GE
Energy

Extreme Wind Speed – Risk and Mitigation

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Introduction

Certain wind project sites may experience extreme wind speeds caused by a severe weather situation, such as a hurricane or tornado. Since extreme wind events may result in mechanical load levels that can lead to damage or failure of wind turbine components, the purpose of this document is to inform customers about risk from extreme wind events and suggest risk mitigation actions that are based on recognized industry practices.

GE's wind turbines are designed to withstand a certain level of loading caused by an extreme wind event. As defined in the IEC 61400-1 wind turbine design/safety standard, the largest wind speed to be considered is called "Ve50," which is the maximum gust over a 50-year return period for a 3-second averaging time. In a Ve50 situation, the control system of the wind turbine is assumed to be able to pitch the blades in a feathered position, resulting in minimal rotor torque. *Table 1* lists the Ve50 limits for different GE wind turbines for the site conditions specified in the IEC 61400-1standard.

Turbine Model	Ve50 (m/s) at Hub Height
1.5xle or 2.3	52.5
1.5sle	55
1.5s, 2.5s, or 2.5xl	59.5
1.5se	70

Table 1. 50-year, 3-sec wind speed gust (Ve50) limits for GE wind turbines at hub height.
(For site conditions specified in the IEC 61400-1 standard.)

Actual Ve50 limits can vary based on site-specific conditions, and the Ve50 limits in *Table 1* assume the following site conditions [1]:

- Maximum flow inclination angle: 8 degrees
- Air density: 1.225 kg/m^3 (sea level)
- Vertical wind shear exponent: 0.11

The Ve50 limits in *Table 1* apply as long as the site-specific conditions are within those specified by the IEC standard.[1] If any or several of the site conditions in terms of flow inclination angle, air density, and vertical wind shear exceed those specified in the IEC 61400-1 standard, the actual Ve50 limit of the wind turbine of interest may be lower than that listed in *Table 1* and GE should review these conditions. Also, if one or several blades should fail to pitch to a feathered position, the maximum wind speed the wind turbine can sustain may be lower than the values listed in *Table 1*, for given site conditions.

Risk

Wind turbine component damage or failure can occur when extreme wind produces forces on the wind turbine plant buildings/machines above the Ve50 design limit. Failures may not only prohibit the operation of the wind turbine, but could also lead to third party risk. Natural disasters such as hurricanes and tornadoes are well documented and the areas they affect are well defined, but their occurrence and behavior are not well anticipated.[2] Furthermore, other natural storming wind producers such as—but not limited to—squall lines, microburst, or extra-tropical cyclones can occur at anytime, regardless of the location on the globe. With today's meteorological knowledge, predicting the maximum wind speed from a storm is unrealistic in most cases.[3]

The mode of failure of a wind turbine due to an extreme wind event cannot be generalized and depends on the turbine type and configuration, as well as the specifics of the extreme wind event and site conditions. Examples of possible failure scenarios include blade failure or a tower buckling or overturning. When winds are above the cut-out speed, the wind turbine should have its blades idling in a position creating minimal torque on the rotor. This is the only safety mechanism other than the yaw control. If a grid failure were to occur in conjunction with an extreme wind event—which is a likely scenario—the yaw control will become inactive. The loss of yaw control could increase the likelihood of damage/failure in the case of an extreme wind event. Also, the grid components/structures could also be part of the potential windborne debris. At this time, GE has no modeling capability in place that can predict the impact made to a wind plant if an extreme wind event occurs.

Risk Mitigation

The decision to build a wind site and to protect the public from negative impacts of an extreme wind event is the responsibility of the project developer/owner. For some types of wind events—such as tropical cyclones—there is meteorological expertise/data to quantify the probability of occurrence of a wind gust above the design limit of the wind turbine that is being considered for a particular area.[4] Based upon recognized industry practices, GE suggests that the following actions be considered when siting turbines in order to mitigate risk resulting from extreme wind speed events:

- **Turbine Siting.** For sites located in well-known storm areas, where winds could lead to extreme damaging gusts, a good approach is to assess the remoteness of the potential wind plant. As mentioned before, some natural disasters could lead to extreme wind speeds above the design limit of GE's wind turbines. Remote areas usually tend to reduce the potential for collateral damage in the event of storming winds, however the risk to wind turbine equipment is independent of the remoteness of the site.
- **Physical and Visual Warnings.** Should a customer decide to build on a site with extreme wind risk, GE recommends that the site be made private by using a fence and visual warning signs at the boundary of every site—regardless of its location.
- **Turbine Deactivation.** Ensure that equipment is in good working order and that turbine control systems designed to protect equipment in the event of an extreme wind speed occurrence are operational.
- **Operator Safety.** Restrict access to the wind plant by site personnel while extreme wind speed conditions exist. If site personnel must access the site while extreme wind speed conditions either exist or are probable, safety precautions may include remotely shutting down the turbine, yawing to place the turbine rotor on the opposite side of the tower access door, and parking vehicles at a safe distance from the tower. Operating a wind turbine that has experienced an extreme wind event may not be safe and the wind turbine should be thoroughly inspected before normal operation is resumed.

References

The following informative papers address the topic of wind turbines/extreme wind events and safety. These papers are created and maintained by other public and private organizations. GE does not control or guarantee the accuracy, relevance, timeliness, or completeness of this outside information. Further, the order of the references is not intended to reflect their importance, nor is it intended to endorse any views expressed or products or services offered by the authors of the references.

[1] *International Standard – IEC 61400-1, Wind Turbines – Part 1: Design Requirements.* Third Edition 2005-8 – IEC ref # IEC 61400-1:2005 (E).

[2] *Hurricanes...Unleashing Nature's Fury: A Preparedness Guide,* National Oceanic and Atmospheric Administration – NOAA.

[3] Hironori Kikugawa and Bogusz Bienkiewicz, *Wind Damages and Prospects for Accelerated Wind Damage Reduction in Japan and in the United States.*

[4] Christopher W. Landsea*, Craig Anderson**, Noel Charles***, Gilbert Clark***, Jason Dunion*, Jose Fernandez-Partagas*****, Paul Hungerford***, Charlie Neumann****, Mark Zimmer***: *The Atlantic Hurricane Database Re-analysis Project Documentation for 1851-1910. Alterations and Addition to the HURDAT Database.*

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***Florida International University, Miami
****SAIC, Miami
*****Deceased, Contributed as a Chapter for the RPI Book, Revised - 6 January 2003.

[5] Fujita, T.T., 1971, *Proposed Characterization of Tornadoes and Hurricanes by Area and Intensity.* Satellite and Meso-meteorology Research Project Report 91, Univ. of Chicago, 42 pp. See *Table A-1* (Potential wind damages according to wind speed for supporting technical information.)

Appendix

Potential Wind Damages According to Wind Speed Distribution

Scale wind speed (mph – m/s)	Damage description
40-72 – 17.9-36.7	Some damage to chimneys and TV antennae; breaks twigs off trees, pushes over shallow-rooted trees.
73-112 – 32.1-49.5	Peels surfaces off roofs; windows broken; light trailer houses pushed over or overturned; some trees uprooted or snapped; moving automobiles pushed off road.
113-157 – 50.0-69.6	Roofs torn off frame houses leaving strong upright walls; weak buildings in rural areas demolished; trailer houses destroyed; large trees snapped or uprooted; railroad boxcars pushed over; light object missiles generated; cars blown off highway.
158-206 – 70.6-92.09	Roofs and some walls torn off frame houses; some rural buildings completely demolished; trains overturned; steel-framed hangar-warehouse type structures torn; cars lifted off the ground; most trees in a forest uprooted, snapped, or leveled.
207-260 – 92.53-116.23	Whole frame houses leveled, leaving piles of debris; steel structures badly damaged; trees debarked by small flying debris; cars and trains thrown some distance or rolled considerable distances; large missiles generated.
261-318 – 116.68-142.16	Whole frame houses tossed off foundations; steel-reinforced concrete structures badly damaged.

Table A-1. Potential wind damages according to wind speed distribution.
(See Ref. [5] for technical source material.)

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