Upward Lightning Exposure Assessment for Wind Power Plants in Low Altitude Thunderstorms using COMSOL Multiphysics®

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INTRODUCTION: Cold season thunderstorms (or thunderstorms with low cloud height) are a threat for wind turbines in several areas of the world because the charge of the thundercloud is much closer to the earth compared to warm season thunderstorms (Kitagawa & Michimoto, 1994). As a consequence, the electric field around the grounded wind turbine is much higher during these storms, triggering so-called upward lightning flashes (Wang, Takagi, T, H, & Hashimoto, 2008). Wind turbines being tall and pointy grounded structures are particularly affected, since the electric field around the tip of the blades can be several orders of magnitude larger than the ambient electric field (See Figure 2) , sparking the initiation of frequent upward lightning strokes.

GOAL: To create a procedure that predicts which wind turbines are affected by upward lightning flashes in low altitude thunderstorms.

Parameters: The distance between ground and the charged thundercloud as well as the propagation direction of the storm determines which wind turbines are predominantly affected by upward lightning. Also cloud potential is a factor.

Measurement:

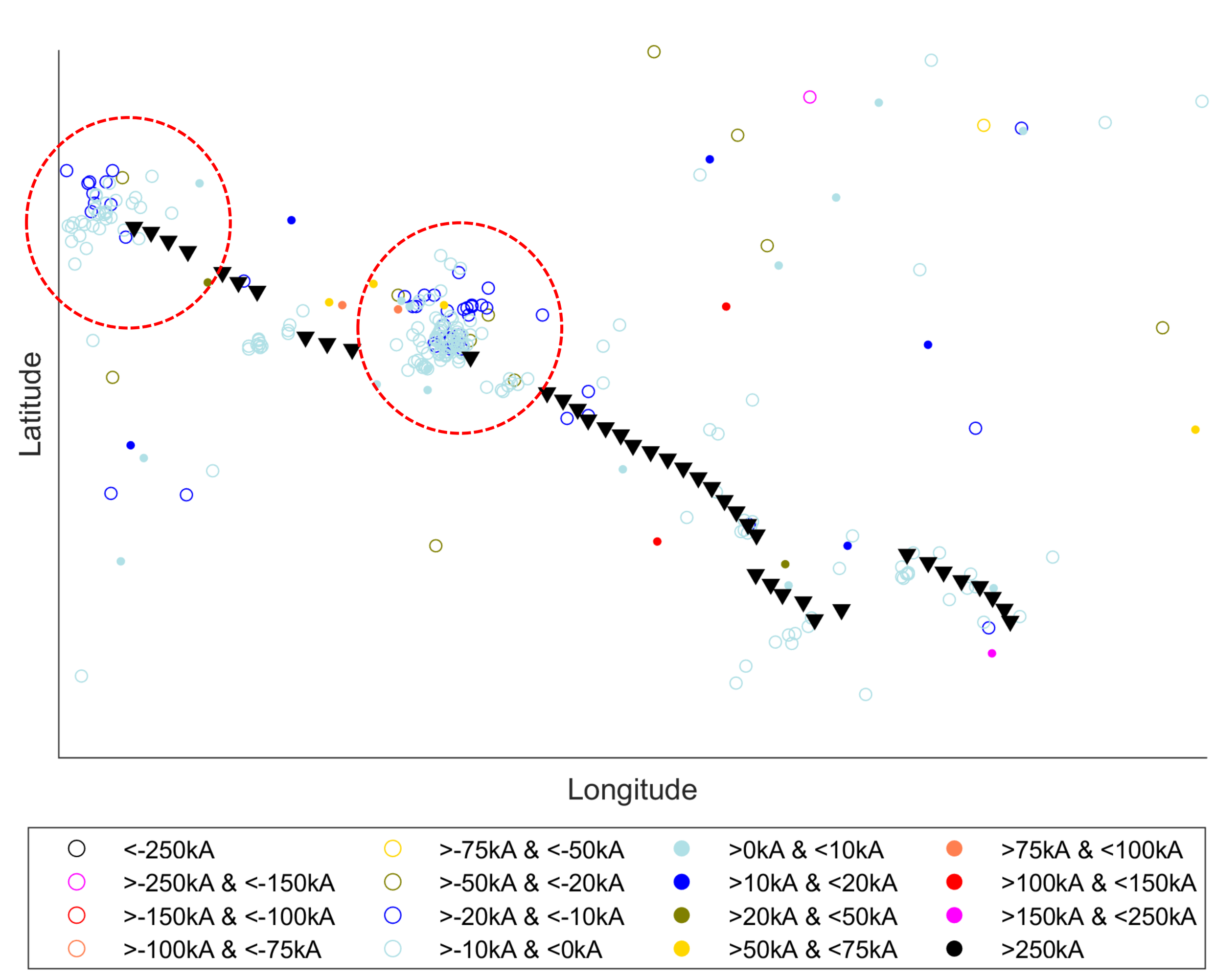

Figure 3. Measured lightning exposure in a wind power plant during 10 thunderstorm days with low cloud height.

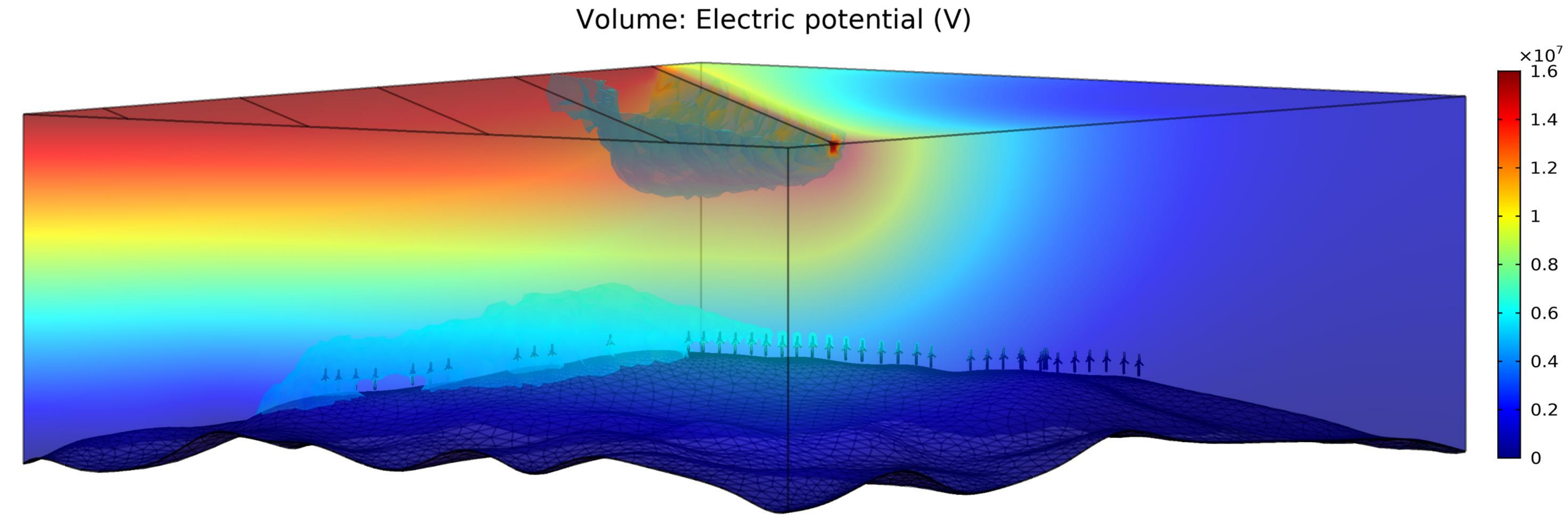

Figure 1. The cold season thundercloud approaches the wind power plant from a certain direction and at a certain height. The electric field (Turquoise cloud) around the turbines is enhanced at the left side but insignificant at the right side.

Methodology:

1. Implement elevation data of wind farm.
2. Place wind turbines in model.
3. Determine wind direction and height of -10° isotherm during previous thunderstorms.
4. Simulate thunderstorm as a propagating voltage plane with the Electrostatic Interface in Comsol and a Livelink to Matlab. Meteorological parameters provide initial conditions for the model.
5. The simplified upward lightning inception model by Goelian/Becerra & Cooray determines if sufficient voltage is apparent at the tip of each wind turbine blade to develop upward lightning.
6. Probability of lightning flash is calculated by comparison of charge magnitude on developed leaders.

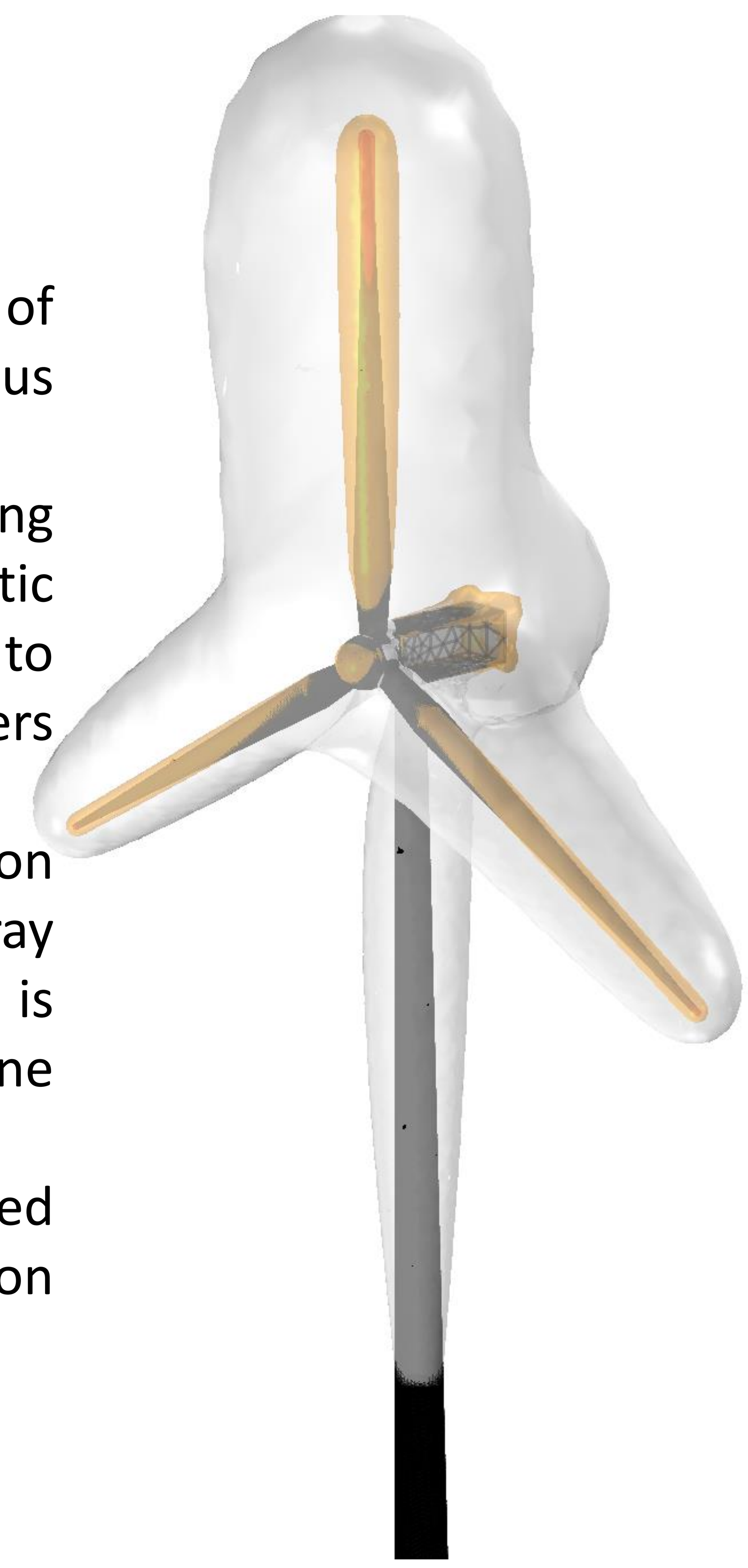

Figure 2. Illustration of electric field around wind turbine. The highest field is located at the tip of the upward facing blade (red), The mid-span part of the blade and the end of the nacelle are characterized by medium field areas (yellow). The tower and the inner side of the nacelle are characterized by low electric field magnitudes (white).

Result:

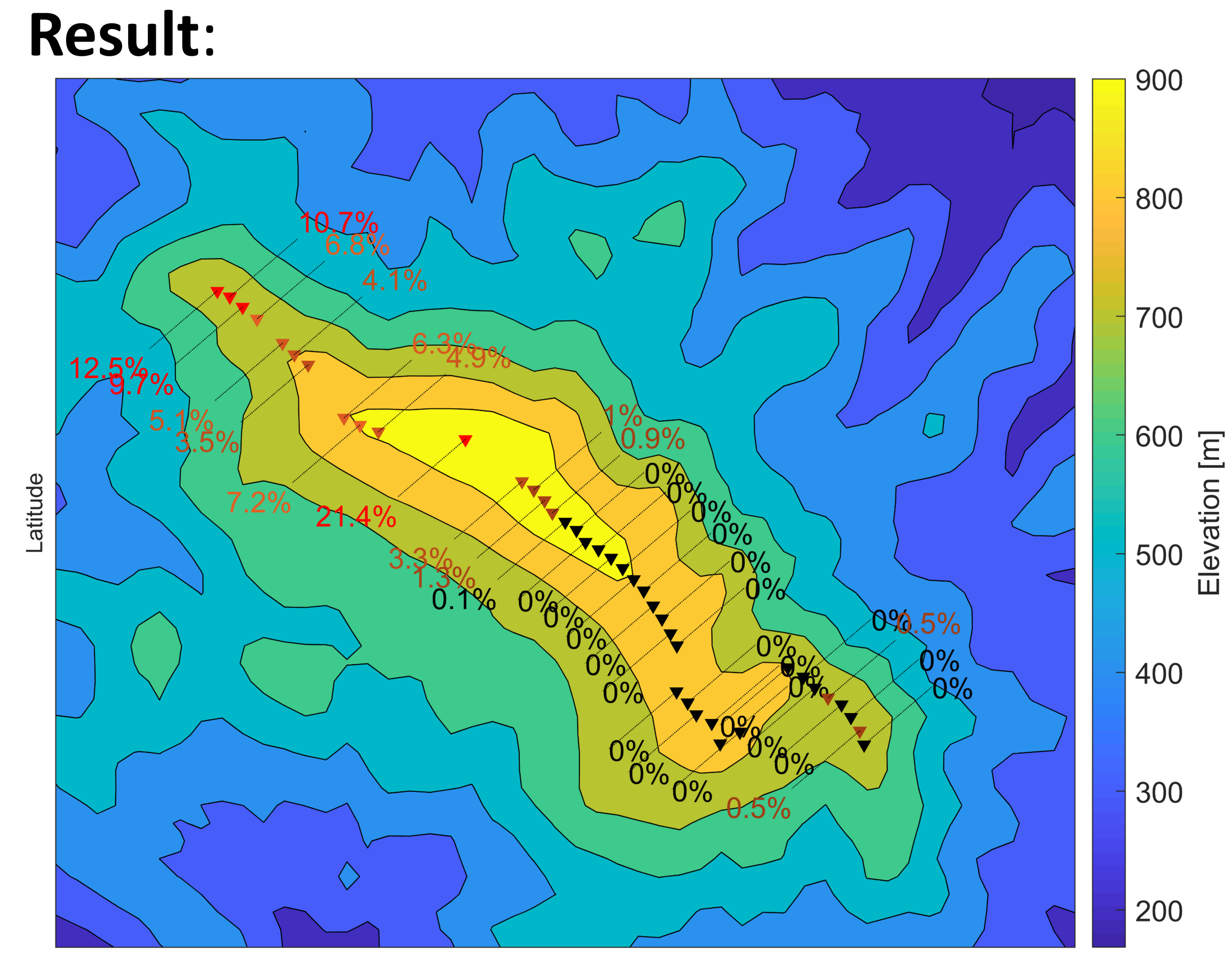

Figure 4. Simulation Results: The calculated lightning exposure is mainly focused on the north-west corner and on the wind turbine with the highest elevation. Turbines in the south-western area are less likely exposed to upward lightning.

Conclusion:

A good agreement between simulation and measurement is found. By determining which turbines in a wind farm are most likely struck by lightning discharges, the wind turbine operator may improve existing lightning protection, adjust maintenance schedules or install lightning measurement devices which supports the maintenance process. This so called lightning "Lightning Micro Siting" may be conducted before or after construction of a wind power plant.

REFERENCES:

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