecter	○	○	⊙

Table 4-7: HV switchgear variants and features

#### 4.5.1 IEC 50/60Hz version

<b>HV Switchgear</b>	
<b>Type description</b>	Gas Insulated Switchgear
<b>Applied standards</b>	IEC 62271-103 IEC 62271-1, 62271-100, 62271-102, 62271-200
<b>Insulation medium</b>	SF <sub>6</sub>
<b>Rated voltage</b>	
<b>U<sub>r</sub> 24.0kV</b>	19.1-22.0 kV
<b>U<sub>r</sub> 36.0kV</b>	22.1-33.0 kV
<b>U<sub>r</sub> 40.5kV</b>	33.1-36.0 kV
<b>Rated insulation level AC // LI Common value / across isolation distance</b>	
<b>U<sub>r</sub> 24.0kV</b>	50 / 60 // 125 / 145 kV
<b>U<sub>r</sub> 36.0kV</b>	70 / 80 // 170 / 195 kV
<b>U<sub>r</sub> 40.5kV</b>	85 / 90 // 185 / 215 kV
<b>Rated frequency</b>	50 Hz / 60 Hz
<b>Rated normal current</b>	630 A
<b>Rated Short-time withstand current</b>	
<b>U<sub>r</sub> 24.0kV</b>	20 kA
<b>U<sub>r</sub> 36.0kV</b>	25 kA
<b>U<sub>r</sub> 40.5kV</b>	25 kA

<b>HV Switchgear</b>	
<b>Rated peak withstand current 50 / 60 Hz</b>	
<b>U<sub>r</sub> 24.0kV</b>	50 / 52 kA
<b>U<sub>r</sub> 36.0kV</b>	62.5 / 65 kA
<b>U<sub>r</sub> 40.5kV</b>	62.5 / 65 kA
<b>Rated duration of short-circuit</b>	1 s
<b>Internal arc classification (option)</b>	
<b>U<sub>r</sub> 24.0kV</b>	IAC A FLR 20 kA, 1 s
<b>U<sub>r</sub> 36.0kV</b>	IAC A FLR 25 kA, 1 s
<b>U<sub>r</sub> 40.5kV</b>	IAC A FLR 25 kA, 1 s
<b>Connection interface</b>	Outside cone plug-in bushings, IEC interface C1.
<b>Loss of service continuity category</b>	LSC2
<b>Ingress protection</b>	
<b>Gas tank</b>	IP 65
<b>Enclosure</b>	IP 2X
<b>LV cabinet</b>	IP 3X
<b>Corrosion class</b>	C3

Table 4-8: HV switchgear data for IEC version

#### 4.5.2 IEEE 60Hz version

<b>HV Switchgear</b>	
<b>Type description</b>	Gas Insulated Switchgear
<b>Applied standards</b>	IEEE 37.20.3, IEEE C37.20.4, IEC 62271-200, ISO 12944.
<b>Insulation medium</b>	SF <sub>6</sub>
<b>Rated voltage</b>	
<b>U<sub>r</sub> 38.0kV</b>	22.1-36.0 kV
<b>Rated insulation level AC / LI</b>	70 / 150 kV
<b>Rated frequency</b>	60 Hz
<b>Rated normal current</b>	600 A
<b>Rated Short-time withstand current</b>	25 kA
<b>Rated peak withstand current</b>	65 kA
<b>Rated duration of short-circuit</b>	1 s
<b>Internal arc classification (option)</b>	IAC A FLR 25 kA, 1 s
<b>Connection interface grid cables</b>	Outside cone plug-in bushings, IEEE 386 interface type deadbreak, 600A.
<b>Ingress protection</b>	
<b>Gas tank</b>	NEMA 4X / IP 65
<b>Enclosure</b>	NEMA 2 / IP 2X
<b>LV cabinet</b>	NEMA 2 / IP 3X
<b>Corrosion class</b>	C3

Table 4-9: HV switchgear data for IEEE version

## 4.6 AUX System

The AUX system is supplied from a separate 720/400 V transformer located in the nacelle. The supply to this transformer primary side is provided from converter cabinet. All auxiliary loads in the turbine such as motors, pumps, fans and heaters are supplied from this system.

The control system (DCN's) is also supplied from the Auxiliary Power System in all areas of the turbine.

The 400 V supply from Nacelle is transferred to Tower controller cabinet, which is placed at the entrance platform of the turbine. This supply is then distributed for various 400 & 230 V loads such as service lift, working light system, additional / optional features & general-purpose loads, cabinet internal heating & ventilation. There is a 400/230 V control transformer placed inside tower cabinet which provides supply to the UPS cabinet which is placed very near to the tower cabinet.

There is a 400 V service inlet provided in the tower control cabinet to connect an external power source that allows some of the systems to operate during installation & maintenance / service activities.

The working & emergency light system in Tower & Nacelle is supplied from a small control cabinet which is placed in the entrance platform just beside the turbine entrance door. It is possible to add an optional battery cabinet to the light cabinet if extended back-up time is needed. The internal light in the hub is fed from built-in batteries in the light armature.

Power Sockets	
Single Phase (Nacelle)	230 V (16 A) (standard) 110 V (16 A) (option)
Single Phase (Tower Platforms)	230 V (10 A) (standard) 110 V (16 A) (option)
Three Phase (Nacelle and Tower Base)	3 x 400 V (16 A)

Table 4-10: AUX system data

## 4.7 Wind Sensors

The turbine is equipped with one ultrasonic wind sensor and one mechanical wind vane. The sensors have built-in heaters to minimise interference from ice and snow.

## 4.8 Vestas Multi Processor (VMP) Controller

The turbine is controlled and monitored by the VMP8000 control system.

VMP8000 is a multiprocessor control system comprised of main controller, distributed control nodes, distributed IO nodes and ethernet switches and other network equipment. The main controller is placed in the tower bottom of the turbine. It runs the control algorithms of the turbine, as well as all IO communication.

The communications network is a time triggered Ethernet network (TTEthernet).

The VMP8000 control system serves the following main functions:

- Monitoring and supervision of overall operation.

- Synchronizing of the generator to the grid during connection sequence.
- Operating the wind turbine during various fault situations.
- Automatic yawing of the nacelle.
- OptiTip® - blade pitch control.
- Reactive power control and variable speed operation.
- Noise emission control.
- Monitoring of ambient conditions.
- Monitoring of the grid.
- Monitoring of the smoke detection system.

#### **4.9 Uninterruptible Power Supply (UPS)**

During grid outage, an UPS system will ensure power supply for specific components.

The UPS designed according to EN54 is built by 3 subsystems:

1. 230V AC UPS for all power backup to nacelle and hub control systems
2. 24V DC UPS for power backup to tower base control systems and ready to protect.
3. 230V AC UPS for power backup to internal lights in tower, nacelle and hub.

<b>UPS</b>		
<b>Backup Time</b>	<b>Standard</b>	<b>Optional</b>
<b>Control System*</b> (230V AC and 24V DC UPS)	Up to 30 min	Up to 19.5 hours**
<b>Emergency Lights</b> (230V AC UPS)	30 min	60 min***
<b>Ready to protect</b> (24V DC UPS)	7 days	37 days****

*Table 4-11: UPS data*

*\*The control system includes: the turbine controller (VMP8000), HV switchgear functions, and remote control system.*

*\*\*Requires upgrade of the 230V UPS for control system with extra batteries.*

*\*\*\*Requires upgrade of the 230V UPS for internal light with extra batteries.*

*\*\*\*\*Requires upgrade of the 24V DC UPS with extra batteries.*

It is possible to add optional battery cabinets with UPS for extended back-up time.

**NOTE**

For alternative backup times, consult Vestas.

## 5 Turbine Protection Systems

### 5.1 Braking Concept

The main brake on the turbine is aerodynamic. Stopping the turbine is done by full feathering the three blades (individually turning each blade). Each blade has a hydraulic accumulator to supply power for turning the blade.

In addition, there is a hydraulic activated mechanical disc brake on the medium-speed shaft of the gearbox. The mechanical brake is only used as a parking brake and when activating the emergency stop buttons.

### 5.2 Short Circuit Protections

Breakers	Breaker for Aux. Power.	Breaker 1 for Converter Modules	Breaker 2 for Converter Modules
Breaking Capacity Icu, Ics	Icu 80 kA Ics 75% Icu	Icu 78 kA Ics 50% Icu	78 kA Ics 50% Icu
Making Capacity Icm	193 kA	193 kA	193 kA

Table 5-1: Short circuit protection data

### 5.3 Overspeed Protection

The safety system integrated in the VMP8000 control system monitors the rotor speed, using a combination of sensors in the hub. In case of an overspeed situation, the safety system activates the hydraulic safety pitch system, which will feather the blades and bring the turbine to standstill.

Overspeed Protection	
Sensor Type	MEMS
Trip Level	Variant dependent

Table 5-2: Overspeed protection data

### 5.4 Arc Detection

The turbine is equipped with an Arc Detection system including multiple optical arc detection sensors placed in the HV transformer compartment and the converter cabinet. The Arc Detection system is connected to the turbine safety system ensuring immediate opening of the HV switchgear if an arc is detected.

### 5.5 Smoke Detection

The turbine is equipped with a Smoke Detection system including multiple smoke detection sensors placed in the nacelle, in the transformer compartment, in main electrical cabinets in the nacelle and in the tower base. The Smoke Detection system is connected to the turbine safety system ensuring immediate opening of the HV switchgear if smoke is detected.



## 5.6 Lightning Protection of Blades, Nacelle, Hub and Tower

The Lightning Protection System (LPS) helps protect the wind turbine against the physical damage caused by lightning strikes. The LPS consists of five main parts:

- Air termination system e.g. lightning receptors. All lightning receptor surfaces on the blades are unpainted, excluding the Solid Metal Tips (SMT).
- Down conducting system (a system to conduct the lightning current down through the wind turbine to help avoid or minimise damage to the LPS itself or other parts of the wind turbine).
- Protection against overvoltage and overcurrent.
- Shielding against magnetic and electrical fields.
- Earthing system.

Lightning Protection Design Parameters			Protection Level I
<b>Current Peak Value</b>	$i_{max}$	[kA]	200
<b>Impulse Charge</b>	$Q_{impulse}$	[C]	100
<b>Total Charge</b>	$Q_{total}$	[C]	300
<b>Specific Energy</b>	W/R	[MJ/Ω]	10
<b>Average Steepness</b>	di/dt	[kA/μs]	200

*Table 5-3: Lightning protection design parameters (IEC)*

## 5.7 EMC

The turbine and related equipment fulfil the EU Electromagnetic Compatibility (EMC) legislation:

- DIRECTIVE 2014/30/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility.

The EMC performance is based on fulfilment of following standards:

### Emission

- IEC/CISPR 11 at wind turbine level
- IEC 61000-6-4 for telecommunications

### Immunity

- IEC 61000-6-2 for electronics installed
- IEC 61400-24 for lightning protection of electronics installed

Beside DIRECTIVE 2014/30/EU, electronics related to the functional safety evaluation shall fulfil

- IEC 62061 Safety on machinery (Directive 2006/42/EU Machinery)

## 5.8 RED (Radio Equipment Directive)

Related radio equipment installed in the turbine fulfil the EU legislation:

DIRECTIVE 2014/53/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 April 2014.

## 5.9 EMF (ElectroMagnetic Fields)

Electromagnetic fields in the wind turbine are identified to ensure safe stay for personnel during design, production, operation and service.

The following directive is basis for ensuring minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents.

DIRECTIVE 2013/35/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 June 2013.

## 5.10 Earthing

The Vestas Earthing System consists of individual earthing electrodes interconnected as one joint earthing system.

The Vestas Earthing System includes the TN-system and the Lightning Protection System for each wind turbine. It works as an earthing system for the medium voltage distribution system within the wind farm.

The Vestas Earthing System is adapted for the different types of turbine foundations. A separate set of documents describe the earthing system in detail, depending on the type of foundation.

In terms of lightning protection of the wind turbine, Vestas has no separate requirements for a certain minimum resistance to remote earth (measured in ohms) for this system. The earthing for the lightning protection system is based on the design and construction of the Vestas Earthing System.

A primary part of the Vestas Earthing System is the main earth bonding bar placed where all cables enter the wind turbine. All earthing electrodes are connected to this main earth bonding bar. Additionally, equipotential connections are made to all cables entering or leaving the wind turbine.

Requirements in the Vestas Earthing System specifications and work descriptions are minimum requirements from Vestas and IEC. Local and national requirements, as well as project requirements, may require additional measures.

## 5.11 Corrosion Protection

Classification of corrosion protection is according to ISO 12944-2.

Corrosion Protection	External Areas	Internal Areas
Nacelle	C5-M	C3
Hub	C5-M	C3
Tower	C5-I	C3

Table 5-5: Corrosion protection data for nacelle, hub, and tower

## 6 Safety

The safety specifications in this section provide limited general information about the safety features of the turbine and are not a substitute for Buyer and its agents taking all appropriate safety precautions, including but not limited to (a) complying with all applicable safety, operation, maintenance, and service agreements, instructions, and requirements, (b) complying with all safety-related laws, regulations, and ordinances, and (c) conducting all appropriate safety training and education.

### 6.1 Access

Access to the turbine from the outside is through a door located at the entrance platform approximately 3 meters above ground level. The door is equipped with a lock. Access to the top platform in the tower is by a ladder or service lift. Access to the nacelle from the top platform is by ladder. Access to the transformer room in the nacelle is controlled with an interlock. Unauthorised access to electrical switchboards and power panels in the turbine is prohibited according to IEC 60204-1 2006.

### 6.2 Escape

The primary evacuation route is through the tower via the tower ladder. In case the tower is blocked the secondary option is to descent directly from nacelle to ground via the service hatch.

It is a prerequisite that one or more descent devices are available in the turbine when there are people present in the turbine. A dedicated attachment point for a descent device is provided above the hatch.

For rescue the normal access routes can be used, in addition to this it is possible to lower an injured person to the ground through the crane hatch, the hatch in the spinner or from the nacelle roof.

The hatch in the roof can be opened from both the inside and outside. Evacuation from the service lift is by ladder.

An emergency response plan, placed in the turbine, describes evacuation and escape routes.

### 6.3 Rooms/Working Areas

The tower and nacelle are equipped with power sockets for electrical tools for service and maintenance of the turbine.

## 6.4 Floors, Platforms, Standing, and Working Places

All floors have anti-slip surfaces. There is one floor per tower section.

Rest platforms are provided at intervals of 9 metres along the tower ladder between platforms.

## 6.5 Service Lift

The service lift can be delivered as an option. Please contact Vestas for additional details.

## 6.6 Work restraint and fall arrest

The tower ladder is equipped with a fall arrest system, either a rigid anchor line or a wire.

The service areas in the turbines are equipped with anchor points. The anchor point may be used for work positioning, fall restraint, fall arrest and to attach a descent device to perform rescue or escape from the turbine.

Anchor points are coloured yellow and are tested to 22.5 kN.

## 6.7 Moving Parts, Guards, and Blocking Devices

All moving parts in the nacelle are shielded.

The turbine is equipped with a rotor lock to block the rotor and drive train.

Blocking the pitch of the blade can be done both automatically and manually with a mechanical blade lock.

## 6.8 Lights

The turbine is equipped with lights in the tower, nacelle and hub.

There is emergency light in case of the loss of electrical power.

## 6.9 Emergency Stop

There are emergency stop buttons in the nacelle, hub and tower.

## 6.10 Power Disconnection

The turbine is equipped with breakers to allow for disconnection from all power sources during inspection or maintenance. The switches are marked with signs and are located in the nacelle and bottom of the tower.

## 6.11 Fire Protection/First Aid

When there are people present in the turbine following fire and safety equipment must be available. In the nacelle: A first aid kit, a handheld fire extinguisher, and a fire blanket. In the tower a handheld fire extinguisher and a fire blanket at the entrance platform.

## 6.12 Warning Signs

Warning signs placed inside or on the turbine must be reviewed before operating or servicing the turbine.

## 6.13 Manuals and Warnings

The Vestas Corporate OH&S Manual and manuals for operation, maintenance and service of the turbine provide additional safety rules and information for operating, servicing or maintaining the turbine.

## 7 Environment

### 7.1 Chemicals

Chemicals used in the turbine are evaluated according to the Vestas Wind Systems A/S Environmental System certified according to ISO 14001:2015. The following chemicals are used in the turbine:

- Anti-freeze to help prevent the cooling system from freezing.
- Gear oil for lubricating the main bearing, gearbox and generator
- Hydraulic oil to pitch the blades and operate the brake.
- Grease for yaw system lubrication
- Transformer insulation liquid for HV transformer
- Various cleaning agents and chemicals for maintenance of the turbine.

## 8 Design Codes

### 8.1 Design Codes – Structural Design

The turbine design has been developed and verified in accordance with, but not limited to, the following main standards:

Design Codes	
<b>Nacelle and Hub</b>	IEC 61400-1 Edition 4 EN 50308
<b>Tower (IEC)</b>	IEC 61400-1 Edition 4
<b>Tower (DIBt)</b>	IEC 61400-1 Edition 3 Richtlinie für Windenergieanlagen, DIBt, Ausgabe: Oktober 2012
<b>Blades</b>	DNV-OS-J102 IEC 1024-1 IEC 60721-2-4 IEC 61400 (Part 1, 12 and 23) DEFU R25 DS/EN ISO 12944-2
<b>Gearbox</b>	IEC 61400-4
<b>Generator</b>	IEC 60034 (relevant parts)
<b>Transformer</b>	IEC 60076-11, IEC 60076-16, CENELEC HD637 S1
<b>Lightning Protection</b>	IEC 61400-24:2010
<b>Safety of Machinery, Safety-related Parts of Control Systems</b>	IEC 13849-1
<b>Safety of Machinery – Electrical Equipment of Machines</b>	IEC 60204-1

Table 8-1: Design codes

## 9 Colours

### 9.1 Nacelle Colour

Colour of Vestas Nacelles	
<b>Standard Nacelle Colour</b>	RAL 7035 (light grey)
<b>Standard Logo</b>	Vestas

Table 9-1: Colour, nacelle

### 9.2 Tower Colour

Colour of Vestas Tower Section		
	External:	Internal:
<b>Standard Steel Tower</b>	RAL 7035 (light grey)	RAL 9001 (cream white)
<b>Standard Concrete Hybrid Tower</b>	<b>Concrete part:</b> Unpainted concrete, corresponds approx. to RAL 7023 (concrete grey) <b>Steel part:</b> RAL 7035 (light grey)	<b>Concrete part:</b> Unpainted concrete, corresponds approx. to RAL 7023 (concrete grey) <b>Steel part:</b> RAL 9001 (cream white)
<b>Option for Concrete Hybrid Tower</b>	Concrete part can be painted with RAL 7035 (light grey)	

Table 9-2: Colour, tower

### 9.3 Blade Colour

Blade Colour	
<b>Standard Blade Colour</b>	RAL 7035 (light grey). All lightning receptor surfaces on the blades are unpainted, excluding the Solid Metal Tips (SMT).
<b>Tip-End Colour Variants</b>	RAL 2009 (traffic orange), RAL 3020 (traffic red)
<b>Gloss</b>	< 30% ISO 2813

Table 9-3: Colour, blades

## 10 Operational Envelope and Performance Guidelines

Actual climate and site conditions have many variables and should be considered in evaluating actual turbine performance. The design and operating parameters set forth in this section do not constitute warranties, guarantees, or representations as to turbine performance at actual sites.

### 10.1 Climate and Site Conditions

Values refer to hub height:

Extreme Design Parameters	
Wind Climate	All
Ambient Temperature Interval (Standard Temperature Turbine)	-40° to +50°C

Table 10-1: Extreme design parameters

### 10.2 Operational Envelope – Temperature and Altitude

Values below refer to hub height and are determined by the sensors and control system of the turbine.

Operational Envelope – Temperature	
Ambient Temperature Interval	-20° to +45°C
Ambient Temperature Interval (Low Temperature Operation)	-30° to +45°C

Table 10-2: Operational envelope – temperature

#### NOTE

The wind turbine will stop producing power at ambient temperatures above 45°C.

For turbine variant specific information related to power performance within the operational envelope, please refer to turbine variant specific Performance Specifications.

For the low temperature operation of the wind turbine, consult Vestas for site specific evaluation.

The turbine is designed for use at altitudes up to 1000 m above sea level as standard and optional up to 2000 m above sea level.



### 10.3 Operational Envelope – Grid Connection

Operational Envelope – Grid Connection		
Nominal Phase Voltage	[U <sub>NP</sub> ]	720 V
Nominal Frequency	[f <sub>N</sub> ]	50/60 Hz
Maximum Frequency Gradient	±4 Hz/sec.	
Maximum Negative Sequence Voltage	3% (connection) 2% (operation)	
Minimum Required Short Circuit Ratio at Turbine HV Connection	5.0 (contact Vestas for lower SCR levels)	
Maximum Short Circuit Current Contribution	1.05 p.u. (continuous) 1.45 p.u. (peak)	

Table 10-3: Operational envelope – grid connection

The generator and the converter will be disconnected if\*:

Protection Settings	
Voltage Above 110%** of Nominal for 1800 Seconds	792 V
Voltage Above 116% of Nominal for 60 Seconds	835 V
Voltage Above 125% of Nominal for 2 Seconds	900 V
Voltage Above 136% of Nominal for 0.150 Seconds	979 V
Voltage Below 90%** of Nominal for 180 Seconds (FRT)	648 V
Voltage Below 85% of Nominal for 12 Seconds (FRT)	612 V
Voltage Below 80% of Nominal for 4.8 Seconds (FRT)	576 V
Frequency is Above 106% of Nominal for 0.2 Seconds	53/63.6 Hz
Frequency is Below 94% of Nominal for 0.2 Seconds	47/56.4 Hz

Table 10-4: Generator and converter disconnecting values

#### NOTE

\* Over the turbine lifetime, grid drop-outs are to occur at an average of no more than 50 times a year.

\*\* The turbine may be configured for continuous operation @ +/- 13 % voltage. Reactive power capability is limited for these widened settings to an extent that is yet to be determined.

### 10.4 Operational Envelope – Reactive Power Capability

For turbine variant specific reactive power capability, please refer to the variant specific Performance Specification.

## 10.5 Performance – Fault Ride Through

The turbine is designed to stay connected during grid disturbances within the voltage tolerance curve as illustrated below:

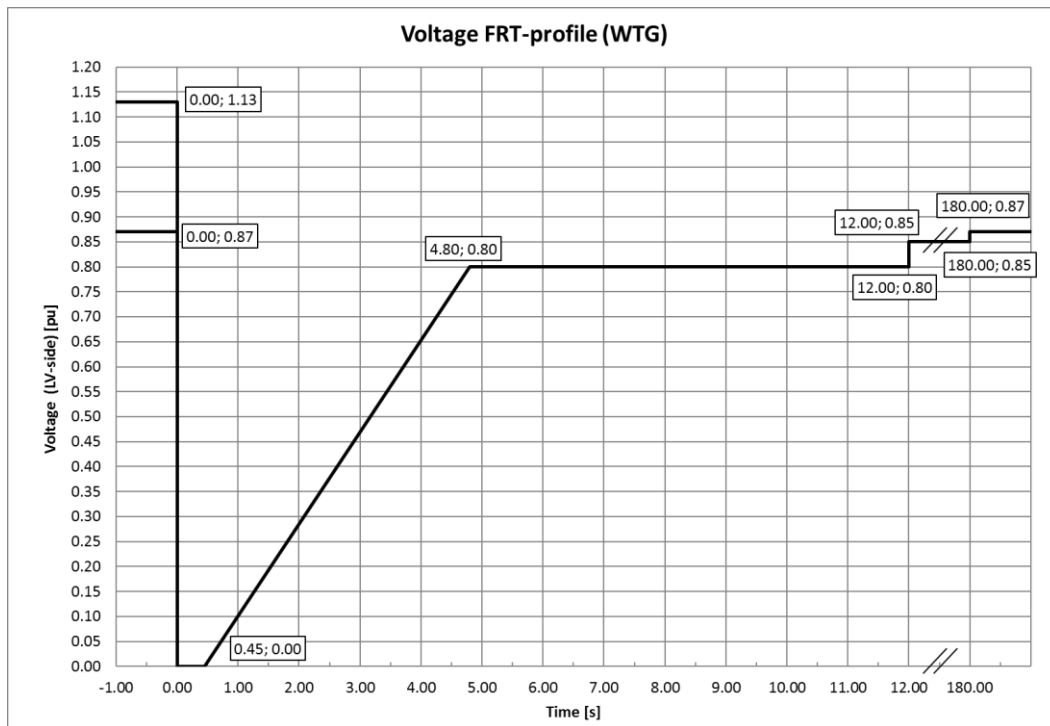


Figure 10-1: Low voltage tolerance curve for symmetrical and asymmetrical faults, where U represents voltage as measured on the grid.

For grid disturbances outside the tolerance curve in Figure 10-1, the turbine will be disconnected from the grid.

### NOTE

All fault ride through capability values are preliminary and subject to change.

Power Recovery Time	
Power Recovery to 90% of Pre-Fault Level	Maximum 0.1 seconds

Table 10-5: Power recovery time

## 10.6 Performance – Reactive Current Contribution

The reactive current contribution depends on whether the fault applied to the turbine is symmetrical or asymmetrical.

### NOTE

All reactive current contribution values are preliminary and subject to change.

### 10.6.1 Symmetrical Reactive Current Contribution

During symmetrical voltage dips, the wind farm will inject reactive current to support the grid voltage. The reactive current injected is a function of the measured grid voltage.

The default value gives a reactive current part of 1 p.u. of the rated active current at the high voltage side of the HV transformer. Figure 10-2, indicates the reactive current contribution as a function of the voltage. The reactive current contribution is independent from the actual wind conditions and pre-fault power level. As seen in Figure 10-2, the default current injection slope is 2% reactive current increase per 1% voltage decrease. The slope can be parameterized between 0 and 10 to adapt to site specific requirements.

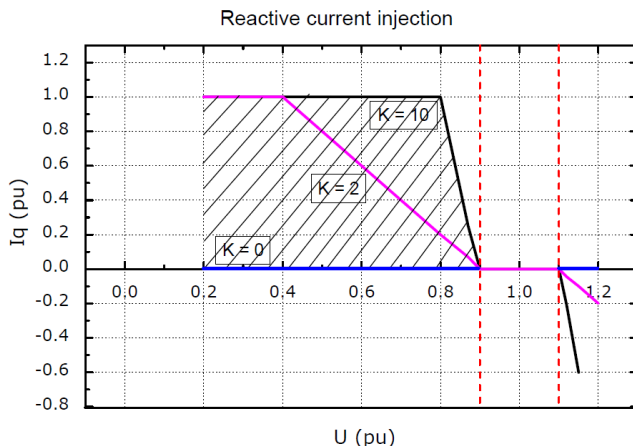


Figure 10-2: Reactive current injection

### 10.6.2 Asymmetrical Reactive Current Contribution

The injected current is based on the measured positive sequence voltage and the used K-factor. During asymmetrical voltage dips, the reactive current injection is limited to approximate 0.4 p.u. to limit the potential voltage increase on the healthy phases.

## 10.7 Performance – Multiple Voltage Dips

The turbine is designed to handle re-closure events and multiple voltage dips within a short period of time due to the fact that voltage dips are not evenly distributed during the year. For example, the turbine is designed to handle 10 voltage dips of duration of 200 ms, down to 20% voltage, within 30 minutes.

## 10.8 Performance – Active and Reactive Power Control

The turbine is designed for control of active and reactive power via the VestasOnline® SCADA system.

Maximum Ramp Rates for External Control	
<b>Active Power</b>	0.1 p.u./sec for max. power level change of 0.3 p.u. 0.3 p.u./sec for max. power level change of 0.1 p.u.
<b>Reactive Power</b>	20 p.u./sec

Table 10-6: Active/reactive power ramp rates (values are preliminary)

To support grid stability the turbine is capable to stay connected to the grid at active power references down to 10 % of nominal power for the turbine. For active power references below 10 % the turbine may disconnect from the grid.

### 10.9 Performance – Voltage Control

The turbine is designed for integration with VestasOnline® voltage control by utilising the turbine reactive power capability.

### 10.10 Performance – Frequency Control

The turbine can be configured to perform frequency control by decreasing the output power as a linear function of the grid frequency (over frequency). Dead band and slope for the frequency control function are configurable.

### 10.11 Distortion – Immunity

The turbine is able to connect with a pre-connection (background) voltage distortion level at the grid interface of 8% and operate with a post-connection voltage distortion level of 8%.

### 10.12 Main Contributors to Own Consumption

The consumption of electrical power by the wind turbine is defined as the power used by the wind turbine when it is not providing energy to the grid. This is defined in the control system as Production Generator 0 (zero).

The VMP8000 control system has a hibernate mode that reduces own consumption when possible. Similarly, cooling pumps may be turned off when the turbine idles.

The components in Table 10-7 have the largest influence on the own consumption of the wind turbine. The values given are maximum component consumption, but the average consumption can be lower depending on the actual conditions, the climate, the wind turbine output, the cut-off hours, etc.

Main contributors to Own Consumption	V150	V162
Hydraulic Motor	2 x 22 kW	3 x 18.5 kW
Yaw Motors	Max 23 kW	Max 26 kW
Generator Cooling Fans	4 x 2.5 kW	
Water Heating	10 kW	
Water Pumps	4 kW + 7.5 kW	
Oil Pump for Gearbox Lubrication	7.5 kW	
Controller Including Heating Elements for the Hydraulics and all Controllers	Approximately 3 kW	
HV Transformer No-load Loss	See section 4.3 HV Transformer	

Table 10-7: Main contributors to own consumption data (values are preliminary).

**11 Drawings**

**11.1 Structural Design – Illustration of Outer Dimensions**

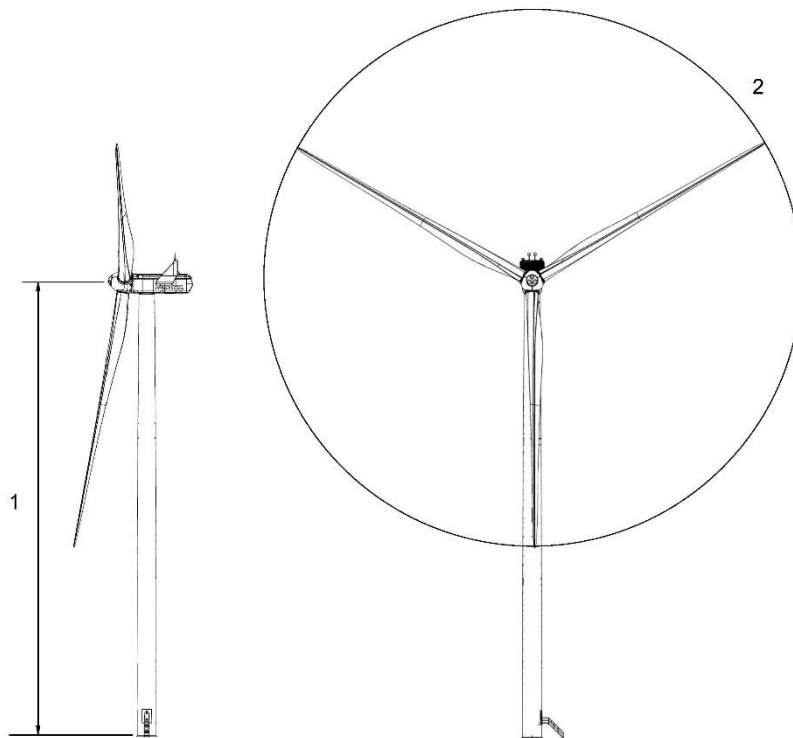


Figure 11-1: Illustration of outer dimensions – structure

- 1 Hub heights: See Performance Specification
- 2 Rotor diameter: 150/162 m

## 12 General Reservations, Notes and Disclaimers

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- The general descriptions in this document apply to the current version of the EnVentus™ turbines. Updated versions of the EnVentus™ turbines, which may be manufactured in the future, may differ from this general description. In the event that Vestas supplies an updated version of the EnVentus™ turbine, Vestas will provide an updated general description applicable to the updated version.
- Vestas recommends that the grid shall be as close to nominal as possible with limited variation in frequency and voltage.
- A certain time allowance for turbine warm-up must be expected following grid dropout and/or periods of very low ambient temperature.
- All listed start/stop parameters (e. g. wind speeds and temperatures) are equipped with hysteresis control. This can, in certain borderline situations, result in turbine stops even though the ambient conditions are within the listed operation parameters.
- The earthing system must comply with the minimum requirements from Vestas and be in accordance with local and national requirements and codes of standards.
- This document, General Description, is not an offer for sale, and does not contain any guarantee, warranty and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method). Any guarantee, warranty and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method) must be agreed to separately in writing.