Guiding the light

Damage from lightning can prove costly, lead to downtime and even put turbines out of action altogether. But when mother nature calls, could a solution be as simple as putting a coat on? PES discusses the issue with Neal Fine PhD, Founder and CEO of Arctura.

PES: A very warm welcome to PES. I'm fascinated to learn more about Arctura and where the business sits in relation to the wind and renewable energy sectors. Could you give a brief company background to start us off?

Neal Fine: Thank you, it's very nice to speak with you. So, Arctura is a group of technologists that share a passion for wind energy. I launched the company in 2015 to introduce new technologies that will improve wind energy and lower costs for the industry.

Although the wind industry has enjoyed a continuous period of growth over the last few decades, my colleagues and I see a need for new technologies that will help to keep the cost of energy low so that the momentum can be sustained.

We have made it our mission to develop products and technologies that reduce wind energy costs and increase energy production. Making wind more competitive in the grid energy market is Arctura's contribution to accelerating the green energy transition.

PES: So, Arctura develops technologies to make wind energy more competitive. Are you targeting costs of manufacturing, operational costs, or something else?

NF: Well, the primary focus of our near-term products and technologies is to reduce operational costs and increase revenues for wind farm owners and operators.

We also have some longer-term technologies in the pipeline that are aimed at other segments, including wind turbine manufacturers, but our current focus is on the owners and operators and their unique pain points.

PES: Tell me about a near-term product that targets the wind farm operators. What problem are you looking to solve?

NF: We are really excited about our first product, which addresses the problem of lightning damage to wind turbine blades.

Neal Fine

Lightning remains a stubborn problem for the industry.

If you operate a wind farm in the United States, from Texas and Oklahoma on up to Iowa and the Dakotas, then lightning is likely either the number one or two cause of maintenance costs and downtime for your assets. And the problem for the industry is likely to get worse in the future, as wind turbines get taller and as lightning activity increases due to climate change.

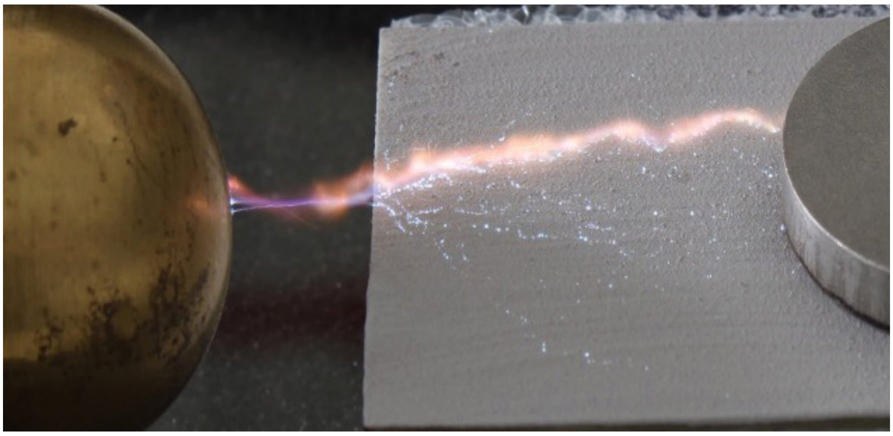
Most wind turbines, of course, come equipped with a lightning protection system. They typically consist of one or more metal disk receptors, mounted flush to the surface of the blade and electrically connected to a large metal down conductor inside the blade, designed to safely conduct the lightning charge to ground.

When a charged cloud is overhead, little fingers of electrical arcs called streamers form in the air around these metal components. Some of those grow longer and evolve into leaders that leave the surface of the blade.

When the lightning protection system works well, as it often does, a leader from the receptor connects with a downward leader from the cloud, and the charge makes it safely to ground without damaging anything.

However, this process doesn't always go as planned. Frequently, one of the leaders that initiates inside the blade instead wins the race to connect with the downward leader from the cloud, resulting in punctures, split trailing edges, and sometimes catastrophic damage when the blade catches fire.

And that's the crux of the problem; the receptors don't work as well as intended, and lightning will instead often puncture through the blade skin and connect directly to the down conductor. This leads to significant repair costs and down time for the operator.



A small-scale coating development test showing points of early ionization and the surface flashover that follows

A high voltage test of a wind turbine blade demonstrating the desired outcome, a surface flashover to the lightning receptor

PES: How are you addressing this problem?

NF: We have developed a blade coating, essentially a polyurethane-based topcoat, that is applied on the outside surface of the blade in the vicinity of the receptors. The coating is designed to make it more likely that the lightning will attach at the receptors and less likely that it will puncture the blade skin and attach directly to the down conductor inside the blade.

Our patented formula includes a mixture of small conductive particles of a certain size, shape, material, and concentration. The coating is not designed to be a current-carrying conductor. Instead, the conductive particles disrupt the electric field in the air adjacent to the surface.

This leads to early ionization and to increased streamer activity around the receptors, so that if a strike occurs it will be much more likely to transfer the energy through the highly conductive ionized channel in the air above the surface to the receptors and safely to ground via the down conductor. In this way, our coating makes it much less likely that the lightning will penetrate the skin of the blade.

We call it the ArcGuide™ coating, because it guides the lightning to the receptors on the blade. It's an upgrade to the existing lightning protection system that gives the turbine added protection. The formula was developed and tested over a four-year period with funding from the US Department of Energy.

PES: Very interesting. How has this technology been validated?

NF: We are working with the lightning experts at Lightning Technologies, an NTS Company, in Pittsfield, MA, where they have a lightning lab that is used to certify new blade designs that must pass the IEC Standard for lightning protection.

Using that facility, we tested a set of used GE 1.5sle blades that had been removed from a wind farm during a repowering project. Based on that experimental campaign, the data suggests that the ArcGuide™ coating, when applied around the tip receptor of each blade in a fleet of turbines, will result in about a 70% reduction in the number of punctures experienced by the fleet. That could have a significant impact on the overall performance of the wind farms that are most impacted by lightning.

We are now piloting the product on two wind farms, one in New Jersey and the other in Illinois. In both pilot studies, which are running concurrently, the ArcGuide™ coating has been applied to a group of GE 1.5sle turbines.

The sites were chosen in part based on the high likelihood that the turbines will be struck by lightning in the next year or so. Since lightning is a stochastic and unpredictable phenomenon, we are using these pilot studies to confirm what we already learned in the lab regarding the robustness of the coating.

We expect these studies to show that, in real-world conditions, the coating will not be damaged by lightning strikes or other environmental effects such as rain, particle impacts, sun exposure, etc.

PES: How are you planning to go to market with this product?

NF: We are partnering with a manufacturer that sells coating products to the wind industry. We are in the process of negotiating a technology license with that company and expect to officially launch the product later this year or early in 2023.

PES: Are there other products that you are developing for wind farm operators?

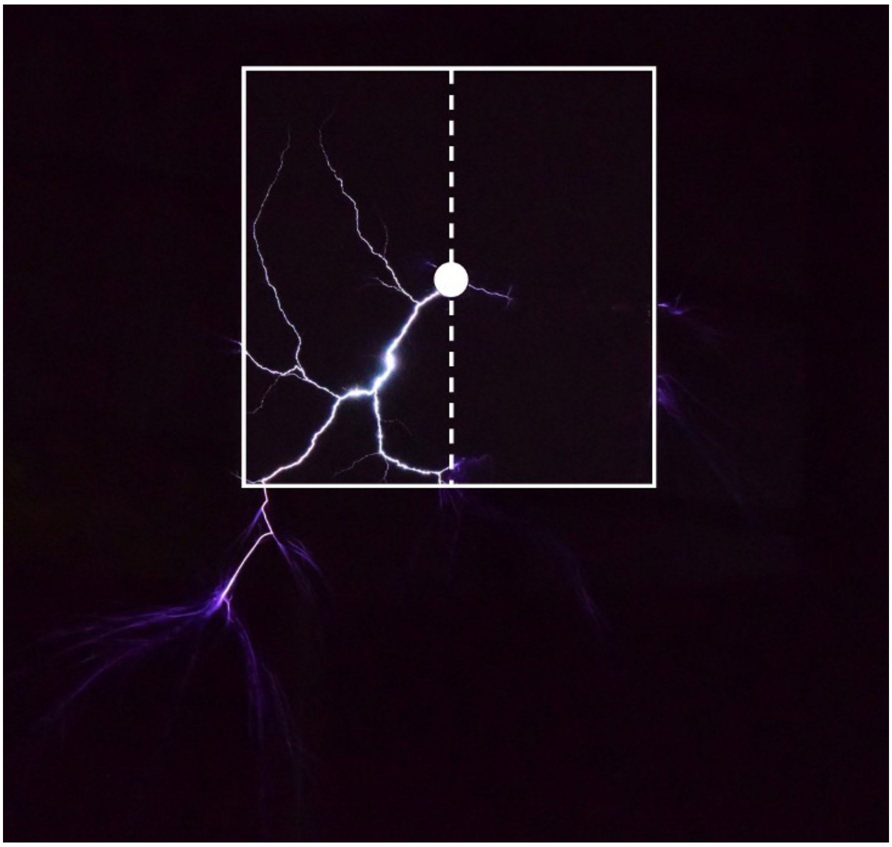
NF: Yes. While the lightning protection product will help to reduce operations and maintenance costs for wind farm operators, we are also developing a new wind farm control tool that will increase wind farm revenue by increasing annual energy production.

We are also actively working on two other technologies that have longer runways that address important issues related to wind and sustainability. One involves the introduction of new control actuators on wind turbine blades, which will allow next generation wind turbines to react more quickly to turbulence and wind gusts.

The other strays a little bit out of the wind energy lane, and focuses on developing a new approach to synthesizing nitric acid using only air, water, and electricity, without the need for fossil fuels.

PES: Tell me more about the wind farm control tool and how it will increase annual energy production.

NF: Wind farms today consist of an array of independently controlled turbines. We envision a future where wind turbines are collectively controlled to optimize yaw angles with the objective of continuously maximizing the total array power generation when operating in below-rated wind speeds.



The visualization of a panel with a lightning receptor at the center showing increased streamer and leader formation on the left half, treated with the ArcGuide™ coating, compared to the right half, coated with a standard topcoat. The increased electrical activity on the left makes it more likely that lightning will connect safely to the receptor and less likely that it will puncture the material

This will compensate for losses that are often caused by the wakes of upwind turbines impinging on downwind turbines, as well as losses associated with misalignment or otherwise non-optimal yaw angles.

PES: Other companies and research groups are looking into wind farm optimization. What makes your approach different?

NF: While other research groups are pursuing a similar objective using AI and machine learning algorithms, or model-based supervisory control schemes, we are developing a novel method that we believe will prove to be higher performing, more robust, easier to implement, and less costly than these other approaches.

Our method uses a model-free control framework known as Extremum Seeking Control (ESC), which is a popular control method used in the automotive and other industries. A 'model-free' approach is important with this application because the behavior of turbulent wakes behind wind turbines is notoriously difficult to model and depends strongly on many variables that are difficult to track.

AI algorithms that are trained to recognize patterns in large data sets are problematic for similar reasons, wake behavior changes as weather patterns change, making AI pattern recognition difficult. Our approach remains robust and simple while dispensing with these challenges.

Moreover, we are introducing the industry to a whole new class of controllers that we are betting will be the future control framework for the industry as a whole because of its simplicity, robustness, and lack of reliance on physical models, big data, or large capital investments. This framework is so compelling that we are setting our sights on an industry-wide application on all future wind turbines.

PES: What is your plan for introducing this product and how is it being funded?

NF: We are currently talking to several wind farm operators and turbine manufacturers about piloting the technology later this year. We will likely down-select to one farm for a limited initial pilot study, to be funded by a grant that we recently received from the National Science Foundation.

Next year, we intend to expand to additional wind farms. We are beginning to interview investors and strategic partners that are interested in helping us scale this rapidly across the industry.

www.arcturawind.com