REGIONE AUTONOMA DELLA SARDEGNA

PROVINCE DI NUORO E SASSARI

COMUNE DI BITTI

COMUNE DI BUDDUSO'

PROGETTO PER LA REALIZZAZIONE DEL PARCO EOLICO "BITTI - TERENASS"

Potenza complessiva 56 MW

PROGETTO DEFINITIVO

DELL'IMPIANTO, DELLE OPERE CONNESSE E DELLE INFRASTRUTTURE INDISPENSABILI

PA-R.1.1

ELEMENTI TECNICI

AEROGENERATORE DI PROGETTO

COMMITTENTE

GREEN ENERGY SARDEGNA 2
S.r.L.

Piazza del Grano 3
39100 Bolzano, Italia

GRUPPO DI LAVORO

Ing. Giorgio Floris: Coordinatore e progettista opere civili, elettriche e sottostazione

Ing. Matteo Floris: Collaborazione progettazione parte civile, elettrica e sottostazione

Geom. Francesco Troncia: rilievi, elaborazioni grafiche e progettazione

Dott. Geol. Fausto Pani: relazione paesaggistica - Sia - studio geologico simulazioni fotografiche

Dott. Maurizio Medda: relazione faunistica e piano di monitoraggio faunistico

Dott. Agr. Paolo Callioni - Dott. For. Carlo Poddi: relazione pedo agronomica e vegetazionale

Dott. For. Carlo Poddi:relazione impatto acustico ante operam e bassa frequenza

Dott.ssa Archeo. Giuseppina Manca di Mores: relazione archeologica

Ing.Vincenzo Pinna: calcoli strutturali

Ing. Michele Losito, consulente scientifico Prof. Gianluca Gatto: relazione sui principali ponti radio nell'area del parco

Ce.Pi.Sar.: piano monitoraggio chirotteri

SCALA:

FIRME

ORDINE INGEGNERI PROVINCIA CAGLIARI
N. 2192
Dr. Ing. Giorgio Floris

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00	Prima emissione				Luglio 2020

REGIONE AUTONOMA DELLA SARDEGNA

Comuni di Bitti (Nuoro), Onanì (Nuoro) e Buddusò (Sassari)

GREENENERGYSARDEGNA2

Green Energy Sardegna 2 Srl
Piazza del Grano 3, Bolzano, P.IVA e Cod. Fisc. 02993950217

PROGETTO DEL PARCO EOLICO "BITTI-TERENASS", DELLE OPERE CONNESSE E DELLE INFRASTRUTTURE INDISPENSABILI

ELEMENTI TECNICI AEROGENERATORE DI PROGETTO

INDICE

1 DESCRIZIONE AEROGENERATORE

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 (limitata a 5,09 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 sostengo, 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 mq.

2 DATI CARATTERISTICI

Posizione rotore: sopravento
Regolazione di potenza: a passo variabile
Diametro rotore: max 170 m
Area spazzata: max 22.698 mq
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	89
4	328
5	758
6	1376
7	2230
8	3351
9	4617
10	5090
11	5090
12	5090
13	5090
14	5090
15	5090
16	5090

17	5090
18	5090
19	5090
20	5090
21	5090
22	5090
23	5090
24	5090
25	4964

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 ai fini di redigere:

- studio di impatto acustico (modello commerciale con impatto peggiorativo)
- 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 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.

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-5.6 MW
2. Siemens-Gamesa SG170-115 m HH-6.2 MW

Per entrambi i modelli si considera la limitazione della curva di potenza ad una potenza pari a quella massima dell’aerogeneratore di progetto, ossia 5,09 MW.

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 comporterebbe le seguenti conseguenze:

- al momento del rilascio dell’autorizzazione alla costruzione del progetto, il modello commerciale scelto potrebbe essere superato dal punto di vista delle migliori tecnologie disponibili da altri modelli più recenti. Si potrebbero, per esempio, avere modelli analoghi in grado di garantire la stessa performance energetica con minori impatti ambientali. E questo beneficio non sarebbe quindi conseguibile;
- il venditore dello specifico modello commerciale potrebbe avvalersi di una sorta di situazione di monopolio e quindi fissare il prezzo fuori dal mercato, obbligando il proponente a realizzare un progetto non sostenibile economicamente.

Developer Package
SG 6.0-170

Application of the Developer Package

The Developer Package serves the purpose of informing customers about the latest planned product development from Siemens Gamesa Renewable Energy 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 6.0-170 in cases where financial institutes, governing bodies, or permitting entities require product specific information in their decision processes.

All technical data contained in the Developer Package is subject to change owing to ongoing technical developments 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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Developer Package
SG 6.0-170

Table of content

Introduction

The SG 6.0-170 is a new wind turbine of the next generation Siemens Gamesa Onshore Geared product platform called Siemens Gamesa 5.X, which builds on the Siemens Gamesa design and operational experience in the wind energy market.

With a new 83.5 m blade and an extensive tower portfolio including hub heights ranging from 100 m to 165 m, the SG 6.0-170 aims at becoming a new benchmark in the market for efficiency and profitability.

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

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

Technical Description

Rotor-Nacelle

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

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

Blades

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

Rotor Hub

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

Drive train

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

Main Shaft

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

Main Bearings

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

Gearbox

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

Generator

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

Mechanical Brake

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

Yaw System

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

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

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

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

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

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

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

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

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

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

Technical Specifications

Rotor

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

Blade

Type .... Self-supporting
Blade length .... 83,5 m
Max chord .... 4.5 m
Aerodynamic profile........ Siemens Gamesa proprietary airfoils
Material .... G (Glassfiber) – CRP (Carbon Reinforced Plastic)
Surface gloss .... Semi-gloss, < 30 / ISO2813
Surface color................. Light grey, RAL 7035 or White, RAL 9018

Aerodynamic Brake

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

Load-Supporting Parts

Hub .... Nodular cast iron
Main shaft .... Nodular cast iron
Nacelle bed frame .... Nodular cast iron

Mechanical Brake

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

Nacelle Cover

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

Generator

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

Grid Terminals (LV)

Baseline nominal power . 6.0 MW / 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 .... 100 m to 165 m and site-specific

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

Operational Data

Cut-in wind speed .... 3 m/s
Rated wind speed .... 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

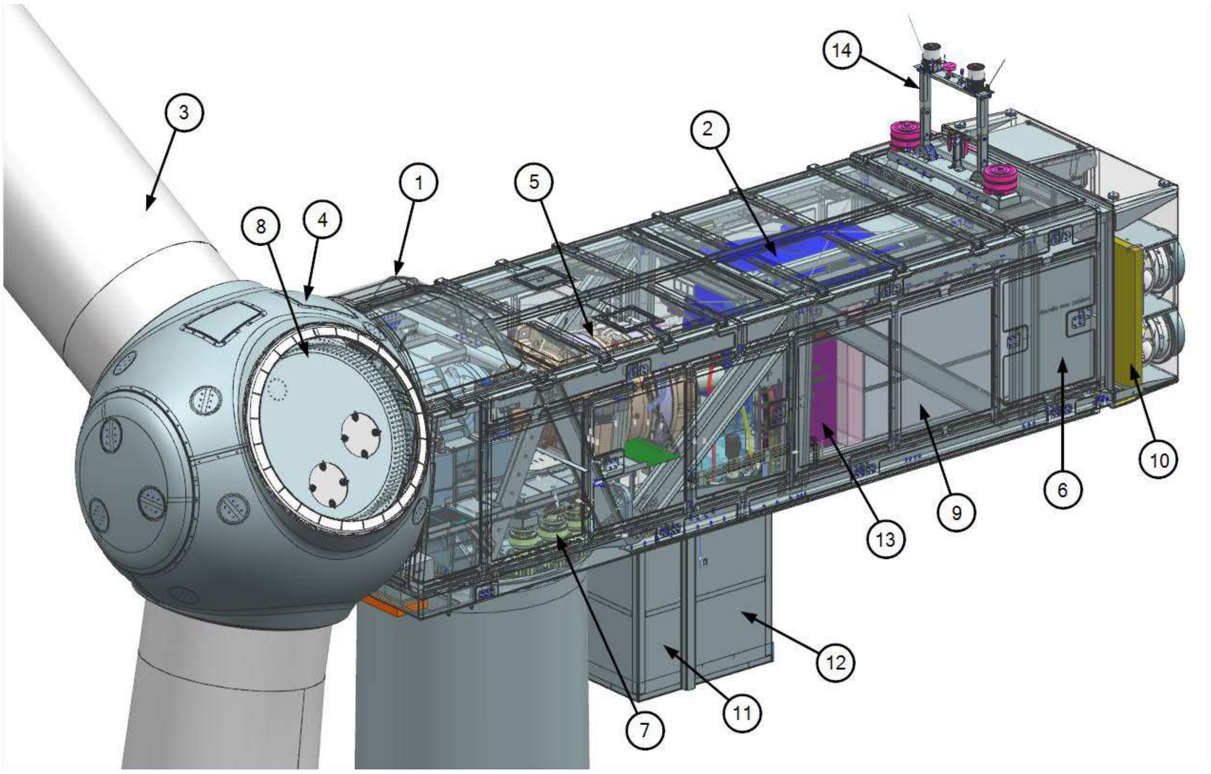
Weight

Modular approach........... Different modules depending on restriction

Nacelle Arrangement

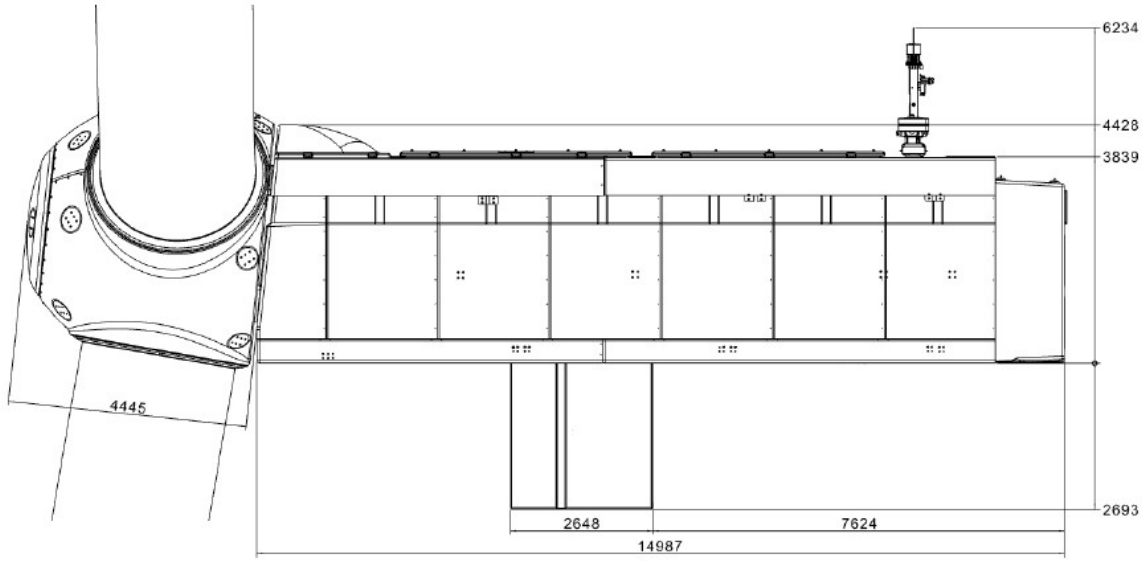
The design and layout of the nacelle are preliminary and may be subject to changes during the development of the product.

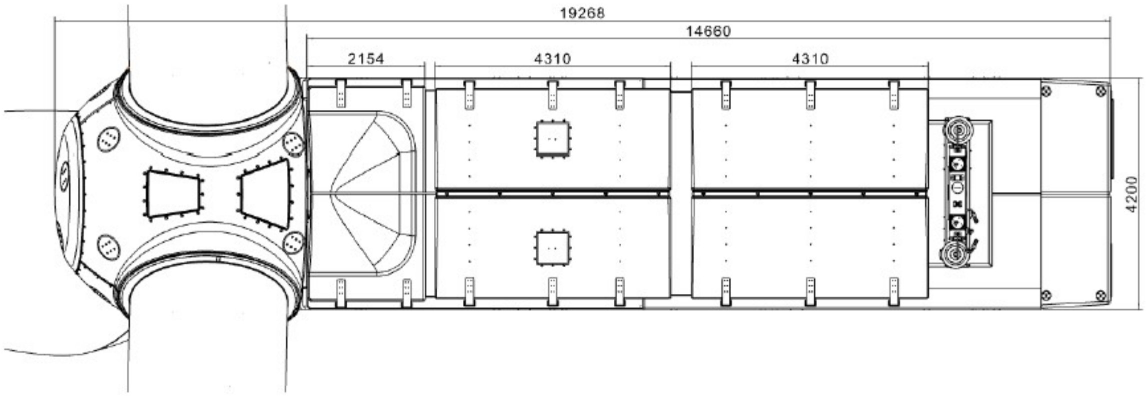
Item	Description	Item	Description
1	Canopy		
2	Generator	8	Blade bearing
3	Blades	9	Converter
4	Spinner/hub	10	Cooling
5	Gearbox	11	Transformer
6	Control panel	12	Stator cabinet.
		13	Front Control Cabinet
		14	Aviation structure



Nacelle Dimensions

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

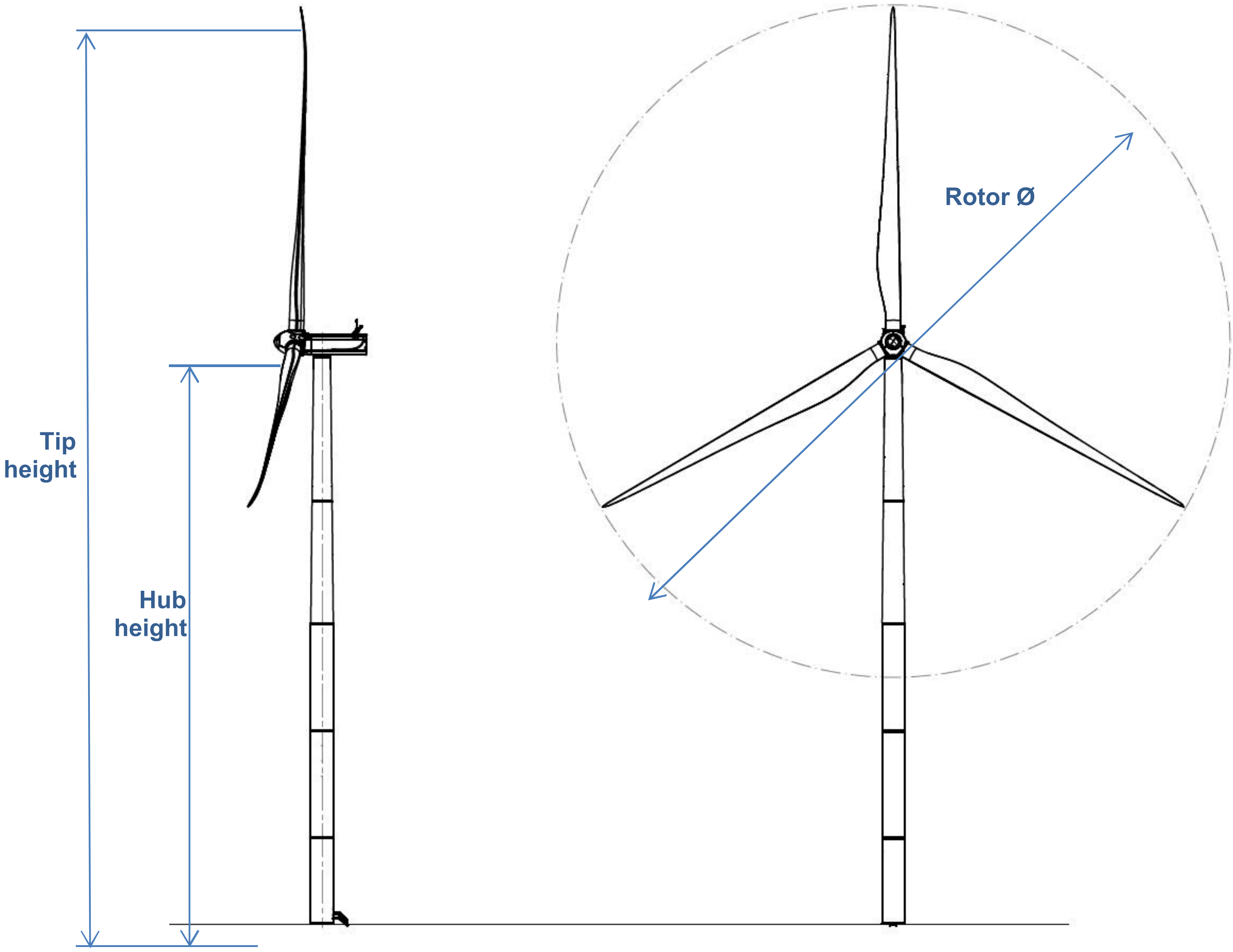




Several modularized solutions are designed to optimize nacelle and hub transportation, subject to project specific conditions.

- 3 modules (heaviest module <95t): Hub, nacelle, drive train
- 4 modules (heaviest module <79t): Hub, nacelle, drive train, transformer
- 6 modules (heaviest module <62t): Hub, nacelle, gearbox, main shaft, transformer and generator

Preliminary Elevation Drawing



Blade Sales Drawing

Tower dimensions

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

Preliminary information:

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

	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)	13.564	18.200	23.800	26.880	29.970
Total weight (T)	84.958	84.328	84.548	71.771	63.863
Volume (CBM)	228	363	470	584	498

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

	Concrete Section 1	Steel Section 2	Steel Section 3	Steel Section 4
External diameter upper flange (m)	4.668	4.300	4.300	3.574
External diameter lower flange (m)	7.888	4.300	4.,300	4.300
Section's height (m)	100.29	17.970	21.385	21.531

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

Foundation Dimensions and loads

The SG 6.0-170 foundation design inputs for T115 can be found on the following documents: D2372547.

Foundation loads inputs for T115 m can be found on the following document: D2370721

Detailed information about foundation loads will be available upon request

Design Climatic Conditions

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

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

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

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

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

Subject	ID	Issue	Unit	Value
6. Dust	6.1	Dust definitions	-	IEC 60721-3-4:1995
	6.2	Working environmental conditions	mg/m^3	Average Dust Concentration (95% time) → $0.05\ mg/m^3$
	6.3	Concentration of particles	mg/m^3	Peak Dust Concentration (95% time) → $0.5\ mg/m^3$
7. Hail	7.1	Maximum hail diameter	mm	20
	7.2	Maximum hail falling speed	m/s	20
8. Ice	8.1	Ice definitions	-	-
	8.2	Ice conditions	Days/yr	7
9. Solar radiation	9.1	Solar radiation definitions	-	IEC 61400-1
	9.2	Solar radiation intensity	W/m^2	1000
10. Humidity	10.1	Humidity definition	-	IEC 61400-1
	10.2	Relative humidity	%	Up to 95
11. Obstacles	11.1	If the height of obstacles within 500m of any turbine location height exceeds 1/3 of (H – D/2) where H is the hub height and D is the rotor diameter then restrictions may apply. Please contact Siemens Gamesa Renewable Energy for information on the maximum allowable obstacle height with respect to the site and the turbine type.		
12. Precipitation[3]	12.1	Annual precipitation	mm/yr	1100

[3] 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.

Flexible Rating Specifications

The SG 6.0-170 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[4].

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 6.0-170 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 6.0-170 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 analysed for more demanding site conditions.

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[5]
						Cos Phi	Voltage Range	Frequency range	
SG 6.0-170	AM 0	6.2	106	D2075729	D2359593	0.9	[0.95,1.12] Un	±3% Fn	30ºC
SG 6.0-170	AM-1	6.1	106	D2356499	D2359593	0.9	[0.95,1.12] Un	±3% Fn	33ºC
SG 6.0-170	AM-2	6.0	106	D2356509	D2359593	0.9	[0.95,1.12] Un	±3% Fn	35ºC
SG 6.0-170	AM-3	5.9	106	D2356523	D2359593	0.9	[0.95,1.12] Un	±3% Fn	37ºC
SG 6.0-170	AM-4	5.8	106	D2356539	D2359593	0.9	[0.95,1.12] Un	±3% Fn	38ºC
SG 6.0-170	AM-5	5.7	106	D2356376	D2359593	0.9	[0.95,1.12] Un	±3% Fn	39ºC
SG 6.0-170	AM-6	5.6	106	D2356368	D2359593	0.9	[0.95,1.12] Un	±3% Fn	40ºC

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

Noise Reduction System (NRS) Modes

The Noise Reduction System is an optional module available with the basic SCADA configuration and it therefore requires the presence of a SGRE SCADA system to work. NRS Modes are noise curtailed modes enabled by the Noise Reduction System. The purpose of this system is to limit the noise emitted by any of the functioning turbines and thereby comply with local regulations regarding noise emissions.

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

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

Rotor Configuration	NRS Mode	Rating [MW]	Noise [dB(A)]	Power Curve Document	Acoustic Emission Document	Max temperature With Max active power and electrical capabilities[6]
SG 6.0-170	N1	6.00	105.5	D2323420	D2359593	30ºC
SG 6.0-170	N2	5.80	104.5	D2314784	D2359593	30ºC
SG 6.0-170	N3	5.24	103.0	D2314785	D2359593	30ºC
SG 6.0-170	N4	5.12	102.0	D2314786	D2359593	30ºC
SG 6.0-170	N5	4.87	101.0	D2314787	D2359593	30ºC
SG 6.0-170	N6	4.52	100.0	D2314788	D2359593	30ºC
SG 6.0-170	N7	3.60	99.0	D2314789	D2359593	30ºC

Control Strategy

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

6 Please refer to "High Temperature Power De-rating Specification" for more details'.

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

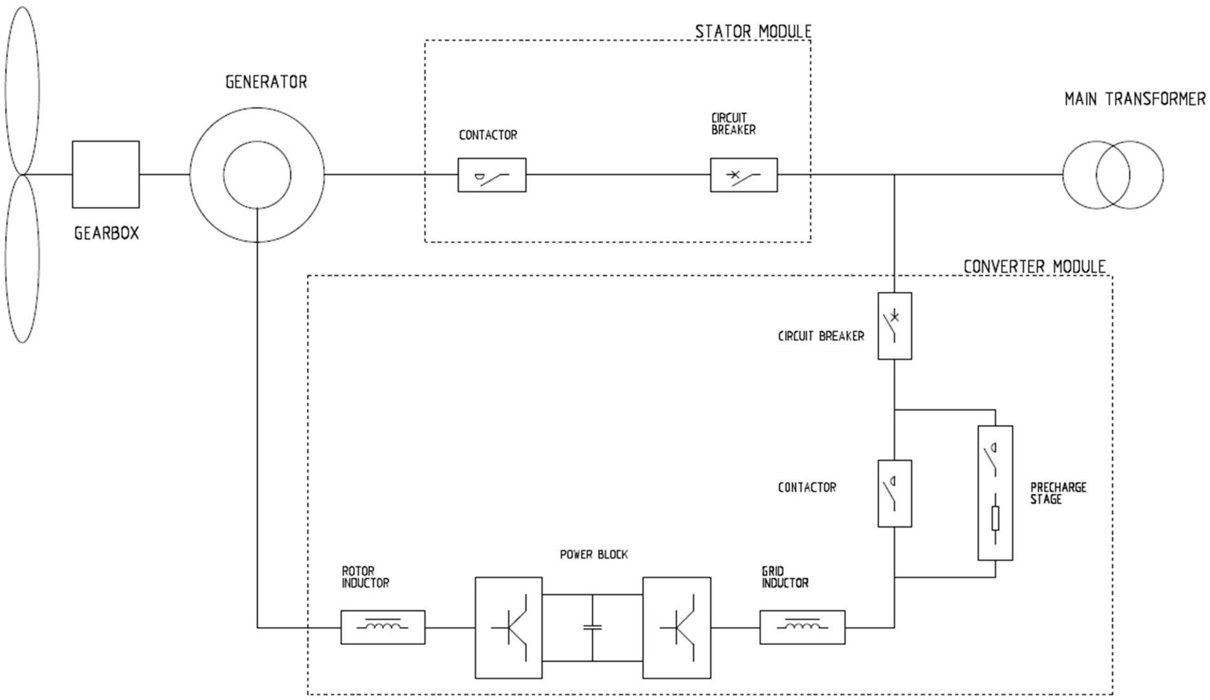
Transformer impedance requirement	8.5 % - 10.5%
Secondary voltage	690 V
Vector group	Dyn 11 or Dyn 1 (star point earthed)

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

All data are subject to tolerances in accordance with IEC.

Simplified Single Line Diagram



Transformer Specifications ECO 30 kV

Transformer

Type	Liquid filled
Max Current	7.11 kA + harmonics at nominal voltage ± 10 %
Nominal voltage	30/0.69 kV
Frequency	50 Hz
Impedance voltage	9.5% ± 8.3% at ref. 6.5 MVA
Loss (P_0 /$P_{k75°C}$)................	4.77/84.24 kW
Vector group	Dyn11
Standard.......................	IEC 60076 ECO Design Directive

Transformer Cooling

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

Transformer Monitoring

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

Transformer Earthing

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

Switchgear Specifications

General

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

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

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

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

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

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

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

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

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

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

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

The switchgear is located below the tower structure. 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.

Optionally, the switchgear can be delivered with surge arresters installed in between the switchgear and wind turbine transformer on the outgoing bushings of the circuit breaker feeder.

Technical Data for Switchgear

Switchgear	
Make	TBD
Type	TBD
Rated voltage	20-40,5(Um) kV
Operating voltage	20-40,5(Um) kV
Rated current	630 A
Short time withstand current	20 kA/1s
Peak withstand current	50 kA
Power frequency withstand voltage	70 kV
Lightning withstand voltage	170 kV
Insulating medium	SF_6
Switching medium	Vacuum
Consist of	2/3/4 panels
Grid cable feeder	Cable riser or line cubicle
Circuit breaker feeder	Circuit breaker
Degree of protection, vessel	IP65
Internal arc classification IAC:	A FL 20 kA 1s
Pressure relief	Downwards
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 Cables	630 A bushings type C
Grid cable feeder	M16
	Max 2 feeder cables
Cable entry	From bottom
Cable clamp size (cable outer diameter) **	26 - 38mm 36 - 52mm 50 - 75mm
Circuit breaker feeder	630 A bushings type C
Cable entry	M16
	From bottom
Interface to turbine control	
Breaker status	
SF6 supervision	1 NO contact
External trip	1 NO contact

*Cable clamps are not part of switchgear delivery.

Grid Performance Specification, 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 are based on the assumption that the electrical network is designed to be compatible with operation of the wind turbine. SGRE will provide a document with guidance to perform an assessment of the network's compatibility.

Fault Ride Through (FRT) Capability

The wind turbine is capable of operating when voltage transient events occur on the interconnecting transmission system above and below the standard voltage lower limits and time slot according to Figure 1 and Figure 2.
This performance assumes that the installed amount of wind turbines is in the right proportion to the strength of the grid, which means that the short circuit ratio (Sk/Sn) and the X/R ratio of the grid at the wind turbine transformer terminals must be adequate.
Evaluation of the wind turbine's fault ride through capability in a specific system must be based on simulation studies using the specific network model and a dynamic wind turbine model provided by SGRE. This model is a reduced order model, suitable for balanced simulations with time steps between 4-10 ms.
The standard voltage limits for the Siemens Gamesa 5.X, 50 Hz wind turbine are presented in Figure 1 between 0 - 70 seconds.

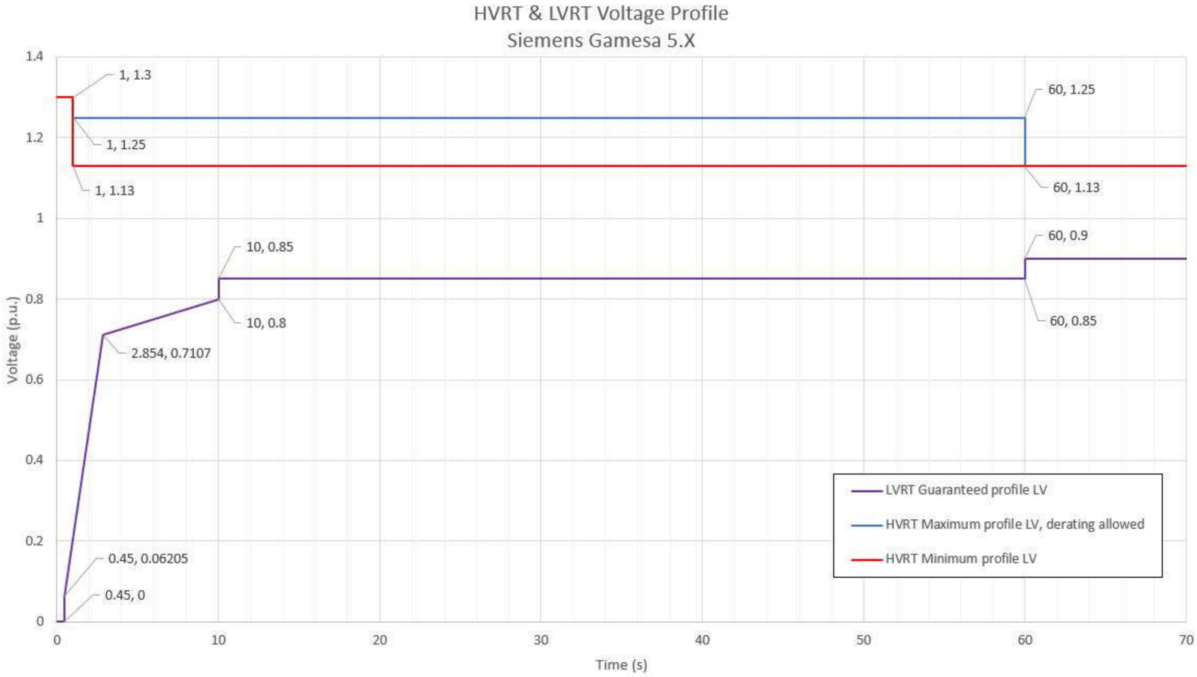


Figure 1. High and Low voltage limits for Siemens Gamesa 5.X, 50 Hz wind turbine in the range of 0-70 seconds. The nominal voltage is 690 V
(i.e. 1 p.u.).

Power Factor (Reactive Power) Capability
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).

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

Frequency Capability
The wind turbine can operate in the frequency range between 46 Hz and 54 Hz, making a difference between a steady state operation (full simultaneity): ±3%, and transients' events (limited simultaneity): ±8%, over rated frequency.
Simultaneities of main operation parameters shall be considered for evaluating the permitted operation ranges, mainly:

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

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

Voltage Capability
The voltage operation range for the wind turbine is between 85% and 113% of nominal voltage at the low voltage side of the wind turbine transformer. The voltage can be up to 130% for 1s, see Figure 1. The wind turbine's target voltage shall stay between 95% and 105% to support the best possible performance by staying within the operation limits.
Beyond ±10% of voltage deviation, automatic voltage support algorithms could execute Reactive Power control, to secure a continuous operation of the Wind Turbine Generator and maximizing the availability, overriding external control and setpoints of Reactive Power.

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

Reactive Power -Voltage Control
The power plant controller can operate in two 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

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/voltage reference. Finally, 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 response accordingly from the wind turbine.

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

All data are subject to tolerances in accordance with IE

Grid Performance Specification, 60 Hz

This document describes the grid performance of the SG5.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 are based on the assumption that the electrical network is designed to be compatible with operation of the wind turbine. SGRE will provide a document with guidance to perform an assessment of the network's compatibility.

Fault Ride Through (FRT) Capability

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

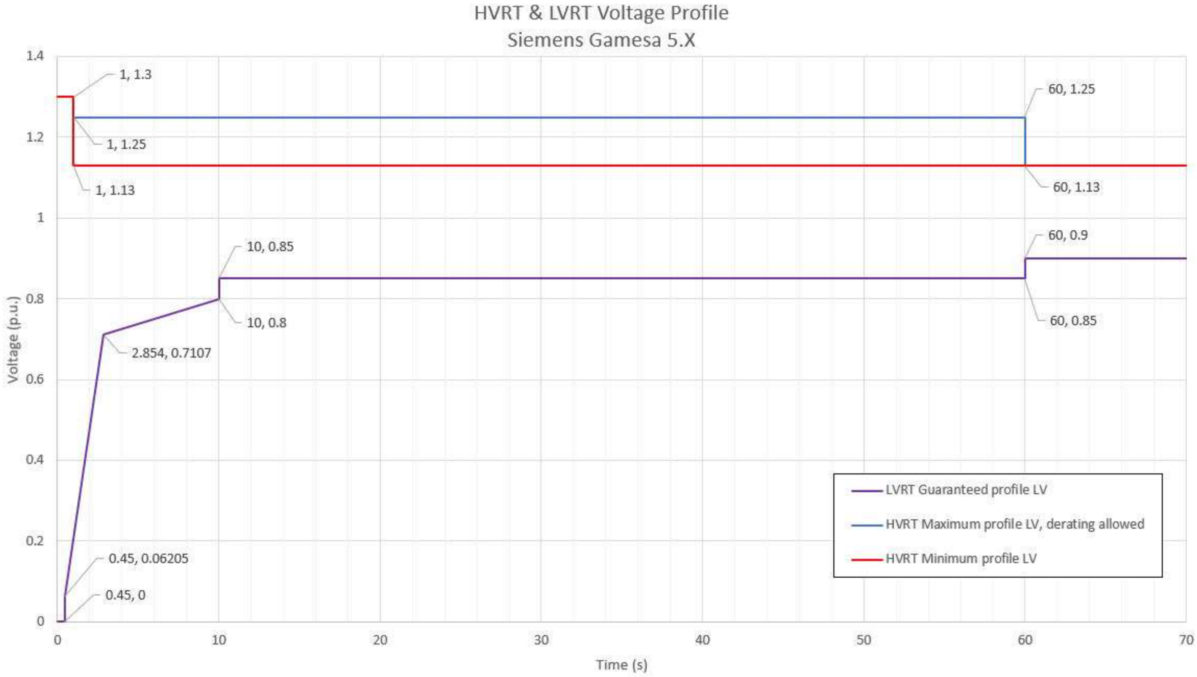


Figure 1. High and Low voltage limits for Sieemns Gamesa 5.X, 60 Hz wind turbine in the range of 0-70 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).

Power Factor (Reactive Power) Capability

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).

Supervisory Control and Data Acquisition (SCADA) Capability

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

Frequency Capability

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

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

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

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

Voltage Capability

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

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

Flicker and Harmonics

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

Reactive Power -Voltage Control

The power plant controller can operate in two 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

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/voltage reference. Finally, 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 response accordingly from the wind turbine.

Frequency Control

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

Reactive Power Capability, 50 and 60 Hz

This document describes the reactive power capability of SG 6.0-170, 50/60 Hz wind turbines during active power production. SG 6.0-170 wind turbines are equipped with a B2B Partial load frequency converter which allows the wind turbine to operate in a wide power factor range.

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 and grid conditions.

Between others, the Reactive Power Capability at a given Operating Conditions depends on existing Active Power, internal temperature of Wind Turbine Generator 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.

Reactive Power Capability Curves

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

Figure 1 shows the guaranteed reactive power capability depending on the generated Active Power at various voltages at the LV terminals, starting by 90% of rated voltage.

The reference external temperature is set to maximum (SG 6.0-170, 6.2MW, 30ºC ext Temp).

Maximum capabilities when reducing ambient temperatures or increasing voltage level are higher but not shown in this document as specific studies shall be carried out in case of necessity.

Operation at voltages in between 86% to 90% over rated is considered a special situation where both Reactive Power and Active power may be de-rated depending on Operation Condition of the Wind Turbine Generator, especially dependent on the Ambient Temperature.

Between voltages of +112% and +113%, as well as between 85% and 86%, Reactive Power Controller enters in Voltage Saturation Mode and will not allow an amount of Reactive Power generation or consumption that would cause a self-trip due to over or under voltage protections, caused by the own operation of the turbine. These levels are possible to be set.

Figure 2 includes reactive power capability at no wind operating conditions (QwP0).

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

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

These figures consider Wind Turbine operation around its expected generator speed for each operation condition. 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.

The guaranteed values of Reactive Power for those operational points in between the shown borders and corners of the figures, can be calculated by means of linear interpolation. Guaranteed values of Reactive Power in voltages over 0.95pu, are considered constant and fixed in the given values.

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.

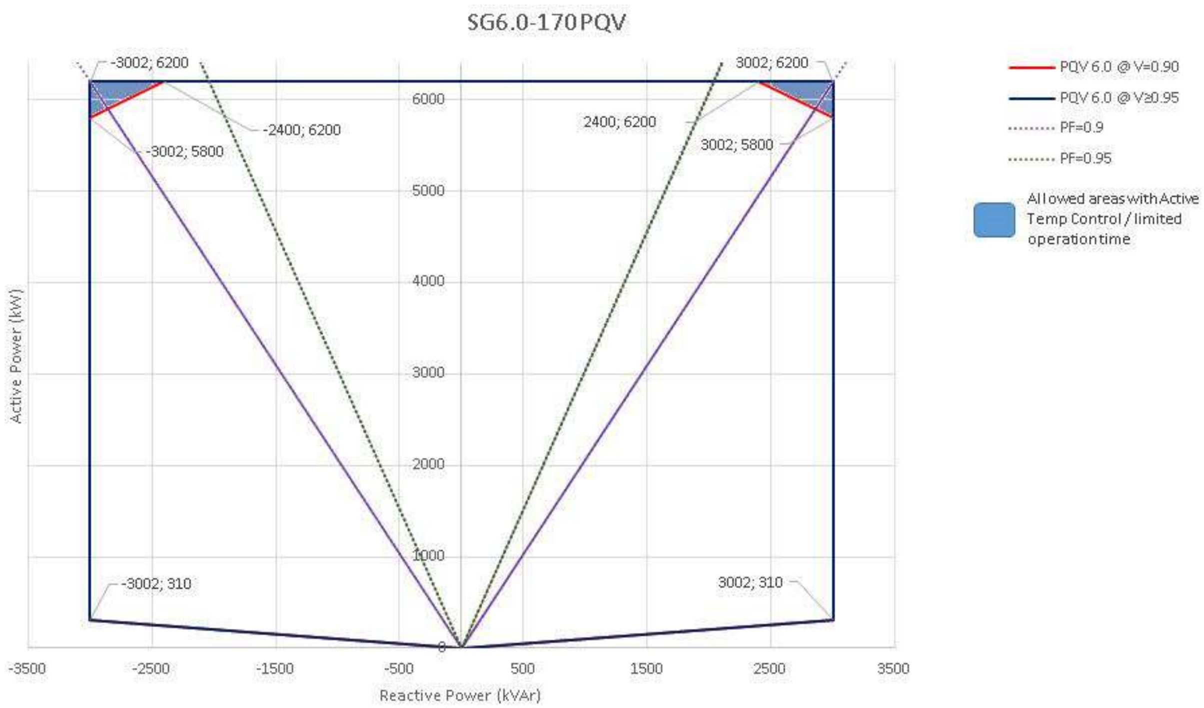


Figure 1: Reactive power capability curves, 50/60 Hz Wind Turbine, at LV terminals. External Ambient Temperature dependency included for Flex Rating operation description

SG 6.0-170 Prated = 6.2MW				
Active Power [kW]	V = 0.9pu		V ≥ 0.95pu	
	Reactive Power [kVAr]	Power Factor	Reactive Power [kVAr]	Power Factor
0	0 *	--*	0 *	--*
300	3002	0,9	3002	0,9
5800	3002	0,9	3002	0,9
6200	2400	0,933	3002	0,9

Table 1: Reactive power capability curves, 50/60 Hz Wind Turbine, at LV terminals. External Ambient Temperature dependency included for Flex Rating operation description

* Reactive Power at no wind conditions applies

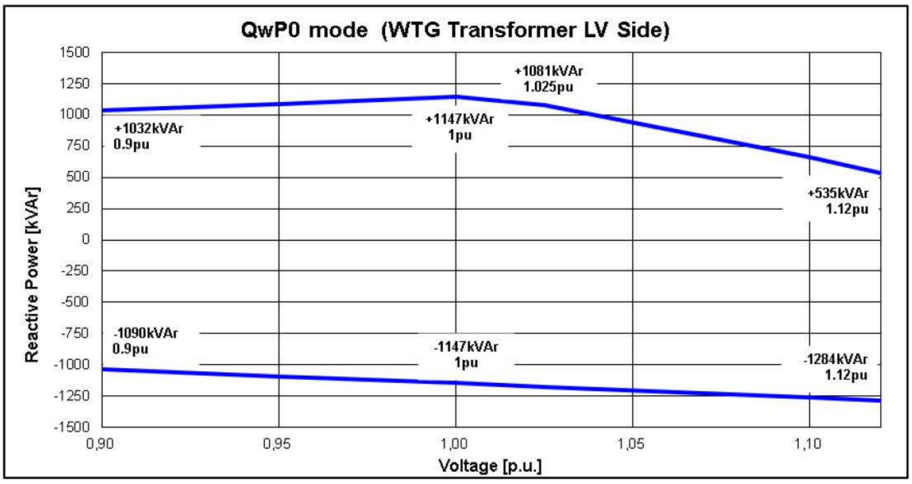


Figure 2: Reactive power capability at no wind (QwP0)

Using the standard Grid Transformer parameters, next table summarizes the expected Reactive Power Capability referenced to HV terminals when considering the Grid Transformer Reactive Power consumption and the declared LV PQV capability from Table 1.

Note: These values shall be used only as reference as are fully dependent on Grid Transformer variant, construction and brand. In general, it is considered that a deviation up to ±10% in Reactive Power consumption can exist between variants.

SG 6.0-170 Text = 30ºC Prated = 6,2MW					
Active Power [% over rated]	Active Power [kW]	V_{LV_side} = 0,9pu		V_{LV_side} ≥ 0,95pu	
		Reactive Power HV side [kVAr]		Reactive Power HV side [kVAr]	
0%	0	0 **	**	0 **	**
5%	300	2873	-3139	2873	-3139
16%	1000	2860	-3152	2860	-3152
24%	1500	2842	-3171	2842	-3171
32%	2000	2816	-3196	2816	-3196
40%	2500	2783	-3229	2783	-3229
48%	3000	2743	-3269	2743	-3269
56%	3500	2696	-3316	2696	-3316
65%	4000	2641	-3371	2641	-3371
73%	4500	2579	-3433	2579	-3433
81%	5000	2510	-3503	2510	-3503
89%	5500	2433	-3579	2433	-3579
94%	5800	2384	-3629	2384	-3629
100%	6200	1759	-3049	2314	-3699

Table 2: Reactive power capability curves, 50/60 Hz Wind Turbine, at HV terminals.

SCADA, System Description

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

Main features
The SCADA system has the following main features:

- On-line supervision and control accessible via 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.

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.

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.

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

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

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

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

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

Grid measuring station and Wind Farm Controler
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.

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

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.

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

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

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

Codes and Standards

INTRODUCTION AND SCOPE

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.

CODES AND STANDARDS

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.

GENERAL

- IEC-RE Operational Document: OD-501, Type and Component Certification Scheme*
  - *IEC-RE is the substitute of IEC 61400-22:2010 Ed.1, Wind turbines – Part 22: Conformity testing and certification.

- *IEC 61400-1:2019 Ed.4 Wind turbines –. Part 1: Design requirements*
- *IEC 61400-11:2012 + AMD1:2018, Wind turbine generator systems Part 11: Acoustic noise measurement techniques*
- *IEC 61400-12-1:2017, Ed.1, Wind Turbine Generator Systems Part 12: 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*
- *EN 10083:2006, Quenched and tempered steels - Part 1: Technical delivery conditions for special steels (Main shaft)*
- *EN 1563:2012, 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 life - Life modification factor aDIN and calculation of the modified rating life*
- *ISO 76:2006 Rolling bearings - Static load ratings*
- *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 4413:2011 Hydraulic fluid power -- General rules and safety requirements for systems and their components*
- *DIN 51524-3_1990 Pressure fluids - Hydraulic oils - Part 3: HVLP hydraulic oils, Minimum requirements*
- *ISO 16889:2008 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*
- DNVGL-ST-0126:2016 *Support structures for wind turbines*

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

GEARBOX

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

ELECTRICAL

- *IEC 61400-21:2008 Wind turbine generator systems - Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines*
- *IEC 61400-24 Ed. 1.0 (2010) Wind turbines - Part 24: Lightning protection.*
- *IEC* 60076-16:2018 – Power transformers - Part 16: Transformers for wind turbine applications

- *EN 60204-1:2006 (+correct 2010) Safety of machinery - Electrical equipment of machines - Part 1: General requirements*
- *EN 61000-6-2:2005 Electromagnetic compatibility (EMC) - Part 6-2: Generic standards – Immunity for industrial environments.*
- *EN 61000-6-4:2007 Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments.*
- *EN 61439-1:2014 Low-voltage switchgear and control gear assemblies. General rules*
- *EN 61439-2:2011 Low-voltage switchgear and control gear assemblies. Power switchgear and control gear assemblies*

- *Low Voltage Directive 2014/35/EU*
- *EMC Directive* 2014/30/EU

QUALITY

- ISO 9001:2015 Quality management systems – Requirements

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

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)*

Other Performance Features

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

High Wind Derated operational mode

In the case of SG 6.0-170 high wind derated mode, it is enabled as it can be observed on the different power curves included in this document. The power production is limited once wind speed exceeds a threshold value defined by design, until cut-out wind speed is reached and the wind turbine stops producing power. This functionality extends the range of operation in high wind conditions limiting turbine loads dependent of maximum operational wind speed, providing more predictable energy output, minimizing production losses, and improving grid stability by reducing the risk of simultaneous power cut outs.

High Temperature Ride Through (also known as Temperature De-Rating)

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

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

High temperature kit could be included in case operating range needs to be extended.

The control system, considering the defined turbine type and altitude above sea level, will dynamically adjust the maximum allowed power as a function of the ambient temperature.

Ice Detection System

Ice Detection System (Default)

The default ice detection method is an integrated part of the Siemens Gamesa Renewable Energy (SGRE) wind turbine controller. It is a software solution that can be used to detect ice on the turbine blades by comparing actual performance data to the turbine nominal power curve. The actual performance is based on 10 minutes average data. If the actual performance is below the low power ice detection power curve, then under certain conditions it is reasonable to assume that the low power production is caused by ice build-up on the blades. This method of ice detection is only available when the turbine is operating.

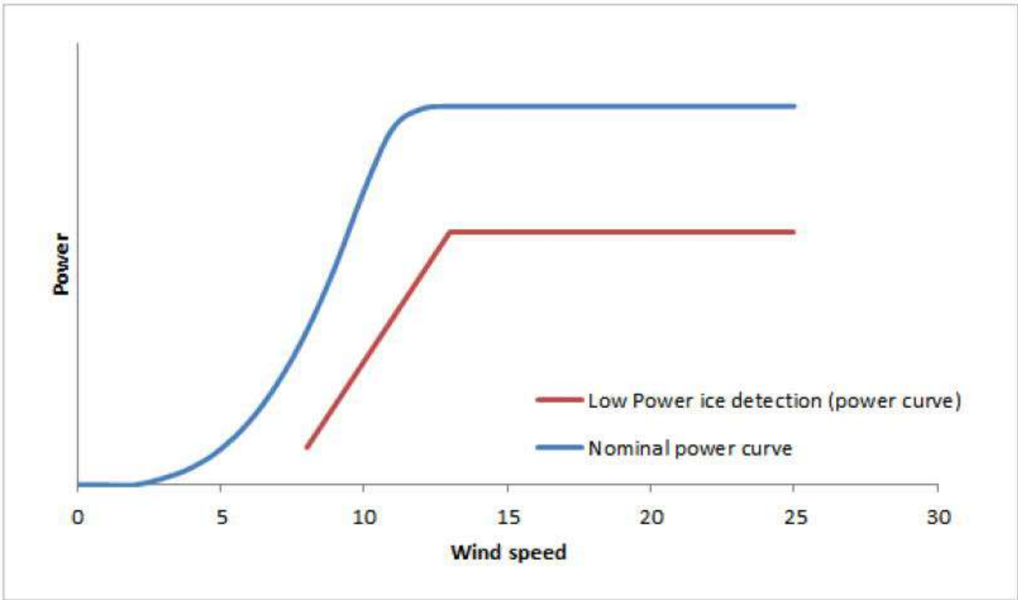


Figure 1: Illustrative comparison of the low power ice detection power curve and the nominal power curve.

Ice Detection Sensors

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. This may be followed by a de-icing sequence (if de-icing is installed), or yaw to a predefined position until it is deemed safe to restart.

Enhanced Ice Detection Function (Optional)

An enhanced ice detection function is an optional safety system, which is primarily used on sites exposed to icy conditions. The system will provide information to the wind turbine controller about the potential risk of ice on the rotor blades.
The algorithm is based on an ice probability calculation evaluating performance, temperature, humidity (additional sensor installed), wind speed and a nacelle-mounted ice sensor (additional sensor installed). Depending on the site requirements the alarm may cause a turbine stop, a visual and/or acoustic warning on site (optional) and/or – if installed – the rotor blade de-icing system is activated. The alarm is active until the site conditions are back to a regular state.

Certification

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

System Architecture

The system consists of the following parts:

- Sensors including control and evaluation units (Optional)
- Interface to the SGRE wind turbine controller
- Alarm communication to the SGRE SCADA system
- Installation and maintenance according to the valid contract clauses

Integration in SCADA System

SCADA interface for Ice Detection system enables the following:

- Set predefined ice conditions using ice parameters
- Enable or disable automatic stop of turbines
- Enable or disable automatic restart of turbines
- Group turbines for auto stop and auto restart. The SCADA system recommends to group ice sensor installed turbines along with turbines on which ice sensors are not installed.

Default ice parameters are set in SCADA interface. Depending on requirements, default ice parameters can be modified to configure new ice conditions through the SCADA interface.

- Ice Restart Delay: Turbines which are stopped due to ice is restarted only if ice is not reported during the ice restart delay in seconds configured by the user.
- Ice Stop Delay: Turbines are stopped due to ice only if ice is detected on turbines for more than the ice stop delay in seconds configured by the user.
- Ambient Temperature Duration: Duration in seconds when Ice Ambient Temperature configured by the user remains or exceeds, to restart the turbines which are stopped due to ice.
- Ambient Temperature Threshold: The minimum temperature in Celsius configured by the user which sets a condition to restart turbines stopped due to ice formation on blades. The ambient temperature must exceed the Ice Ambient temperature configured by the user for duration in seconds as specified in Ambient Temperature duration. Setting of ice ambient temperature and Ambient temperature duration prevents turbines from rapidly switching between ice start and ice stop operations.
- Activation Time: The Ice Control Start time and Ice Control End time configured by the user in the interface defines the activation time. Turbines are stopped due to ice when current time falls within the time range configured in 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. SCADA system recommends setting time ranges such that turbines can be stopped during the day and started at night.

Ice build-up on the turbine can possibly cause damage to objects and people in the vicinity. It is the sole responsibility of the owner of the turbine(s) to ensure that the public is protected from ice being thrown from the turbine(s). The Owner must always ensure that the operation of the turbine(s) comply with any restriction applicable to the turbine(s), irrespective of whether such restrictions follows from permits, legislation or otherwise. Siemens Gamesa Renewable Energy accepts no responsibility for any violation of requirements.

Restricted
Document no.: 0081-5017 V01
2019-01-24

General Description

EnVentus™ 5 MW

Vestas Wind Systems A/S · Hedeager 42 · 8200 Aarhus N · Denmark · www.vestas.com

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See general reservations, notes and disclaimers (including, section 12, p. 35) to this general description.

1 Introduction

This *General Description* contains data and general descriptions of the EnVentus™ 5MW wind turbine range. The EnVentus™ 5MW 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™ 5MW 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 m²	20611 m²
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	1.57 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 bedplate.

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 bedplate.

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

As an option the nacelle can be 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 with flange connections and modular internals, certified according to relevant type approvals, are available as standard options for several WTG configuration and hub height options. Tower structure is designed according to modular dimensions allowing the reuse of internals building blocks attached to the tower wall by means of welded connections and magnets.

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

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

Raised foundations 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.

Towers	
Type	Tubular steel towers Larger diameter steel towers

Table 3-14: Tower structure data

3.14 Nacelle Bedplate and Cover

The nacelle bedplate is in two parts and consists of a cast iron front part and a girder structure rear part. The front of the nacelle bedplate 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 front nacelle bedplate.

The crane girders are attached to the bedplate rear part.

The nacelle cover is attached to the nacelle bedplate. 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 bedplate front.

Type Description	Material
Nacelle Cover	GRP
Bedplate Front	Cast iron
Bedplate Rear	Girder structure

Table 3-15: Nacelle bedplate 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.

Generator	
Type	Permanent Magnet Synchronous generator
Rated Power [P_N]	Up to 5850 kW (depending on turbine variant)
Frequency range [f_N]	0-138 Hz
Voltage, Stator [U_{NS}]	3 x 800 V (at rated speed)
Number of Poles	36
Winding Type	Form with Vacuum Pressurized Impregnation
Winding Connection	Star
Operational speed range	0-460 rpm
Overspeed Limit (2 minutes)	TBD
Temperature Sensors, Stator	PT100 sensors placed in the stator hot spots.
Insulation Class	H
Enclosure	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]	6850 kVA
Rated Grid Voltage	3 x 720 V
Rated Generator Voltage	3 x 800 V
Rated Grid Current	5500 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 open breathing and equipped with an external water cooling circuit. The insulation liquid used is environmental 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:

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

4.3.1 General transformer data

Transformer	
Type description	Ecodesign liquid immersed transformer.
Basic layout	3 phase, 3 limb, 2 winding transformer.
Applied standards	IEC 60076-1, IEC 60076-16, IEC 61936-1
Cooling method	KF/WF
Rated power	7000 kVA
Rated voltage, turbine side	
U_m 1.1kV	0.720 kV
Rated voltage, grid side	
U_m 24.0kV	19.1-22.0 kV
U_m 36.0kV	22.1-33.0 kV
U_m 40.5kV	33.1-36.0 kV
Insulation level AC / LI / LIC	
U_m 1.1kV	3 / - / - kV
U_m 24.0kV	50 / 125 / 138 kV

Transformer	
U_m 36.0kV	70 / 170 / 187 kV
U_m 40.5kV	80 / 200 / 220 kV
Off-circuit tap changer	None
Frequency	50 Hz / 60 Hz
Vector group	Dyn11
No-load current	~ 0.5 % [1]
Positive sequence short-circuit impedance @ rated power, 75°C	9.9 % [1,2]
Positive sequence short-circuit resistance@ rated power, 75°C	~1.0 % [1]
Zero sequence short-circuit impedance@ rated power, 75°C	~9.0 % [1]
Zero sequence short-circuit resistance@ rated power, 75°C	~1.0 % [1]
No-load reactive power	~35 kVAr [1]
Full load reactive power	~700 kVAr [1]
Inrush peak current	5-8 x $\hat{I}_n$ [1]
Half crest time	~ 0.6 s [1]
Sound power level	≤ 80 dB(A) [1]
Max altitude	2000 m [1]
Insulation system	Hybrid insulation system. Winding insulation: 120 (E), Thermally Upgrader Paper 130 (B), High temperature insulation Other materials can have different class.
Average winding temperature rise	Class 120 (E) ≤75 K [1] Class 130 (B) ≤85 K [1]
Insulation liquid, Type/Fire point	Synthetic ester, biodegradable/ K-class (>300°C)
Insulation liquid, Amount	≤ 3000 kg [1]
Corrosion class	C3 [1]
Weight	≤11000 kg [1]
Overvoltage protection	Plug-in surge arresters on HV bushings [1]
High voltage bushings	Outer cone, interface C1 [1]

Table 4-3: General transformer data.

4.3.2 Ecodesign - 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 Ecodesign requirement.
The maximum losses are described by the PEI limit section of Figure 4-1 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.

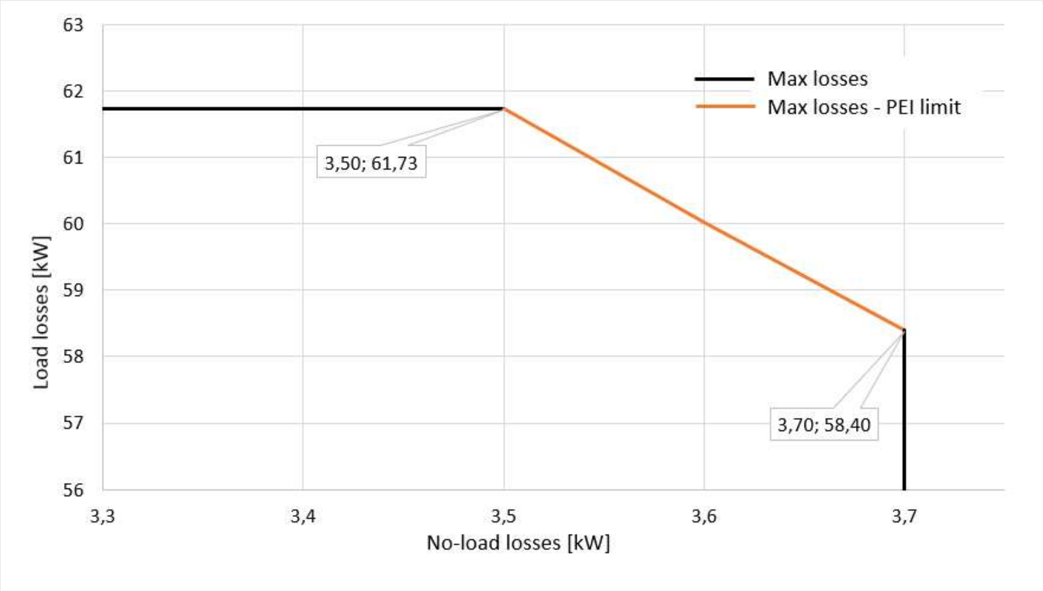

Figure 4-1- Transformer losses allowable area

The actual load losses vary depend on the operation mode of the turbine, hence in *Table 4-4* the load losses are provided at different operation modes for the two loss variants. For further recalculation of load losses at different operation modes, refer to Figure 4-1

Transformer losses				
Applied standards	Commission Regulation No 548/2014.			
Peak Efficiency Index (PEI)	≥ 99.580			
Loss variant 1				
No-load loss	3.50 kW			
Load loss @ power, 75°C	**@7000kVA** ≤61.73kW	**@5600kVA** ≤39.51kW [3]	**@5400kVA** ≤36.74kW [3]	**@5000kVA** ≤31.50kW [3]
Loss variant 2				
No-load loss	3.70 kW			
Load loss @ power, 75°C	**@7000kVA** ≤58.40kW	**@5600kVA** ≤37.38kW[3]	**@5400kVA** ≤34.75kW[3]	**@5000kVA** ≤29.80kW[3]

Table 4-4: Transformer losses for Ecodesign IEC 50 Hz/60 Hz version.

Figure 4-2- Transformer load losses scaling.

NOTE
[1] Values are preliminary and could be subjected for change.
[2] Subjected to standard IEC tolerances.
[3] 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	
High-Voltage Cable Insulation Compound	Improved ethylene-propylene (EP) based material-EPR or high modulus or hard grade ethylene-propylene rubber-HEPR
Pre-terminated	T-Connector Type-C in transformer end. T-Connector Type-C in switchgear end.
Maximum Voltage	24 kV for 19.1-22.0 kV rated voltage 42 kV for 22.1-36.0 kV rated voltage
Conductor Cross Sections	3x70 + 70 mm^2 (Single PE core) 3x70 + 3x70/3 mm^2 (Split PE core)

Table 4-5: 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 4-6. 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 4-7 for the IEC version and in Table 4-8 for the IEEE version.

HV Switchgear			
Variant	**Basic**	**Streamline**	**Standard**
IEC standards	○	⊙	⊙
IEEE standards	⊙	○	⊙
Vacuum circuit breaker panel	⊙	⊙	⊙
Overcurrent, short-circuit and earth fault protection	⊙	⊙	⊙
Disconnector / 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	⊙	⊙	⊙

HV Switchgear			
Variant	**Basic**	**Streamline**	**Standard**
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 disconnector panels for grid cables – max three panels (configurable)	○	⦿	⦿
Earthing switch for grid cables	○	⦿	⦿
Internal arc classification	○	⦿	⦿
Supervision on MCB's	○	⦿	⦿
Motor operation of switch disconnector	○	○	⦿
SCADA operation and feedback of circuit breaker	○	○	⦿
SCADA operation and feedback of switch disconnector	○	○	⦿

Table 4-6: HV switchgear variants and features

4.5.1 IEC 50/60Hz version

HV Switchgear	
Type description	Gas Insulated Switchgear
Applied standards	IEC 62271-103 IEC 62271-1, 62271-100, 62271-102, 62271-200
Insulation medium	SF_6
Rated voltage	
U_r 24.0kV	19.1-22.0 kV
U_r 36.0kV	22.1-33.0 kV
U_r 40.5kV	33.1-36.0 kV
Rated insulation level AC // LI **Common value / across isolation distance**	
U_r 24.0kV	50 / 60 // 125 / 145 kV
U_r 36.0kV	70 / 80 // 170 / 195 kV
U_r 40.5kV	85 / 90 // 185 / 215 kV
Rated frequency	50 Hz / 60 Hz
Rated normal current	630 A
Rated Short-time withstand current	
U_r 24.0kV	20 kA
U_r 36.0kV	25 kA
U_r 40.5kV	25 kA

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

Table 4-7: HV switchgear data for IEC version

4.5.2 IEEE 60Hz version

HV Switchgear	
Type description	Gas Insulated Switchgear
Applied standards	IEEE 37.20.3, IEEE C37.20.4, IEC 62271-200, ISO 12944.
Insulation medium	SF_6
Rated voltage	
U_r 38.0kV	22.1-36.0 kV
Rated insulation level AC / LI	70 / 150 kV
Rated frequency	60 Hz
Rated normal current	600 A
Rated Short-time withstand current	25 kA
Rated peak withstand current	65 kA
Rated duration of short-circuit	1 s
Internal arc classification (option)	IAC A FLR 25 kA, 1 s
Connection interface grid cables	Outside cone plug-in bushings, IEEE 386 interface type deadbreak, 600A.
Ingress protection	
Gas tank	NEMA 4X / IP 65
Enclosure	NEMA 2 / IP 2X
LV cabinet	NEMA 2 / IP 3X
Corrosion class	C3

Table 4-8: 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 4-9: 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 system is built by 2 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 optional SCADA Power Plant Controller.

UPS		
Backup Time	**Standard**	**Optional**
Control System* **(230V AC and 24V DC UPS)**	Up to 30 min	Up to 400 min**
Emergency Lights **(230V AC UPS)**	30 min	60 min***
Optional SCADA Power Plant Controller **(24V DC UPS)**	N/A	48 hours****

Table 4-10: 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 generator rpm and the main shaft rpm are registered by inductive sensors and calculated by the wind turbine controller to protect against overspeed and rotating errors.

The safety-related partition of the VMP8000 control system monitors the rotor rpm. In case of an overspeed situation, the safety-related partition of the VMP8000 control system activates the emergency feathered position (full feathering) of the three blades independently of the non-safety related partition of VMP8000 control system.

Overspeed Protection	
Sensors Type	Inductive
Trip Level	TBD

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
Current Peak Value	i_{max}	[kA]	200
Impulse Charge	$Q_{impulse}$	[C]	100
Total Charge	Q_{total}	[C]	300
Specific Energy	W/R	[MJ/Ω]	10
Average Steepness	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)

The turbine and related equipment fulfil the EU legislation for installed radio equipment:

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 crane 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.

Foot supports are placed in the turbine for maintenance and service purposes.

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 cylinder can be done with mechanical tools in the hub.

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

Table 8-1: Design codes

9 Colours

9.1 Nacelle Colour

Colour of Vestas Nacelles	
Standard Nacelle Colour	RAL 7035 (light grey)
Standard Logo	Vestas

Table 9-1: Colour, nacelle

9.2 Tower Colour

Colour of Vestas Tower Section		
	External:	**Internal:**
Standard Tower Colour	RAL 7035 (light grey)	RAL 9001 (cream white)

Table 9-2: Colour, tower

9.3 Blade Colour

Blade Colour	
Standard Blade Colour	RAL 7035 (light grey). All lightning receptor surfaces on the blades are unpainted, excluding the Solid Metal Tips (SMT).
Tip-End Colour Variants	RAL 2009 (traffic orange), RAL 3020 (traffic red)
Gloss	< 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 (Standard Turbine)	-20° to +45°C
Ambient Temperature Interval (Low Temperature Turbine)	-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 options of the wind turbine, 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.

10.3 Operational Envelope – Grid Connection

Operational Envelope – Grid Connection		
Nominal Phase Voltage	[U_{NP}]	720 V
Nominal Frequency	[f_N]	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.

All protection settings are preliminary and subject to change.

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:

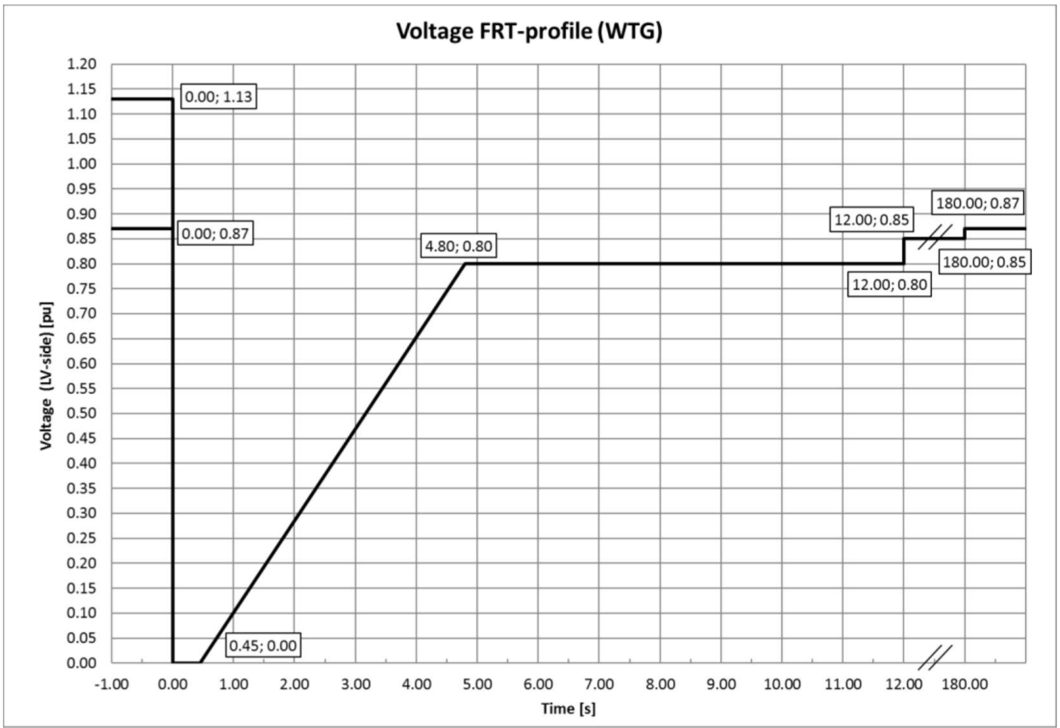

Figure 10-1: Low voltage tolerance curve for symmetrical and asymmetrical faults, where U represents voltage as measured on the grid.

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.

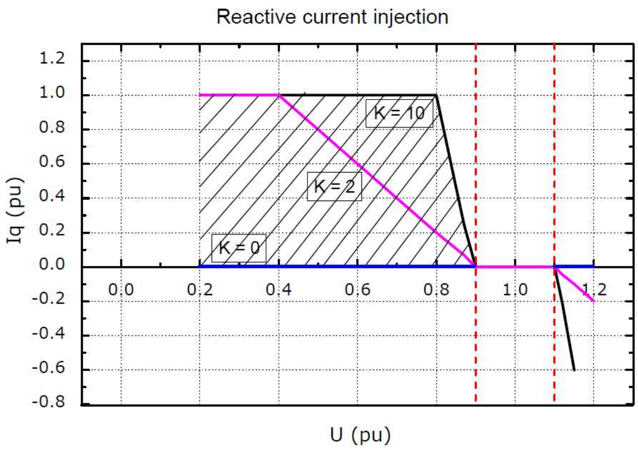

Figure 10-2: Reactive current injection

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	
Active Power	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.
Reactive Power	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 19 kW	2 x 44 kW
Yaw Motors	22 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 0 HV Transformer	

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

11 Drawings

11.1 Structural Design – Illustration of Outer Dimensions

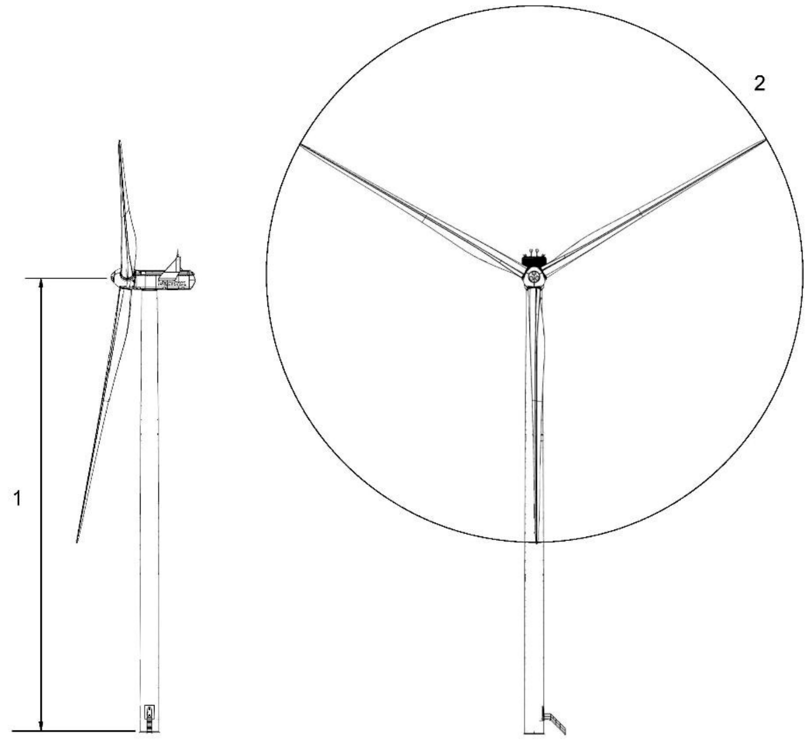

Figure 11-1: Illustration of outer dimensions – structure

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

12 General Reservations, Notes and Disclaimers

-
- The general descriptions in this document apply to the current version of the EnVentus™ 5 MW turbines. Updated versions of the EnVentus™ 5 MW 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™ 5 MW, 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.

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Document no.: 0081-5098 V01
2019-01-24

Performance Specification

EnVentus™ 5 MW
V162-5.6 MW 50/60 Hz

Vestas Wind Systems A/S · Hedeager 42 · 8200 Arhus N · Denmark · www.vestas.com

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See general reservations, notes and disclaimers (including, Section 5, p. 13) to this Performance Specification.

1 General Description

The Vestas V162-5.6 MW is a wind turbine variant within the EnVentus™ 5 MW turbine range. It is a pitch regulated upwind turbine with active yaw and a three-blade rotor. The V162-5.6 MW turbine has a rotor diameter of 162 m and a rated power of 5.6 MW.

For more details, please refer to the General Description of the EnVentus™ 5MW turbine range (General Description EnVentus™ 5 MW - 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
IEC 61400-22	IEC S	119 / 125 / 149 m
DIBt 2012	DIBt S	119 / 148 / 166 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	**5.6 MW**	**5.6 MW**	**5.6 MW**
Hub Height	**119**	**125**	**149**
Average design parameters - IEC			
Wind Speed (10 min average), V_{ave}	7.4 m/s	8.5 m/s	7.9 m/s
Weibull Scale Factor, *C*	8.4 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, *α*	0.30	0.20	0.30
Inflow Angle (vertical)	8°	8°	8°
Extreme design parameters – IEC			
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**	**DIBt S**
Hub Height	**119 m**	**148 m**	**166 m**
Power Rating	**5.6 MW**	**5.6 MW**	**5.6 MW**
Average design parameters – DIBt			
Wind Speed (10 min average), V_{ave}	7.1 m/s	7.3 m/s	7.5 m/s
I_{ref} acc. to IEC 61400-1	S	S	S
Turbulence Intensity, I_{90} (90% quant.)	S	S	S
Extreme design parameters – DIBt			
Extr Wind Speed (10 min average), V_{50}	39.4 m/s	37.0 m/s	37.6 m/s
Survival Wind Speed (3 s gust), V_{e50}	55.2 m/s	51.8 m/s	52.6 m/s
Turbulence intensity, $I_{v(z)}$	12.8%	12.3%	12.1%
Wind Shear, α	0.20	0.20	0.20
Inflow Angle	8°	8°	8°

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

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**	
	Mode 0	**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 (Standard Turbine)	-20° to +45°C
Ambient Temperature Interval (Low Temperature Turbine)	-30° to +45°C

NOTE The wind turbine will stop producing power at ambient temperatures above 45°C. For the low temperature options of the wind turbine 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.

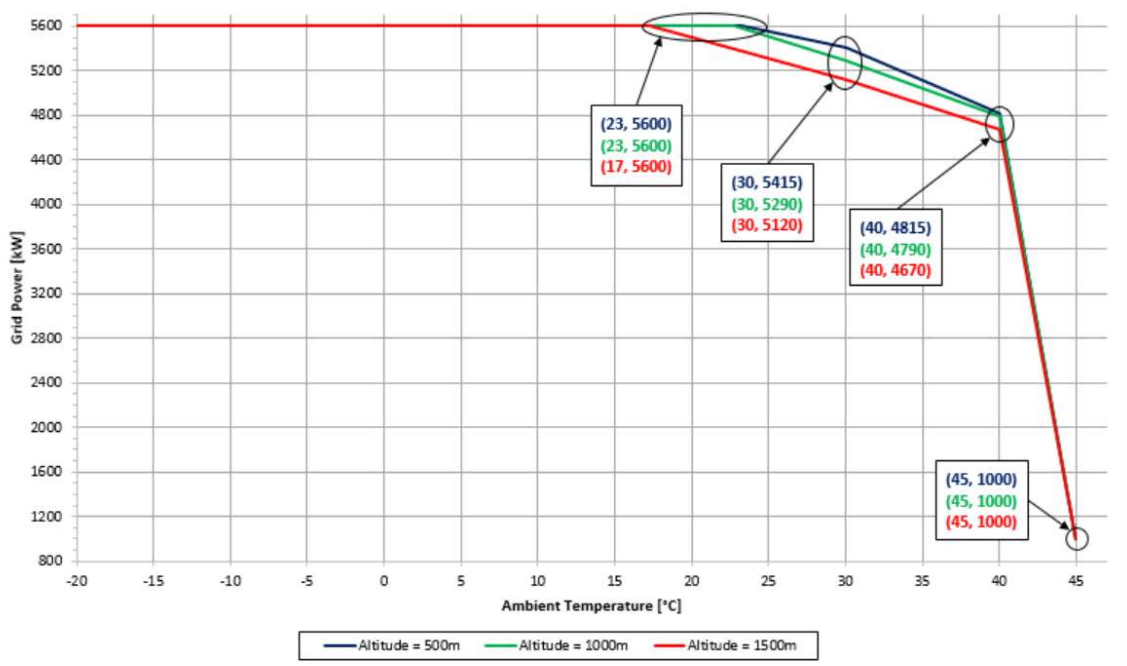


Figure 3-1: Temperature dependant derated operation.

NOTE All derating settings are preliminary and subject to change.

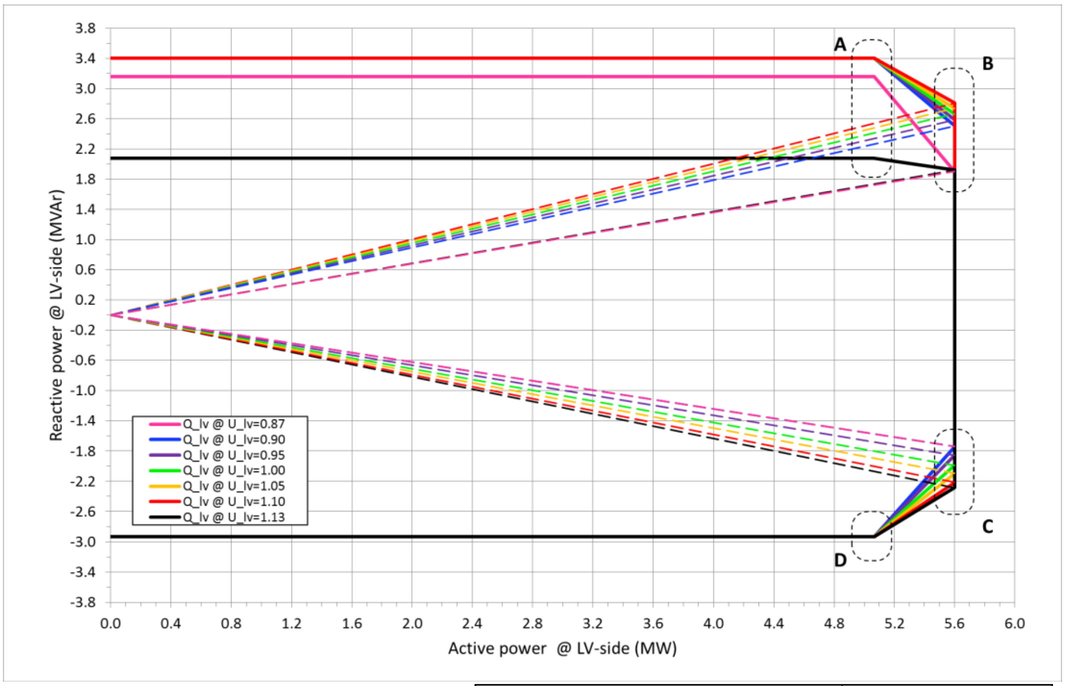
3.4 Operational Envelope – Conditions for Power Curve and Ct Values (at Hub Height)

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, *α*	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 ±2°
Grid Voltage	Nominal Voltage ±2.5%
Grid Frequency	Nominal Frequency ±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 3-2:



	Coordinates								Power factor	
Point:	A		B		C		D		B (Capacitive)	C (Inductive)
Coordinate:	x (P)	y (Q)	x (P)	y (Q)	x (P)	y (Q)	x (P)	y (Q)		
Reactive power [kVAr] @ LV side @ U_lv = 0.87 p.u. voltage	5.067	3.160	5.600	1.900	5.600	-1.739	5.067	-2.933	0.947	0.955
Reactive power [kVAr] @ LV side @ U_lv = 0.90 p.u. voltage	5.067	3.400	5.600	2.503	5.600	-1.739	5.067	-2.933	0.913	0.955
Reactive power [kVAr] @ LV side @ U_lv = 0.95 p.u. voltage	5.067	3.400	5.600	2.584	5.600	-1.856	5.067	-2.933	0.908	0.949
Reactive power [kVAr] @ LV side @ U_lv = 1.00 p.u. voltage	5.067	3.400	5.600	2.664	5.600	-1.987	5.067	-2.933	0.903	0.942
Reactive power [kVAr] @ LV side @ U_lv = 1.05 p.u. voltage	5.067	3.400	5.600	2.736	5.600	-2.093	5.067	-2.933	0.898	0.937
Reactive power [kVAr] @ LV side @ U_lv = 1.10 p.u. voltage	5.067	3.400	5.600	2.807	5.600	-2.213	5.067	-2.933	0.894	0.930
Reactive power [kVAr] @ LV side @ U_lv = 1.13 p.u. voltage	5.067	2.080	5.600	1.919	5.600	-2.283	5.067	-2.933	0.946	0.926

Figure 3-2: Reactive power capability.

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

NOTE All reactive power capabilities are preliminary and subject to change.

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**
0	104 dBA	Yes (standard)	119 / 125 / 148 / 149 / 166 m
0-0S	106.8 dBA	No (option)	119 / 125 / 148 / 149 / 166 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**
SO2	102 dBA	Yes (standard)	119 / 125 / 148 / 149 / 166 m
SO3	101 dBA	Yes (standard)	119 / 125 / 148 / 149 / 166 m
SO4	100 dBA	Yes (standard)	119 / 125 / 148 / 149 / 166 m
SO5	99 dBA	Yes (standard)	119 / 125 / 148 / 149 / 166 m
SO6	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 HH148 – 0075-8517
V162 HH149 – 0079-6675
V162 HH166 – 0075-8514

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

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 V162-5.6 MW wind turbine. Updated versions of the V162-5.6 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 V162-5.6 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 0

6.1 Power Curves, Mode 0

	Air density [kg/m³]													
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	15	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**	925	952	979	1005	1032	1059	1086	1113	1139	1166	1193	1246	1273
6.5	**1574**	1200	1235	1269	1303	1337	1371	1405	1439	1473	1506	1540	1608	1641
7.0	**1990**	1525	1567	1610	1652	1694	1737	1779	1821	1864	1906	1948	2032	2074
7.5	**2467**	1896	1948	2000	2052	2104	2156	2208	2260	2312	2364	2415	2519	2570
8.0	**3010**	2319	2382	2445	2508	2571	2634	2697	2760	2822	2885	2948	3073	3135
8.5	**3617**	2794	2869	2945	3020	3095	3170	3245	3320	3394	3469	3543	3690	3764
9.0	**4257**	3313	3401	3489	3577	3665	3751	3836	3922	4008	4091	4174	4337	4418
9.5	**4834**	3851	3947	4043	4139	4235	4324	4414	4504	4593	4673	4753	4903	4973
10.0	**5256**	4377	4475	4572	4670	4767	4846	4924	5002	5080	5139	5198	5301	5346
10.5	**5482**	4852	4934	5016	5098	5180	5233	5285	5338	5390	5421	5451	5499	5516
11.0	**5578**	5238	5294	5349	5405	5460	5483	5506	5528	5551	5560	5569	5583	5588
11.5	**5598**	5460	5485	5509	5533	5558	5565	5573	5581	5589	5592	5595	5598	5599
12.0	**5600**	5548	5558	5568	5578	5589	5591	5594	5597	5599	5600	5600	5600	5600
12.5	**5600**	5576	5582	5587	5592	5598	5598	5599	5599	5600	5600	5600	5600	5600
13.0	**5600**	5587	5590	5594	5597	5600	5600	5600	5600	5600	5600	5600	5600	5600
13.5	**5600**	5593	5595	5597	5598	5600	5600	5600	5600	5600	5600	5600	5600	5600
14.0	**5600**	5595	5596	5598	5599	5600	5600	5600	5600	5600	5600	5600	5600	5600
14.5	**5600**	5596	5597	5598	5599	5600	5600	5600	5600	5600	5600	5600	5600	5600
15.0	**5600**	5597	5598	5598	5599	5600	5600	5600	5600	5600	5600	5600	5600	5600
15.5	**5600**	5597	5598	5599	5599	5600	5600	5600	5600	5600	5600	5600	5600	5600
16.0	**5600**	5598	5598	5599	5599	5600	5600	5600	5600	5600	5600	5600	5600	5600
16.5	**5600**	5598	5599	5599	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600
17.0	**5600**	5599	5599	5599	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600
17.5	**5600**	5599	5599	5599	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600
18.0	**5600**	5594	5595	5596	5597	5598	5598	5598	5598	5599	5599	5599	5600	5600
18.5	**5568**	5528	5532	5536	5540	5544	5548	5551	5555	5558	5562	5565	5571	5574
19.0	**5418**	5335	5343	5351	5359	5367	5374	5381	5388	5396	5403	5410	5425	5432
19.5	**5179**	5073	5082	5091	5100	5110	5120	5129	5139	5149	5159	5169	5189	5199
20.0	**4894**	4796	4804	4812	4820	4828	4837	4846	4855	4864	4874	4884	4903	4913
20.5	**4609**	4516	4525	4533	4541	4549	4558	4566	4575	4584	4592	4601	4618	4628
21.0	**4329**	4242	4250	4257	4265	4272	4280	4288	4295	4303	4312	4320	4338	4346
21.5	**4043**	3960	3967	3974	3982	3989	3996	4004	4011	4019	4027	4035	4051	4059
22.0	**3764**	3689	3696	3702	3709	3715	3722	3729	3736	3744	3750	3757	3772	3780
22.5	**3488**	3414	3420	3425	3431	3437	3444	3451	3458	3465	3473	3480	3495	3501
23.0	**3203**	3133	3139	3145	3151	3156	3164	3170	3178	3184	3191	3197	3209	3214
23.5	**2914**	2849	2855	2860	2866	2872	2878	2885	2891	2897	2903	2909	2920	2926
24.0	**2616**	2551	2556	2562	2567	2573	2579	2585	2591	2598	2604	2610	2622	2627

6.2 Ct Values, Mode 0

Wind speed [m/s]	Air density kg/m³													
	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**	0.911	0.912	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	0.855	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	**0.796**	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.796	0.796	0.796	0.796	0.795
7.0	**0.795**	0.797	0.797	0.797	0.797	0.797	0.796	0.796	0.796	0.796	0.795	0.795	0.794	0.794
7.5	**0.797**	0.800	0.800	0.800	0.799	0.799	0.799	0.799	0.798	0.798	0.798	0.797	0.796	0.796
8.0	**0.796**	0.801	0.800	0.800	0.800	0.799	0.799	0.799	0.798	0.798	0.797	0.797	0.796	0.795
8.5	**0.792**	0.798	0.798	0.798	0.797	0.797	0.796	0.795	0.795	0.794	0.794	0.793	0.791	0.790
9.0	**0.766**	0.789	0.788	0.787	0.786	0.785	0.783	0.781	0.778	0.776	0.773	0.770	0.762	0.758
9.5	**0.703**	0.761	0.757	0.753	0.749	0.745	0.739	0.734	0.729	0.723	0.717	0.710	0.695	0.687
10.0	**0.621**	0.713	0.707	0.700	0.693	0.687	0.678	0.669	0.660	0.651	0.641	0.631	0.610	0.599
10.5	**0.531**	0.654	0.644	0.634	0.624	0.614	0.603	0.591	0.580	0.568	0.556	0.543	0.519	0.507
11.0	**0.449**	0.589	0.577	0.564	0.551	0.538	0.525	0.511	0.498	0.485	0.473	0.461	0.438	0.428
11.5	**0.382**	0.515	0.501	0.487	0.473	0.459	0.447	0.435	0.423	0.411	0.402	0.392	0.373	0.364
12.0	**0.328**	0.443	0.430	0.418	0.406	0.393	0.383	0.373	0.363	0.353	0.345	0.337	0.321	0.314
12.5	**0.286**	0.382	0.371	0.361	0.351	0.340	0.332	0.323	0.315	0.307	0.300	0.293	0.280	0.274
13.0	**0.251**	0.332	0.324	0.315	0.306	0.297	0.290	0.283	0.276	0.269	0.263	0.257	0.246	0.241
13.5	**0.223**	0.293	0.285	0.278	0.270	0.262	0.256	0.250	0.244	0.238	0.233	0.228	0.218	0.214
14.0	**0.199**	0.259	0.253	0.246	0.240	0.233	0.228	0.223	0.217	0.212	0.208	0.203	0.195	0.191
14.5	**0.178**	0.232	0.226	0.220	0.214	0.209	0.204	0.199	0.195	0.190	0.186	0.182	0.175	0.171
15.0	**0.161**	0.208	0.203	0.198	0.193	0.187	0.183	0.179	0.175	0.171	0.168	0.164	0.158	0.155
15.5	**0.146**	0.188	0.183	0.179	0.174	0.169	0.166	0.162	0.159	0.155	0.152	0.149	0.143	0.140
16.0	**0.132**	0.170	0.166	0.162	0.158	0.154	0.151	0.147	0.144	0.141	0.138	0.135	0.130	0.128
16.5	**0.121**	0.155	0.151	0.147	0.144	0.140	0.137	0.134	0.131	0.128	0.126	0.123	0.119	0.117
17.0	**0.111**	0.141	0.138	0.135	0.131	0.128	0.126	0.123	0.120	0.118	0.115	0.113	0.109	0.107
17.5	**0.102**	0.130	0.127	0.124	0.121	0.118	0.116	0.113	0.111	0.109	0.107	0.105	0.101	0.099
18.0	**0.095**	0.120	0.117	0.114	0.112	0.109	0.107	0.104	0.102	0.100	0.098	0.096	0.093	0.091
18.5	**0.087**	0.109	0.107	0.104	0.102	0.100	0.098	0.096	0.094	0.092	0.090	0.089	0.085	0.084
19.0	**0.078**	0.097	0.095	0.093	0.091	0.089	0.087	0.086	0.084	0.082	0.081	0.080	0.077	0.076
19.5	**0.070**	0.086	0.084	0.082	0.081	0.079	0.077	0.076	0.075	0.073	0.072	0.071	0.069	0.068
20.0	**0.062**	0.076	0.074	0.073	0.071	0.070	0.068	0.067	0.066	0.065	0.064	0.063	0.061	0.060
20.5	**0.054**	0.067	0.065	0.064	0.063	0.061	0.060	0.059	0.058	0.057	0.056	0.055	0.054	0.053
21.0	**0.048**	0.059	0.058	0.057	0.055	0.054	0.053	0.052	0.051	0.051	0.050	0.049	0.048	0.047
21.5	**0.043**	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.045	0.045	0.044	0.043	0.042	0.041
22.0	**0.038**	0.046	0.045	0.044	0.043	0.042	0.041	0.041	0.040	0.039	0.039	0.038	0.037	0.037
22.5	**0.033**	0.040	0.039	0.039	0.038	0.037	0.036	0.036	0.035	0.035	0.034	0.034	0.033	0.032
23.0	**0.029**	0.035	0.034	0.034	0.033	0.033	0.032	0.032	0.031	0.031	0.030	0.030	0.029	0.028
23.5	**0.026**	0.031	0.030	0.029	0.029	0.028	0.028	0.028	0.027	0.027	0.026	0.026	0.025	0.025
24.0	**0.022**	0.026	0.026	0.025	0.025	0.025	0.024	0.024	0.024	0.023	0.023	0.023	0.022	0.022

6.3 Sound Curves, Mode 0

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^3**	
Wind speed at hub height [m/s]	**Sound Power Level at Hub Height [dBA]** **Mode 0 (Blades with serrated trailing edge)**	**Sound Power Level at Hub Height [dBA]** **Mode 0-0S (Blades without serrated trailing edge)**
3	93.5	96.3
4	93.7	96.5
5	94.3	97.1
6	97.3	100.1
7	100.2	103.0
8	102.9	105.7
9	104.0	106.8
10	104.0	106.8
11	104.0	106.8
12	104.0	106.8
13	104.0	106.8
14	104.0	106.8
15	104.0	106.8
16	104.0	106.8
17	104.0	106.8
18	104.0	106.8
19	104.0	106.8
20	104.0	106.8

6.4 Power Curves, Sound Optimized Mode SO2

	Air density [kg/m³]												
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	**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

6.5 Ct Values, Sound Optimized Mode SO2

	Air density kg/m³													
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	0.065	0.064	0.063	0.062	0.061	0.059	0.058

6.6 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/m³**
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

6.7 Power Curves, Sound Optimized Mode SO3

	Air density [kg/m³]													
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

6.8 Ct Values, Sound Optimized Mode SO3

	Air density kg/m³													
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**	0.803	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

6.9 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^3**
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

6.10 Power Curves, Sound Optimized Mode SO4

	Air density [kg/m³]													
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

6.11 Ct Values, Sound Optimized Mode SO4

	Air density kg/m³													
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	**0.798**	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	**0.803**	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	**0.802**	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	**0.798**	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	**0.784**	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	**0.749**	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	**0.692**	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	**0.630**	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	**0.549**	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	**0.472**	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	**0.405**	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	**0.349**	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	**0.301**	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	**0.262**	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	**0.229**	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	**0.202**	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	**0.180**	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	**0.161**	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	**0.145**	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	**0.130**	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	**0.118**	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	**0.106**	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	**0.097**	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	**0.088**	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	**0.081**	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	**0.075**	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	**0.069**	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	**0.063**	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	**0.058**	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	**0.054**	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

6.12 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/m³**
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

6.13 Power Curves, Sound Optimized Mode SO5

	Air density [kg/m³]													
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	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

6.14 Ct Values, Sound Optimized Mode SO5

	Air density kg/m³													
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	**0.799**	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	**0.803**	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	**0.797**	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	**0.786**	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	**0.754**	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	**0.703**	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	**0.633**	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	**0.554**	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	**0.481**	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	**0.416**	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	**0.358**	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	**0.307**	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	**0.267**	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	**0.235**	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	**0.208**	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	**0.185**	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	**0.165**	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	**0.148**	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	**0.133**	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	**0.121**	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	**0.110**	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	**0.100**	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	**0.092**	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	**0.084**	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	**0.078**	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	**0.072**	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	**0.067**	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	**0.062**	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	**0.057**	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	**0.054**	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

6.15 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^3**
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

6.16 Power Curves, Sound Optimized Mode SO6

Air density [kg/m³]													
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

6.17 Ct Values, Sound Optimized Mode SO6

	Air density kg/m³													
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

6.18 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^3**
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