REGIONE PUGLIA

PROVINCIA di FOGGIA

COMUNE di FOGGIA

Proponente

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Opera

## Progetto di un impianto eolico composto da n. 10 Aerogeneratori nel Comune di Foggia (FG) alla località "La Stella - Duanera"

Oggetto

Folder:
PROGETTO - Parte A

Nome Elaborato:
U5U1VR6_ARCH_DOC_A10

Descrizione Elaborato:
Piano di manutenzione dell'impianto

| | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| 00 | Gennaio 2020 | Progetto definitivo | Vega | Arch. A. Demaio | Wind Energy La Rocca |
| Rev. | Data | Oggetto della revisione | Elaborazione | Verifica | Approvazione |

Scala: Fs

Formato:

Codice Pratica U5U1VR6

INDICE



INDICE FIGURE

# A. PARTE GENERALE

## A.1 Componenti dell'impianto

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

- 10 aerogeneratori di grande taglia
- 1 cavidotto interrato di impianto a 30 kV
- 1 cabina di raccolta delle linee di impianto
- 1 cavidotto interrato di collegamento tra la cabina di raccolta e sottostazione costituito da due o più terne da 30 kV
- 1 stallo produttore di trasformazione 30-150 kV
- 1 cavidotto da 150kV per il collegamento tra stallo produttore e sottostazione di Lucera

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

## A.2 Schede Tecniche dei Componenti dell'impianto

### AEROGENERATORE

Le macchine proposte hanno le seguenti caratteristiche:

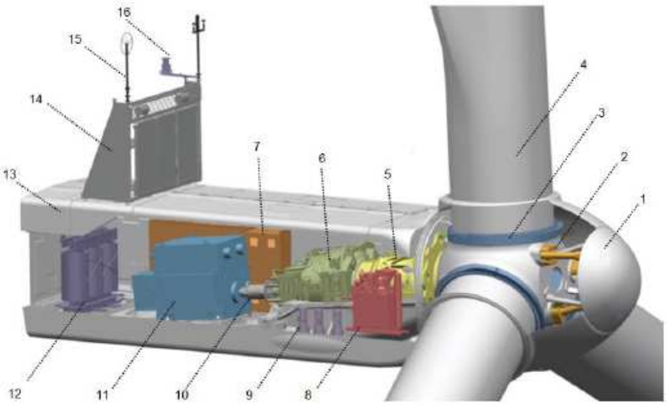
- grande taglia con diametro rotore fino a 145 m;
- altezza mozzo fino a 107,5 m, comunque altezza complessiva, altezza mozzo più pala, non superiore a 180m)

L'aerogeneratore di riferimento è SG. 4.3-145 da 4.3 MW di potenza nominale, con altezza mozzo pari a 107,5 m. Tale turbina descrive e riassume le caratteristiche del gruppo di turbine idonee al sito.

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

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

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




| | | | |
|---|---|---|---|
| 1 | Rotor cover | 9 | Yaw system |
| 2 | Pitch system | 10 | High speed shaft |
| 3 | Blade bearings | 11 | Generator |
| 4 | Blades | 12 | Transformer |
| 5 | Low speed shaft | 13 | Nacelle cover |
| 6 | Gearbox | 14 | Cooling system |
| 7 | Electrical cabinets | 15 | Wind sensors |
| 8 | Hydraulic group | 16 | Beacon system |

*Figura 1 - Navicella SG 4.3-145*

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

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

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

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

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

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

## COMPONENTI PRINCIPALI DELLA TURBINA

### Pale:

- Numero: 3
- Lunghezza: 72,5 m
- Materiale: materiale composito a matrice epossidica rinforzata con fibra di vetro e carbonio

### Rotore:

- Diametro 145 m
- Area spazzata 16.506 mq

### Sistema di controllo del passo (pitch control):

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

### Mozzo:

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

### Generatore e convertitore di frequenza:

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

### Sistema di imbardata (yaw control):

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

## CAVI ELETTRICI

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

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

SOTTOSTAZIONE MT/AT

Lo schema elettrico dell'impianto è descritto dall'unifilare di tav. U5U1VR6_ARCH_TAV_B16_schema unifilare. La produzione elettrica del parco eolico, costituito da 10 aerogeneratori, viene raccolta con due differenti cabine. La sottostazione dell'impianto è nel Comune di Lucera.

I lavori prevedono la presenza di un trasformatore 30/150 kV, la strumentazione di misura e tutti i vari servizi ausiliari. Per la componentistica si veda la Relazione "U5U1VR6_ARCH_DOC_A03_RelazioneImpianti".

La sottostazione verrà collegata con cavo AT a 150kV con la stazione elettrica di Lucera. Per la stazione utente si rimanda alla tav. U5U1VR6_ARCH_TAV_B13_SSE_stallo

### A.3 Schemi di Funzionamento dell'impianto

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

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

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

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

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

- U5U1VR6_ARCH_TAV_B16_schema unifilare

## B. SISTEMA DI MANUTENZIONE DELL'IMPIANTO

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

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

- ✓ accesso alla navicella dall'interno della torre con utilizzo di ascensore;
- ✓ montacarichi esterno
- ✓ notevole disponibilità di spazio nella navicella per interventi facili ed ergonomici
- ✓ accesso al mozzo agevole direttamente dalla navicella
- ✓ facilità nel raggiungere tutti i componenti
- ✓ sicurezza durante la manutenzione grazie alla protezione di tutte le parti rotanti
- ✓ in caso di necessità, la macchina consente lo smontaggio di molti componenti

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

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

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

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

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

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

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

## D. PROGRAMMA DI MANUTENZIONE

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

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

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

In particolare, le principali azioni riguardanti la torre sono:

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

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

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

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

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

## E. ALLEGATI

[1] SGRE ON SG 4.3-145 Developer Package

Foggia, Gennaio 2020

Il tecnico

Arch. Antonio Demaio

# Developer Package SG 4.5-145

**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 (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 4.5-145 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. Information contained within the Developer Package may not be treated separately or out of the context of the Developer Package.

The information contained in the Developer Package may not be used as legally binding documentation and cannot be used in contracts between SGRE and any other parties. This Developer Package contains preliminary technical data on SGRE turbines currently under development and can be used in an indicative capacity only.

All technical data is subject to change according to the technical development of the wind turbine.

SGRE and its affiliates reserve the right to change the below specifications without prior notice.

# Developer Package
# SG 4.5-145

**Table of content**

# Introduction

The SG 4.5-145 is the first wind turbine of the new Siemens Gamesa 4.X Platform, the next generation Siemens Gamesa Onshore Geared product series, which builds on the Siemens & Gamesa design and operational experience in the wind energy market.

With a brand new 71m blade, a 4.5 MW generator and a tower portfolio with hub heights ranging from 90m to 157.5m, the SG 4.5-145 aims at becoming a new benchmark in the market for efficiency and profitability.

This Developer Package describes the turbine technical specifications and provides preliminary 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**
The SG 4.5–145 Siemens Gamesa blade is made up of fiberglass infusion-molded components. The blade structure uses aerodynamic shells containing embedded spar-caps, bonded to two main epoxy-fiberglass-balsa/foam-core shear webs. The SG 4.5–145 SGRE blade uses 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**
A forged main shaft ensures a comfortable access from the nacelle cover to the hub.

**Main Bearings**
The low speed shaft of the wind turbine is supported by two spherical 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 which is cooled with a liquid/air cooling system.

**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 and sliding plain 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. It is self-diagnosing and has a touch panel and display for easy readout of status and for adjustment of settings.

**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. The power conversion system is water cooled and has a modular arrangement for easy maintenance.

**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 is 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 is enough. 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..........................145 m
Swept area ......................16,506 m²
Power regulation .............Pitch & torque regulation with variable speed
Rotor tilt...........................6 degrees

**Blade**
Type ................................Self-supporting
Blade length ....................71.0 m
Root chord.......................2.856 m
Aerodynamic profile ........Siemens Gamesa proprietary airfoils
Material ...........................GRE (Glassfiber Reinforced Epoxy)
Surface gloss ..................Semi-gloss, < 30 / ISO2813
Surface color .................. Light grey, RAL 7035 or Papyrus White, RAL 9018

**Aerodynamic Brake**
Type ................................Full span pitching
Activation.........................Active, hydraulic

**Load-Supporting Parts**
Hub.................................Nodular cast iron
Main shaft........................Forged steel
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................................Papyrus White, RAL 9018

**Generator**
Type................................Asynchronous, DFIG

**Grid Terminals (LV)**
Baseline nominal power ..4.5 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 ...............................SGRE Wind Turbine Control architecture
SCADA system ...............SGRE SCADA System

**Tower**
Type ...............................Tubular steel / Hybrid

Hub height ......................90 - 157 m, site-specific

Corrosion protection .......Painted
Surface gloss .................Semi-gloss, <30 / ISO-2813

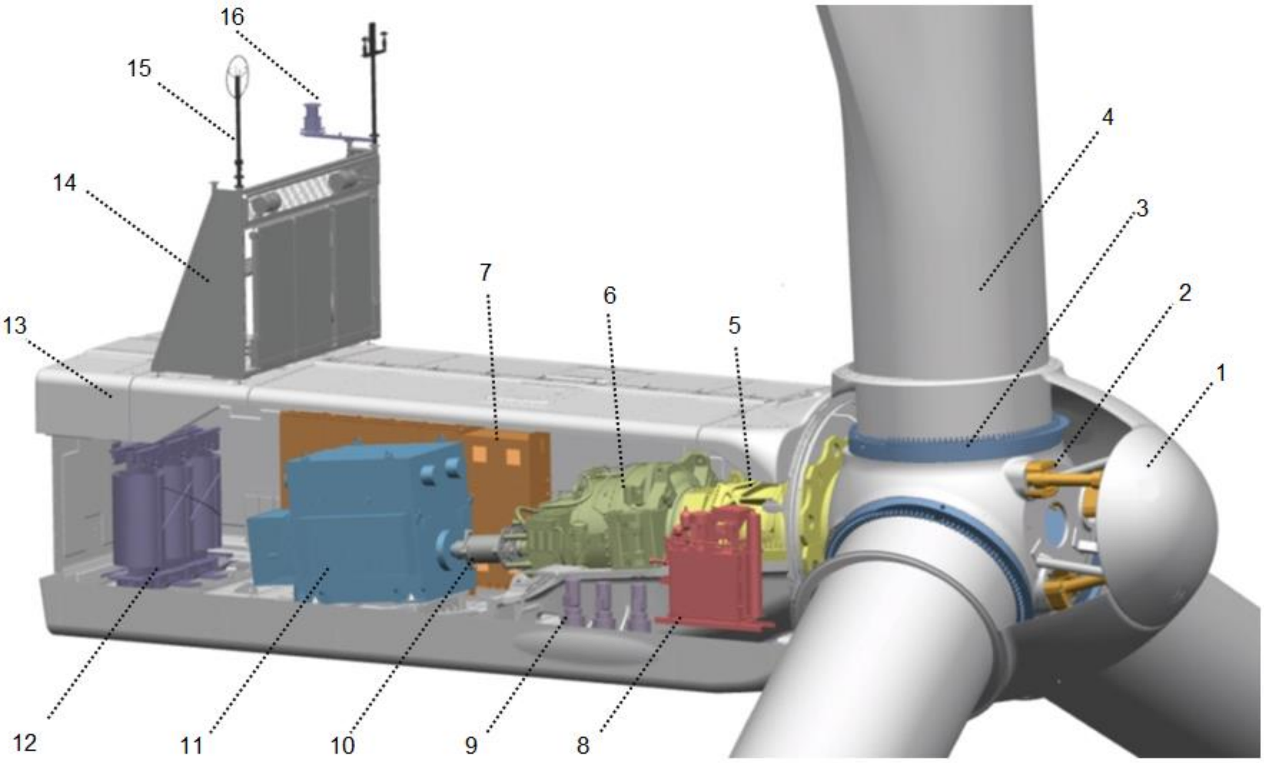
Color ..............................Papyrus White, RAL 9018

**Operational Data**
Cut-in wind speed ...........3 m/s
Rated wind speed ...........10.7 m/s (steady wind without turbulence, as defined by IEC61400-1)
Cut-out wind speed .........27 m/s
Restart wind speed..........24 m/s

**Weight**
Modular approach........... All modules weight lower than 95 t for transport

# Nacelle Arrangement

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




| | | | |
|---|---|---|---|
| **1** | Rotor cover | **9** | Yaw system |
| **2** | Pitch system | **10** | High speed shaft |
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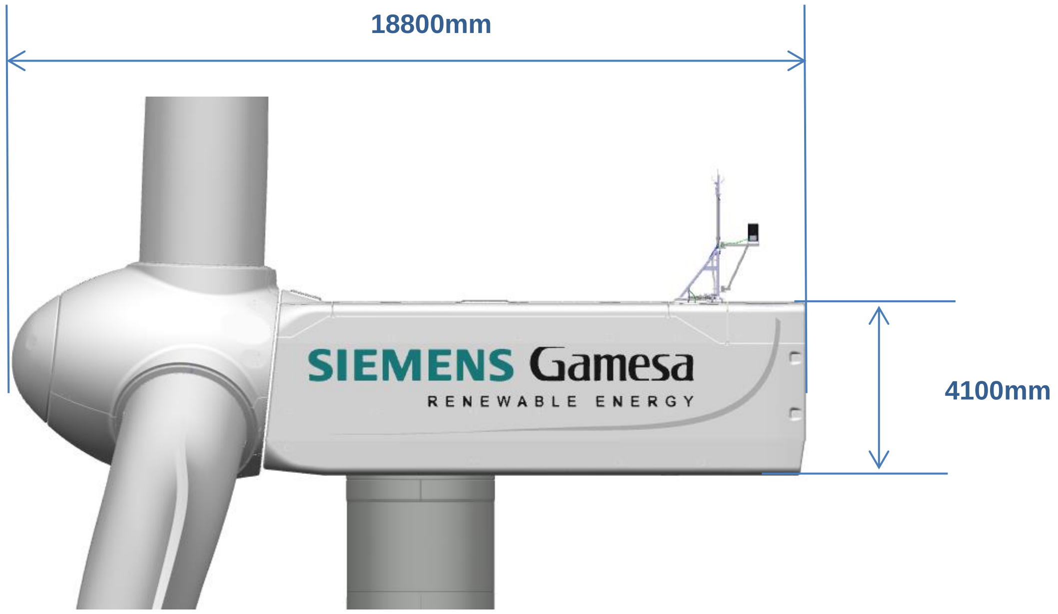
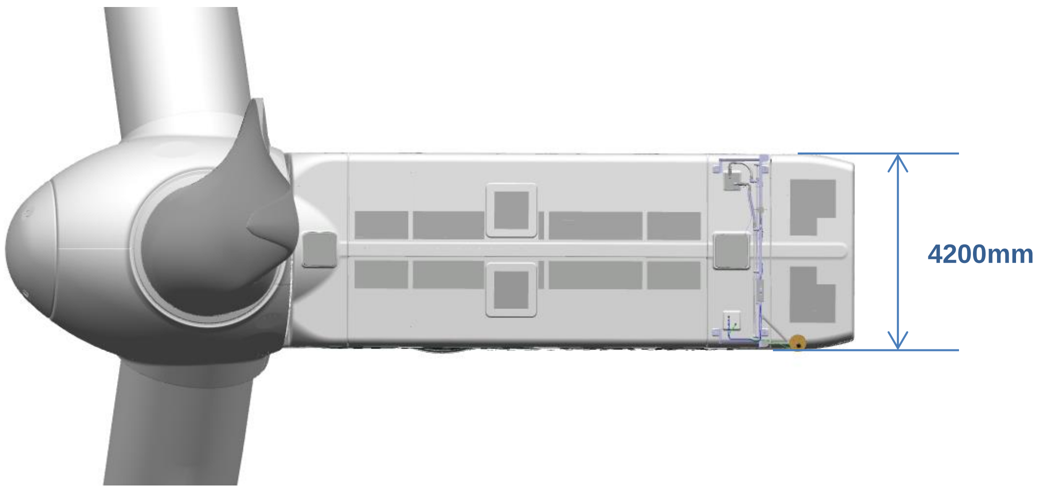
| **7** | Electrical cabinets | **15** | Wind sensors |
| **8** | Hydraulic group | **16** | Beacon system |

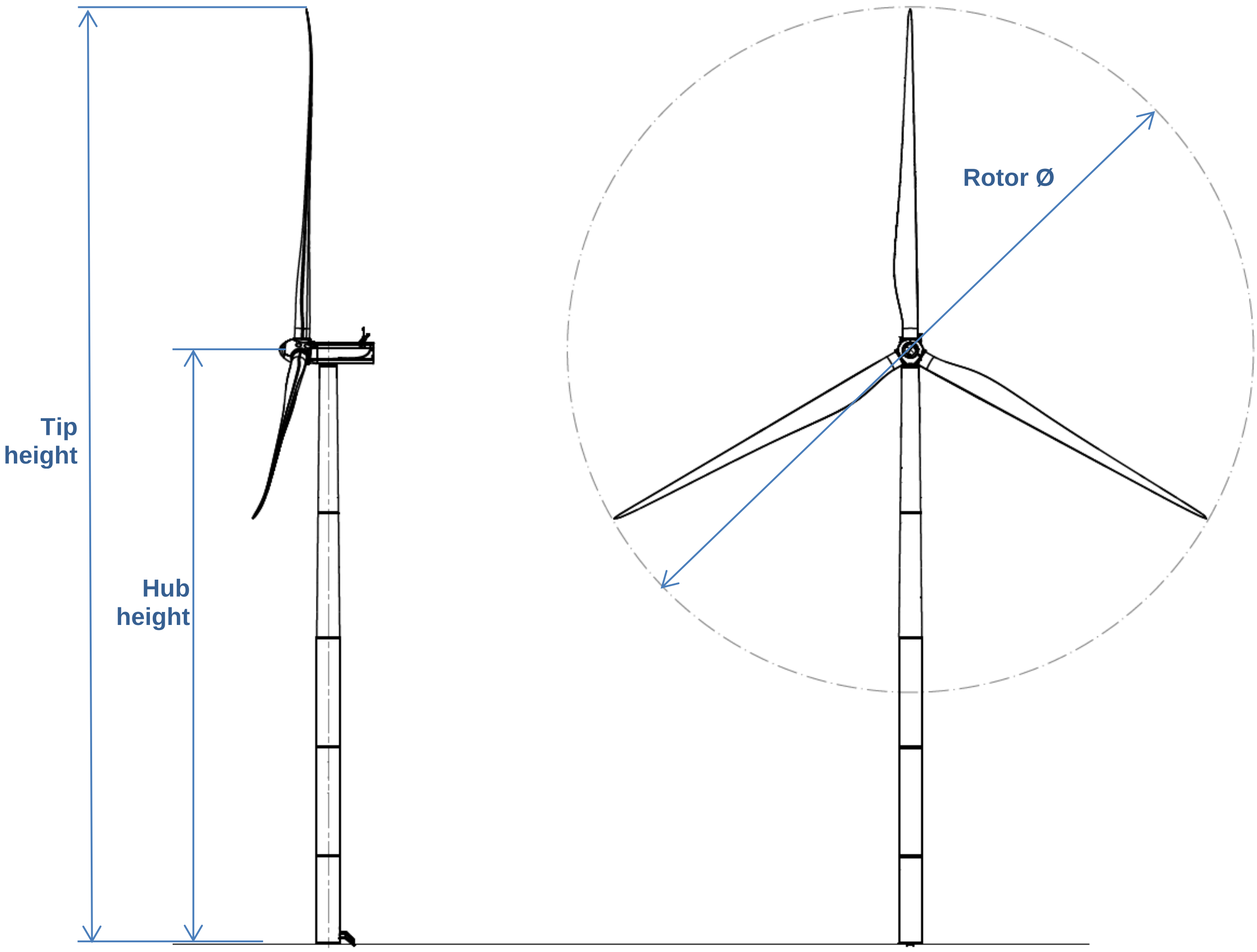
# Nacelle Dimensions

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



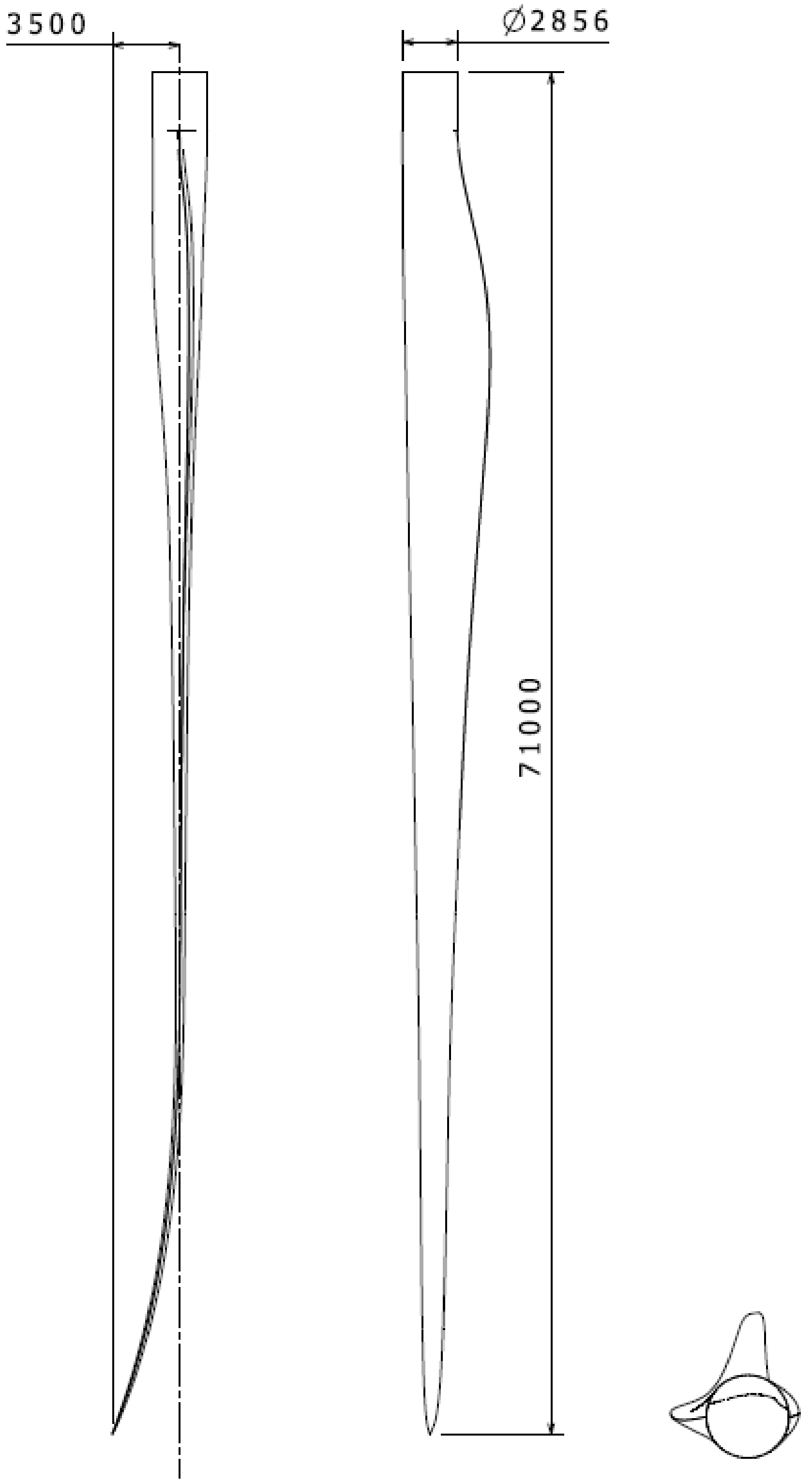



# Elevation Drawing




| | |
|---|---|
| Tip height | 162.5m, 180m, 200m, 230m |
| Hub height | 90m, 107.5m, 127.5m, 157.5m |
| Rotor diameter | 145m |

# Blade Drawing




Dimensions in millimeters.

# 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 the completion by the Client of the “Project Climatic Conditions” form.

| Subject | ID | Issue | Unit | Value |
|---|---|---|---|---|
| **Wind, operation** | 1.1 | Wind definitions | - | IEC 61400-1[1] |
| | 1.2 | IEC class | - | IIB |
| | 1.3 | Mean air density, ρ | kg/m³ | 1.225 |
| | 1.4 | Mean wind speed, $V_{ave}$ | m/s | 8.5 |
| | 1.5 | Weibull scale parameter, A | m/s | 9.59 |
| | 1.6 | Weibull shape parameter, k | - | 2 |
| | 1.7 | Wind shear exponent, α | - | 0.20 |
| | 1.8 | Reference turbulence intensity at 15 m/s, $I_{ref}$ | - | 0.14 |
| | 1.9 | Standard deviation of wind direction | Deg | 8 |
| | 1.10 | Maximum flow inclination | Deg | 8 |
| | 1.11 | Minimum turbine spacing, in rows | D | 3 |
| | 1.12 | Minimum turbine spacing, between rows | D | 5 |
| **Wind, extreme** | 2.1 | Wind definitions | | IEC 61400-1 |
| | 2.2 | Air density, ρ | kg/m³ | 1.225 |
| | 2.3 | Reference wind speed average over 10 min at hub height, $V_{ref}$ | m/s | 42.5 |
| | 2.4 | Maximum 3 s gust in hub height, $V_{e50}$ | m/s | 59.5 |
| | 2.5 | Maximum hub height power law index, α | - | 0.11 |
| **Temperature** | 3.1 | Temperature definitions | - | IEC 61400-1 |
| | 3.2 | Minimum temperature at 2 m, stand-still, $T_{min, s}$ | Deg.C | -30 |
| | 3.3 | Minimum temperature at 2 m, operation, $T_{min, o}$ | Deg.C | -20 |
| | 3.4 | Maximum temperature at 2 m, nominal operation, $T_{max, o}$ | Deg.C | 35 |
| | 3.5 | Maximum temperature at 2 m, stand-still, $T_{max, s}$ | Deg.C | 50 |
| **Corrosion** | 4.1 | Atmospheric-corrosivity category definitions | - | ISO 12944-2 |
| | 4.2 | Internal nacelle environment (corrosivity category) | - | C3 |
| | 4.3 | Exterior environment (corrosivity category) | - | C5-M |
| **Lightning** | 5.1 | Lightning definitions | - | IEC61400-24:2010 |
| | 5.2 | Lightning protection level (LPL) | - | LPL 1 |
| **Dust** | 6.1 | Dust definitions | - | IEC 60721-3-4:1995 |
| | 6.2 | Working environmental conditions | mg/m³ | Average Dust Concentration (95% time) → 0.05 mg/m3 |
| | 6.3 | Concentration of particles | mg/m³ | Peak Dust Concentration (95% time) → 0.5 mg/m3 |
| **Hail** | 7.1 | Maximum hail diameter | mm | 20 |
| | 7.2 | Maximum hail falling speed | m/s | 20 |
| **Ice** | 8.1 | Ice definitions | - | - |
| | 8.2 | Ice conditions | Days/yr | 7 |

[1] All mentioning of IEC 61400-1 refers to IEC 61400-1 Ed3.0 2005/A1:2010.

| Subject | ID | Issue | Unit | Value |
|---|---|---|---|---|
| **Solar radiation** | 9.1 | Solar radiation definitions | - | IEC 61400-1 |
| | 9.2 | Solar radiation intensity | $W/m^2$ | 1000 |
| **Humidity** | 10.1 | Humidity definition | - | IEC 61400-1 |
| | 10.2 | Relative humidity | % | Up to 95 |
| **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. | | |

# Standard Power Curve, Standard power operational mode

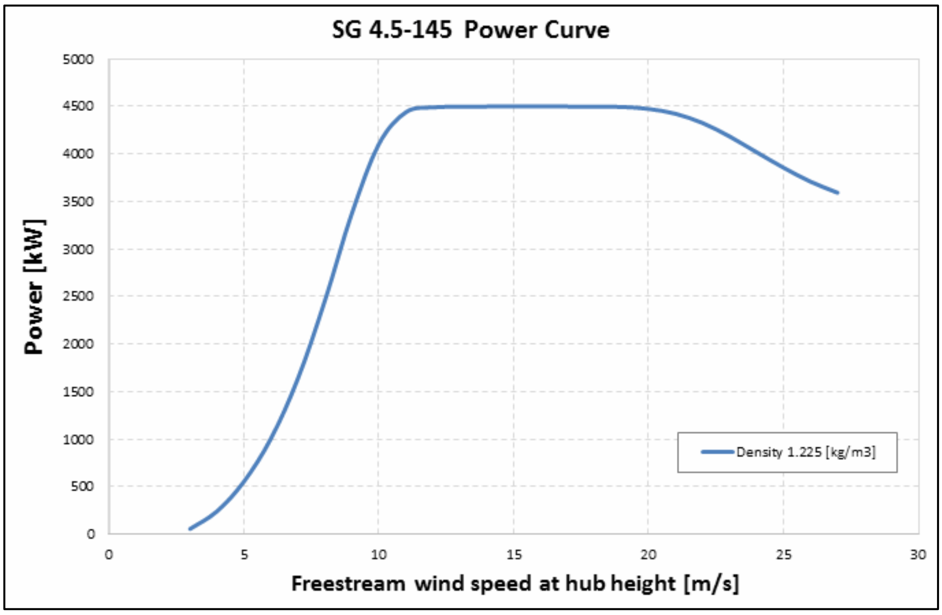
Air density 1.225 kg/m3
Validity range:

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

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

Next table shows the electrical power [kW] as a function of the wind speed [m/s] horizontal referred to the hub height, averaged in ten minutes, for air density = 1.225 kg/m³. The power curve does not include losses in the transformer and high voltage cables. The power curve is for the standard version of the turbine.

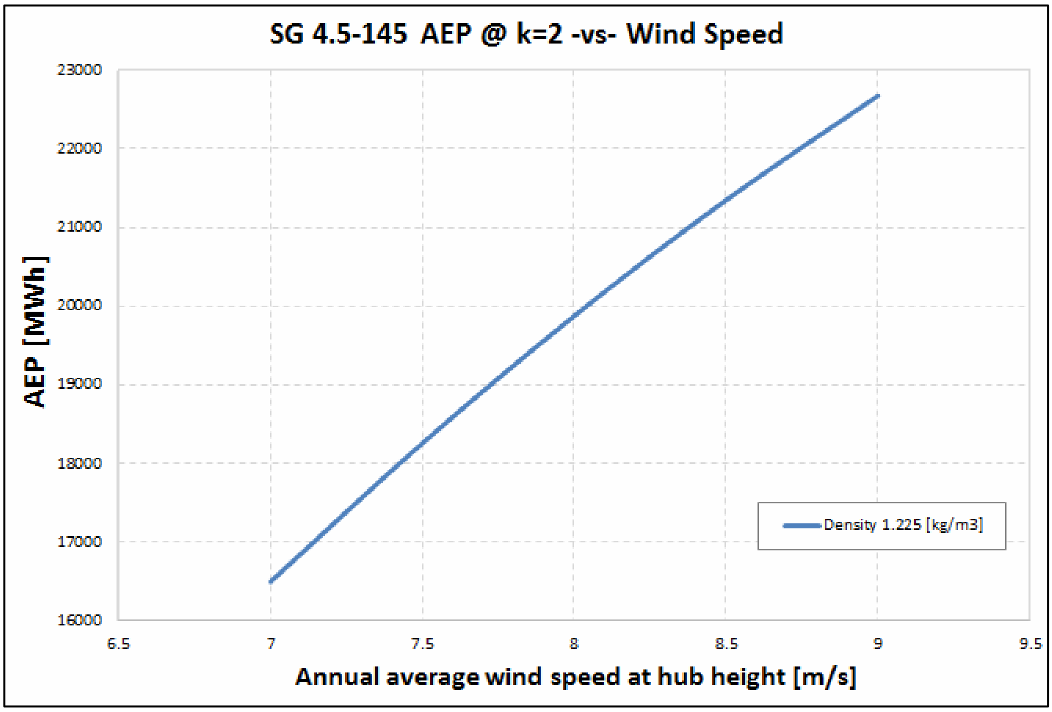
| SG 4.5-145 | |
|---|---|
| **Wind Speed [m/s]** | **Power [kW]** |
| 3 | 57 |
| 4 | 243 |
| 5 | 556 |
| 6 | 1010 |
| 7 | 1640 |
| 8 | 2459 |
| 9 | 3376 |
| 10 | 4105 |
| 11 | 4440 |
| 12 | 4491 |
| 13 | 4498 |
| 14 | 4500 |
| 15 | 4500 |
| 16 | 4500 |
| 17 | 4500 |
| 18 | 4499 |
| 19 | 4495 |
| 20 | 4475 |
| 21 | 4423 |
| 22 | 4326 |
| 23 | 4185 |
| 24 | 4020 |
| 25 | 3856 |
| 26 | 3709 |
| 27 | 3593 |



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

| ***AEP [MWh]*** | | **Annual Average Wind Speed [m/s] at Hub Height** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ***5*** | ***5.5*** | ***6*** | ***6.5*** | ***7*** | ***7.5*** | ***8*** | ***8.5*** | ***9*** | ***9.5*** | ***10*** |
| ***Weibull K*** | ***1.5*** | 9251 | 10993 | 12659 | 14222 | 15667 | 16985 | 18171 | 19225 | 20149 | 20948 | 21628 |
| | ***2*** | 8447 | 10533 | 12605 | 14605 | 16496 | 18256 | 19874 | 21346 | 22672 | 23854 | 24894 |
| | ***2.5*** | 7611 | 9861 | 12196 | 14518 | 16752 | 18849 | 20783 | 22544 | 24131 | 25551 | 26813 |

Annual Production [MWh] SG 4.5-145 wind turbine for the standard version, as a function of the annual mean wind speed at hub height, and for different Weibull parameters. Air density 1.225 kg/m3.



# Standard Ct Curve, Standard power operational mode

Air density 1.225 kg/m3
Validity range:

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

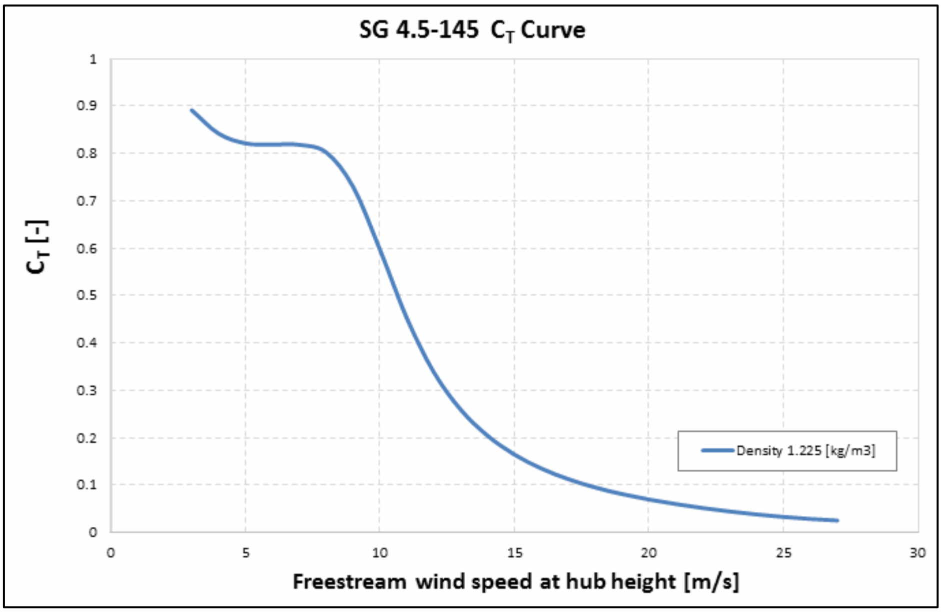
Other considerations: Clean rotor blades, undisturbed air flow, turbine operated within nominal limits according to the Electrical Specification.

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

Ct is defined by the following expression:
Ct = F / (0.5*ad*w^2*A)

where
F = Rotor force [N]
ad = Air density [kg/m3]
w = Wind speed [m/s]
A = Swept area of rotor [m2]

| SG 4.5-145 | |
|---|---|
| **Wind Speed [m/s]** | **$C_T$ [-]** |
| 3 | 0.8914 |
| 4 | 0.8422 |
| 5 | 0.8214 |
| 6 | 0.8191 |
| 7 | 0.8184 |
| 8 | 0.8023 |
| 9 | 0.7299 |
| 10 | 0.5966 |
| 11 | 0.4521 |
| 12 | 0.3386 |
| 13 | 0.2595 |
| 14 | 0.2044 |
| 15 | 0.1647 |
| 16 | 0.1353 |
| 17 | 0.1128 |
| 18 | 0.0953 |
| 19 | 0.0813 |
| 20 | 0.0699 |
| 21 | 0.0603 |
| 22 | 0.0519 |
| 23 | 0.0446 |
| 24 | 0.0383 |
| 25 | 0.0331 |
| 26 | 0.0289 |
| 27 | 0.0255 |



# Power Curve, Air density, Standard power operational mode

Air density 1.225 kg/m3
Validity range:

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

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

Next table shows the electrical power [kW] as a function of the wind speed [m/s] horizontal referred to the hub height, averaged in ten minutes, for different air densities [kg/m$^3$]. The power curve does not include losses in the transformer and high voltage cables. The power curve is for the standard version of the turbine.

| ***P [kW]*** | ***Air Density [kg/m3]*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ***Wind Speed [m/s]*** | **1.225** | **1.06** | **1.09** | **1.12** | **1.15** | **1.18** | **1.21** | **1.24** | **1.27** |
| ***3*** | 57 | 42 | 45 | 48 | 50 | 53 | 56 | 58 | 61 |
| ***4*** | 243 | 202 | 209 | 217 | 224 | 232 | 239 | 247 | 254 |
| ***5*** | 556 | 472 | 488 | 503 | 518 | 533 | 549 | 564 | 579 |
| ***6*** | 1010 | 865 | 891 | 918 | 944 | 970 | 997 | 1023 | 1049 |
| ***7*** | 1640 | 1410 | 1452 | 1494 | 1535 | 1577 | 1619 | 1661 | 1702 |
| ***8*** | 2459 | 2121 | 2182 | 2244 | 2306 | 2367 | 2429 | 2490 | 2551 |
| ***9*** | 3376 | 2938 | 3021 | 3103 | 3183 | 3262 | 3338 | 3413 | 3484 |
| ***10*** | 4105 | 3714 | 3798 | 3877 | 3949 | 4016 | 4076 | 4131 | 4181 |
| ***11*** | 4440 | 4251 | 4304 | 4348 | 4383 | 4412 | 4432 | 4448 | 4459 |
| ***12*** | 4491 | 4465 | 4474 | 4480 | 4484 | 4488 | 4490 | 4492 | 4493 |
| ***13*** | 4498 | 4493 | 4494 | 4495 | 4496 | 4497 | 4498 | 4498 | 4499 |
| ***14*** | 4500 | 4498 | 4499 | 4499 | 4499 | 4499 | 4499 | 4500 | 4500 |
| ***15*** | 4500 | 4500 | 4500 | 4500 | 4500 | 4500 | 4500 | 4500 | 4500 |
| ***16*** | 4500 | 4500 | 4500 | 4500 | 4500 | 4500 | 4500 | 4500 | 4500 |
| ***17*** | 4500 | 4500 | 4500 | 4500 | 4500 | 4500 | 4500 | 4500 | 4500 |
| ***18*** | 4499 | 4499 | 4499 | 4499 | 4499 | 4499 | 4499 | 4499 | 4499 |
| ***19*** | 4495 | 4495 | 4495 | 4495 | 4495 | 4495 | 4495 | 4495 | 4495 |
| ***20*** | 4475 | 4475 | 4475 | 4475 | 4475 | 4475 | 4475 | 4475 | 4475 |
| ***21*** | 4423 | 4423 | 4423 | 4423 | 4423 | 4423 | 4423 | 4423 | 4423 |
| ***22*** | 4326 | 4326 | 4326 | 4326 | 4326 | 4326 | 4326 | 4326 | 4326 |
| ***23*** | 4185 | 4185 | 4185 | 4185 | 4185 | 4185 | 4185 | 4185 | 4185 |
| ***24*** | 4020 | 4020 | 4020 | 4020 | 4020 | 4020 | 4020 | 4020 | 4020 |
| ***25*** | 3856 | 3856 | 3856 | 3856 | 3856 | 3856 | 3856 | 3856 | 3856 |
| ***26*** | 3709 | 3709 | 3709 | 3709 | 3709 | 3709 | 3709 | 3709 | 3709 |
| ***27*** | 3593 | 3593 | 3593 | 3593 | 3593 | 3593 | 3593 | 3593 | 3593 |

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

| ***AEP [MWh] @ k=2*** | | **Annual Average Wind Speed [m/s] at Hub Height** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ***5*** | ***5.5*** | ***6*** | ***6.5*** | ***7*** | ***7.5*** | ***8*** | ***8.5*** | ***9*** | ***9.5*** | ***10*** |
| ***Density [kg/m3]*** | ***1.06*** | 7441 | 9384 | 11353 | 13286 | 15143 | 16894 | 18524 | 20023 | 21386 | 22611 | 23698 |
| | ***1.09*** | 7631 | 9604 | 11594 | 13543 | 15408 | 17163 | 18792 | 20287 | 21644 | 22861 | 23939 |
| | ***1.12*** | 7818 | 9818 | 11830 | 13792 | 15665 | 17422 | 19049 | 20540 | 21890 | 23100 | 24169 |
| | ***1.15*** | 8002 | 10028 | 12059 | 14033 | 15912 | 17671 | 19296 | 20782 | 22126 | 23327 | 24388 |
| | ***1.18*** | 8182 | 10233 | 12282 | 14267 | 16152 | 17911 | 19534 | 21014 | 22351 | 23545 | 24597 |
| | ***1.21*** | 8359 | 10434 | 12499 | 14494 | 16383 | 18143 | 19763 | 21238 | 22568 | 23753 | 24797 |
| | ***1.225*** | 8447 | 10533 | 12605 | 14605 | 16496 | 18256 | 19874 | 21346 | 22672 | 23854 | 24894 |
| | ***1.24*** | 8534 | 10630 | 12710 | 14715 | 16607 | 18367 | 19983 | 21452 | 22775 | 23953 | 24988 |
| | ***1.27*** | 8705 | 10822 | 12916 | 14929 | 16824 | 18583 | 20195 | 21659 | 22975 | 24145 | 25172 |

Annual Production [MWh] SG 4.5-145 wind turbine for the standard version, as a function of the annual mean wind speed at hub height and for different air densities considering a Rayleigh wind speed distribution.

# Ct Curve, Air Density, Standard power operational mode

Air density 1.225 kg/m3
Validity range:

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

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

The calculated Ct curve data are valid for air densities as stated below, clean rotor blades, substantially horizontal, undisturbed air flow, normal turbulence intensity and normal wind shear.

| ***$C_T$ [-]*** | ***Air Density [kg/m3]*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ***Wind Speed [m/s]*** | **1.225** | **1.06** | **1.09** | **1.12** | **1.15** | **1.18** | **1.21** | **1.24** | **1.27** |
| ***3*** | 0.8914 | 0.8914 | 0.8914 | 0.8914 | 0.8914 | 0.8914 | 0.8914 | 0.8914 | 0.8914 |
| ***4*** | 0.8422 | 0.8422 | 0.8422 | 0.8422 | 0.8422 | 0.8422 | 0.8422 | 0.8422 | 0.8422 |
| ***5*** | 0.8214 | 0.8214 | 0.8214 | 0.8214 | 0.8214 | 0.8214 | 0.8214 | 0.8214 | 0.8214 |
| ***6*** | 0.8191 | 0.8191 | 0.8191 | 0.8191 | 0.8191 | 0.8191 | 0.8191 | 0.8191 | 0.8191 |
| ***7*** | 0.8184 | 0.8184 | 0.8184 | 0.8184 | 0.8184 | 0.8184 | 0.8184 | 0.8184 | 0.8184 |
| ***8*** | 0.8023 | 0.8026 | 0.8026 | 0.8026 | 0.8025 | 0.8025 | 0.8024 | 0.8022 | 0.8019 |
| ***9*** | 0.7299 | 0.7388 | 0.7381 | 0.7370 | 0.7356 | 0.7338 | 0.7313 | 0.7283 | 0.7247 |
| ***10*** | 0.5966 | 0.6338 | 0.6288 | 0.6231 | 0.6164 | 0.6091 | 0.6009 | 0.5921 | 0.5829 |
| ***11*** | 0.4521 | 0.5088 | 0.4991 | 0.4890 | 0.4785 | 0.4680 | 0.4574 | 0.4468 | 0.4364 |
| ***12*** | 0.3386 | 0.3924 | 0.3819 | 0.3718 | 0.3618 | 0.3523 | 0.3431 | 0.3342 | 0.3258 |
| ***13*** | 0.2595 | 0.3023 | 0.2936 | 0.2853 | 0.2774 | 0.2700 | 0.2629 | 0.2562 | 0.2498 |
| ***14*** | 0.2044 | 0.2374 | 0.2306 | 0.2242 | 0.2181 | 0.2124 | 0.2070 | 0.2018 | 0.1970 |
| ***15*** | 0.1647 | 0.1906 | 0.1853 | 0.1802 | 0.1755 | 0.1710 | 0.1668 | 0.1627 | 0.1589 |
| ***16*** | 0.1353 | 0.1560 | 0.1517 | 0.1477 | 0.1439 | 0.1403 | 0.1369 | 0.1337 | 0.1306 |
| ***17*** | 0.1128 | 0.1297 | 0.1262 | 0.1229 | 0.1198 | 0.1169 | 0.1141 | 0.1115 | 0.1090 |
| ***18*** | 0.0953 | 0.1093 | 0.1064 | 0.1037 | 0.1011 | 0.0987 | 0.0964 | 0.0942 | 0.0921 |
| ***19*** | 0.0813 | 0.0931 | 0.0907 | 0.0884 | 0.0862 | 0.0842 | 0.0823 | 0.0804 | 0.0787 |
| ***20*** | 0.0699 | 0.0799 | 0.0779 | 0.0759 | 0.0741 | 0.0724 | 0.0707 | 0.0692 | 0.0677 |
| ***21*** | 0.0603 | 0.0688 | 0.0670 | 0.0654 | 0.0638 | 0.0624 | 0.0610 | 0.0597 | 0.0584 |
| ***22*** | 0.0519 | 0.0591 | 0.0576 | 0.0562 | 0.0549 | 0.0537 | 0.0525 | 0.0514 | 0.0503 |
| ***23*** | 0.0446 | 0.0506 | 0.0494 | 0.0482 | 0.0471 | 0.0461 | 0.0451 | 0.0441 | 0.0432 |
| ***24*** | 0.0383 | 0.0434 | 0.0424 | 0.0414 | 0.0404 | 0.0396 | 0.0387 | 0.0379 | 0.0372 |
| ***25*** | 0.0331 | 0.0374 | 0.0365 | 0.0357 | 0.0349 | 0.0342 | 0.0334 | 0.0328 | 0.0321 |
| ***26*** | 0.0289 | 0.0326 | 0.0318 | 0.0311 | 0.0304 | 0.0298 | 0.0292 | 0.0286 | 0.0280 |
| ***27*** | 0.0255 | 0.0288 | 0.0281 | 0.0275 | 0.0269 | 0.0263 | 0.0258 | 0.0253 | 0.0248 |

# Standard Acoustic Emission

**Noise Level (LW):** Values reported correspond to the average estimated Sound Power Level emitted by the WTG at hub height, called LW in TS IEC-61400-14. LW values are expressed in dB(A). To obtain LWd value, as defined in IEC-61400-14, it must be applied a 2 dB increase to LW.

**dB(A):** LW is expressed in decibels applying the “A” filter as required by IEC.

Noise generated at standard power operation mode LW is **107.8 dB(A).**

Noise values included in the present document correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade.

| SG 4.5-145 | |
|---|---|
| **Wind Speed [m/s]** | **LW [dB(A)]** |
| 3 | 95.1 |
| 3.5 | 95.1 |
| 4 | 95.1 |
| 4.5 | 95.1 |
| 5 | 95.5 |
| 5.5 | 97.6 |
| 6 | 99.7 |
| 6.5 | 101.5 |
| 7 | 103.2 |
| 7.5 | 104.7 |
| 8 | 106.2 |
| 8.5 | 107.6 |
| 9 | 107.8 |
| 9.5 | 107.8 |
| 10 | 107.8 |
| 10.5 | 107.8 |
| 11 | 107.8 |
| 11.5 | 107.8 |
| 12 | 107.8 |
| 12.5 | 107.8 |
| 13 | 107.8 |
| 13.5 | 107.8 |
| 14 | 107.8 |
| 14.5 | 107.8 |
| 15 | 107.8 |

Noise values included in the present document correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade.

# Noise Reduction System (NRS) operational modes

The Noise Reduction System NRS is an optional module available with the basic SCADA configuration and it therefore requires the presence of a SGRE SCADA system to work.

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. This allows wind farms to be located close to urban areas, limiting the environmental impact that they imply.

Noise control is achieved through reducing the active power and rotational speed of the wind turbine. This reduction is dependent on the wind speed.

The task of the Noise Reduction System is to control 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.

In order to do this, the SCADA control has to consider the wind speed of each turbine, its direction, and a configured schedule/calendar.

There can be up to 8 low noise modes, besides the full operation one. Noise levels corresponding to each mode are the following:

| Mode: | FP | N1 | N2 | N3 | N4 | N5 | N6 | N7 | N8 |
|---|---|---|---|---|---|---|---|---|---|
| Noise Level [dB(A)] | 107.8 | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99 | 98 |

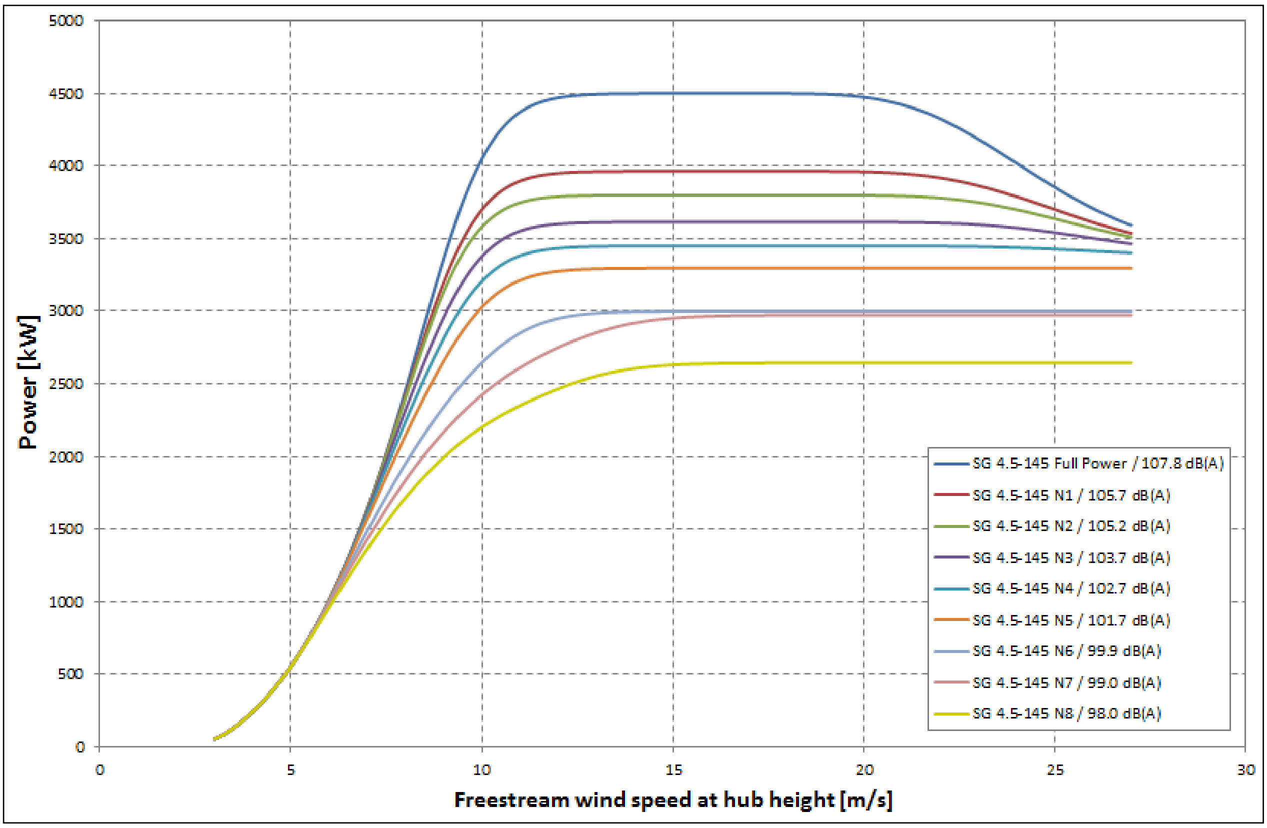
Noise values included in the present document correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade.

Depending on the type of tower selected, some of the low noise modes defined above may not be compatible. In the following table, feasibility of low noise modes vs tower is presented. Low noise modes feasibility vs other tower designs will be analyzed upon request.

| SG 4.5-145 | N1 | N2 | N3 | N4 | N5 | N6 | N7 | N8 |
|---|---|---|---|---|---|---|---|---|
| H= 90 m (Steel, baseline design) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| H= 107.5 m (Steel, baseline design) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| H= 127.5 m (Steel, baseline design) | No | No | No | No | Yes | Yes | Yes | Yes |

Next table presents the power production as a function of the horizontal wind speed measured at hub height for different noise reduction mode settings.

| ***P [kW]*** | ***Low Noise Operation Mode*** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***Wind Speed [m/s]*** | **N1 105.7 dB(A)** | **N2 105.2 dB(A)** | **N3 103.7 dB(A)** | **N4 102.7 dB(A)** | **N5 101.7 dB(A)** | **N6 99.9 dB(A)** | **N7 99.0 dB(A)** | **N8 98.0 dB(A)** |
| ***3*** | 57 | 57 | 57 | 57 | 57 | 57 | 57 | 57 |
| ***4*** | 243 | 243 | 243 | 243 | 243 | 243 | 243 | 243 |
| ***5*** | 556 | 556 | 556 | 556 | 556 | 556 | 556 | 555 |
| ***6*** | 1010 | 1010 | 1010 | 1009 | 1007 | 995 | 981 | 961 |
| ***7*** | 1638 | 1636 | 1623 | 1604 | 1574 | 1490 | 1432 | 1366 |
| ***8*** | 2422 | 2404 | 2320 | 2240 | 2147 | 1951 | 1837 | 1717 |
| ***9*** | 3198 | 3134 | 2958 | 2814 | 2658 | 2341 | 2168 | 1994 |
| ***10*** | 3700 | 3581 | 3378 | 3207 | 3029 | 2647 | 2424 | 2202 |
| ***11*** | 3897 | 3747 | 3552 | 3382 | 3214 | 2851 | 2612 | 2350 |
| ***12*** | 3950 | 3790 | 3602 | 3435 | 3276 | 2951 | 2751 | 2466 |
| ***13*** | 3961 | 3798 | 3612 | 3447 | 3292 | 2987 | 2854 | 2554 |
| ***14*** | 3963 | 3800 | 3615 | 3449 | 3295 | 2997 | 2920 | 2607 |
| ***15*** | 3964 | 3800 | 3615 | 3450 | 3296 | 2999 | 2953 | 2631 |
| ***16*** | 3964 | 3800 | 3615 | 3450 | 3296 | 3000 | 2967 | 2641 |
| ***17*** | 3964 | 3800 | 3615 | 3450 | 3296 | 3000 | 2972 | 2644 |
| ***18*** | 3964 | 3800 | 3615 | 3450 | 3296 | 3000 | 2973 | 2645 |
| ***19*** | 3963 | 3800 | 3615 | 3450 | 3296 | 3000 | 2974 | 2645 |
| ***20*** | 3960 | 3799 | 3615 | 3450 | 3296 | 3000 | 2974 | 2645 |
| ***21*** | 3948 | 3794 | 3614 | 3450 | 3296 | 3000 | 2974 | 2645 |
| ***22*** | 3919 | 3779 | 3609 | 3449 | 3296 | 3000 | 2974 | 2645 |
| ***23*** | 3865 | 3748 | 3597 | 3446 | 3296 | 3000 | 2974 | 2645 |
| ***24*** | 3789 | 3700 | 3574 | 3439 | 3296 | 3000 | 2974 | 2645 |
| ***25*** | 3702 | 3638 | 3542 | 3429 | 3296 | 3000 | 2974 | 2645 |
| ***26*** | 3613 | 3571 | 3503 | 3416 | 3296 | 3000 | 2974 | 2645 |
| ***27*** | 3537 | 3511 | 3466 | 3402 | 3296 | 3000 | 2974 | 2645 |


Power [kW]
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
Freestream wind speed at hub height [m/s]
SG 4.5-145 Full Power / 107.8 dB(A)
SG 4.5-145 N1 / 105.7 dB(A)
SG 4.5-145 N2 / 105.2 dB(A)
SG 4.5-145 N3 / 103.7 dB(A)
SG 4.5-145 N4 / 102.7 dB(A)
SG 4.5-145 N5 / 101.7 dB(A)
SG 4.5-145 N6 / 99.9 dB(A)
SG 4.5-145 N7 / 99.0 dB(A)
SG 4.5-145 N8 / 98.0 dB(A)

Next table presents the Ct as a function of the horizontal wind speed measured at hub height for different noise reduction mode settings. The calculated Ct curve data are valid for clean rotor blades, substantially horizontal, undisturbed air flow, normal turbulence intensity and normal wind shear.

| ***$C_T$ [-]*** | ***Low Noise Operation Mode*** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***Wind Speed [m/s]*** | **N1 105.7 dB(A)** | **N2 105.2 dB(A)** | **N3 103.7 dB(A)** | **N4 102.7 dB(A)** | **N5 101.7 dB(A)** | **N6 99.9 dB(A)** | **N7 99.0 dB(A)** | **N8 98.0 dB(A)** |
| ***3*** | 0.8920 | 0.8920 | 0.8920 | 0.8920 | 0.8920 | 0.8920 | 0.8920 | 0.8920 |
| ***4*** | 0.8431 | 0.8431 | 0.8431 | 0.8431 | 0.8431 | 0.8431 | 0.8431 | 0.8431 |
| ***5*** | 0.8197 | 0.8197 | 0.8197 | 0.8197 | 0.8196 | 0.8190 | 0.8173 | 0.8129 |
| ***6*** | 0.8194 | 0.8194 | 0.8186 | 0.8160 | 0.8097 | 0.7816 | 0.7564 | 0.7242 |
| ***7*** | 0.8160 | 0.8129 | 0.7920 | 0.7675 | 0.7357 | 0.6646 | 0.6234 | 0.5810 |
| ***8*** | 0.7705 | 0.7568 | 0.7015 | 0.6587 | 0.6148 | 0.5353 | 0.4945 | 0.4544 |
| ***9*** | 0.6648 | 0.6431 | 0.5829 | 0.5409 | 0.4998 | 0.4262 | 0.3892 | 0.3536 |
| ***10*** | 0.5228 | 0.5002 | 0.4584 | 0.4276 | 0.3972 | 0.3381 | 0.3067 | 0.2763 |
| ***11*** | 0.3906 | 0.3724 | 0.3470 | 0.3267 | 0.3071 | 0.2672 | 0.2429 | 0.2176 |
| ***12*** | 0.2931 | 0.2796 | 0.2630 | 0.2491 | 0.2360 | 0.2100 | 0.1943 | 0.1738 |
| ***13*** | 0.2258 | 0.2158 | 0.2037 | 0.1935 | 0.1840 | 0.1658 | 0.1574 | 0.1408 |
| ***14*** | 0.1787 | 0.1710 | 0.1617 | 0.1538 | 0.1465 | 0.1326 | 0.1286 | 0.1150 |
| ***15*** | 0.1445 | 0.1384 | 0.1310 | 0.1247 | 0.1189 | 0.1079 | 0.1059 | 0.0947 |
| ***16*** | 0.1190 | 0.1140 | 0.1079 | 0.1028 | 0.0981 | 0.0891 | 0.0879 | 0.0786 |
| ***17*** | 0.0994 | 0.0953 | 0.0903 | 0.0860 | 0.0821 | 0.0747 | 0.0738 | 0.0660 |
| ***18*** | 0.0841 | 0.0807 | 0.0764 | 0.0729 | 0.0696 | 0.0633 | 0.0626 | 0.0561 |
| ***19*** | 0.0719 | 0.0691 | 0.0654 | 0.0624 | 0.0596 | 0.0543 | 0.0537 | 0.0481 |
| ***20*** | 0.0621 | 0.0597 | 0.0566 | 0.0540 | 0.0515 | 0.0470 | 0.0464 | 0.0417 |
| ***21*** | 0.0540 | 0.0520 | 0.0493 | 0.0471 | 0.0450 | 0.0410 | 0.0405 | 0.0364 |
| ***22*** | 0.0472 | 0.0456 | 0.0433 | 0.0414 | 0.0396 | 0.0361 | 0.0357 | 0.0321 |
| ***23*** | 0.0413 | 0.0400 | 0.0383 | 0.0366 | 0.0351 | 0.0320 | 0.0316 | 0.0285 |
| ***24*** | 0.0361 | 0.0353 | 0.0340 | 0.0327 | 0.0313 | 0.0286 | 0.0282 | 0.0254 |
| ***25*** | 0.0318 | 0.0312 | 0.0303 | 0.0293 | 0.0282 | 0.0257 | 0.0254 | 0.0229 |
| ***26*** | 0.0281 | 0.0278 | 0.0272 | 0.0265 | 0.0255 | 0.0233 | 0.0230 | 0.0208 |
| ***27*** | 0.0251 | 0.0249 | 0.0246 | 0.0241 | 0.0233 | 0.0213 | 0.0210 | 0.0190 |

The table below contains the noise levels as a function of the horizontal wind speed measured at hub height for different noise reduction mode settings.

| ***Noise [dB(A)]*** | ***Low Noise Operation Mode*** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***Wind Speed [m/s]*** | **N1 105.7 dB(A)** | **N2 105.2 dB(A)** | **N3 103.7 dB(A)** | **N4 102.7 dB(A)** | **N5 101.7 dB(A)** | **N6 99.9 dB(A)** | **N7 99.0 dB(A)** | **N8 98.0 dB(A)** |
| ***3*** | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 |
| ***3.5*** | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 |
| ***4*** | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 |
| ***4.5*** | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 | 95.1 |
| ***5*** | 95.5 | 95.5 | 95.5 | 95.5 | 95.5 | 95.5 | 95.5 | 95.5 |
| ***5.5*** | 97.6 | 97.6 | 97.6 | 97.6 | 97.6 | 97.6 | 97.6 | 97.6 |
| ***6*** | 99.7 | 99.7 | 99.7 | 99.7 | 99.7 | 99.7 | 99.0 | 98.0 |
| ***6.5*** | 101.5 | 101.5 | 101.5 | 101.5 | 101.5 | 99.9 | 99.0 | 98.0 |
| ***7*** | 103.2 | 103.2 | 103.2 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***7.5*** | 104.7 | 104.7 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***8*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***8.5*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***9*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***9.5*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***10*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***10.5*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***11*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***11.5*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***12*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***12.5*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***13*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***13.5*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***14*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***14.5*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |
| ***15*** | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99.0 | 98.0 |

Noise values included in the present document correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade.

The 1/3 octave band noise spectra expressed as A-weighted sound power level for a given frequency band is shown below for 12m/s at hub height, for the standard power operation setting as well as the low noise modes.

| | Noise [dB(A)] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ***1/3 octave band, center frequency [Hz]*** | **Standard Power 4.5MW** | **N1** | **N2** | **N3** | **N4** | **N5** | **N6** | **N7** | **N8** |
| | **107.8 dB(A)** | **105.7 dB(A)** | **105.2 dB(A)** | **103.7 dB(A)** | **102.7 dB(A)** | **101.7 dB(A)** | **99.9 dB(A)** | **99.0 dB(A)** | **98.0 dB(A)** |
| 10 | 46.1 | 46.1 | 46.1 | 46.1 | 46.1 | 46.1 | 46.1 | 46.1 | 46.1 |
| 12.5 | 51.8 | 51.8 | 51.8 | 51.8 | 51.8 | 51.8 | 51.8 | 51.7 | 51.7 |
| 16 | 57.5 | 57.5 | 57.5 | 57.4 | 57.4 | 57.4 | 57.3 | 57.3 | 57.3 |
| 20 | 62.9 | 62.8 | 62.8 | 62.7 | 62.6 | 62.6 | 62.5 | 62.4 | 62.3 |
| 25 | 67.5 | 67.4 | 67.3 | 67.2 | 67 | 66.9 | 66.7 | 66.6 | 66.5 |
| 31.5 | 72.2 | 72 | 71.9 | 71.7 | 71.4 | 71.3 | 71 | 70.8 | 70.7 |
| 40 | 76.4 | 76.1 | 76 | 75.7 | 75.3 | 75.1 | 74.6 | 74.4 | 74.2 |
| 50 | 81 | 80.5 | 80.4 | 80.1 | 79.5 | 79.2 | 78.6 | 78.3 | 78 |
| 63 | 85.3 | 84.7 | 84.6 | 84.1 | 83.3 | 82.9 | 82.2 | 81.8 | 81.4 |
| 80 | 87.8 | 87 | 86.9 | 86.3 | 85.3 | 84.8 | 83.8 | 83.4 | 82.8 |
| 100 | 89.7 | 88.8 | 88.5 | 87.9 | 86.6 | 86 | 84.8 | 84.2 | 83.6 |
| 125 | 91.2 | 90.1 | 89.8 | 89 | 87.5 | 86.7 | 85.3 | 84.6 | 83.8 |
| 160 | 92.2 | 90.9 | 90.5 | 89.5 | 87.7 | 86.8 | 85.2 | 84.3 | 83.4 |
| 200 | 93.4 | 91.2 | 90.7 | 89.1 | 88.1 | 87.1 | 85.2 | 84.2 | 83.2 |
| 250 | 94.9 | 92.7 | 92.2 | 90.6 | 89.6 | 88.6 | 86.7 | 85.7 | 84.7 |
| 315 | 95.3 | 93.1 | 92.6 | 91 | 90 | 89 | 87.1 | 86.1 | 85.1 |
| 400 | 95 | 92.8 | 92.3 | 90.7 | 89.7 | 88.7 | 86.8 | 85.8 | 84.8 |
| 500 | 95.1 | 92.9 | 92.4 | 90.8 | 89.8 | 88.8 | 86.9 | 85.9 | 84.9 |
| 630 | 96.7 | 94.5 | 94 | 92.4 | 91.4 | 90.4 | 88.5 | 87.5 | 86.5 |
| 800 | 96.5 | 94.3 | 93.8 | 92.2 | 91.2 | 90.2 | 88.3 | 87.3 | 86.3 |
| 1000 | 97.5 | 95.3 | 94.8 | 93.2 | 92.2 | 91.2 | 89.3 | 88.3 | 87.3 |
| 1250 | 98.2 | 96 | 95.5 | 93.9 | 92.9 | 91.9 | 90 | 89 | 88 |
| 1600 | 98.1 | 95.9 | 95.4 | 93.8 | 92.8 | 91.8 | 89.9 | 88.9 | 87.9 |
| 2000 | 97 | 94.8 | 94.3 | 92.7 | 91.7 | 90.7 | 88.8 | 87.8 | 86.8 |
| 2500 | 95.6 | 93.4 | 92.9 | 91.3 | 90.3 | 89.3 | 87.4 | 86.4 | 85.4 |
| 3150 | 93.4 | 91.2 | 90.7 | 89.1 | 88.1 | 87.1 | 85.2 | 84.2 | 83.2 |
| 4000 | 90.3 | 88.1 | 87.6 | 86 | 85 | 84 | 82.1 | 81.1 | 80.1 |
| 5000 | 86 | 83.8 | 83.3 | 81.7 | 80.7 | 79.7 | 77.8 | 76.8 | 75.8 |
| 6300 | 80.8 | 78.6 | 78.1 | 76.5 | 75.5 | 74.5 | 72.6 | 71.6 | 70.6 |
| 8000 | 75 | 72.8 | 72.3 | 70.7 | 69.7 | 68.7 | 66.8 | 65.8 | 64.8 |
| 10000 | 70.4 | 68.2 | 67.7 | 66.1 | 65.1 | 64.1 | 62.2 | 61.2 | 60.2 |

Further information about noise spectra, including other wind speeds, is available upon request.

Noise values included in the present document correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade.

# Electrical Specifications

**Nominal output and grid conditions**

| | |
|---|---|
| Nominal power | 4500 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 | 4650 kW |
| Nominal speed | 1120 rpm-6p (50Hz)<br>1344 rpm-6p (60Hz) |

**Generator Protection**

| | |
|---|---|
| Insulation class | Stator F/H<br>Rotor F/H |
| Winding temperatures | 6 Pt 100 sensors |
| Bearing temperatures | 2 Pt 100 |
| Slip Rings | 1 Pt 100 |
| Grounding brush | On side no coupling |

**Generator Cooling**

| | |
|---|---|
| Cooling system | Liquid cooling |
| Internal ventilation | Air |
| Control parameter | Winding, Liquid, Bearings temperature |

**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 Requirements**

| | |
|---|---|
| Nominal grid frequency | 50 or 60 Hz |
| Minimum voltage | 90 % of nominal |
| Maximum voltage | 112 % of nominal |
| Minimum frequency | 94 % of nominal |
| Maximum frequency | 106 % of nominal |
| Maximum voltage imbalance (negative sequence of component voltage). | ≤5 % |
| Max short circuit level at controller's grid Terminals (690 V) | 67 kA |

**Power Consumption from Grid** (approximately)

| | |
|---|---|
| At stand-by,No yawing | 10 kW |
| At stand-by, yawing | 41 kW |

**Controller back-up**

| | |
|---|---|
| UPS Controller system | Online UPS, Li battery |
| Back-up time | 1 min |
| Back-up time Scada | 24 h |

**Transformer Requirements**

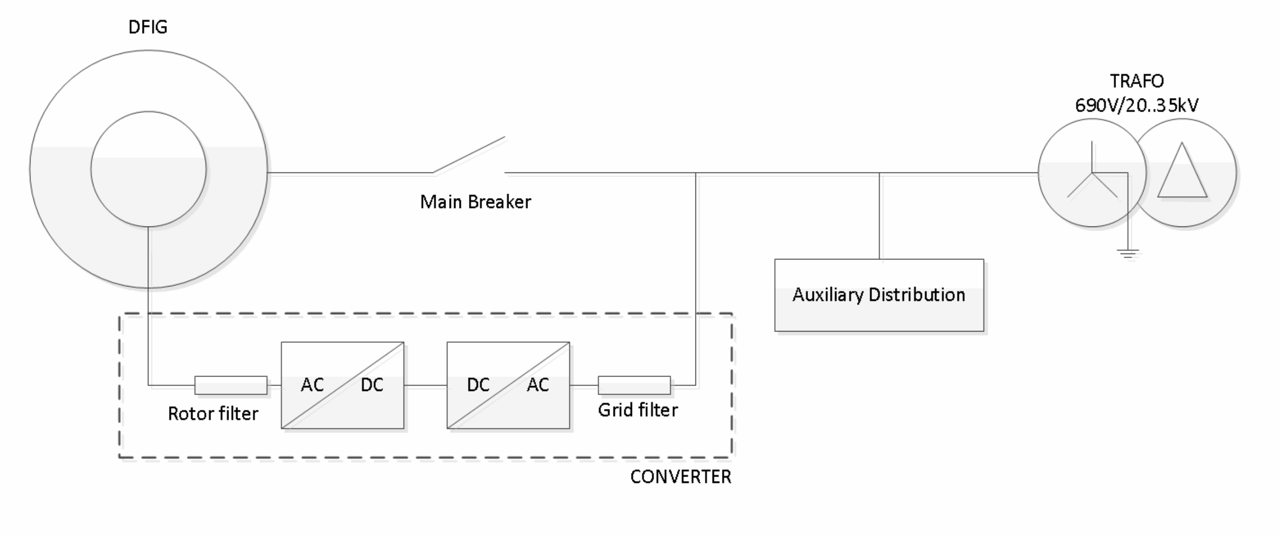
| | |
|---|---|
| Transformer impedance requirement | 8.0 % -9.5% |
| Secondary voltage | 690 V |
| Vector group | Dyn 11 or Dyn 1 (star point earthed) |

**Earthing Requirements**

| | |
|---|---|
| Earthing system | Acc. to IEC62305-3 ED 1.0:2006 |
| 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 ................................. | Dry type |
| Nominal power ................. | 5350 kVA @nominal voltage +/- 10 % |
| Nominal voltage ............... | 30/0.69 kV |
| Frequency ........................ | 50 Hz |
| Transformer impedance .... | 10.7% |
| Loss ($P_0$ /$P_{n120^\circ C}$) ............... | 4.8/39 kW |
| Vector group ..................... | Dyn11 |
| Offload tap changer .......... | +/- 2.5% / +/- 5 % |
| Standard…………………... | IEC 60076<br>ECO Design Directive |

### Transformer Cooling

| | |
|---|---|
| Cooling system…………… | AF |
| Ventilation ………………… | Forced ventilation of the transformer room |
| Control parameter............. | Winding & Magnetic core temperature |

### Transformer Monitoring

| | |
|---|---|
| WindingTemperature……… | PT100 sensor |
| Mag. Core temperature… | PT100 sensor |

### Transformer Earthing

| | |
|---|---|
| Star point ........................ | The star point of the transformer must be connected to earth |

# Transformer Specifications 34.5 kV*

### Transformer

| | |
|---|---|
| Type ................................. | Dry type |
| Nominal power ................. | 5500 kVA @nominal voltage +12/-10 % |
| Nominal voltage ............... | 34.5/0.69 kV |
| Frequency ........................ | 60 Hz |
| Transformer impedance .... | 9.5% |
| Loss ($P_0$ /$P_{n120^\circ C}$) ............... | 8/45 kW |
| Vector group ..................... | Dyn1 |
| Offload tap changer .......... | +/- 2.5% / +/- 5 % |
| Standard…………………... | IEEE std C57.12 |

### Transformer Cooling

| | |
|---|---|
| Cooling system…………… | AF |
| Ventilation ………………… | Forced ventilation of the transformer room |
| Control parameter............. | Winding & Magnetic core temperature |

### Transformer Monitoring

| | |
|---|---|
| WindingTemperature……… | PT100 sensor |
| Mag. Core temperature… | PT100 sensor |

### Transformer Earthing

| | |
|---|---|
| Star point ........................ | The star point of the transformer must be connected to earth |

**All data are subject to tolerances in accordance with IEC.**
***Example for an ECO 30kV and 34.5kV transformers. For other Medium Voltage transformers, consult with SGRE**

# Switchgear Specifications

The installation of a switchgear is an option available upon request. The minimum requirements that must be complied with, from the point of view of electrical protection, are:

**Switchgear Specification (38 kV)**

### Technical Data for Switchgear

| **Switchgear** | |
|---|---|
| Type | CGM.3 |
| Rated voltage | 38 kV |
| Operating voltage | 30 - 36 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 | 1, 2 or 3 panels |
| Grid cable feeder | Load break switch or direct cable riser |
| Circuit breaker feeder | Circuit breaker |
| Degree of protection, vessel | IPX8 |
| Degree of protection, front cover | IP2XD |
| Degree of protection, LV Comp. | IP2XD |
| Internal arc classification IAC: | A FL 20 kA 1s |
| Pressure relief | Down |
| Standard | IEC 62271 |
| Temperature range | -30°C to +40°C |

| **Grid Cable feeder** | |
|---|---|
| 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 CB switch | Closed, open, earthed |
| Switch mechanism | Spring operated |
| Tripping mechanism | Stored energy |
| Motor voltage | Under request |
| Control | Local |
| Coil for external trip | 230 V AC |
| Voltage detection system | Capacitive |

| **Protection** | |
|---|---|
| Over-current relay | Ekor.wtp |
| Functions | 50/51 50N/51N |
| Power supply | Dual (Self & Aux. powered) |
| Current transformer | 300/1A; 0.18VA, Cl. 5P20 |

| **Interface- MV Cables** | |
|---|---|
| Grid cable feeder | 630A bushings type C M16<br>Max 2 feeder cables |
| Cable entry | From bottom |
| Cable clamp size (cable outer diameter) | up to 48mm |
| Circuit breaker feeder | 630 A bushings type C M16 |
| Cable entry | From bottom |

| **Interface to turbine control** | |
|---|---|
| Breaker status | 1 NO + 1 NC contacts |
| Insulation supervision | Under request |
| External trip | 230 V AC |

**All data are subject to tolerances in accordance with IEC.**
**Example for a 38 kV Switchgear. For other Medium Voltage variants or different grounding systems, contact SGRE.**

# Preliminary Foundation Loads

Detailed information about foundation loads will be available upon request.

# Tower Dimensions

SG 4.5-145 presents a tower portfolio with hub heights ranging from 90m to 157.5m. Information for the baseline towers is included below:

- Tower hub height 90m. Baseline design.

| TOWER HH 90 SG 4.5-145 | | | | |
|---|---|---|---|---|
| | **Section 1 (bottom)** | **Section 2** | **Section 3** | **Section 4 (top)** |
| **External diameter upper flange (m)** | 4.030 | 4.023 | 4.017 | 3.503 |
| **External diameter lower flange (m)** | 4.278 | 4.030 | 4.023 | 4.017 |
| **Section´s height (m)** | 18.040 | 23.960 | 21.000 | 25.000 |
| **Section structural weight (kgs)** | 69105.0 | 64484.8 | 40171.5 | 43050.0 |
| **Section total weight (kgs)** | 70837.1 | 65563.0 | 41116.5 | 44175.0 |
| **Total tower height (m)** | **88.000** | | | |
| **Total tower weight (kg)** | **221691.6** | | | |

- Tower hub height 107.5m. Baseline design.

| TOWER HH 107.5 SG 4.5-145 | | | | | |
|---|---|---|---|---|---|
| | **Section 1 (bottom)** | **Section 2** | **Section 3** | **Section 4** | **Section 5 (top)** |
| **External diameter upper flange (m)** | 4.4365 | 4.4290 | 4.4215 | 4.4170 | 3.5030 |
| **External diameter lower flange (m)** | 4.6780 | 4.4365 | 4.4290 | 4.4215 | 4.4170 |
| **Section´s height (m)** | 13.325 | 18.180 | 19.995 | 27.000 | 27.000 |
| **Section structural weight (kgs)** | 68911.6 | 68791.4 | 56596.8 | 56356.5 | 48198.1 |
| **Section total weight (kgs)** | 70694.8 | 69609.5 | 57496.6 | 57571.5 | 49413.1 |
| **Total tower height (m)** | **105.510** | | | | |
| **Total tower weight (kg)** | **304785.5** | | | | |

- Tower hub height 127.5m. Baseline design.

| **TOWER HH 127.5 SG 4.5-145** | | | | | | |
|---|---|---|---|---|---|---|
| | **Section 1 (bottom)** | **Section 2** | **Section 3** | **Section 4** | **Section 5** | **Section 6 (top)** |
| **External diameter upper flange (m)** | 4.605 | 4.4325 | 4.429 | 4.125 | 3.819 | 3.503 |
| **External diameter lower flange (m)** | 4.680 | 4.605 | 4.4325 | 4.429 | 4.125 | 3.819 |
| **Section´s height (m)** | 13.510 | 17.595 | 19.975 | 22.980 | 24.440 | 27.000 |
| **Section structural weight (kgs)** | 74573.9 | 74376.5 | 69994.0 | 65147.9 | 52271.2 | 46346.0 |
| **Section total weight (kgs)** | 76523.3 | 75168.2 | 70892.9 | 66182.0 | 53371.0 | 47561.0 |
| **Total tower height (m)** | **125.510** | | | | | |
| **Total tower weight (kg)** | **389698.5** | | | | | |

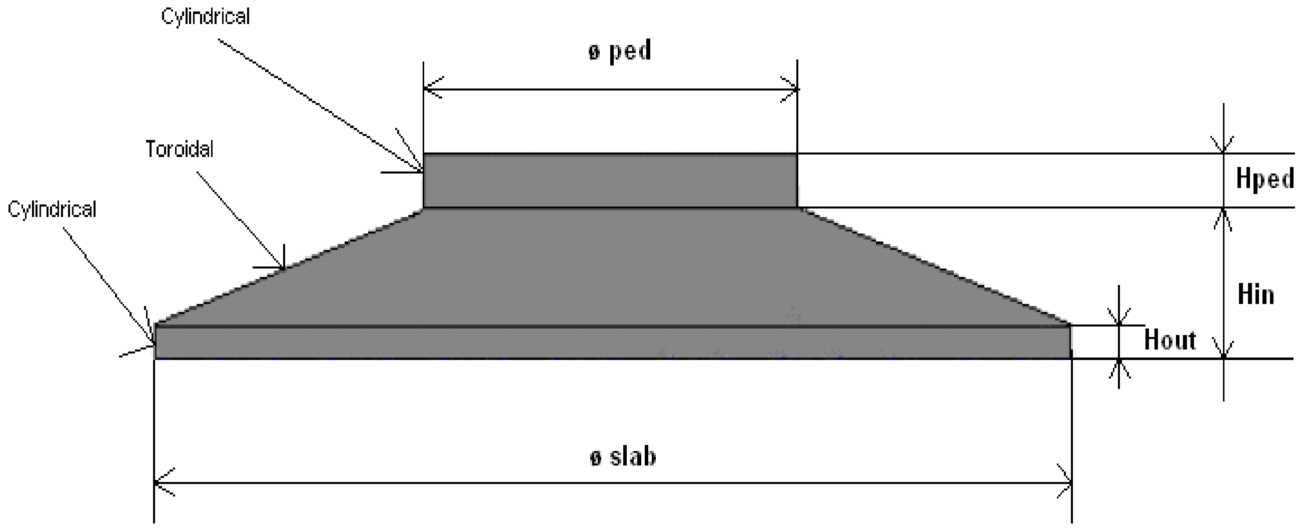
Information about other tower heights will be available upon request.

# Estimated Foundation Design

**Hub height: 107.5 m**

**Volumes**

| | |
|---|---|
| Concrete volume | ~559.61 m³, C35/45 – C45/55 MPa |
| Reinforcement steel | ~52007 kg, B 500 S |




| FOUNDATION GEOMETRY | |
|---|---|
| øslab= Slab diameter [m] | 20.80 |
| Hout= Outter egde height [m] | 0.50 |
| Hin= Inner edge height [m] | 3.0 |
| øped= Pedestal diameter [m] | 5.50 |
| Hped= Pedestal height [m] | 0.50 |

**The estimated foundation design is based on the following assumptions:**

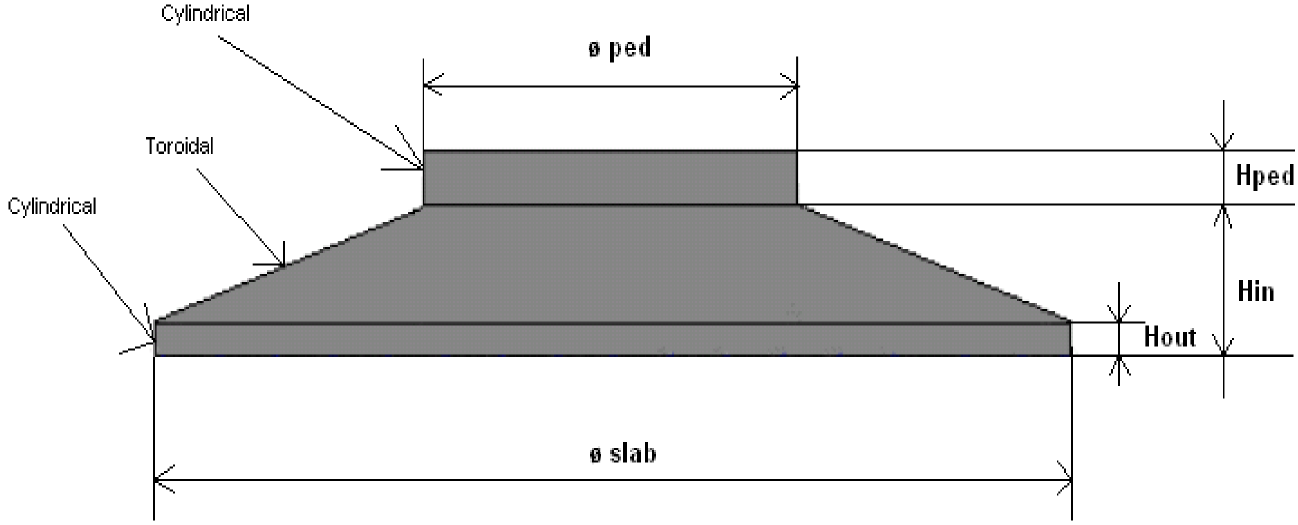
- Gravity based flat foundation without buoyancy
- Specific weight of backfill 18.0 kN/m³
- Friction angle 30.0°

**Additional factors that may impact the foundation design:**
Soil conditions, country, designer practice, national codes and standards.

**Hub height: 127.5 m**

**Volumes**

| | |
|---|---|
| Concrete volume | ~635.09 m³, C35/45 – C50/60 MPa |
| Reinforcement steel | ~63240 kg, B 500 S |




| FOUNDATION GEOMETRY | |
|---|---|
| øslab= Slab diameter [m] | 22.30 |
| Hout= Outter egde height [m] | 0.50 |
| Hin= Inner edge height [m] | 3.0 |
| øped= Pedestal diameter [m] | 5.50 |
| Hped= Pedestal height [m] | 0.50 |

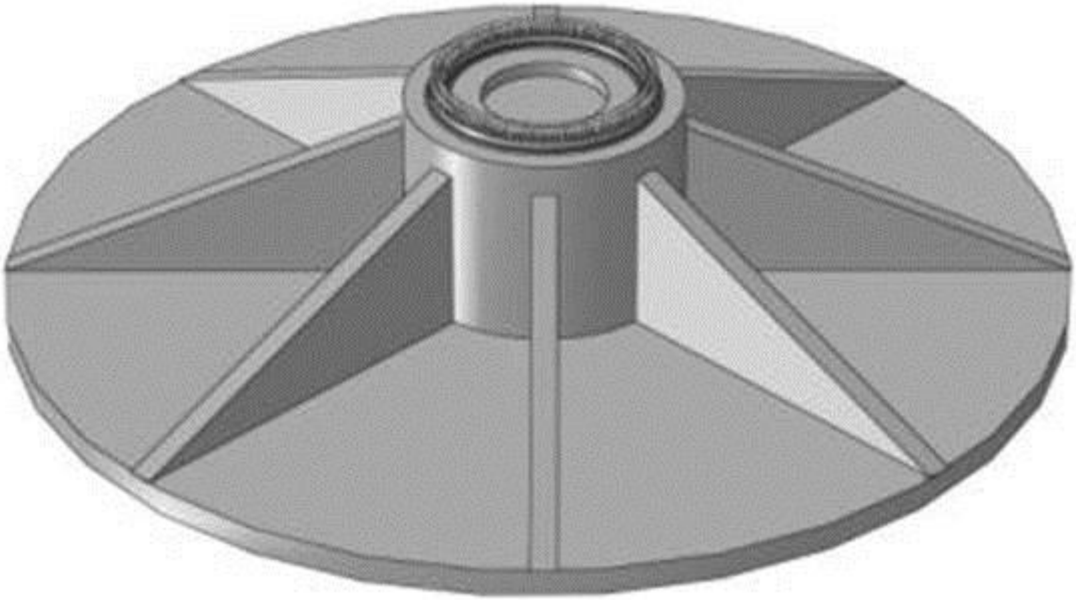
**The estimated foundation design is based on the following assumptions:**

- Gravity based flat foundation without buoyancy
- Specific weight of backfill 18.0 kN/m³
- Friction angle 30.0°

**Additional factors that may impact the foundation design:**
Soil conditions, country, designer practice, national codes and standards.

Although the standard and most common foundation concept is the previously shown circular tapered slab, it is also possible to design, based on site specific conditions, the optimized “8 Walls foundation”.

See figure below:



# Preliminary Grid Performance Specification, 50 Hz

**General**
This document describes the grid performance of the SG 4.5-145, 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 in PSS/E. This model is a reduced order model, suitable for balanced simulations with time steps between 4-10 ms.

The standard voltage limits for the SG 4.5-145, 50 Hz wind turbine are presented in Figure 1 between 180 - 1000 seconds and in Figure 2 between 0.4 – 100 seconds.

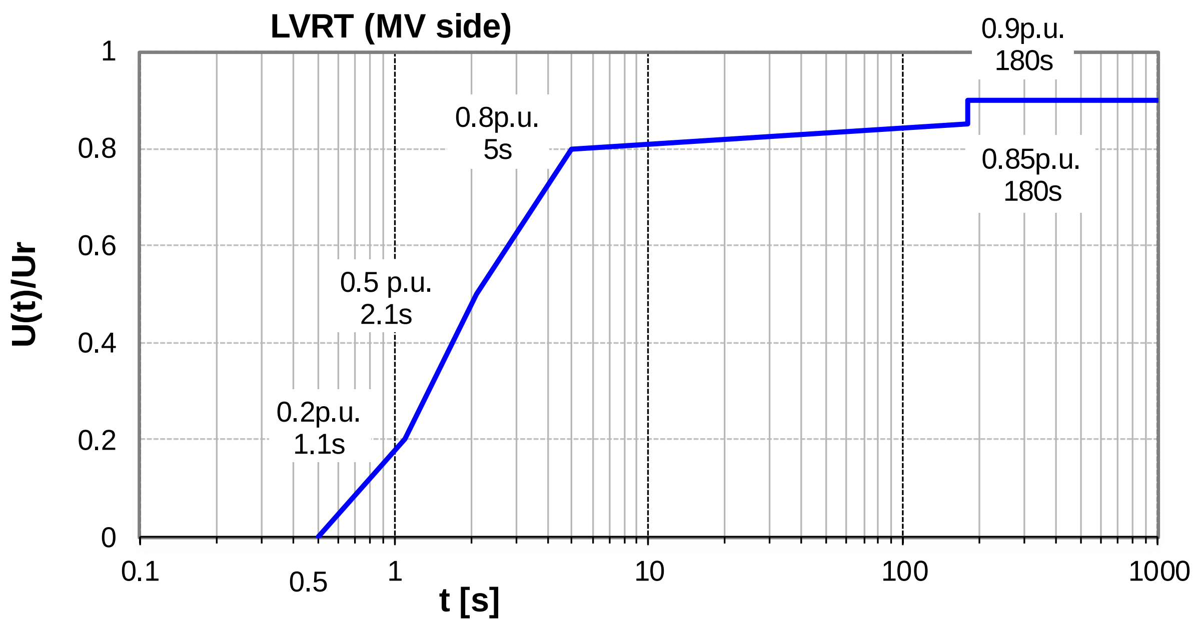



**Figure 1.** Lower voltage limits for SG 4.5-145, 50 Hz wind turbine in the range of 0-1000 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).

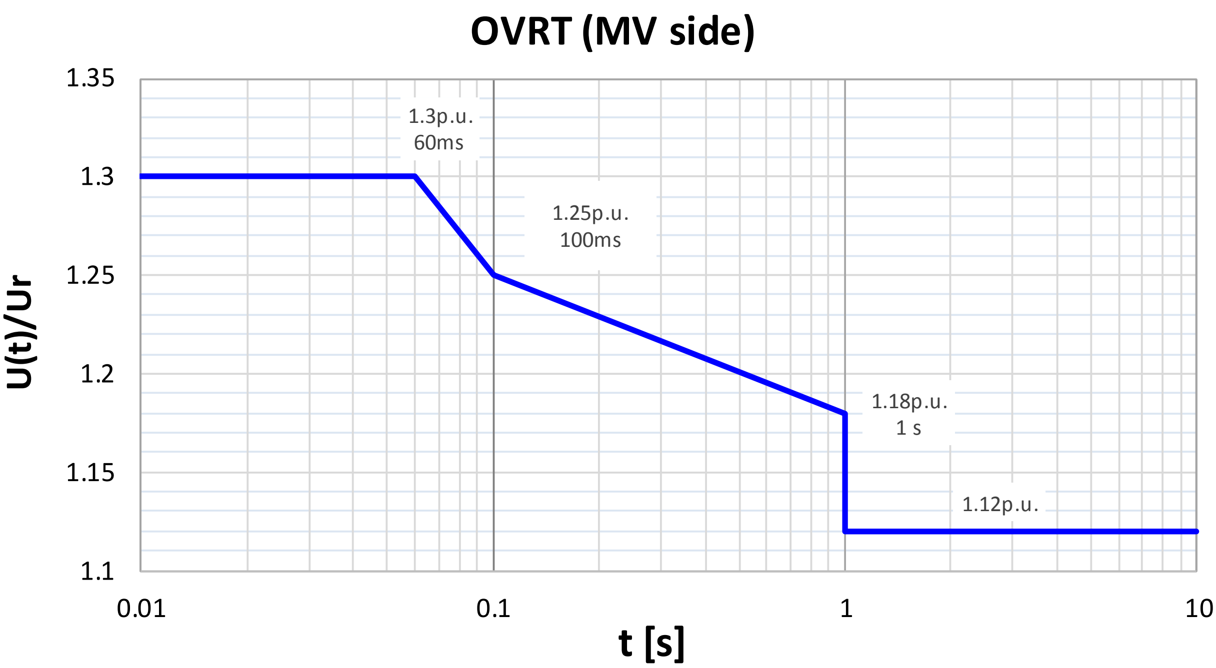



**Figure 2.** Upper voltage limits for SG 4.5-145, 50 Hz wind turbine in the range of 0-10 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).

**Power Factor (Reactive Power) Capability**
The wind turbine is able to operate in a power factor range of 0.9 leading to 0.9 lagging at the low voltage side of the wind turbine transformer, at nominal balanced voltage and nominal frequency. The control mode for the wind turbine is with reactive power set-points.

**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 is able to operate in the frequency range between 47 Hz and 53 Hz.

**Voltage Capability**
The voltage operation range for the wind turbine is between 90% and 112% of nominal voltage at the low voltage side of the wind turbine transformer. The voltage can be up to 130% for 60ms, see Figure 2. The wind turbine’s target voltage shall stay between 95% and 105% in order to support the best possible performance by staying within the operation limits.

**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 four different modes:

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

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

**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 IEC.**

# Preliminary Grid Performance Specification, 60 Hz

**General**
This document describes the grid performance of the SG 4.5-145, 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 3 and Figure 4.

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

The standard voltage limits for the SG 4.5-145, 60 Hz wind turbine are presented in Figure 3 between 180 - 1000 seconds and in Figure 4 between 0.4 – 100 seconds.

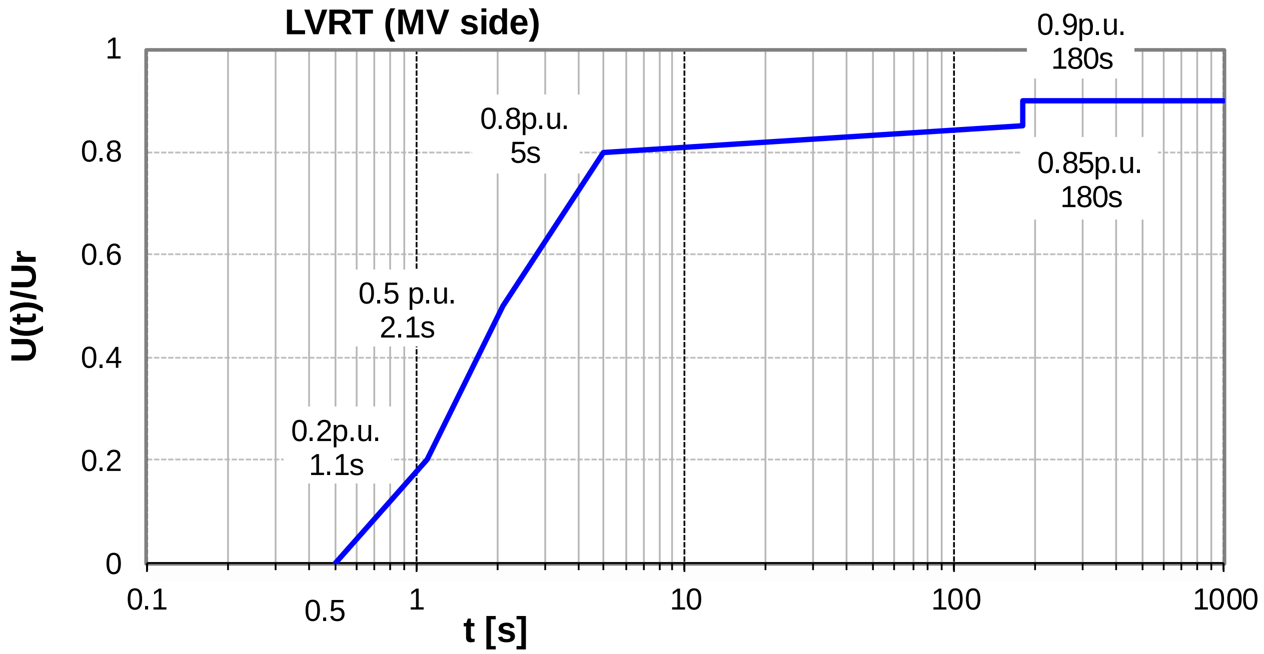



**Figure 3.** Lower voltage limits for SG 4.5-145, 60 Hz wind turbine in the range of 0-1000 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).

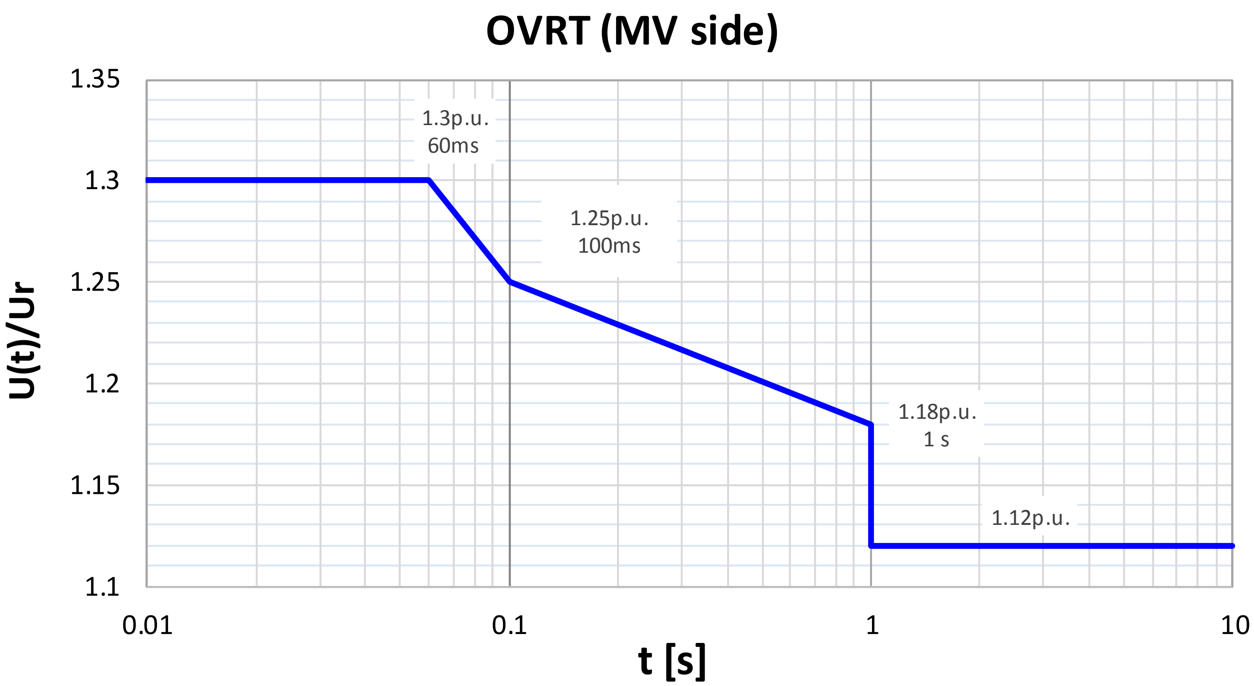



**Figure 4.** Upper voltage limits for SG 4.5-145, 60 Hz wind turbine in the range of 0-10 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).

**Power Factor (Reactive Power) Capability**
The wind turbine is able to operate in a power factor range of 0.9 leading to 0.9 lagging at the low voltage side of the wind turbine transformer, at nominal balanced voltage and nominal frequency. The control mode for the wind turbine is with reactive power set-points.

**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 is able to operate in the frequency range between 56.4 Hz and 63.6 Hz.

**Voltage Capability**
The voltage operation range for the wind turbine is between 90% and 112% of nominal voltage at the low voltage side of the wind turbine transformer. The voltage can be up to 130% for 60ms, see Figure 4. The wind turbine's target voltage shall stay between 95% and 105% in order to support the best possible performance by staying within the operation limits

**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 four different modes:

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

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

**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 IEC.**

# Reactive Power Capability, 50 Hz

**General**
This document describes the reactive power capability of SG 4.5-145, 50 Hz wind turbines during active power production. SG 4.5-145 wind turbines are equipped with a B2B Partial load frequency converter which allows the wind turbine to operate in a wide power factor range.

**Reactive Power Capability Curves**

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

Figure 5 shows the reactive power capability on the LV side of the wind turbine depending on the generated power at LV terminals.

Figure 6 shows the reactive power capability on the LV side of the wind turbine transformer at various voltages between 0.90 p.u. and 1.13 p.u. at the LV terminals.

Figure 7 includes reactive power capability at no wind (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.

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

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

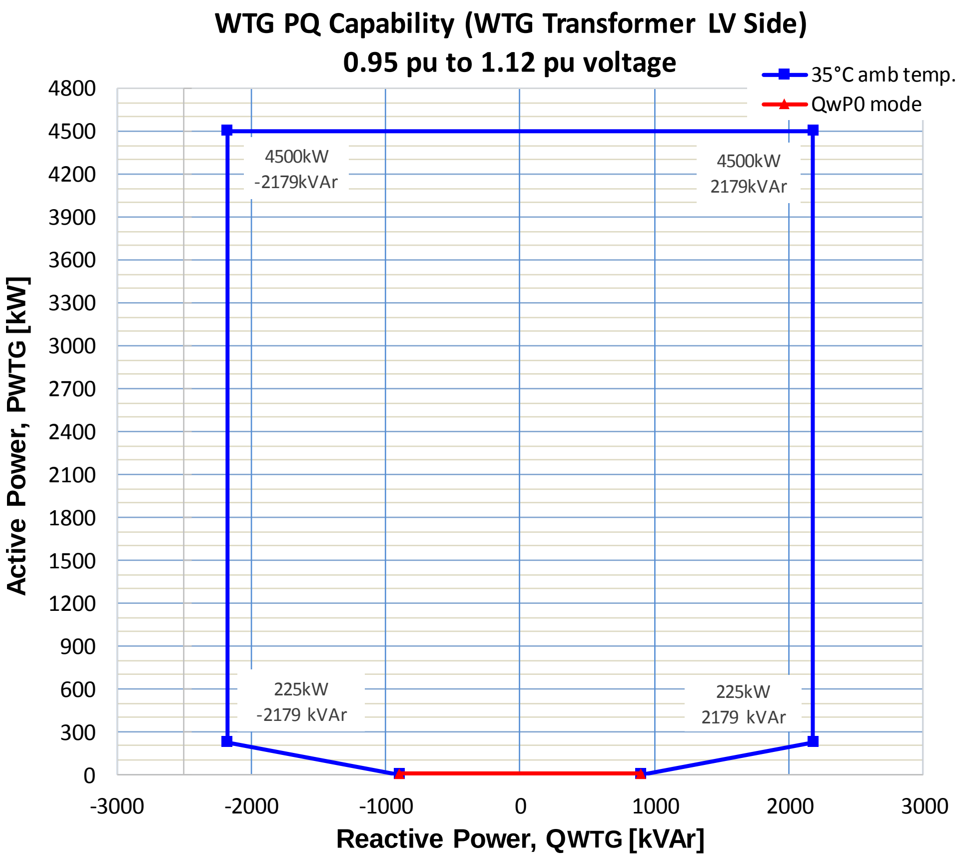



**Figure 5**: Reactive power capability curves, 50 Hz wind turbine, at LV side of wind turbine transformer.

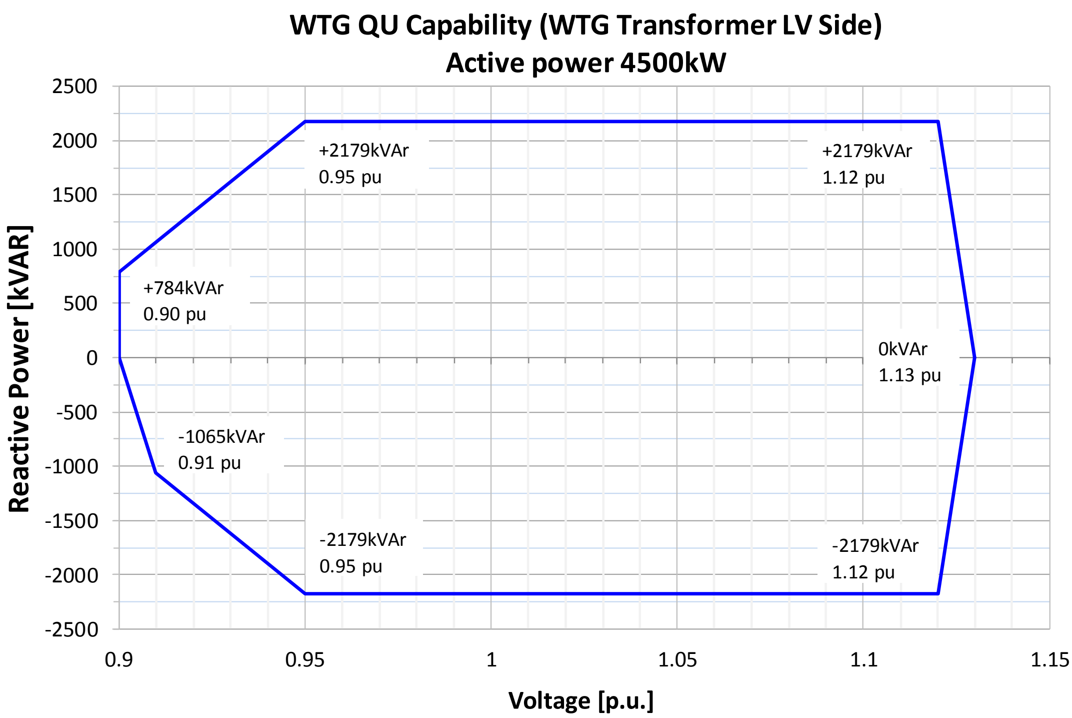



**Figure 6.** Reactive power capability versus voltage.

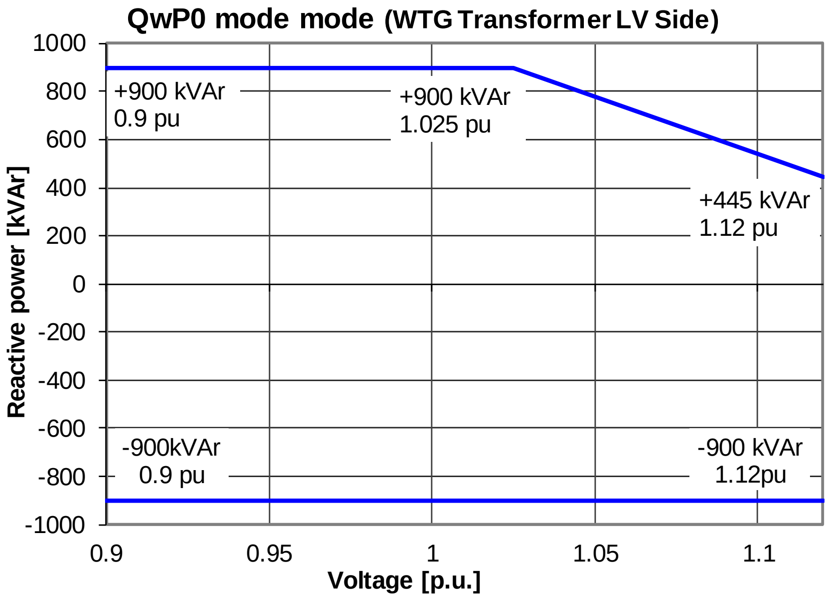



**Figure 7**. Reactive power capability at no wind (QwP0)

**All data are subject to tolerances in accordance with IEC.**

# Reactive Power Capability, 60 Hz

**General**
This document describes the reactive power capability of SG 4.5-145, 60 Hz wind turbines during active power production. SG 4.5-145 wind turbines are equipped with a B2B Partial load frequency converter which allows the wind turbine to operate in a wide power factor range.

**Reactive Power Capability Curves**
The reactive power capability for the wind turbine at the LV side of the wind turbine transformer will be presented in the following Figures.

Figure 8 shows the reactive power capability on the LV side of the wind turbine depending on the generated power at LV terminals.

Figure 9 shows the reactive power capability on the LV side of the wind turbine transformer at various voltages between 0.90 p.u. and 1.13 p.u. at the LV terminals.

Figure 10 includes reactive power capability at no wind (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.

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

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

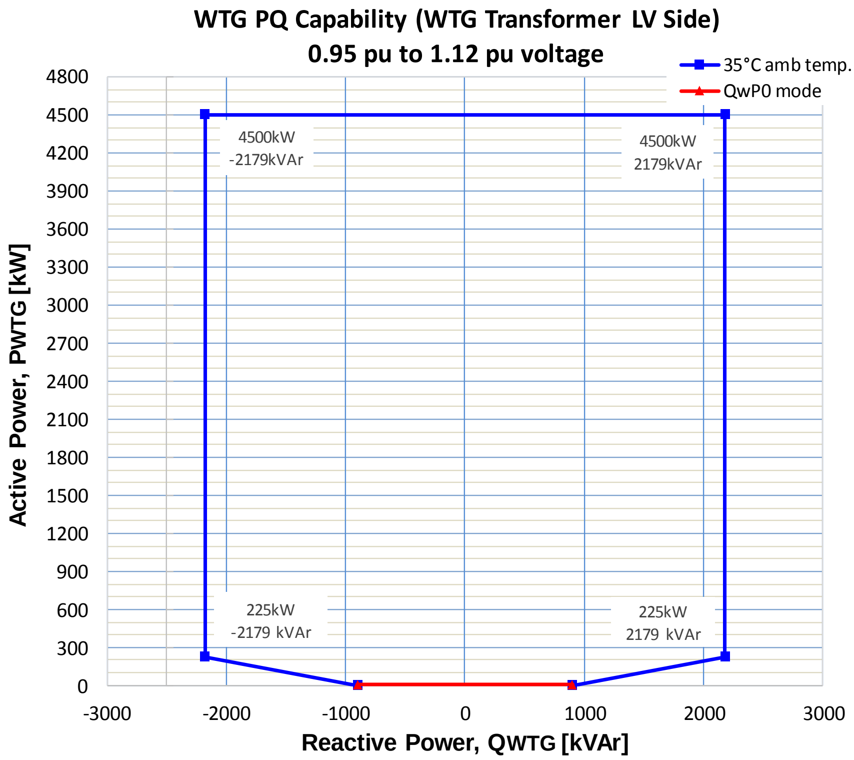



**Figure 8.** Reactive power capability curves, 60 Hz wind turbine, at LV side of wind turbine transformer

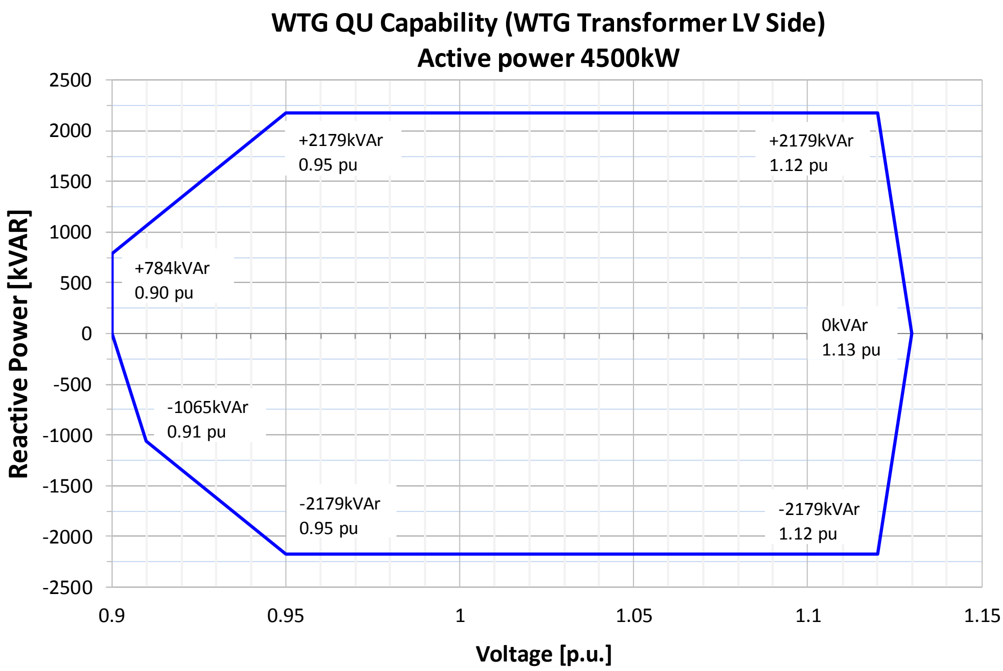



**Figure 9.** Reactive power capability versus voltage

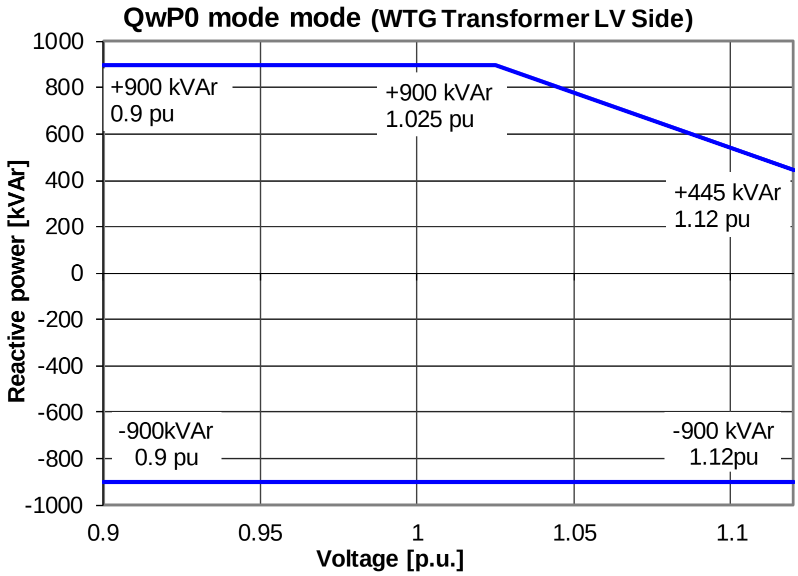



**Figure 10.** Reactive power capability at no wind (QwP0).

# SCADA, System Description

**General**

This is a general description of the Siemens Gamesa Renewable Energy (SGRE) SCADA System.

WindNet® PRO SCADA is a wind farm management tool. Overall, the SCADA enables:

- Supervising, monitoring and/or controlling not only wind turbines in a given wind farm, but also other components installed in the wind farm such as meteorological masts, substations, measuring devices, etc.
- Storing and managing information, which provides an advanced capacity to generate reports.
- Connecting to control centers or higher level management systems.
- Wind farm power regulation for both active as well as reactive power.
- Wind farm electricity generation based on environmental conditions.

In short, the SCADA system is an indispensable communications gateway for incoming and outgoing wind farm data.

**Main Features**

The WindNet® PRO SCADA system has the following main features:

- Wind turbine supervision and control.
- Meteorological mast supervision.
- Supervision and control of the wind farm's feed-in substation.
- Alarms and notifications SGRE management.
- Reporting for technical and economic wind farm exploitation.
- Access security via user and profile management.
- Multiple-wind farm management capacity enabling various wind farms to be managed from a single SCADA installation. Optimized SQL database for data management.
- Integration with the SGRE preventive maintenance system (PMS)
- Integration with SGRE support systems for managing payment features
- Additionally, the SGRE SCADA system has the following optional features:
- Data server for access and/or integration in upper systems: OPC-DA server, OPC-HDA server, MODBUS client/server and DNP3 client/server.
- Integration of the SGRE Power Manager tool, which includes the active power/frequency regulating tools and reactive power/voltage regulation for the wind farm (up to two points of connection for each SCADA installation)
- NRS® (Noise Reduction System) to safeguard the acoustic integrity of the area based on wind direction and time
- Shadow Control System to prevent the undesired effects of shadows in residential areas near the wind farm
- Wake Cancellation System for protecting wind turbines from intense turbulence based on wind direction
- Ice Detection System for protecting the surrounding area against ice thrown from wind turbine blades
- Bat Shield System for protecting bats

- Bird Detection System for protecting birds
- SGRE Messenger application for distributing SMS and/or email messages to operators and maintenance technicians (SIM card not included)
- Communication Manager integration with the cut-off switch feature to prevent remote wind turbine operation while maintaining continuous wind turbine monitoring, in addition to a slow buffer feature to retrieve and send data to the SCADA following an extended period of disconnected communication.
- ODBC access to the database.
- Integration of GUYS, SGRE's yawing interruption system. This system works from installed diesel generators that supply power to the auxiliary circuits in the wind turbines. It has been designed to enable the wind turbine to yaw automatically in conditions of strong gusty winds.

**Main System Capabalities**

WindNet® PRO has successfully undergone a certification process that enables it to guarantee the following for 5-second sampling periods:

- 99.99% data acquisition reliability.
- 99.99% reliability in the publication of information by OPC-DA (up to 100,000 variables for a single OPC client connected or 10,000 variables for 10 simultaneous clients).
- 99.99% correlation between the information displayed in real time (OPC-DA) and the recovered log (OPC-HDA, ODBC, Trends or through reporting tools).
- 100% correlation of log (historical) data recovered by any of the 4 methods (OPC-HDA, ODBC, Trends and reporting tools).

The WindNet® PRO storage system has a guaranteed 5-year storage of analog, digital, AWES and 10min variables, accessible online, and 15 additional years for recoverable data backup

**Wind Farm Management System**

SGRE's wind farm management system comprises the central system WindOne®, Service Operations Center (SOC), the SCADAs installed in wind farms and the wide area network (WAN) that links them all together.

During maintenance and/or the warranty period, wind farms with SGRE wind turbines must be integrated in the central system WindOne® under the control of the SOC (Service Operations Center). This system compiles data from all connected wind farms, checking and storing the retrieved data in keeping with the specified storage policy. The centralization of wind farm supervision offers excellent resources for monitoring the product, maintenance planning and reports on operating status and maintenance intended for clients. WindOne® likewise offers the Delegated Dispatch function in communication with the Network Operator with a view to keeping the electricity grid stable.

External access to the wind farm from WindOne® requires both primary and redundant communications lines to guarantee the availability of communications. Both lines and communications equipment are supplied by SGRE. Nonetheless, other communications solutions can be assessed whenever they meet the technical requirements for communications specified by SGRE.

**Communication Network in Wind Farm**

A wind farm's internal communications infrastructure is a network that links the SGRE SCADA system to the various wind farm devices (e.g., wind turbines, meteorological masts and substations).
Internal wind farm communications are based on a local area network (LAN) with Ethernet communications on ring-configured fiber optics. This is a "logical" round-trip ring through the same fiber optic cable so that the send path runs through two fibers and the return path runs through another two in the same cable. The wind turbines alternate where fibers connect to one another in the routing to prevent long links whenever possible.

The selection of the fiber optics for the wind farm and the overall layout of the ring network must meet SGRE specifications and will always be defined or validated by SGRE.
Likewise, the final configuration of a specific LAN network for a given wind farm will be jointly agreed between SGRE and the wind farm client.

External communication outside the wind farm through external protocols and/or SCADA clients can be based on any type of telecommunications system such as satellite links, ADSL/DSL lines, GPRS links, PSTN modems, GSM modems, etc. The primary criteria for selecting the appropriate means are the bandwidth requirements, need for continuous or on-demand connection, and the amount of data exchanged

**Client Interface**

Wind farm operators can view all the data in a simple and intuitive user interface based on web browser technology.
All operational aspects and access to SCADA system options are available through a standard web browser, though the latest version of Google Chrome is recommended

**Data Analysis**

WindNet® PRO includes 3 different wind farm data analysis tools:

- Reports: designed for exploitation reports
- Trending: designed for in-depth analysis of wind turbine variables.
- Comparatives: designed for instantaneously comparing two variables of all the wind turbines in the farm.

# Codes and Standards

The wind turbine is designed and certified with an external certification body according to:

- IEC 61400-1:2005 +AMD1:2010 Edition 3 - Wind turbines - Part 1: Design requirements
- IEC 61400-22:2010 Edition 1 - Wind turbines – Part 22: Conformity testing and certification
- ISO 9001:2015 - Quality management systems – Requirements.
- Directive 2006/42/CE - Machinery (MD)

# Other Performance Features

Siemens Gamesa Renewable Energy (SGRE) offers the following optional performance features for SG 4.5-145 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 4.5-145 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 Derated operational mode (also known as Power Derating due to external ambient temperature and altitude)**

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 4.5-145 could operate assuring the integrity of all components.

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**

A default IDS is included in SG 4.5-145. This system is required in order to prevent the turbine operating under non desirable ice conditions that could represent an out-of-design situation with risk for the turbine integrity or H&S.

The default IDS can be improved by application of additional features, described as follows:

- Ice on nacelle sensor (optional kit). Additional sensor is installed to detect ice on nacelle.
- Improved ice on blade detection algorithm (optional, only available when blade de-icing system is installed). It requires additional hardware. It is a more complex ice detection algorithm defined based on ice probability calculation, and it is a valuable complement for improving the blade de-icing system performance.

**Noise Reduction System**

The Noise Reduction System NRS is an optional module available with the basic SCADA configuration and it therefore requires the existence of a SGRE SCADA system to work.

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. This allows wind farms to be located close to urban areas, limiting the environmental impact that they imply.

**Bat Protection System**

To support the installation of wind turbines in areas that constitute a natural habitat for bats, SGRE has developed a Bat Protection System. Bats are usually more active at certain times of the night and at certain times of the year, depending on the local habitat and/or migration routes. The purpose of the SGRE Bat Protection System is to monitor the local environmental conditions in order to reduce the risk of impact on bats.

Specific environmental conditions can be monitored by means of dedicated additional sensors: temperature, light, humidity and rainfall. If conditions for the existence of bats are met, the Bat Protection System tool will request the wind turbines to be paused. As soon as one of the conditions is no longer met, the affected wind turbine will return to its initial status prior to receiving the pause order from the tool, depending on the configured hysteresis values.

The tool does not require all the sensors associated with the conditions to be installed and, depending on each site, the sensors needed will be configured. If there is no sensor for a specific environmental variable, condition is configured as fulfilled.

Additionally, Bat Protection System can be configured to be triggered depending on calendar (day/time), wind speed range or wind direction.

**Bird Detection System**

The Bird Detection System is a stand-alone system that monitors the wind farm’s surrounding air space and detects flying birds in real time. At the same time, it is capable of handling real-time actions related to bird detection, such as warning and deterring birds at risk of colliding with the wind turbines or automatic shutdown of the selected wind turbines.