PO.145

Lightning Attachment to Wind Turbines in Central Kansas: Video, Observations, Correlation with the NLDN and in-situ Peak Current Measurements

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INTRODUCTION

Background

- Lightning strikes to wind turbines is an important problem for wind turbine manufacturers and wind farm operators. Lightning can damage blades leading to lower capacity factors, expensive repairs, and liability disputes
- The use of remote sensing technologies like Vaisala's US National Lightning Detection Network (NLDN) allows wind farm operators to identify potential lightning strikes and inspect turbine damage. It is less costly to repair lightning damage if it is identified early

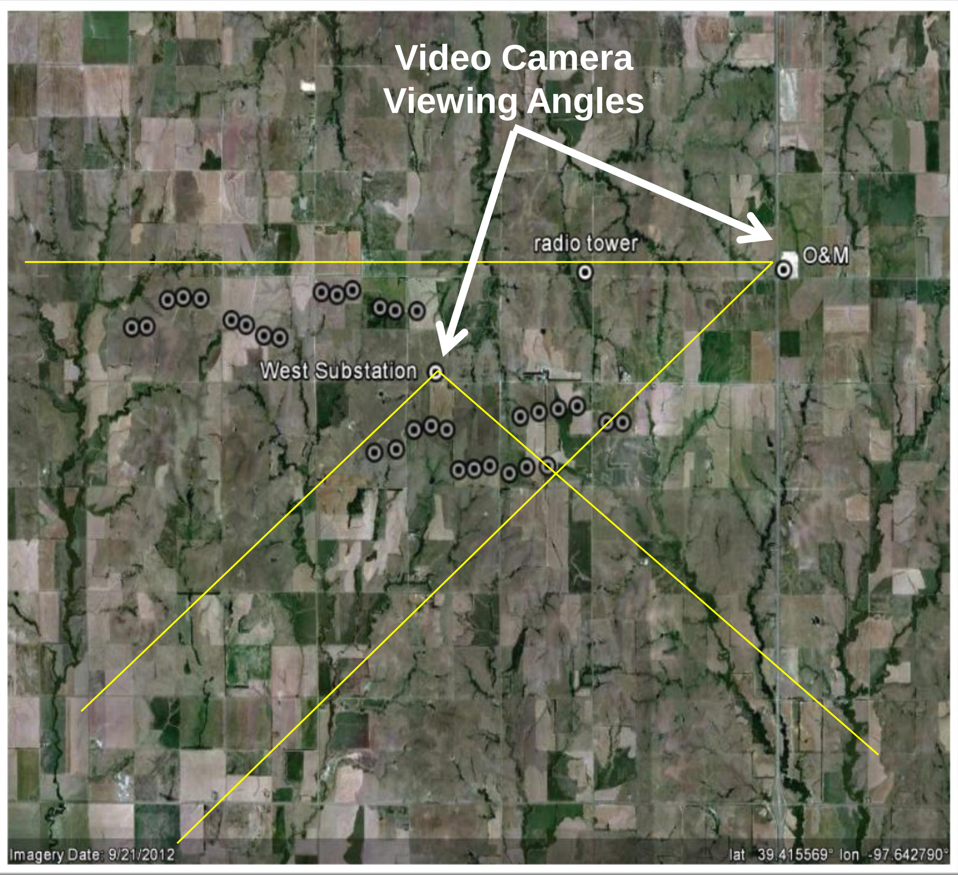
Industry Questions

- What percentage of lightning attachments to wind turbines are upward leading flashes that are not detected by lightning detection networks and do these events cause damage to wind turbines?
- What is the attractive radius (distance from a tall object where a downward flash will attach) of a wind turbine and how does this compare to a stationary tower?

Study Approach

- Deploy auto-triggered video cameras at a wind farm in Kansas with wind turbines equipped to measure lightning current transients in the blades
- Lightning data from the US NLDN was compared to video recordings of turbine strikes to determine the accuracy of the NLDN, the average attractive radius of wind turbines, and likelihood of upward lightning originating from the turbines
- Lightning strikes to a stationary radio tower were compared with strikes to turbines in order to evaluate the differences in attractive radius between the two

OBSERVATION SYSTEMS



VIDEO

- Two (2) 60 fps PC-based systems using ufoCapture software

TURBINE BLADE CURRENT

- Current in conductor attached to receptors on blades

LIGHTNING DATA

- US National Lightning Detection network (NLDN) cloud-to-ground stroke and in-cloud flash data

OTHER

- Electric field mills, radiation waveforms from lightning sensors and radar data

OBSERVATIONS SUMMARY

Video Observations

- Seven (7) turbine strikes recorded, three (3) of which were upward
- Two (2) radio tower strikes were recorded, one (1) of which was upward
- Two (2) had no return strokes (triggered by nearby +CG stroke)

US NLDN Data

- 491 NLDN events were recorded within 1 km of wind turbines during this time (219 in west area of wind farm visible to video)
- 229 events were CG, 262 events were in-cloud (IC)
- Not all events were captured on camera due to equipment issues and limited field of view

Upward Cases

- NLDN reported (geo-located) no return strokes
- NLDN waveforms showed "impulsive" magnetic fields with inferred peak currents of less than 2-3 kA
- Blade damage occurred for 1 of the 3 cases (not caught on video)

Effective Attractive Radius (EAR)

$$\frac{A_{TurbineStrike}}{A_{Total}} = \frac{\#_{turbineStrikes}}{\#_{groundContacts}}$$

- Computed for the entire wind farm (N turbines)
- **R = 276 m** (hub height = 80 m, max height with blade = 120 m)

Radio Tower (231 m tall, within the wind farm)

- 1 of 3 NLDN –CG reports within 300 m struck the tower and 1 of 8 reports within 500 m struck the tower, 1 upward flash observed
- 3 turbines experienced the same number of direct attachments (2)
- Previous research shows EAR should be ~300 m which is consistent with our observations, but wind turbines with much shorter height had similar EAR

VIDEO RECORDINGS

Cloud-to-Ground Cases

15 June 2012

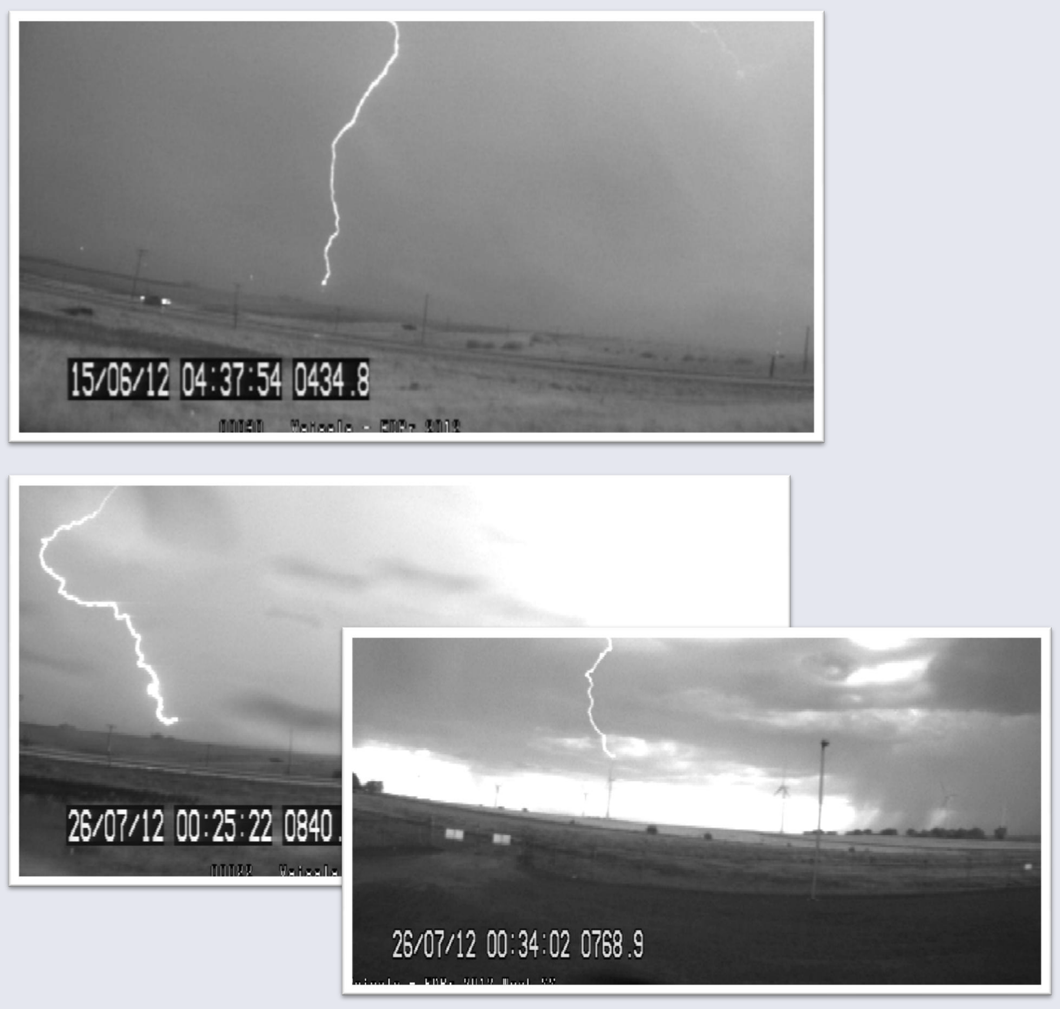
- CG strike to one (1) turbine

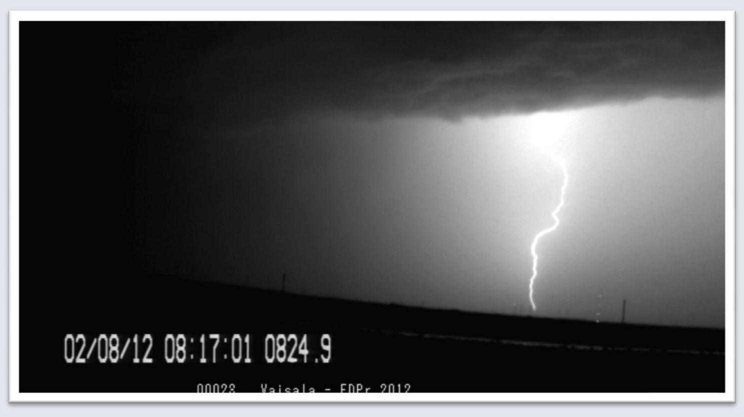
26 July 2012

- CG strikes to two (2) turbines with both causing blade damage

2 August 2012

- CG strike to one (1) turbine

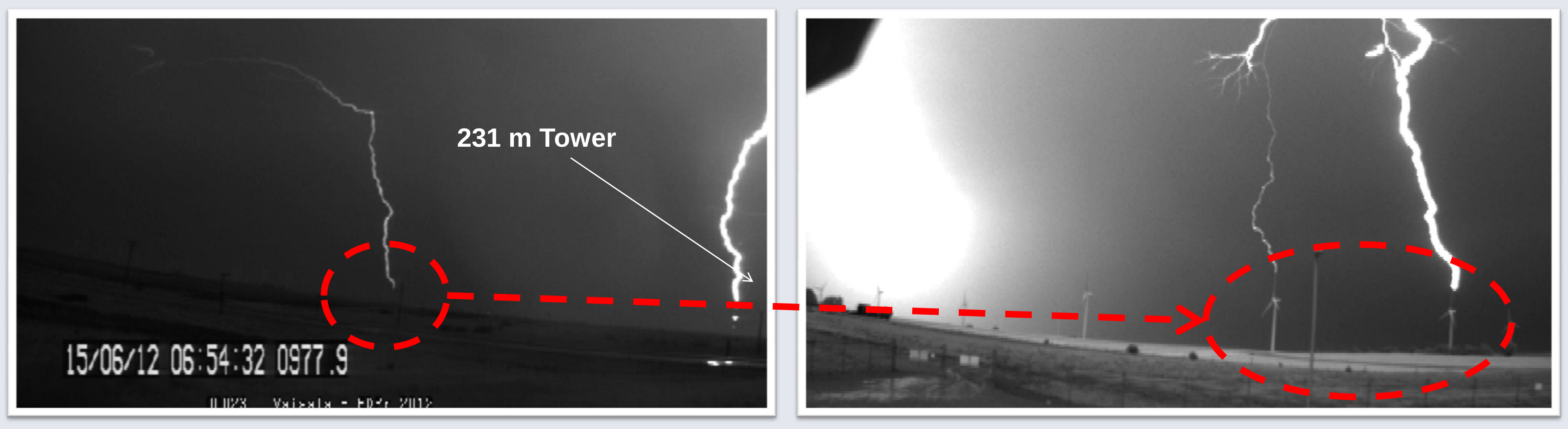




Upward Flash Cases

15 June 2012

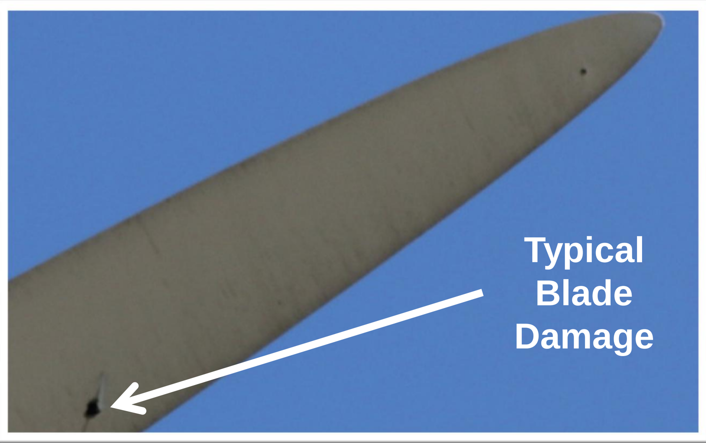
- +CG triggers upward lightning from two (2) turbines and a radio tower simultaneously



7 September 2012

- CG strikes to two (2) turbines with both causing blade damage

CONCLUSIONS



1. All lightning attachments to turbines were to the blades
2. US NLDN detection efficiency for downward attachment lightning was 100%
   - Upward lightning attachment to turbines was most-easily initiated by nearby +CG strokes and had low currents with 100% DE
   - However, 0% DE for "return-stroke like" current measured in the blade
3. There was no correlation observed between the lightning peak current or charge transfer and resultant damage to turbine blades
   - This may be explained due to current in the blade spar rather than in the down conductor where the current is measured
   - Blade damage was more likely to occur as a result of a direct downward negative cloud-to-ground flash
4. Wind turbines may have a larger Effective Attractive Radius for lightning
   - Possibly because space charge around the moving blades is inhibited
5. It is advisable to inspect wind turbine lightning protection systems regularly to minimize the risk of damage from lightning strikes

References

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