



Summit Wind Blade Throw 4-25.docx

April 25, 2017

Epsilon Ref. 4817

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Todd R. Hopper
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 SALKA LLC
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 Via email at thopper@salkaenergy.com

Subject: Altamont Wind (Summit) – Blade Throw Analysis

Dear Mr. Hopper:

Epsilon Associates, Inc. (Epsilon) has been retained by SALKA LLC to conduct a blade throw analysis for the Summit Wind Project in Alameda County, California. Epsilon has conducted blade throw analyses for projects in California, including Alameda County, Solano County, Kern County, Contra Costa County, and Los Angeles County. The purpose of the analysis is to assess potential blade throw distances using common assumptions and determine if, in the rare event a blade is dislodged from a turbine, it could collide with a sensitive receptor (e.g. residence), or passing vehicle, transmission line, or adjacent parcel.

For this analysis, a total of thirty two (32) site locations were evaluated; not all of these site locations will be used in the final design. Two turbine models were analyzed, one of which will be selected for the final design. Epsilon used the following characteristics in the blade throw analysis:

Turbine Model:	Vestas 2.2-110	GE 2.5-116
Hub Height:	95 meters	90 meters
Rotor Diameter:	110 meters	116 meters
Blade Length:	54 meters	56.9 meters
Maximum rotational speed:	14.9 rpm	15.7 rpm
Blade center-of-gravity from center:	16 meters	16 meters

Calculations in the California Energy Commission's Permitting Setback Requirements for Wind Turbines in California, prepared by the California Wind Energy

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Collaborative, November 2006, report number CEC-500-2005-184, (the “CEC report”) were used as a guide to calculate blade throw. The calculations follow the simple ballistics model prediction in Section 3.4.1 of that report, which has precedent in several permitted projects. Epsilon is unaware of any other state or local standards for blade throw analyses outside of this report. The key assumptions in the calculations are stated below, and are the same ones used in blade throw analyses for other recently approved wind projects. The calculations are for the release of an entire blade at the maximum nominal rotor speed. They do not address throw of a blade fragment or rotor overspeed conditions, both of which are less likely¹, but either of which could cause a blade throw range longer than shown in the analysis. To provide context, the likelihood of a blade fragment or overspeed failure is estimated at approximately one-third and one one-hundredth that of an entire blade failure, respectively².

Aerodynamic forces, assumed to be much smaller than the rotor’s weight, were not included in the model and the blade was assumed to travel and land in its original plane of rotation. A consideration of aerodynamic forces or out-of-plane projection would involve more complex computational fluid dynamics (CFD) modeling, requiring much more detailed information than is currently available (i.e., blade geometry, weight distribution, air flow, etc.) and introduce a significant amount of uncertainty. Additionally, blade throw was assumed to occur anywhere in a 360-degree direction around each wind turbine (independent of wind direction).

The CEC report notes that “the maximum range in a vacuum is achieved when the release angle is 45°” (page 21). However, this is only true for an object that is released and lands at the same elevation. In practice, turbines are placed on towers at elevated locations to increase the height of the rotors, and this additional height gives objects

1 Rademakers & Braam, *Guidelines on the environmental risk of wind turbines in the Netherlands*, March 2004, Table 1

2 H. Braam and G.J. van Mulekom, *Analysis of Risk-Involved Incidents of Wind Turbines*. Translated by J. M. Hopemans and C.P. Van Dam and included as Attachment 1 in *Permitting Setback Requirements for Turbines in California* Prepared for the California Energy Commission (CEC) by the California Wind Energy Collaborative (CWEC), November 2006, CEC-500-2005-184, Table 6.1.

a further distance to fall. That further distance means that a flatter release angle will achieve the maximum range.

Epsilon evaluated elevation data for the project area, derived from USGS Digital Elevation Model (DEM). For each proposed turbine location, Epsilon determined the maximum elevation drop within 800 feet from the turbine base. That elevation drop ranges from 30 to 88 meters depending on the turbine location. For each turbine location, Epsilon conducted the blade throw calculation conservatively assuming the blade would fall to that lowest elevation (irrespective of the direction thrown). To account for this variation in terrain height surrounding the wind turbines, a variety of release angles were modeled. Both “overhand” and “underhand” release angles were calculated.

For the Vestas turbines, calculating the maximum throw distance for release of entire blade at the maximum rotor speed, accounting for the maximum elevation drop at each location, conservatively neglecting air resistance, results in a maximum distance (depending on local terrain) between 141 and 163 meters, which is up to 1.1 times the Total Turbine Height (TTH).

For the GE turbines, calculating the maximum throw distance for release of entire blade at the maximum rotor speed, accounting for the maximum elevation drop at each location, conservatively neglecting air resistance, results in a maximum distance (depending on local terrain) between 146 and 173 meters, which is up to 1.2 times the TTH.

The attached Figures 1 and 2 show the maximum calculated blade-throw radii as shaded circles around each wind turbine for the Vestas (Figure 1) and the GE (Figure 2) turbines. Again, not all of these turbine locations will be used.

Based on a review of the aerial photography, the maximum blade through distances will not extend to the traveled roadways in the vicinity of the Project (Altamont Pass Road, Interstate 580, Vasco Road, publicly-accessible sections of Dyer Road and Goecken Road). Similarly, transmission lines in the project area are also beyond maximum blade throw distances for both turbine models, based on available data. Finally, the maximum blade throw distances predicted for each turbine do not extend to the 27 specific residential receptor locations provided by you.

The true probability of an impact depends on the number of blade throw events over the operational life of the project, the effect of aerodynamic forces on the blade or blade fragment governed by the principles of fluid mechanics and the laws of motion,

Mr. Todd Hopper
SALKA, LLC
April 25, 2017

4

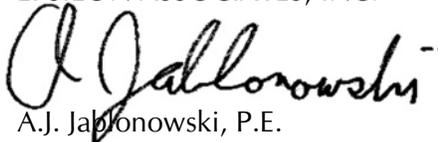
the frequency distribution of wind speed and direction, rotor speed, the location, number, size, and shape of each blade or fragment, and the number of receptors likely to be located within the release area. The largest fragments would experience the highest aerodynamic drag forces and are most likely to hit the ground nearest to the base of the turbine. As a result, the probability of an impact with large fragments decreases significantly as one moves away from the turbine.

To reduce the likelihood of blade throw-related incidents, the Vestas 2.2-110 and GE 2.5-116 wind turbines, like most modern wind turbine technology, are designed to shut down automatically under cut-out wind speed conditions higher than the rated wind speed at hub height. Both turbine models also come equipped with pitch control to minimize system stress in all wind environments.

If you have any questions on this report, please contact me at (978) 461-6202, or by e-mail at ajablonowski@epsilonassociates.com.

Sincerely,

EPSILON ASSOCIATES, INC.



A.J. Jablonowski, P.E.
Principal

