LIGHTING STRIKES TO WIND TURBINES AND THE FINANCIAL IMPACT

WHITE PAPER

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THE LIGHTNING PROBLEM

Leading insurance companies in the industry have shown that lightning strikes account for about 25% of all loss claims on wind farms. Blade tips are the highest point on the turbine structure and attract the majority of lightning strikes, so the highest percentage of damage is to the blades. The financial impact of this damage can be very significant. With a typical blade claim averaging around $250,000, repairs for a company owning multiple farms could be in the millions.

To understand the scope of the lightning problem, we need to identify where the biggest areas exist today. Figure 1 represents cloud to ground lightning strikes and the frequency of the average flash density per square kilometer per year. Warm colors are high lightning concentration areas. These also align closely with high wind production areas as outlined in black.

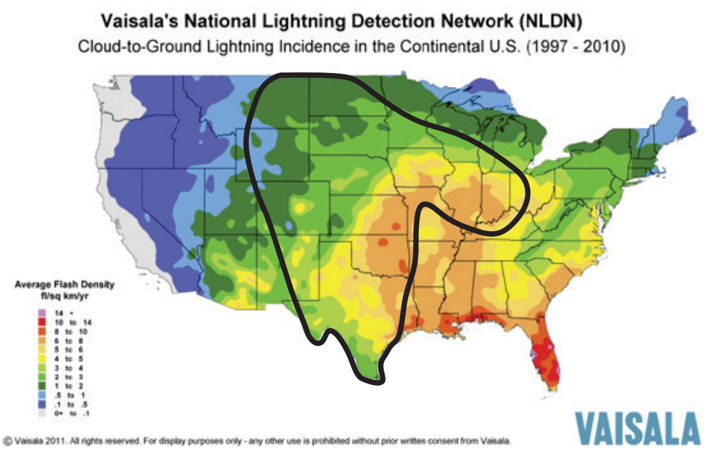

Figure 1

Each lightning strike to a turbine blade can lead to degradation over time, and turbines in high lightning frequency areas have a greater chance of being struck repetitively. It may not be the first strike that impacts the blade, or even the second or the third, but those repetitive strikes will continue to degrade the blade over time. It is likely that the fourth or fifth strikes may cause major damage. If that damage could have been detected earlier, after the first or second strikes, the damage could have been addressed when the problem was still minor.

MOVING INTO THE FUTURE

Up to this point, turbine height technology has been 80 to 100 m, however current trends in the wind farm industry are moving toward turbine height growth. (Fig 2) The future turbine height is predicted to increase to 110 to 140 m turbines. These new taller turbines are already being manufactured and going into both the ground and the water.

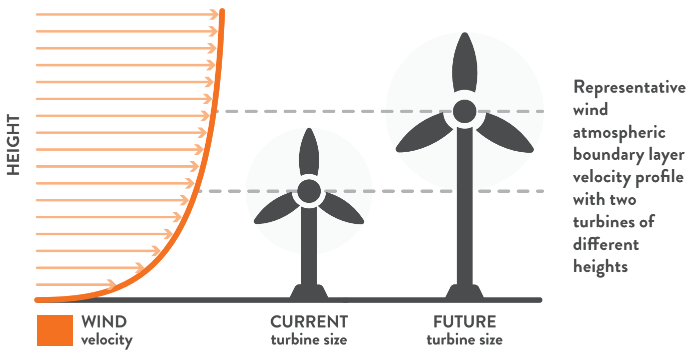

Figure 2

In a report from the US Dept of Energy 'Enabling Wind Power Nationwide' May 2015, we can start to understand the affect the taller turbine height and wind farm expansion will have on the future. Fig 3 is a current view using a 30% net capacity factor based on current wind technology of 80 to 100 m turbines. High wind production areas in dark blue show heavy concentration in the central United States and very little in the southeastern United States. Figure 4 takes a look at the future with the new 110 to 140 m turbines, and using the same 30% net capacity. You can see the growth of wind power production in the southeastern United States.

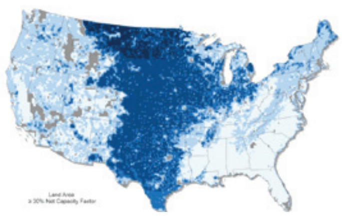

Figure 3

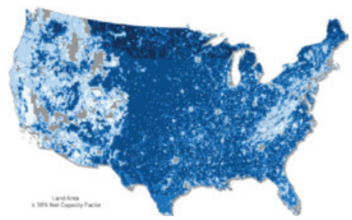

Figure 4

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With this expansion of wind power into the southeast United States, we can again look at cloud to ground lightning strikes and the frequency of the average flash density per square kilometer per year. As seen in Fig 5, the Southeast has a high lightning density occurrence, with future wind production areas outlined in black. Clearly the frequency of lightning striking wind turbines will only increase in the future. Taller turbines attracting more strikes will mean more damage. Additionally, the University of California Berkeley published a study in 2014 in the Journal of Science[1]. Part of that study indicated that lightning strikes are expected to increase by up to 50% due to climate change. Factoring in the new taller wind turbines, expansion to the southeastern part of the US, and an expected increase in lightning up to 50%, this will continue to be a major concern for the wind farm industry going forward.

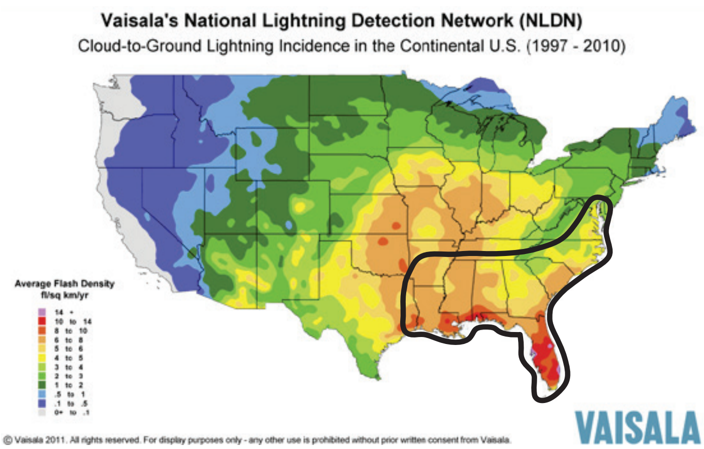

Figure 5

TOOLS FOR IDENTIFICATION AND ANALYSIS USING INDJI WATCH

Having a good situational awareness tool when a lightning event is happening in real time, will allow you to see the impact of the event on your assets, giving you an early assessment of the severity of the event. In figure 6, using the Indji Watch Wind Farm Operations software, you can see that there are many lightning strikes (represented by the green and pink + signs) being plotted in relation to a wind farm indicated on the right side of the image. Once the event has occurred, the next step in the process is the ability to perform a post event analysis or post storm analysis to collect the data you need, assess the event and then go forward to make informed decisions.

If a fault has occurred during a storm, there is a good chance the fault may have been caused by lightning. Your SCADA system will have recorded the time of the faults or trips to wind turbines. The Indji Watch Lightning Fault Analyst can quickly tell if there was lightning near a wind turbine and also give the distance between where the strike occurred and the asset.

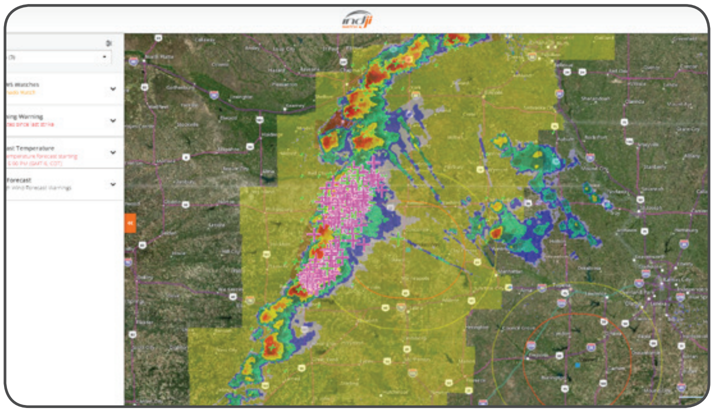

Figure 6

To perform a post event analysis, you will need to decide if you wish to investigate all the turbines at the site for possible lightning impact or examine a specific wind turbine. Use your SCADA data to help you decide if the entire site should be reviewed, or if it appears the damage may be limited to a small area. Once that determination has been made, the date, time and search window can be defined in the Indji Watch product and within seconds the results of the analysis will appear.

Figure 7

In figure 7, you can see an example of results from such a search. You will see your lightning strikes within the area you have selected. Each strike will be listed in a tabular format along with the date, time, polarity and intensity.

INTERPRETING THE RESULTS – DID MY TURBINE GET HIT?

Now that you have the data, you can research further. You can measure to see how far away the lightning strike was from the wind turbine, and confirm that data with the information your SCADA system provides. You can also determine the strength, or amplitude, of the lightning strike and what time the strike occurred. Amplitude is the flow rate of electrical charge and will range anywhere from 1 to over 200kA. This is important because the greater the amplitude, the stronger the electrical charge. Also important is the polarity of the strike. The polarity is going to be either positive or negative and is determined by where the lightning originates in the storm cloud. Positive lightning strikes make up only about 5% or less of all lightning, and can also be more powerful. Why is that?

- Positive strikes originate in the upper levels of the storm. The amount of air that the flash must burn through to reach the ground is usually much greater, therefore the electrical field is typically much stronger than a negative strike.
- The flash duration of a positive polarity strike is also longer, and its peak charge and potential can be 10 times that of a negative strike. As much as 300,000 amps or 1 billion volts.

Due to the dangerous nature of positive strikes, they should be looked at closely. A bolt out of the blue is a lightning strike that occurs far away from the parent thunderstorm; often 10 to 20 miles or more. Typically, the bolt out of the blue strikes are positive in nature and are serious from a safety standpoint.

Daily reports of lightning strikes can also be very helpful. They contain the location of the turbine, the time the strike occurred, how far away the strike was from the turbine, in addition to other relevant data, and provide an easy way of keeping an accounting of which turbines have been struck repeatedly over a period of time (ie: monthly or over the lightning season). Reports can also allow for collaborative decisions to occur. The site manager, regional manager and lead technician all in different geographic locations, can view the same report, and easily choose the right course of action.

LEVERAGING YOUR FINDINGS WITH EMERGING TECHNOLOGY

New technologies are changing the way blade and turbine inspections are being done. The FAA has approved the use of drones to fly below a height of 200 ft during the daytime hours. Special exemptions are given to wind farms that allow the drone to be flown as high as 500 ft which is needed to do a full inspection of a blade. Drones can make inspections faster, easier and more safe than traditional methods. The traditional labor-intensive approach will allow about 30% of a fleet of turbines to be inspected annually. An entire farm can be monitored frequently, thoroughly and problems can be spotted on an immediate basis with the use of a drone. Drones not only provide a new operations and maintenance method to reduce cost, but drones increase the safety during inspections. A person outside on the ground flying a drone via remote control and doing an inspection is much safer than a technician hanging from a rope several hundred feet above the ground where the wind could suddenly pick up and reach threshold levels. While drones are not superior, and traditional methods will still continue, this new emerging technology has definite advantages and is increasing in use. The use of drones is creating third party providers, as-well-as the 'Do it yourself' owner/operators, who will self-perform inspections using drones. This allows the wind farm owner to quickly do on-demand drone inspections, and any damage can then be repaired while it is minor.

APPLYING THE TECHNOLOGY TO YOUR BUSINESS

The analysis of lightning data matters. Studies and industry experts agree that you will find 25 – 30% more damage of blades by using lightning data and analyzing that data. This data allows you to find and address blade damage issues early when repair costs are lower instead of a major blade repair that averages $250,000. By focusing your inspection with targeted data, you will be able to minimize downtime, which has an immediate impact on the bottom line. For example, one study shows the cost of downtime for a 2 megawatt turbine can average about $1,200 per day in lost power production.

CONCLUSION

Lightning is a serious problem for wind turbines and blades in the wind farm industry. Technological advances such as taller turbines will increase those problems. So accurate blade inspections will become critical. The good news is that technology exists today that will allow you to mitigate the problem, lessen the impact lightning will have on your turbines and overall improve your operations and maintenance bottom line in a positive way.

REFERENCES

[1] D. M. Romps, J. T. Seeley, D. Vollaro, J. Molinari. Projected increase in lightning strikes in the United States due to global warming. Science, 2014; 346 (6211): 851 DOI: 10.1126/science.1259100