

The converter is located in the nacelle and has a grid side voltage rating of 650 V. The generator side voltage rating is up to 750 V dependent on generator speed.

Converter	
Rated Apparent Power [ $S_N$ ]	4400 kVA
Rated Grid Voltage	3 x 650 V
Rated Generator Voltage	3 x 750 V
Rated Grid Current	3900 A ( $\leq 30^\circ\text{C}$ ambient) / 3950 ( $\leq 20^\circ\text{C}$ ambient)
Rated Generator Current	3400 A ( $\leq 30^\circ\text{C}$ ambient) / 3450 ( $\leq 20^\circ\text{C}$ ambient)
Enclosure	IP54

Table 4-2: Converter data.

### 4.3 HV Transformer

The step-up HV transformer is located in a separate locked room in the back of the nacelle. The transformer is a three-phase, two-winding, dry-type transformer that is self-extinguishing. The windings are delta-connected on the high-voltage side unless otherwise specified.

The transformer comes in different versions depending on the market where it is intended to be installed.

- For 50 Hz regions the transformer is as default designed according to IEC standards. However, on special request, a 60 Hz transformer based on IEC standards could also be delivered. Refer to Table 4-3.
- For turbines installed in Member States of the European Union, it is required to fulfil the Ecodesign regulation No 548/2014 and No 2019/1783 set by the European Commission. Refer to Table 4-4.

The transformer supplied for countries under EU legislation will be:

- Eco-design based on Tier 1 requirements (effective in EU until 1 July 2021)<sup>1</sup>.
  - Eco-design based on Tier 2 requirements (effective in EU from 1 July 2021)<sup>1</sup>.
- For 60 Hz regions the transformer is as default designed mainly according to IEEE standards but on areas not covered by IEEE standards, the design is also based on parts of the IEC standards. Refer to Table 4-5.

<sup>1</sup> The date reflects date for shipment of transformer from manufacturer.

#### 4.3.1 IEC 50 Hz/60 Hz version

Transformer			
Type description	Dry-type cast resin transformer.		
Basic layout	3 phase, 2 winding transformer.		
Applied standards	IEC 60076-11, IEC 60076-16, IEC 61936-1.		
Cooling method	AF		
Rated power	4000 kVA		
Rated voltage, turbine side			
U <sub>m</sub> 1.1kV	0.650 kV		
Rated voltage, grid side			
U <sub>m</sub> 12.0kV	10.0-11.0 kV		
U <sub>m</sub> 24.0kV	11.1-22.0 kV		
U <sub>m</sub> 36.0kV	22.1-33.0 kV		
U <sub>m</sub> 40.5kV	33.1-36.0 kV		
Insulation level AC / LI / LIC			
U <sub>m</sub> 1.1kV	3 <sup>1</sup> / - / - kV		
U <sub>m</sub> 12.0kV	28 <sup>1</sup> / 75 / 75 kV		
U <sub>m</sub> 24.0kV	50 <sup>1</sup> / 125 / 125 kV		
U <sub>m</sub> 36.0kV	70 <sup>1</sup> / 170 / 170 kV		
U <sub>m</sub> 40.5kV	80 <sup>1</sup> / 170 / 170 kV		
Off-circuit tap changer	±2 x 2.5 %		
Frequency	50 Hz / 60Hz		
Vector group	Dyn5		
No-load loss <sup>3</sup>			
U <sub>m</sub> 12.0kV	7.5 kW		
U <sub>m</sub> 24.0kV	7.5 kW		
U <sub>m</sub> 36.0kV	7.5 kW		
U <sub>m</sub> 40.5kV	7.5 kW		
Load loss @ power consumption HV, 120°C	@4000kVA <sup>3</sup>	@3600kVA <sup>5</sup>	@3450kVA <sup>5</sup>
U <sub>m</sub> 12.0kV	31.8 kW	25.8kW	23.7kW
U <sub>m</sub> 24.0kV	31.8 kW	25.8kW	23.7kW
U <sub>m</sub> 36.0kV	31.8 kW	25.8kW	23.7kW
U <sub>m</sub> 40.5kV	31.8 kW	25.8kW	23.7kW
No-load reactive power <sup>2</sup>	~29 kVAr		
Full load reactive power <sup>2</sup>	~387 kVAr		
No-load current <sup>2</sup>	~0.5 %		
Positive sequence short-circuit impedance@ rated power, 120°C <sup>3</sup>	9.0 %		
Positive sequence short-circuit resistance@ rated power, 120°C <sup>2</sup>	~0.8 %		
Zero sequence short-circuit impedance@ rated power, 120°C <sup>2</sup>	~8.5 %		
Zero sequence short-circuit resistance@ rated power, 120°C <sup>2</sup>	~0.8 %		
Inrush peak current <sup>2</sup>			
Dyn5	5-8 x $\hat{I}_n$		
YNyn0	8-12 x $\hat{I}_n$		
Half crest time <sup>2</sup>	~0.6 s		
Sound power level	≤ 80 dB(A)		

Transformer	
Average temperature rise at max altitude	≤90 K
Max altitude <sup>4</sup>	2000 m
Insulation class	155 (F)
Environmental class	E2
Climatic class	C2
Fire behaviour class	F1
Corrosion class	C4
Weight	≤9500 kg
Temperature monitoring	PT100 sensors in LV windings and core
Overvoltage protection	Surge arresters on HV terminals
Temporary earthing	3 x Ø20 mm earthing ball points

Table 4-3: Transformer data for IEC 50 Hz/60 Hz version

#### NOTE

- <sup>1</sup> @1000m. According to IEC 60076-11, AC test voltage is altitude dependent.  
<sup>2</sup> Based on an average of calculated values across voltages and manufacturers.  
<sup>3</sup> Subjected to standard IEC tolerances.  
<sup>4</sup> Transformer max altitude may be adjusted to match turbine location.  
<sup>5</sup> Information values based on operation mode, see See Figure 4-1.

#### 4.3.2 Ecodesign - IEC 50 Hz/60 Hz version

Transformer	
Type description	Ecodesign dry-type cast resin transformer.
Basic layout	3 phase, 2 winding transformer.
Applied standards	IEC 60076-11, IEC 60076-16, IEC 61936-1, Commission Regulation No 548/2014 and Commission Regulation No 2019/1783.
Cooling method	AF
Rated power	4000 kVA
Rated voltage, turbine side	
U <sub>m</sub> 1.1kV	0.650 kV
Rated voltage, grid side	
U <sub>m</sub> 12.0kV	10.0-11.0 kV
U <sub>m</sub> 24.0kV	11.1-22.0 kV
U <sub>m</sub> 36.0kV	22.1-33.0 kV
U <sub>m</sub> 40.5kV	33.1-36.0 kV
Insulation level AC / LI / LIC	
U <sub>m</sub> 1.1kV	3 <sup>1</sup> / - / - kV
U <sub>m</sub> 12.0kV	28 <sup>1</sup> / 75 / 75 kV
U <sub>m</sub> 24.0kV	50 <sup>1</sup> / 125 / 125 kV
U <sub>m</sub> 36.0kV	70 <sup>1</sup> / 170 / 170 kV
U <sub>m</sub> 40.5kV	80 <sup>1</sup> / 170 / 170 kV
Off-circuit tap changer	±2 x 2.5 %
Frequency	50 Hz / 60 Hz
Vector group	Dyn5

Transformer			
No-load reactive power <sup>2</sup>	~17 kVAr		
Full load reactive power <sup>2</sup>	~379 kVAr		
No-load current <sup>2</sup>	~0.5 %		
Positive sequence short-circuit impedance@ rated power, 120°C <sub>3</sub>	9.0 %		
Positive sequence short-circuit resistance@ rated power, 120°C <sub>2</sub>	~0.8 %		
Zero sequence short-circuit impedance@ rated power, 120°C <sub>2</sub>	~8.2 %		
Zero sequence short-circuit resistance@ rated power, 120°C <sub>2</sub>	~0.7 %		
Inrush peak current <sup>2</sup>			
Dyn5	5-8 x $\hat{I}_n$		
YNyn0	8-12 x $\hat{I}_n$		
Half crest time <sup>2</sup>	~0.6 s		
Sound power level	≤ 80 dB(A)		
Average temperature rise at max altitude	≤90 K		
Max altitude <sup>4</sup>	2000 m		
Insulation class	155 (F)		
Environmental class	E2		
Climatic class	C2		
Fire behaviour class	F1		
Corrosion class	C4		
Weight	≤9500 kg		
Temperature monitoring	PT100 sensors in LV windings and core		
Overvoltage protection	Surge arresters on HV terminals		
Temporary earthing	3 x Ø20 mm earthing ball points		
Eco Tier 1 design - Maximum losses			
Peak Efficiency Index (PEI) <sup>2</sup>	Ecodesign requirement		
U <sub>m</sub> 12.0kV	> 99.348		
U <sub>m</sub> 24.0kV	> 99.348		
U <sub>m</sub> 36.0kV	> 99.348		
U <sub>m</sub> 40.5kV	> 99.158		
No-load loss <sup>2</sup>			
U <sub>m</sub> 12.0kV	< 5.8 kW		
U <sub>m</sub> 24.0kV	< 5.8 kW		
U <sub>m</sub> 36.0kV	< 5.8 kW		
U <sub>m</sub> 40.5kV	< 6.9 kW		
Load loss @ power consumption HV, 120°C	@4000kVA <sup>2</sup>	@3600kVA <sup>6</sup>	@3450kVA <sup>6</sup>
U <sub>m</sub> 12.0kV	< 29.3 kW	< 23.8 kW	< 21.8 kW
U <sub>m</sub> 24.0kV	< 29.3 kW	< 23.8 kW	< 21.8 kW
U <sub>m</sub> 36.0kV	< 29.3 kW	< 23.8 kW	< 21.8 kW
U <sub>m</sub> 40.5kV	< 37.85 kW	< 30.7 kW	< 28.2 kW
Eco Tier 2 design - Maximum losses			
Peak Efficiency Index (PEI) <sup>2</sup>	Eco-design requirement		

Transformer			
<b>U<sub>m</sub> 12.0kV - 40.5kV</b>	> 99.382		
<b>No-load loss <sup>2</sup></b>			
<b>U<sub>m</sub> 12.0kV - 40.5kV</b>	< 6.9 kW		
<b>Load loss @ power consumption HV, 120°C</b>	<b>@4000kVA<sup>2</sup></b>	<b>@3600kVA<sup>6</sup></b>	<b>@3450kVA<sup>6</sup></b>
<b>U<sub>m</sub> 12.0kV - 40.5kV</b>	< 30.6 kW	< 24.8 kW	< 22.7 kW

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

**NOTE**

<sup>1</sup> @1000m. According to IEC 60076-11, AC test voltage is altitude dependent.

<sup>2</sup> For Ecodesign transformers, PEI is the legal requirement and is calculated according to the Commission Regulation based on rated power, no-load and load losses. Losses are maximum values and will not simultaneously occur in a specific design as this will be incompliant with the PEI requirement.

<sup>3</sup> Based on an average of calculated values across voltages and manufacturers.

<sup>4</sup> Subjected to standard IEC tolerances.

<sup>5</sup> Transformer max altitude may be adjusted to match turbine location.

<sup>6</sup> Information values based on operation mode, see Figure 4-1.

### 4.3.3 IEEE 60Hz version

Transformer			
<b>Type description</b>	Dry-type cast resin transformer.		
<b>Basic layout</b>	3 phase, 2 winding transformer.		
<b>Applied standards</b>	UL 1562, CSA C22.2 No. 47, IEEE C57.12, IEC 60076-11, IEC 60076-16, IEC 61936-1.		
<b>Cooling method</b>	AFA		
<b>Rated power</b>	4000 kVA		
<b>Rated voltage, turbine side</b>			
<b>N<sub>LL</sub> 1.2 kV</b>	0.650 kV		
<b>Rated voltage, grid side</b>			
<b>N<sub>LL</sub> 15.0 kV</b>	10.0-15.0 kV		
<b>N<sub>LL</sub> 25.0 kV</b>	15.1-25.0 kV		
<b>N<sub>LL</sub> 34.5 kV</b>	25.1-34.5 kV		
<b>Insulation level AC / LI &amp; LIC</b>			
<b>N<sub>LL</sub> 1.2 kV</b>	4 <sup>1</sup> / +10 kV		
<b>N<sub>LL</sub> 15.0 kV</b>	34 <sup>1</sup> / +95 kV		
<b>N<sub>LL</sub> 25.0 kV</b>	50 <sup>1</sup> / +125 kV		
<b>N<sub>LL</sub> 34.5 kV</b>	70 <sup>1</sup> / (+150 & -170) or +170 kV		
<b>Off-circuit tap changer</b>	±2 x 2.5 %		
<b>Frequency</b>	60 Hz		
<b>Vector group</b>	Dyn5		
<b>No-load loss <sup>3</sup></b>	7.5 kW		
<b>Load loss @ power consumption HV, 120°C</b>	<b>@4000kVA<sup>3</sup></b>	<b>@3600kVA<sup>5</sup></b>	<b>@3450kVA<sup>5</sup></b>
<b>N<sub>LL</sub> 15.0 kV</b>	31.9 kW	25.9 kW	23.8 kW
<b>N<sub>LL</sub> 25.0 kV</b>	31.9 kW	25.9 kW	23.8 kW
<b>N<sub>LL</sub> 34.5 kV</b>	31.9 kW	25.9 kW	23.8 kW
<b>No-load reactive power <sup>2</sup></b>	~16 kVAr		
<b>Full load reactive power <sup>2</sup></b>	~345 kVAr		

Transformer	
No-load current <sup>2</sup>	~0.5 %
Positive sequence short-circuit impedance@ rated power, 120°C <sup>3</sup>	~9.0 %
Positive sequence short-circuit resistance@ rated power, 120°C <sup>2</sup>	~0.8 %
Zero sequence short-circuit impedance@ rated power, 120°C <sup>2</sup>	~8.3 %
Zero sequence short-circuit resistance@ rated power, 120°C <sup>2</sup>	~0.7 %
Inrush peak current <sup>2</sup>	
	<b>Dyn5</b> 6-9 x $\hat{I}_n$
	<b>YNyn0</b> 8-12 x $\hat{I}_n$
Half crest time <sup>2</sup>	~ 0.7 s
Sound power level	≤ 80 dB(A)
Average temperature rise at max altitude	≤ 90 K
Max altitude <sup>4</sup>	2000 m
Insulation class	150°C
Environmental class	E2
Climatic class	C2
Fire behaviour class	F1
Corrosion class	C4
Weight	≤ 9500 kg
Temperature monitoring	PT100 sensors in LV windings and core
Overvoltage protection	Surge arresters on HV terminals
Temporary earthing	3 x Ø20 mm earthing ball points

Table 4-5: Transformer data for IEEE 60 Hz version.

#### NOTE

<sup>1</sup> @1000m. According to IEEE C57.12, AC test voltage is altitude dependent. All values are preliminary.

<sup>2</sup> Based on an average of calculated values across voltages and manufacturers. All values are preliminary.

<sup>3</sup> Subjected to standard IEEE C57.12 tolerances. All values are preliminary.

<sup>4</sup> Transformer max altitude may be adjusted to match turbine location.

<sup>5</sup> Information values based on operation mode, see Figure 4-1.

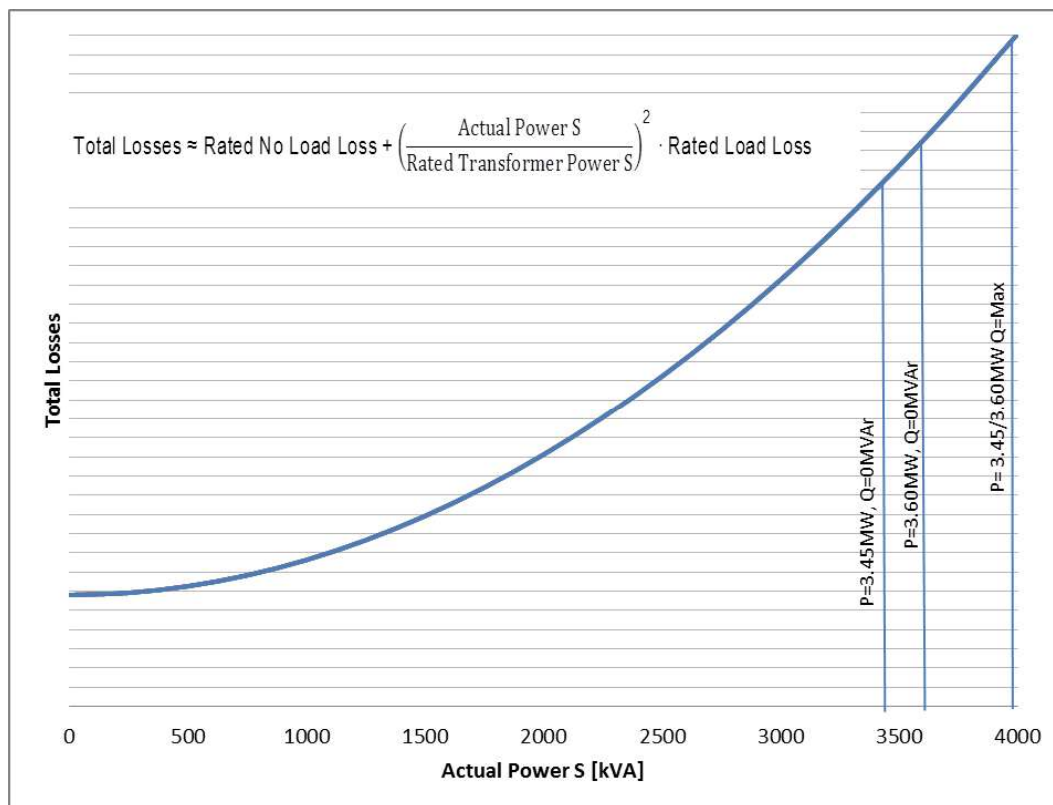


Figure 4-1: Total Losses vs. Actual Power.

#### 4.4 HV Cables

The high-voltage cable runs from the transformer in the nacelle down the tower to the HV switchgear located at the bottom of the tower. The high-voltage cable is a four-core, rubber-insulated, halogen-free, high-voltage cable.

HV Cables	
<b>High-Voltage Cable Insulation Compound</b>	Improved ethylene-propylene (EP) based material-EPR or high modulus or hard grade ethylene-propylene rubber-HEPR
<b>Conductor Cross Section</b>	3 x 70 / 70 mm <sup>2</sup>
<b>Maximum Voltage</b>	24 kV for 10.0-22.0 kV rated voltage 42 kV for 22.1-36.0 kV rated voltage

Table 4-6: HV cables data.

#### 4.5 HV Switchgear

A gas insulated switchgear is installed in the bottom of the tower as an integrated part of the turbine. Its controls are integrated with the turbine safety system which monitors the condition of the switchgear and high voltage safety related devices in the turbine. This ensures all protection devices are fully operational whenever high voltage components in the turbine are energised. The earthing switch of the circuit breaker contains a trapped-key interlock system with its counterpart