Environment AECOM

NextEra Energy Canada, ULC

Final Wind Turbine Specification Report – Goshen Wind Energy Centre

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60155032

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Glossary of Terms

GE .... General Electric
MOE .... Ontario Ministry of the Environment
MW .... Megawatt
NextEra .... NextEra Energy Canada, ULC
O. Reg. 359/09 .... Ontario Regulation 359/09
The Project .... Goshen Wind Energy Centre
REA .... Renewable Energy Approval
TC .... Transport Canada

1. Introduction

Goshen Wind, Inc., a wholly owned subsidiary of NextEra Energy Canada, ULC (NextEra) is proposing to construct a wind energy centre project in the Municipalities of Bluewater and South Huron, Huron County, Ontario. The project will be referred to as the Goshen Wind Energy Centre (the "Project") and will be located on private lands in the vicinity of the shoreline of Lake Huron. The wind turbine technology proposed for the Project is the GE 1.6-100 Wind Turbine and one GE 1.56-100 Wind Turbine, with a total nameplate capacity of 102 MW. The Project is categorized as a Class 4 facility. NextEra is seeking a Renewable Energy Approval (REA) for up to 72 wind turbines for the Project (however, only 63 turbines will be constructed).

This Wind Turbine Specification Report was prepared in accordance with the requirements of the REA process outlined in *Ontario Regulation 359/09* (*O. Reg. 359/09*) and the Technical Guide to Renewable Energy Approvals (Ontario Ministry of the Environment (MOE), 2011).

The following sections outline the specifications of the turbine technology selected for this Project.

1.1 Summary of Wind Turbine Specification Report Requirements

The requirements for the Wind Turbine Specification Report defined under *O.Reg. 359/09* are provided in the following table (Table 1-1).

Table 1-1 Adherence to Wind Turbine Specification Report Requirements

Requirement	Completed	Corresponding Section
The make, model, name plate capacity, hub height above grade and rotational speeds.	Yes	2.0 (Table 2-1)
The acoustic emissions data, determined and reported in accordance with standard CAN/CSA-C61400-11-07, "Wind Turbine Generator Systems – Part II: Acoustic Noise Measurement Techniques", dated October 2007, including the overall sound power level, measurement uncertainty value, octave-band sound power levels (linear weighted) and tonality and tonal audibility.	Yes	3.0 (Appendix A)

1.2 The Proponent

The Project will be owned and operated by Goshen Wind, Inc., a subsidiary of NextEra. NextEra Energy Canada's indirect parent company is NextEra Energy Resources, LLC, a global leader in wind energy generation with a current operating portfolio of over 90 wind energy projects in North America. In Canada, wind energy centres currently owned and operated by NextEra Energy Canada include: Mount Copper and Mount Miller, (both 54 megawatts (MW)) located in Murdochville, Quebec; Pubnico Point, (31 MW) located near Yarmouth, Nova Scotia; and Ghost Pine (82 MW), located in Kneehill County, Alberta.

The primary contacts for the Project are as follows:

Project Proponent	Project Consultant
Nicole Geneau Project Director NextEra Energy Canada, ULC 390 Bay Street, Suite 1720, Toronto, Ontario M5H 2Y2 Phone: 1-416-364-9714 Email: Goshen.Wind@NextEraEnergy.com Website: www.NextEraEnergyCanada.com	Marc Rose Senior Environmental Planner AECOM 300-300 Town Centre Blvd., Markham, Ontario L3R 5Z6 Phone: 905-477-8400 x388 Email: marc.rose@aecom.com

1.3 Project Study Area

The proposed Project is located in Huron County, within the Municipalities of Bluewater and South Huron (refer to Figure 1-1). The Project Study Area consists of the areas being studied for the wind farm components (Wind Energy Centre Study Area), as well as for the interconnection route (i.e., the area being studied for transmission lines to connect the Project to the electrical grid) (Transmission Line Study Area). The Wind Energy Centre Study Area is generally bounded by Klondyke Road to the west, Rogerville Road to the north, Parr Line to the east, and Mount Carmel Drive to the south, in the Municipalities of Bluewater and South Huron. The Transmission Line Study Area is located to the east of the Wind Energy Centre Study Area, and is generally bounded by Parr Line to the west, Thames Road to the north, Perth 164 Road to the east, and Park Road to the south, extending into the Municipality of South Huron.

The location of the Project Study Area was defined early in the planning process for the proposed wind energy facility, based on the availability of wind resources, approximate area required for the proposed Project, and availability of existing infrastructure for connection to the electrical grid. The Project Study Area was used to facilitate information collection.

2. Technical Specifications

With a total nameplate capacity of 102 MW, the Project is categorized as a Class 4 facility under *O. Reg. 359/09*. Although NextEra is seeking an REA for up to 72 wind turbines, only 63 are proposed to be constructed for the Project.

The wind turbine technology proposed for this Project is the GE 1.6-100 Wind Turbine and GE 1.56-100 Wind Turbine (one turbine only). The turbines are 3-bladed, upwind, horizontal-axis wind turbines that are state of the art technology. The turbines have a 100 m rotor diameter with a swept area of 7,854 m; each blade is connected to the main shaft via the hub. The turbine is mounted on an 80 m tubular steel tower which contains an internal ladder provided for maintenance access. The turbine will be constructed on a foundation that is approximately 400 m^2. The foundation consists of poured concrete and steel rebar to provide added strength.

The nacelle houses the main components of the wind turbine such as the rotor shaft, gear box, couplings, control panel, bearing brackets and the generator. The nacelle is equipped with sound-proofing, is ventilated and the interior is illuminated with electric lights. Some of the wind turbines will have external lighting in accordance with the requirements of Transport Canada (TC).

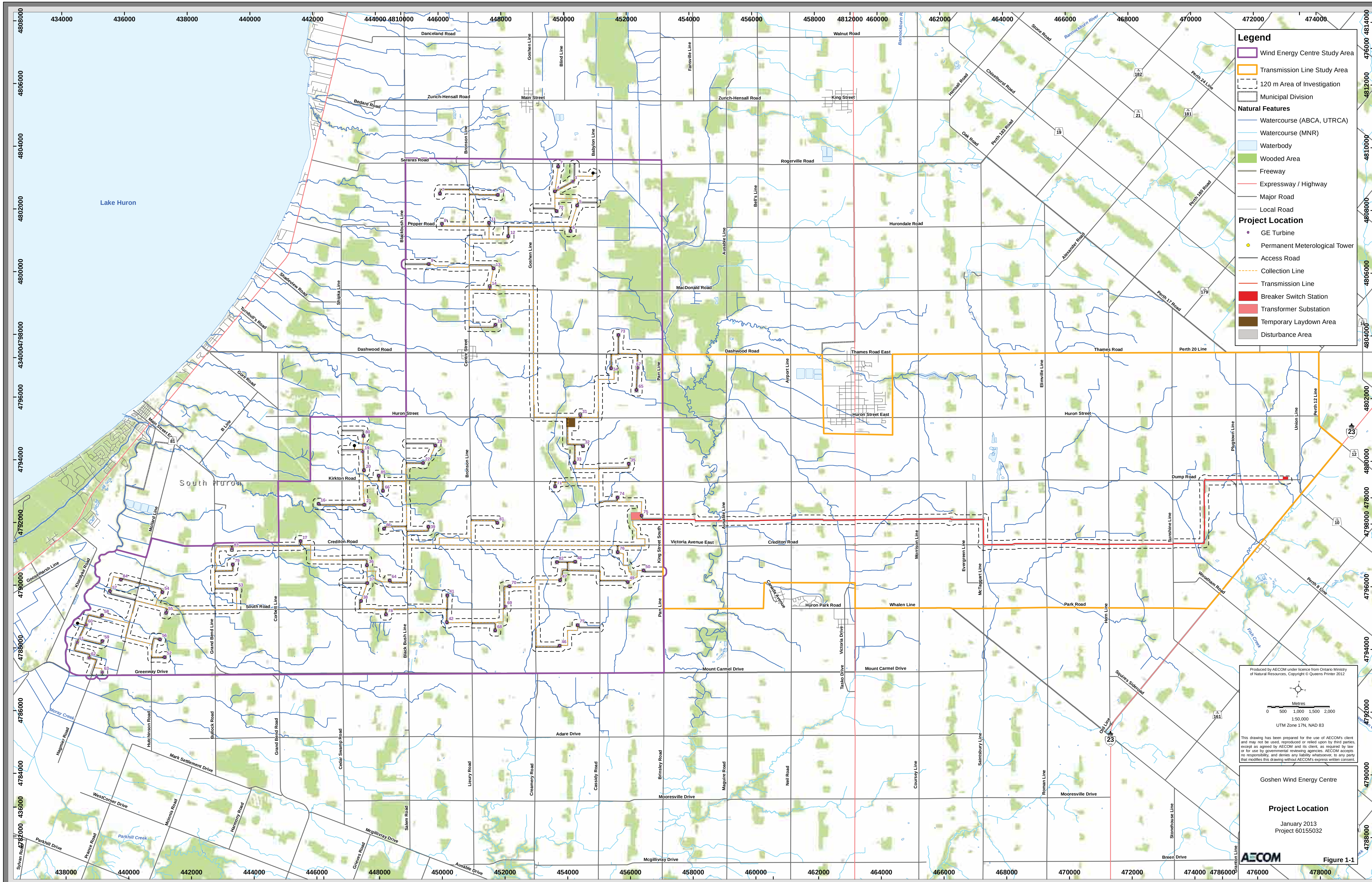
The following table provides a description of the turbines that will be used for the Project. Additional turbine specifications and acoustic emissions data are provided in **Appendix A** as supplied by General Electric.

Table 2-1 Summary of Technical Specifications

Specification	GE 1.6-100 Wind Turbine	GE 1.56-100 Wind Turbine
Make	General Electric	General Electric
Model	1.6-100	1.56-100
Name Plate Capacity	1.62 MW	1.56 MW
Hub Height	80 m	80 m
Rotor Diameter	100 m	100 m
Minimum Rotational Speed	9.75 rpm	9.75 rpm
Maximum Rotational Speed	15.33 rpm	16.2 rpm

3. Acoustic Emissions Data

Please refer to **Appendix A** *Manufacturer Technical Data* for the sound power ratings for the GE 1.6-100 Wind Turbine and the GE 1.56-100 Wind Turbine in addition to the octave band spectra.



Legend
Wind Energy Centre Study Area
Transmission Line Study Area
120 m Area of Investigation
Municipal Division
Natural Features
Watercourse (ABCA, UTRCA)
Watercourse (MNR)
Waterbody
Wooded Area
Freeway
Expressway / Highway
Major Road
Local Road
Project Location
GE Turbine
Permanent Meterological Tower
Access Road
Collection Line
Transmission Line
Breaker Switch Station
Transformer Substation
Temporary Laydown Area
Disturbance Area
Lake Huron
South Huron
Danceland Road
Walnut Road
Zurich-Hensall Road
Main Street
King Street
Bedard Road
Rogerville Road
Hurondale Road
Pepper Road
MacDonald Road
Dashwood Road
Thames Road East
Thames Road
Perth 20 Line
Huron Street
Huron Street East
Kirkton Road
Dump Road
Crediton Road
Victoria Avenue East
South Road
Huron Park Road
Whalen Line
Park Road
Greenway Drive
Mount Carmel Drive
Adare Drive
Mark Settlement Drive
Mooresville Drive
Mcgillivray Drive
Ausable Drive
Woodham Road
Squires Sideroad
Fish Creek
Moray Creek
Parkhill Creek
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Metres
0 500 1,000 1,500 2,000
1:50,000
UTM Zone 17N, NAD 83
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Goshen Wind Energy Centre
Project Location
January 2013
Project 60155032
AECOM
Figure 1-1

Appendix A

Manufacturer Technical Data

Appendix A

Manufacturer Technical Data

Technical Description of the 1.56-100 Wind Turbine and Major Components

The wind turbine is a three bladed, upwind, horizontal-axis wind turbine with a rotor diameter of 100 m. The turbine rotor and nacelle are mounted on top of a tubular tower giving a rotor hub height of 80m. The machine employs active yaw control (designed to steer the machine with respect to the wind direction), active blade pitch control (designed to regulate turbine rotor speed), and a generator/power electronic converter system.

The wind turbine features a distributed drive train design wherein the major drive train components including main shaft bearings, gearbox, generator, yaw drives, and control panel are attached to a bedplate (see Figure 1).

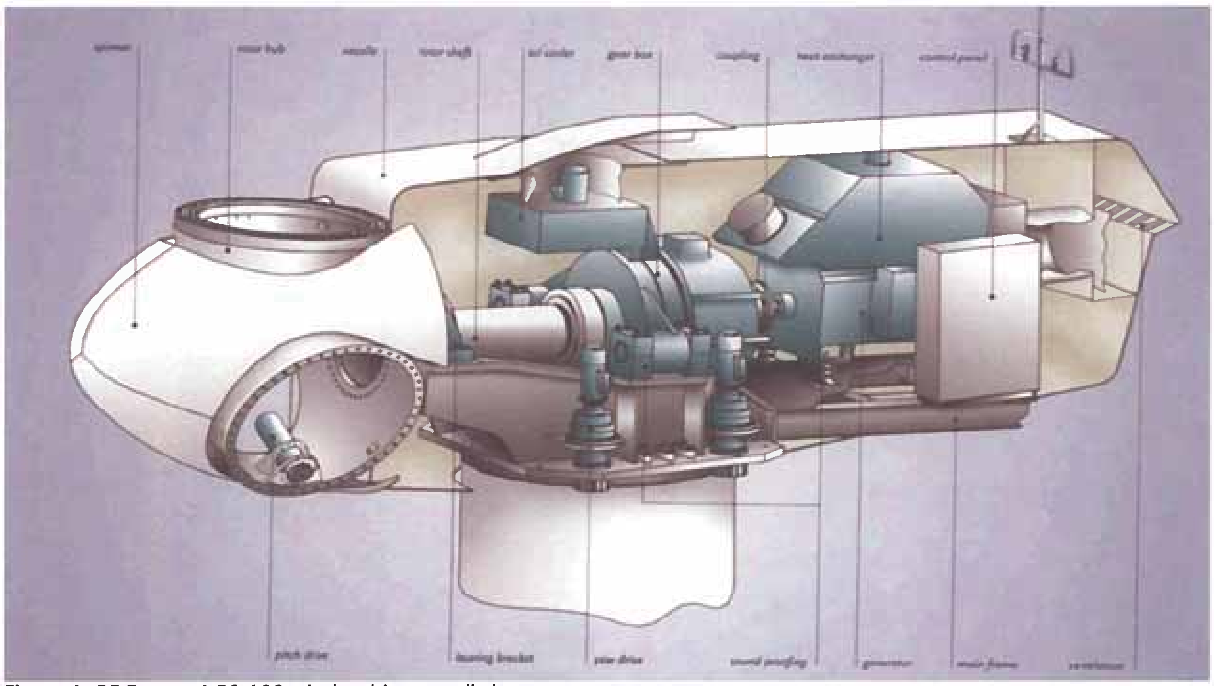

Figure 1: GE Energy 1.56-100 wind turbine nacelle layout

Rotor

The rotor diameter is 100 m, resulting in a swept area of 7,854 m, and is designed to operate between 9.75 and 16.18 revolutions per minute (rpm). Rotor speed is regulated by a combination of blade pitch angle adjustment and generator/converter torque control. The rotor spins in a clock-wise direction under normal operating conditions when viewed from an upwind location.

Full blade pitch angle range is approximately 90°, with the 0°-position being with the airfoil chord line flat to the prevailing wind. The blades being pitched to a full feather pitch angle of approximately 90° accomplishes aerodynamic braking of the rotor; whereby the blades "spill" the wind thus limiting rotor speed.

Blades

There are three rotor blades used on each wind turbine. The airfoils transition along the blade span with the thicker airfoils being located in-board towards the blade root (hub) and gradually tapering to thinner cross sections out towards the blade tip.

Blade Pitch Control System

The rotor utilizes three (one for each blade) independent electric pitch motors and controllers to provide adjustment of the blade pitch angle during operation. Blade pitch angle is adjusted by an electric drive that is mounted inside the rotor hub and is coupled to a ring gear mounted to the inner race of the blade pitch bearing (see Figure 1).

GE's active-pitch controller enables the wind turbine rotor to regulate speed, when above rated wind speed, by allowing the blade to "spill" excess aerodynamic lift. Energy from wind gusts below rated wind speed is captured by allowing the rotor to speed up, transforming this gust energy into kinetic which may then be extracted from the rotor.

Three independent back-up units are provided to power each individual blade pitch system to feather the blades and shut down the machine in the event of a grid line outage or other fault. By having all three blades outfitted with independent pitch systems, redundancy of individual blade aerodynamic braking capability is provided.

Hub

The hub is used to connect the three rotor blades to the turbine main shaft. The hub also houses the three electric blade pitch systems and is mounted directly to the main shaft. Access to the inside of the hub is provided through a hatch.

Gearbox

The gearbox in the wind turbine is designed to transmit power between the low-rpm turbine rotor and high-rpm electric generator. The gearbox is a multi-stage planetary/helical gear design. The gearbox is mounted to the machine bedplate. The gearing is designed to transfer torsional power from the wind turbine rotor to the electric generator. A parking brake is mounted on the high-speed shaft of the gearbox.

Bearings

The blade pitch bearing is designed to allow the blade to pitch about a span-wise pitch axis. The inner race of the blade pitch bearing is outfitted with a blade drive gear that enables the blade to be driven in pitch by an electric gear-driven motor/controller.

The main shaft bearing is a roller bearing mounted in a pillow-block housing arrangement. The bearings used inside the gearbox are of the cylindrical, spherical and tapered roller type. These bearings are designed to provide bearing and alignment of the internal gearing shafts and accommodate radial and axial loads.

Brake System

The electrically actuated individual blade pitch systems act as the main braking system for the wind turbine. Braking under normal operating conditions is accomplished by feathering the blades out of the wind. Any single feathered rotor blade is designed to slow the rotor, and each rotor blade has its own back-up to provide power to the electric drive in the event of a grid line loss.

The turbine is also equipped with a mechanical brake located at the output (high-speed) shaft of the gearbox. This brake is only applied as an auxiliary brake to the main aerodynamic brake and to prevent rotation of the machinery as required by certain service activities.

Generator

The generator is a doubly-fed induction type. The generator meets protection class requirements of the International Standard IP 54 (totally enclosed). The generator is mounted to the bedplate and the mounting is designed so as to reduce vibration and noise transfer to the bedplate.

Flexible Coupling

Designed to protect the drive train from excessive torque loads, a flexible coupling is provided between the generator and gearbox output shaft this is equipped with a torque-limiting device sized to keep the maximum allowable torque below the maximum design limit of the drive train.

Yaw System

A roller bearing attached between the nacelle and tower facilitates yaw motion. Planetary yaw drives (with brakes that engage when the drive is disabled) mesh with the outside gear of the yaw bearing and steer the machine to track the wind in yaw. The automatic yaw brakes engage in order to prevent the yaw drives from seeing peak loads from any turbulent wind.

The controller activates the yaw drives to align the nacelle to the average wind direction based on the wind vane sensor mounted on top of the nacelle.

A cable twist sensor provides a record of nacelle yaw position and cable twisting. After the sensor detects excessive rotation in one direction, the controller automatically brings the rotor to a complete stop, untwists the cable by counter yawing of the nacelle, and restarts the wind turbine.

Tower

The wind turbine is mounted on top of a tubular tower. The tubular tower is manufactured in sections from steel plate. Access to the turbine is through a lockable steel door at the base of the tower. Service platforms are provided. Access to the nacelle is provided by a ladder and a fall arresting safety system is included. Interior lights are installed at critical points from the base of the tower to the tower top.

Nacelle

The nacelle houses the main components of the wind turbine generator. Access from the tower into the nacelle is through the bottom of the nacelle. The nacelle is ventilated. It is illuminated with electric light. A hatch at the front end of the nacelle provides access to the blades and hub. The rotor can be secured in place with a rotor lock.

Anemometer, Wind Vane and Lightning Rod

An anemometer, wind vane and lightning rod are mounted on top of the nacelle housing. Access to these sensors is accomplished through a hatch in the nacelle roof.

Lightning Protection

The rotor blades are equipped with a lightning receptors mounted in the blade. The turbine is grounded and shielded to protect against lightning, however, lightning is an unpredictable force of nature, and it is possible that a lightning strike could damage various components notwithstanding the lightning protection deployed in the machine.

Wind Turbine Control System

The wind turbine machine can be controlled automatically or manually from either an interface located inside the nacelle or from a control box at the bottom of the tower. Control signals can also be sent from a remote computer via a Supervisory Control and Data Acquisition System (SCADA), with local lockout capability provided at the turbine controller.
Service switches at the tower top prevent service personnel at the bottom of the tower from operating certain systems of the turbine while service personnel are in the nacelle. To override any machine operation, Emergency-stop buttons located in the tower base and in the nacelle can be activated to stop the turbine in the event of an emergency.

Power Converter

The wind turbine uses a power converter system that consists of a converter on the rotor side, a DC intermediate circuit, and a power inverter on the grid side.

The converter system consists of a power module and the associated electrical equipment. Variable output frequency of the converter allows operation of the generator.

Technical Data for the 1.56-100

Rotor

Diameter	100 m
Number of blades	3
Swept area	7,854 m_2
Rotor speed range	9.75 to 16.18 rpm
Rotational direction	Clockwise looking downwind
Maximum tip speed	84.7 m/s
Orientation	Upwind
Speed regulation	Pitch control
Aerodynamic brakes	Full feathering

Pitch System

Principle	Independent blade pitch control
Actuation	Individual electric drive

Yaw System

Yaw rate	0.5 degree/s

1.56-100 Calculated Octave Band Spectra – Canada Specific

Table 1 below provides simulated, A-weighted octave band spectra as a function of standardized wind speed at 10 m height, and expressed as apparent sound power levels. The uncertainties for octave sound power levels are generally higher than for total sound power levels. Guidance is given in IEC 61400-11, Annex D.

1.56-100 Octave Band Spectra									
Standard WS at 10m [m/s]		5	5.5	6	6.5	7	8	9	10-Cutout
Hub Height WS at 100m [m/s]		7.2	7.9	8.6	9.3	10	11.5	12.9	14-Cutout
Frequency [Hz]	32	71.2	74.2	76.5	78.8	80.9	81.5	81.5	81.5
	63	80.9	83.9	86.2	88.4	90.5	91.2	91.2	91.2
	125	85.4	88.2	90.1	92.1	94.2	94.8	94.9	94.8
	250	89.1	91.6	91.9	92.5	93.9	94.2	94.2	94.2
	500	90.4	93.3	94.6	95.4	95.7	94.6	94.5	94.5
	1000	88.1	91.4	95.2	98.2	99.6	99.1	98.9	98.8
	2000	85.8	87.7	91.3	94.8	97.2	98	98.1	98.2
	4000	81.4	82.8	84.6	86.5	88.4	88.8	89.2	89.5
	8000	65.9	66.5	68	69.6	71.1	71.2	70.7	70.5
	16000	26.8	24.7	25.9	28.2	30.5	31.8	31.1	31.2
Lwa [dBA]		95.5	98.3	100.4	102.5	104	104	104	104

Table 1: Octave Spectra for 1.56-100 - hub height wind speeds were calculated based on equation (7) from IEC standard 61400-11:2002, using a representative roughness height of 0.05 m

1.56-100 Normal Operation Calculated Tonal Audibility – Canada Specific

The nominal acoustic performances for 1.56-100, 60 Hz version equipped with 100 m rotor diameter (GE 48.7 type blade) operating in normal operation (NO), specified at reference ground measuring distance Ro measurement point #1 per both IEC 61400-11 and GE's "Machine noise performance test" reference guidelines:

- Tonal audibility **$\Delta L_{a,k}$ ≤ 2 dB**.

1.56-100 Testing Uncertainty and Product Variation per IEC/TS 61400-14 Standard

Per IEC/TS 61400-14, L_{WAd} is the maximum apparent sound power level resulting from ***n*** measurements performed according to IEC 61400-11 standard for 95 % confidence level: $L_{WAd} = \overline{L_{WA}}$ + K, where $\overline{L_{WA}}$ is the mean apparent sound power level from ***n*** IEC 61400-11 testing reports and **K = 1,645 · σT**.

The testing standard deviation values **σ_T**, **σ_R** and **σ_P** for measured apparent sound power level are described by IEC/TS 61400-14 where **σ_T** is the total standard deviation, **σ_P** is the standard deviation for product variation and **σ_R** is the standard deviation for test reproducibility.

Assuming **σ_R** < 0.8 dB and **σ_P** < 0.8 dB typical values, leads to calculated **K < 2 dB** for 95 % confidence level.

IEC 61400-11 and IEC/TS 61400-14 Terminology

- **$L_{WA,k}$** is wind turbine apparent sound power level (referenced to 1^{-12} W) measured with A-weighting as function of reference wind speed v_{10m}. Derived from multiple measurement reports per IEC 61400-11, it is considered as a mean value.
- **σ_P** is the product variation i.e. the 1.56-100 unit-to-unit product variation; typically < 0.8 dB
- **σ_R** is the overall measurement testing reproducibility as defined per IEC 61400-11; typically < 0.8 dB with adequate measurement conditions and sufficient amount of data samples
- **σ_T** is the total standard deviation combining both **σ_P** and **σ_R**

GE Energy

- Original Instructions -

Technical Documentation Wind Turbine Generator Systems 1.6-100 with LNTE 50 Hz and 60 Hz

Product Acoustic Specifications

Normal Operation according to IEC Incl. Octave Band Spectra

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1 Introduction

This document summarizes the acoustic emission characteristics of the 1.6-100 with Low Noise Trailing Edge (LNTE) wind turbine for normal operation, including calculated apparent sound power levels $L_{WA,k}$, as well as uncertainty levels associated with the apparent sound power levels, tonal audibility, and calculated third octave band apparent sound power level.

All provided sound power levels are A-weighted.

GE continuously verifies specifications with measurements, including those performed by independent institutes. If a wind turbine noise performance test is carried out, it needs to be done in accordance with the regulations of the international standard IEC 61400-11, ed. 2.1: 2006 and Machine Noise Performance Test document.

2 Normal Operation Calculated Apparent Sound Power Level

The apparent sound power levels $L_{WA,k}$ are initially calculated as a function of the hub height wind speed v_{HH}. The corresponding wind speeds v_{10m} at 10 m height above ground level have been evaluated assuming a logarithmic wind profile. In this case a surface roughness of z_{0ref} = 0.05 m has been used, which is representative of average terrain conditions.

$$v_{10m} = v_{HH} \frac{\ln\left(10m / z_{0ref}\right)}{\ln\left(hub\ height / z_{0ref}\right)}$$ *

The calculated apparent sound power levels $L_{WA,k}$ and the associated octave-band spectra are given in Table 1 and Table 2 for two different hub heights. The values are provided as mean levels as a function of v_{10m} for Normal Operation (NO) over cut-in to cut-out wind speed range. The uncertainties for octave sound power levels are generally higher than for total sound power levels. Guidance is given in IEC 61400-11, Annex D.

1.6-100 with LNTE – A-weighted Octave Spectra (dB)									
Standardized WS at 10 m (m/s)		5	5.5	6	6.5	7	8	9	10-Cutout
Hub height WS at 80 m (m/s)		7.0	7.7	8.4	9.1	9.7	11.1	12.5	14-Cutout
Frequency (Hz)	32	72.1	74.2	76.0	77.8	79.6	80.1	80.2	80.1
	63	81.4	83.5	85.5	87.4	89.2	89.6	89.7	89.6
	125	86.5	88.8	90.8	92.3	93.9	94.4	94.4	94.3
	250	89.7	92.1	94.4	94.7	95.0	95.1	95.2	95.2
	500	89.7	92.4	95.0	95.7	96.3	96.1	96.1	96.5
	1000	86.9	89.1	91.3	93.9	96.4	96.9	97.0	97.2
	2000	87.9	90.1	91.9	93.4	95.0	95.2	94.9	94.3
	4000	83.5	86.1	88.4	88.6	89.0	88.6	87.9	87.2
	8000	63.5	66.7	69.8	69.3	69.7	70.0	68.8	68.7
	16000	18.9	21.5	24.2	25.3	26.5	26.1	26.9	28.8
Total Sound Power Level (dB)		95.8	98.2	100.5	101.6	102.8	103.0	103.0	103.0

Table 1: Normal Operation Calculated Apparent Sound Power Level, 1.6-100 with LNTE with 80 m hub height as a function of 10 m wind speed (z_{0ref} = 0.05 m), the octave band spectra are for information only

* Simplified from IEC 61400-11, ed. 2.1: 2006 equation 7

1.6-100 with LNTE – A-weighted Octave Spectra (dB)									
Standardized WS at 10 m (m/s)		5	5.5	6	6.5	7	8	9	10-Cutout
Hub height WS at 96 m (m/s)		7.1	7.8	8.6	9.3	10.0	11.4	12.8	14-Cutout
Frequency (Hz)	32	72.6	74.7	76.6	78.4	79.8	80.1	80.2	80,1
	63	81.9	84.1	86.0	88.0	89.4	89.6	89.7	89,6
	125	87.1	89.3	91.3	92.8	94.2	94.4	94.4	94,3
	250	90.3	92.7	94.8	94.7	95.1	95.1	95.2	95,2
	500	90.3	93.1	95.5	95.9	96.3	96.1	96.2	96,5
	1000	87.5	89.7	91.9	94.8	96.7	96.9	97.0	97,2
	2000	88.5	90.6	92.4	93.9	95.3	95.1	94.8	94,3
	4000	84.2	86.7	88.8	88.5	89.2	88.3	87.7	87,2
	8000	64.4	67.5	70.2	68.8	70.6	69.3	68.7	68,7
	16000	19.5	22.3	24.7	25.6	26.8	25.9	27.2	28,8
Total Sound Power Level (dB)		96.4	98.8	100.9	101.9	103.0	103.0	103.0	103.0

Table 2: Normal Operation Calculated Apparent Sound Power Level, 1.6-100 with LNTE with 96 m hub height as a function of 10 m wind speed (z_{0ref} = 0.05 m), the octave band spectra are for information only

At 10 m wind speeds lower than 5 m/s the sound power levels decreases, and may get so low that the wind turbine noise becomes indistinguishable from the background noise. For a conservative calculation the data at 5 m/s may be used.

For 10 m wind speeds above 10 m/s, the wind turbine has reached rated power and the blade pitch regulation acts in a way that tends to decrease the noise levels. For a conservative calculation the data at 10 m/s may be used.

The highest normal operation calculated apparent sound power level for the 1.6-100 with LNTE is $L_{WA,k}$ = 103.0 dB.

3 Uncertainty Levels

The apparent sound power levels given above are calculated mean levels. If a wind turbine noise performance test is carried out, it needs to be done in accordance with the regulations of the international standard IEC 61400-11, ed. 2.1: 2006. Uncertainty levels associated with measurements are described in IEC/TS 61400-14.

Per IEC/TS 61400-14, L_{WAd} is the maximum apparent sound power level for 95 % confidence level resulting from n measurements performed according to IEC 61400-11 standard: $L_{WAd} = L_{WA} + K$, where L_{WA} is the mean apparent sound power level from IEC 61400-11 testing reports and $K = 1.645\ \sigma_T$.

The testing standard deviation values σ_T, σ_R and σ_P for measured apparent sound power level are described by IEC/TS 61400-14, where σ_T is the total standard deviation, σ_P is the standard deviation for product variation and σ_R is the standard deviation for test reproducibility.

Assuming $\sigma_R < 0.8$ dB and $\sigma_P < 0.8$ dB as typical values leads to a calculated K < 2 dB for 95 % confidence level.

4 Tonal Audibility

At the reference measuring point R_0 the 1.6-100 with LNTE has a value for tonality of
$\Delta L_{a,k} \leq 2$ dB.

5 IEC 61400-11 and IEC/TS 61400-14 Terminology

- **$L_{WA,k}$** is wind turbine apparent sound power level (referenced to 10^{-12}W) measured with A-weighting as function of reference wind speed **v_{10m}**. Derived from multiple measurement reports per IEC 61400-11, it is considered as a mean value
- **σ_P** is the product variation i.e. the 1.6-100 with LNTE unit-to-unit product variation; typically < 0.8 dB
- **σ_R** is the overall measurement testing reproducibility as defined per IEC 61400-11; typically < 0.8 dB with adequate measurement conditions and sufficient amount of data samples
- **σ_T** is the total standard deviation combining both **σ_P** and **σ_R**
- **K = 1.645 σ_T** is defined per IEC/TS 61400-14 for 95 % confidence level
- **R_0** is the ground measuring distance from the wind turbine tower axis per IEC 61400-11, which shall equal the hub height plus half the rotor diameter
- **$\Delta L_{a,k}$** is the tonal audibility according to IEC 61400-11, described as potentially audible narrow band sound

Reference:

- IEC 61400-1. Wind turbines – part 1: Design requirements. ed. 2. 1999
- IEC 61400-11, wind turbine generator systems part 11: Acoustic noise measurement techniques, ed. 2.1, 2006-11
- IEC/TS 61400-14, Wind turbines – part 14: Declaration of apparent sound power level and tonality values, ed. 1, 2005-03
- MNPT – Machine Noise Performance Test, Technical documentation, GE 2011

Appendix I - Calculated 1/3rd Octave Band Apparent Sound Power Level $L_{WA,k}$

1.6-100 with LNTE - Normal Operation 1/3rd Octave Band Spectra									
Standard WS at 10 m [m/s]		**5**	**5.5**	**6**	**6.5**	**7**	**8**	**9**	**10-Cutout**
Hub Height WS at 80 m [m/s]		**7.0**	**7.7**	**8.4**	**9.1**	**9.7**	**11.1**	**12.5**	**14-Cutout**
Frequency [Hz]	25	61.8	63.9	65.7	67.5	69.2	69.8	69.9	69.8
	32	66.2	68.3	70.1	71.9	73.7	74.2	74.3	74.2
	40	70.2	72.3	74.2	75.9	77.7	78.2	78.3	78.2
	50	73.4	75.5	77.4	79.2	80.9	81.4	81.5	81.4
	63	76.3	78.4	80.4	82.2	84.0	84.4	84.5	84.4
	80	78.6	80.8	82.8	84.7	86.6	87.0	87.0	86.9
	100	80.5	82.7	84.7	86.6	88.4	88.8	88.8	88.7
	125	81.7	83.9	85.9	87.6	89.2	89.6	89.7	89.6
	160	82.8	85.1	87.2	88.4	89.7	90.2	90.3	90.2
	200	84.0	86.3	88.5	89.2	90.1	90.4	90.5	90.5
	250	85.0	87.4	89.7	89.9	90.3	90.4	90.5	90.5
	315	85.6	88.2	90.5	90.5	90.4	90.2	90.3	90.4
	400	85.4	88.1	90.6	90.7	90.8	90.4	90.5	90.7
	500	85.1	87.8	90.5	91.2	91.6	91.3	91.4	91.7
	630	84.0	86.7	89.4	90.9	92.2	92.0	92.1	92.5
	800	82.3	84.8	87.3	89.7	91.9	92.0	92.1	92.5
	1000	81.7	83.8	85.9	88.8	91.6	92.1	92.2	92.5
	1250	82.4	84.3	86.1	88.7	91.4	92.2	92.4	92.4
	1600	82.8	84.8	86.5	88.5	90.7	91.4	91.4	90.9
	2000	83.3	85.4	87.3	88.8	90.3	90.4	90.0	89.4
	2500	83.4	85.6	87.6	88.7	89.7	89.1	88.5	87.9
	3150	81.8	84.2	86.4	86.8	87.3	86.7	86.2	85.3
	4000	77.7	80.6	83.0	82.8	82.9	83.0	82.0	81.4
	5000	72.0	75.1	77.5	77.0	77.3	77.6	76.2	76.0
	6300	63.3	66.5	69.5	69.0	69.4	69.7	68.5	68.4
	8000	51.0	53.9	56.9	57.1	57.9	58.3	57.3	57.0
	10000	36.5	39.1	42.0	42.7	43.9	43.9	43.8	44.1
	12500	18.9	21.5	24.1	25.3	26.5	26.0	26.9	28.8
	16000	-6.1	-3.3	-0.8	0.3	1.2	1.2	3.4	6.4
	20000	-34.1	-30.5	-27.4	-26.9	-26.6	-25.2	-22.4	-18.9
Total apparent sound power level $L_{WA,k}$ [dB]		**95.8**	**98.2**	**100.5**	**101.6**	**102.8**	**103.0**	**103.0**	**103.0**

Table 3: Calculated Apparent 1/3rd Octave Band Sound Power Level (A-weighted) 1.6-100 with LNTE with 80 m hub height as Function of Wind Speed v_{10m}

1.6-100 with LNTE - Normal Operation 1/3rd Octave Band Spectra									
Standard WS at 10 m [m/s]		5	5.5	6	6.5	7	8	9	10-Cutout
Hub Height WS at 96 m [m/s]		7.1	7.8	8.6	9.3	10.0	11.4	12.8	14-Cutout
Frequency [Hz]	25	62.4	64.4	66.2	68.1	69.5	69.8	69.9	69.8
	32	66.7	68.8	70.7	72.5	73.9	74.2	74.3	74.2
	40	70.7	72.8	74.7	76.5	78.0	78.2	78.3	78.2
	50	73.9	76.1	78.0	79.8	81.2	81.5	81.5	81.4
	63	76.8	79.0	80.9	82.8	84.2	84.5	84.5	84.4
	80	79.2	81.4	83.4	85.4	86.8	87.0	87.0	86.9
	100	81.0	83.2	85.2	87.2	88.7	88.8	88.8	88.7
	125	82.3	84.5	86.5	88.1	89.5	89.7	89.7	89.6
	160	83.4	85.7	87.7	88.8	90.0	90.2	90.3	90.2
	200	84.6	86.9	88.9	89.4	90.3	90.5	90.5	90.5
	250	85.6	88.0	90.1	89.9	90.4	90.4	90.5	90.5
	315	86.2	88.8	90.9	90.3	90.4	90.2	90.3	90.4
	400	86.1	88.8	91.0	90.6	90.7	90.4	90.5	90.7
	500	85.8	88.6	91.0	91.3	91.5	91.3	91.4	91.7
	630	84.7	87.5	90.0	91.4	92.2	92.0	92.2	92.5
	800	82.9	85.5	88.0	90.6	92.0	92.0	92.2	92.5
	1000	82.2	84.4	86.7	89.8	91.9	92.1	92.3	92.5
	1250	82.9	84.8	86.7	89.7	91.8	92.3	92.4	92.4
	1600	83.3	85.3	87.0	89.2	91.1	91.4	91.3	90.9
	2000	83.9	85.9	87.8	89.2	90.6	90.4	90.0	89.4
	2500	84.0	86.2	88.1	89.0	89.7	89.1	88.4	87.9
	3150	82.4	84.8	86.8	86.9	87.4	86.5	86.0	85.3
	4000	78.4	81.2	83.3	82.5	83.2	82.7	81.9	81.4
	5000	72.8	75.7	77.8	76.6	77.9	77.0	76.1	76.0
	6300	64.1	67.2	69.9	68.5	70.3	68.9	68.4	68.4
	8000	51.8	54.7	57.4	56.9	58.6	57.9	57.1	57.0
	10000	37.2	39.9	42.5	42.8	44.4	43.6	43.8	44.1
	12500	19.5	22.3	24.7	25.6	26.7	25.9	27.2	28.8
	16000	-5.4	-2.6	-0.3	0.6	1.3	1.4	3.9	6.4
	20000	-33.2	-29.7	-26.8	-26.9	-26.6	-24.7	-21.8	-18.9
Total apparent sound power level $L_{WA,k}$ [dB]		96.4	98.8	100.9	101.9	103.0	103.0	103.0	103.0

Table 4: Calculated Apparent 1/3rd Octave Band Sound Power Level (A-weighted), 1.6-100 with LNTE with 96 m hub height as Function of Wind Speed v_{10m}