ICETHROWER

Mapping and tool for risk analysis

Winterwind, Skellefteå 7 February 2017 Jenny Lundén, Pöyry Sweden



WHAT IS THE PROBLEM?





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WHAT IS THE PROBLEM?

- 1. Wind turbines drop ice pieces occasionally
- 2a. The emotional conclusion is "often" and "long distance" (km!)2b. The pragmatic approach is "now and then" and "within 1D"
- 3. Risk level is generally poorly investigated and hard to calculate





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IS THERE A SOLUTION TO THE PROBLEM?

Level of confidence can be increased by more observations

Discrepancies between different turbines can be investigated

A generic tool to increase the possibility to calculate and communicate risk both for service personnel and for the public





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ICETHROWER – mapping and tool for risk analysis

Project:

- Mapping ice throws in Sweden
- Develop a model to simulate ice throw and assess health & safety risks
- Client: Swedish Energy Authority
- Partners: Dala Vind, Vattenfall Vindkraft and Skellefteå Kraft
- Location: 3 wind farms in Sweden
- Field study: 2013 2016



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WHICH IS OUR APPROACH?

Joint research project within Energimyndigheten's research program "Wind power in cold climate"



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THE ICETHROWER PROJECT

The project is divided into three parts:

- Field study to collect ice data from 3 wind farms in Sweden and create a database for common use
- Verify and integrate the existing tool KASTIS into a common tool box
- Develop a usable simulation tool for risk evaluation based on collected data



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THE FIELD STUDY - METHOD

Three wind farms in Sweden Collect information:

- Physical properties of ice lumps
- Throwing distance
- Meteorological data at the time of ice throw

Data collection during winter 2013 - 2016

Challenges in field work:

- Severe winters -> increased risk
- Mild winters -> less data





THE FIELD STUDY - METHOD

Systematic approach in the search for ice lumps

- Ice lump measurement and classification
- Location of ground impact and throwing distance
- Photographs





THE FIELD STUDY - METHOD

Three wind farms in Sweden

Collect information:

- Physical properties of ice lumps
- Throwing distance

D Over all data from 530 ice lumps was collected!





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THE FIELD STUDY – RESULTS (ALL DATA)



Turbines in the field study had 90 m rotor and 95 m tower (no de-icing system)

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THE FIELD STUDY – RESULTS (ALL DATA)



Turbines in the field study had 90 m rotor and 95 m tower (no de-icing system)

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THE FIELD STUDY – RESULTS (CASE STUDY)



Turbine in the case study had 90 m rotor and 95 m tower (no de-icing system)

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THE FIELD STUDY - RESULTS (CASE STUDY)



Turbine in the case study had 90 m rotor and 95 m tower (no de-icing system)

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THE KASTIS MODEL – SELECTED OUTCOME

Purpose: calibrate and tune the previously developed model KASTIS.

- A developed version of KASTIS was derived in the project, called iceThrow
- The program calculates trajectories for ice lumps released from wind turbine blades during operation using <u>very detailed information</u> of the ice lump

Result:

 The iceThrow model showed that most of the ice lumps in the range 0.1 – 0.4 kg hit the ground with a speed, converted to energy, in the potential lethal region i.e. in excess of 40 J





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THE ICE THROW MODEL - METHOD

A statistical ice throw model was developed using the equations of motion in combination with Monte Carlo simulations.



$$M \frac{d^2 x}{dt^2} = -\frac{1}{2} \rho C_D A \left(\frac{dx}{dt} - U\right) |V| Eq. 3$$
$$M \frac{d^2 y}{dt^2} = -\frac{1}{2} \rho C_D A \left(\frac{dy}{dt}\right) |V| Eq. 4$$
$$M \frac{d^2 z}{dt^2} = -Mg - \frac{1}{2} \rho C_D A \left(\frac{dz}{dt}\right) |V| Eq. 5$$
The relative wind speed is given by,

 $|V| = \sqrt{\left[\left(\frac{dx}{dt} - U\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2\right]} Eq. 6$

Where *M* is the mass of the ice fragment, C_D is the drag coefficient, ρ is air density, U(z) is the wind speed with x-axis parallel to the wind and *g* is the gravity.

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THE ICE THROW MODEL - ASSUMPTIONS

Assumptions used in the ice throw simulations

- Random normal distribution of mass
- Random Weibull distribution based on wind speed and direction
- Turbine specifics (rotor radius, hub height, rotor revolution)



Turbine used in the simulation had 90 m rotor and 95 m tower

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THE ICE THROW MODEL - RESULTS

Example: Turbine with 90 m rotor diameter and 95 m hub height Only using wind from the prevailing wind direction (WNW & NNW)



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THE ICE THROW MODEL - RESULTS



Larger wind turbine -> longer throwing distance However the probability rapidly decreases with distance

Based on 100 000 simulated ice throws, all wind directions included

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EXAMPLE OF RISK ESTIMATE

Two service personnel visit wind farm after indication of icing on the turbines.

- Park the car 10 m from entrance
- Get tools, walk to the turbine (5 min)
- Work for 1 hour inside the turbine
- Walk back to the car, load tools (5 min)

During a working day they visit 5 turbines.

The estimated total risk is then

- 0.009 for the car or 1 in 115 year
- 1.5*10⁻⁴ for 2 service personnel on one working day or 1 in 6 900 years.



Assumptions: car = $10m^2$, one person = $0.5 m^2$ 70 ice lumps released per icing day and turbine. Probability from the red curve on previous slide.

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EXAMPLE OF RISK ESTIMATE CONT.

High or low risk?

In the example the total risk (one working day)

• 1.5*10⁻⁴ for 2 service personnel

or 1 in 6 900 years.

 In comparison the risk of car accident is 5*10⁻⁵
 The estimated risk is considerable high and not acceptable without certain safety provisions.

For the public the risk is lower since they do not know if the turbine are affected by ice. (e.g. the number of ice day / the winter season)

It is important to have warnings signs at the wind farm entrance to alert the public of the potential hazard.



WINTERWIND, Skage textee 000021 6-8 2017 21 Page 000021 111398 Thank you!



CONTACT:

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EXHIBIT A46-2



GE Renewable Energy Onshore Wind

> Kevin Burns Commercial Director M – (518) 698-7803 Kevinm.burns@ge.com 1 River Road Building 53-403L Schenectady, NY 12345

May 30, 2019

NextEra Energy Resources, LLC 700 Universe Blvd. Juno Beach, FL 33408

Subject: Crowned Ridge Wind Project – Setback Requirements

Reference:

- 1. Safety Manual 2015 (GE Reference: Operating_Manual_1-2MW_Safety_EN_r02
- 2. Setback Considerations for Wind Turbine Siting 2018 (GE Reference: Setback Considerations Generic xxHz EN r04)

To Whom It May Concern:

This is to confirm that the GE document <u>Setback Considerations for Wind Turbine Siting</u>, 2018, supersedes the GE document titled <u>Safety Manual 2015</u> for purposes of ice throw safety and GE setback standards.

Please feel free to contact me if any additional information is required.

Sincerely,

R Kevin Burns Commercial Director

CC: Donald Karwisch, Integrated Supply Chain, NextEra Energy Resources, LLC

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF SOUTH DAKOTA

IN THE MATTER OF THE APPLICATION BY CROWNED RIDGE WIND, LLC FOR A) PERMIT OF A WIND ENERGY FACILITY IN GRANT AND CODINGTON COUNTIES

EL19-003

CERTIFICATE OF SERVICE

I hereby certify that true and correct copies of Applicant's hearing exhibits in this

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matter were served electronically to the parties listed below on the 4th day of June, 2019,

addressed to:

Ms. Patricia Van Gerpen **Executive Director** patty.vangerpen@state.sd.us

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Mr. Mikal Hanson Staff Attorney South Dakota Public Utilities Commission 500 E. Capitol Ave. Pierre, SD 57501 <u>Mikal.hanson@state.sd.us</u>

In addition, the parties listed below have accepted service by filing on the docket.

Ms. Cindy Brugman Auditor Codington County 14 First Ave. SE Watertown, SD 57201 cbrugman@codington.org

Ms. Karen Layher Auditor Grant County 210 E. Fifth Ave. Milbank, SD 57252 Karen.Layher@state.sd.us

In addition, the party listed below has accepted service by filing on the docket and

a paper hard copy of said hearing exhibits, excluding confidential materials, to be

provided by hand delivery at the hearing:

Mr. David Ganje Representing Intervenors Mr. Allen Robish. Ms. Amber Christenson, Ms. Kristi Mogen, Ms. Melissa Lynch and Mr. Patrick Lynch Ganje Law Offices <u>davidganje@ganjelaw.com</u>

Miles F. Schumacher

Attorneys for Applicant Lynn, Jackson, Shultz & Lebrun, PC 110 N. Minnesota Ave., Suite 400 Sioux Falls, SD 57104