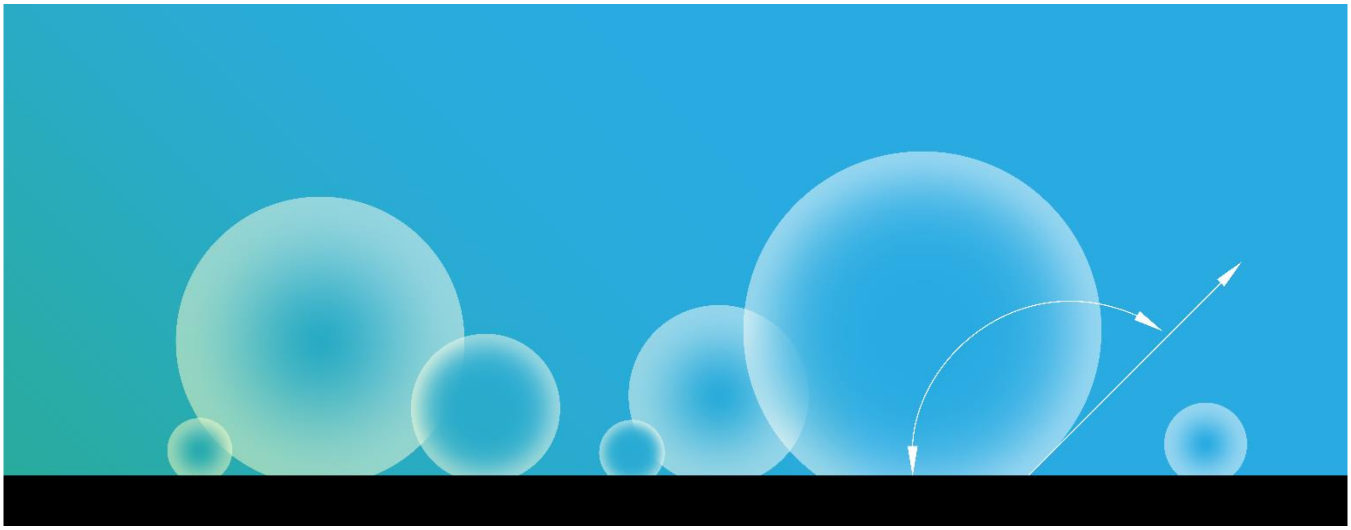
Feature—Repelling Water and Ice



Researchers Look at 'Super' Coatings for Transmission Systems, Power Plants

By Robert Ito

In December 2013, a massive ice storm slammed into Canada and the northeastern United States. Trees and branches fell on power lines and utility poles, and lines toppled under the weight of accumulated ice and snow. Damage exceeded $200 million, and outages climbed to the hundreds of thousands. To help reduce the occurrence and size of future outages, EPRI researchers are focusing on the latest icephobic and super-hydrophobic coatings.

The power system for decades has used traditional hydrophobic coatings, such as the silicone rubber used to cover high-voltage insulators on transmission lines. But silicone rubber is stickier than the porcelain or glass to which it is applied, so it often collects more contaminants that can damage the material it's supposed to protect. Super-hydrophobic coatings, on the other hand, repel water so completely that droplets roll off the surface, taking salt, silt, and other contaminants along with them.

EPRI evaluated 12 advanced coatings from different manufacturers, focusing on their ability to repel ice, water, and contamination on insulators and conductors in transmission systems. Some of these coatings are commercially available for other applications, such as drilling rigs and cruise ships. EPRI found that several coatings improved performance and had no major flaws that could result in component degradation. Field tests later in 2015 will focus on the successful coatings at three separate sites. In 2016, researchers will explore the use of super-hydrophobic materials on power plant components, including steam turbines, steam condensers, and cooling towers. These coatings have commercial potential to reduce power plant damage due to corrosion and erosion, protect transmission lines from salt and icing, and improve grid reliability.

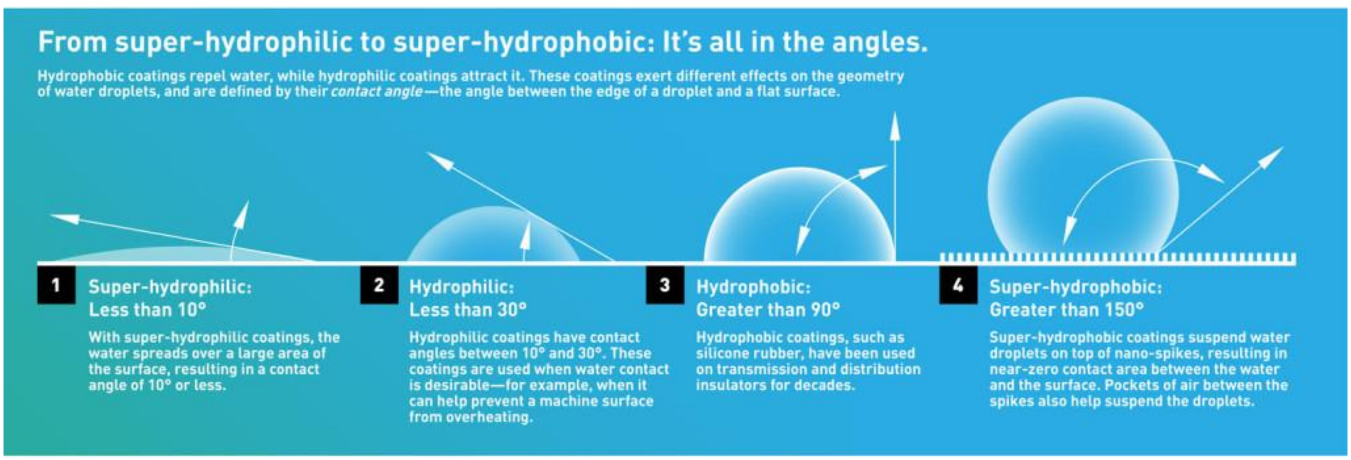
Encouraging Laboratory Tests on Conductors and Insulators

Ice accumulation on conductors, particularly during severe weather, poses enormous dangers to transmission lines. These dangers include conductor galloping, flashovers caused by melting ice, and high dynamic loads when large chunks of ice fall from the conductors. Super-hydrophobic coatings can potentially reduce this accumulation, preventing damage to power lines and improving grid reliability. In coastal regions with salt-laden air or in areas near salted roadways, these coatings have the potential to be used on the insulators that connect transmission line wires to towers as well as to insulators in substations. This can prevent flashovers across insulators due to salt exposure, protecting lines and substation equipment from potential damage.

Since 2012, EPRI Transmission Director Andrew Phillips has led evaluations of these and other applications of icephobic and super-hydrophobic coatings and surfaces. In EPRI laboratories, Phillips' team first tested the extent to which 12 coatings from various manufacturers repel water and ice, reduce contamination buildup, and withstand various environmental conditions and mechanical wear. Next, researchers compared the coatings' performance when applied to insulators and conductors. To test for icephobicity, the team adhered small ice cylinders to coated surfaces and measured the amount of force needed to break them off. To evaluate contamination buildup, they placed coated ceramic insulator bells inside a cage with barn owls at the Carolina Raptor Center and observed their ability to repel owl excrement. To test self-cleaning, they applied a mixture of kaolin and salt to coated surfaces, froze the contaminated samples, and then observed the contaminant layer as the samples thawed.

Findings were particularly encouraging in two key areas—ice adhesion and self-cleaning. In the ice adhesion experiments, coatings reduced the force needed to remove the ice from 900 kilopascals to less than 200 kilopascals, indicating that ice is more likely to fall off with a power line's normal motion in the wind. In the self-cleaning tests, the contaminant layer clumped up away from the surface of all 12 coatings. Future tests will determine how easily and under what conditions these solid clumps will roll off the insulators.

Lab tests on insulators and conductors demonstrated that six different coatings improved performance without damaging components. Following successful field tests on those coatings, commercial applications could come as early as three years, according to Phillips. He expects that initial commercial applications will address problems specific to cold, wet regions, coastal zones, and along freeways.



Identifying Power Plant Applications

In a typical steam turbine at a gas, coal, or nuclear plant, large rotor blades up to 4 feet long spin at 3,600 revolutions per minute. From the steam flow, a film of condensed water builds up on the blades. Droplets form and fly off, striking blades downstream and causing corrosion and other damage to these costly components over time. Super-hydrophobic coatings can potentially reduce this damage by preventing or minimizing droplet formation.

"On a large turbine, a row of blades can cost up to a million dollars, and they need to be replaced about every 10 years," said EPRI Principal Project Manager Sam Korellis. "If we can minimize replacement of these blades, we increase operational time and power production. This application can also increase plant efficiency by improving the condition of the turbine. It's a double win."

Turbine blades are one of several power plant components that Korellis has targeted for potential application of super-hydrophobic coatings and surfaces. Another example: By applying these materials to steam condensers, water beads and drops off immediately, instead of coating condenser tubes with a water film that impedes heat transfer. “This can significantly improve heat transfer in the condenser, resulting in greater efficiency in the steam turbine cycle,” said Korellis, adding that super-hydrophobic coatings also may improve heat transfer in feedwater heaters and cooling towers.

Korellis is looking at material compatibility, durability, and other factors to determine the suitability of different coatings for various power plant applications. For example, some coatings might work well on copper-based tubes but not on steel or titanium. Others might be long-lasting but could scrape off when a component is installed or moved.

Looking to the Future

Phillips begins the final phase of the transmission line research this fall at field sites in New York City (Con Edison), the Catskill Mountains (New York Power Authority), and Georgia (Southern Company). His team will apply six different coatings to insulators and conductors and compare their performance to uncoated insulators and conductors for 18 months. “This research can provide real-world data to help utilities select the most appropriate coating for the specific application under consideration,” said Phillips.

In 2016, EPRI will begin research of super-hydrophobic coatings applied to steam condenser tubes, testing their durability and performance over 12–18 months in the laboratory and, if successful, over a longer period in operating plants. “We’re starting with condenser applications because they offer the biggest and most immediate cost-savings potential,” said Korellis. Also in the near future, he plans to start lab tests on coated and uncoated turbine blades, placing them inside lab-based steam tunnels and observing their performance as high-velocity moisture-laden airstreams hit the blades.

Although various coatings’ longevity and durability remain big unknowns and could pose major obstacles to commercial use, researchers see enormous potential for applications in the power generation. “With further research and testing, these materials can potentially make the power plants more efficient, reliable, and cost-effective,” said Korellis. “They may reduce how much fuel we burn to make a megawatt of electricity, and if we burn less fuel, we pollute less.”

Key EPRI Technical Experts

Andrew Phillips, Samuel Korellis