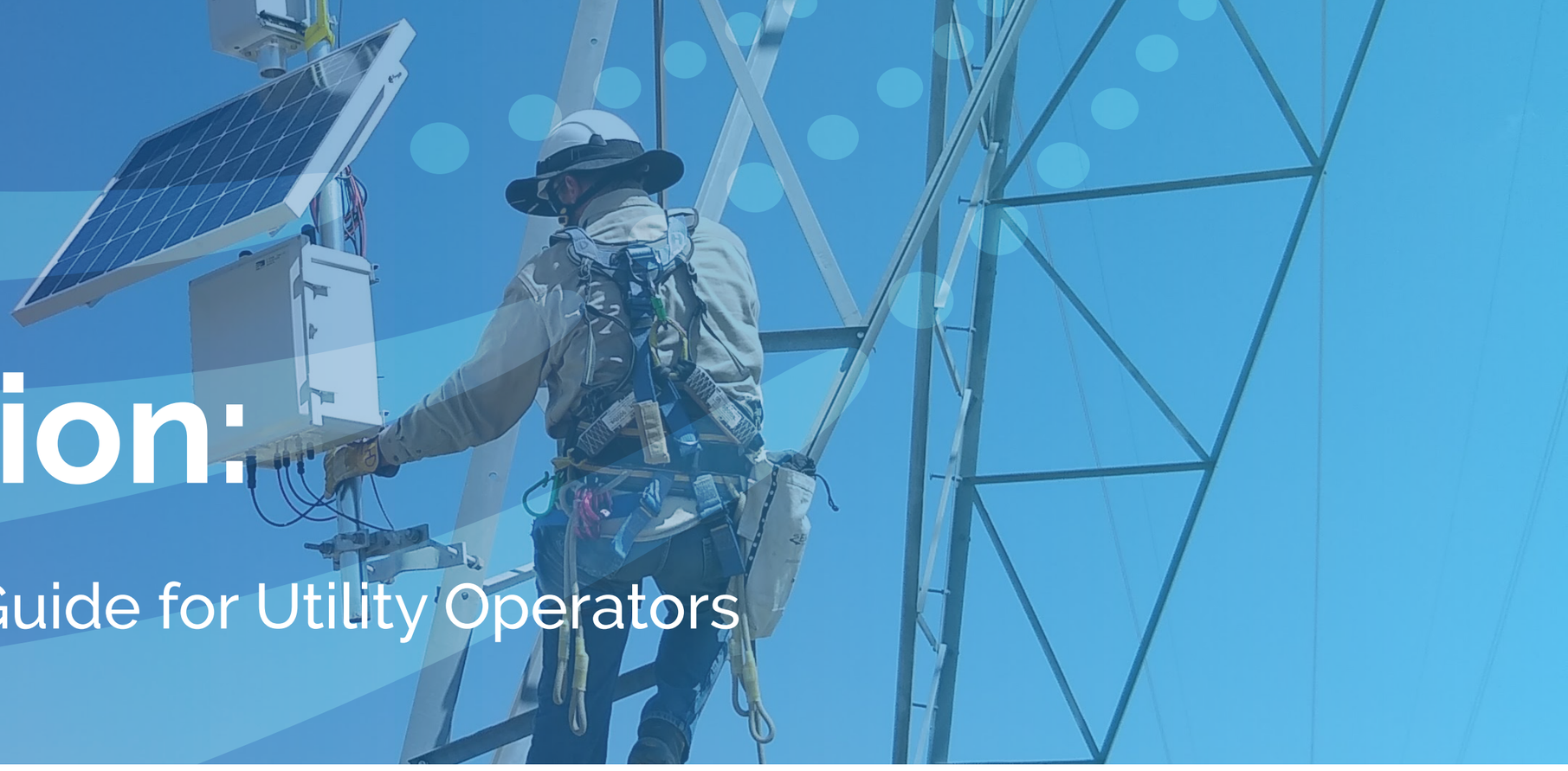

LineVision:

The Icing Event Guide for Utility Operators

Connecting disparate energy centers and traveling through some of the most remote areas, our transmission lines are constantly exposed to different atmospheric conditions. Local weather can have huge impacts on transmission lines' physical states and operations. While hotter temperatures generally mean more significant transmission line sag and stress on the transmission system than cooler days—cold weather presents its own set of challenges to system management due to threats from icing events. As climate crisis impacts bring more low-probability and high-impact weather events, including more cold snaps and polar vortexes, one task that utilities are eager to address is improving grid resiliency by best managing icing events.

Ice buildup on power lines, or icing, can be a common issue for utilities in cold or temperate regions, where storms can deposit thick layers of ice on power assets, including transmission lines, towers and shield wires. Icing typically builds up in temperatures ranging from -15°C to 2°C and can be unpredictable, taking anywhere from several days to less than an hour to build to a critical weight load. Adjacent spans and lines can experience icing differently so that ice can fall from one line while remaining built up on another.

Icing events present risks to the operability of the transmission system and useful life of those transmission assets. The biggest challenge for utility management of icing events is often a simple, foundational issue: knowing when the icing is occurring. Utility operators can prevent critical system failures like line shutdowns or asset damage through simple condition-based monitoring and management with LineVision's suite of technology, including LineAware™, LineHealth™ and the LineRate™ Suite.

CLASSIFICATION OF ICING

In-cloud icing

- Glaze due to super cooled cloud/ fog droplet
- Hard rime
- Soft rime

Precipitation of icing

- Glaze due to freezing rain
- Wet snow accretion
- Dry snow accretion

Ice and snow type	Densisty (kg/m^3)	Description
Glaze Ice	700-900	Pure solid ice, sometimes icicles underneath the wires. The density may vary with the content of air bubbles. Very strong adhesion and difficult to knock off.
Hard rime	300-700	Homogenous structure with inclusions of air bubbles. Pennant shaped against the wind on stiff objects, more or less circular on flexile cables. Strong adhesion and more or less difficult to knock off, even with a hammer.
Soft rime	150-300	Granular structure, "feather-like" or "cauliflower-like". Pennant shaped also on flexible wires. Can be removed by hand.
Wet snow	100-850	Various shapes and structures are possible, mainly dependent on wind speed and torsional stiffness of conductor. When the temperature is close to zero it may have a high content of liquid water, slide to bottom side of the object and slip off easily. If the temperature drops after the accretion, the adhesion strength may be very strong.
Dry snow	50-100	Very light pack of regular snow. Various shapes and structures are possible, very easy to remove by shaking of wires.
Hoar frost	<100	Crystal structure (needle like). Low adhesion, can be blown off.

Source: CIGRÉ TB 291, "Guidelines for Meteorological Icing Models, Statistical Methods and Topographical Effects", April 2006, pp. 11.

In-cloud icing, a particularly dense form, increases the tension of the conductor enough to encourage the utility to melt the ice. Photo: Gerhard Biedenbach, LineVision.

PREVENTING LINE SHUTDOWNS

The LineAware system offers utilities continuous situational awareness monitoring, monitoring the position of the conductors and shield wire using an optical sensor and alerting operators to icing events so they can respond before the ice causes damage or loss of service. Coupled with LineVision's asset management system, LineHealth, the system compares the data from the non-contact optical sensors with digital twin rendering technology to detect when a conductor is experiencing an anomaly, such as excessive sag due to icing.

Utilities are provided with data on the density of precipitation on the conductor, tension and maximum deformation experienced during an event. Applying principles from CIGRE TB291's "Guidelines for meteorological icing models, statistical methods and topographical effects," LineVision's system can help classify the type of ice and snow the lines are experiencing and intelligently monitor the ice buildup and growth rate. With LineVision, utility operators can know when to deploy mitigation actions.

The transmission lines

Deposits of ice on a wire can cause increased sag and clearance violation risks. Utility operators can schedule mitigation actions in advance before any risk to assets or the public occur. De-icing tactics include changing switches to put more power through the line to heat it up and melt the ice off or dispatching technologies like robots that attach to the conductor to travel along it and remove the ice.

Transmission towers

Though rare, the weight of extreme line sags can also exert weight on a transmission structure beyond what they were designed for, causing its arms to break or topple over. Additionally, asymmetric ice loads from ice shedding can exert a torque force onto and damage a tower and tower members. LineHealth identifies damage to towers, tower members or insulator strings by tracking changes to the sag or temperature characteristics of the conductor. LineHealth can also detect when a conductor slips in the suspension clamps due to asymmetric ice loads on adjacent spans and triggers an inspection alert.

The shield wires

Some of the more significant line shutdowns, however, come from the lesser known transmission asset–the shield wire. They are positioned on top of a transmission structure for protection against lightning and generally are a smaller and weaker line. The shield wire struggles more than the other lines to withstand the weight of icing and can sag significantly, often enough to touch a conductor line. This type of shield wire sag causes a fault condition with the tower's phases and trips the line out of service. LineVision's optical sensors pick up movements in the shield wire as well as the conductors to trigger mitigation actions such as shutting a line out of service before coming in contact with the shield wire.

Ice has dropped on the outer phases only. The middle phases are still carrying ice. Photo: Gerhard Biedenbach, LineVision.

Ice has dropped in the left span but is still available on the right span. Suspension insulator swings to balance the tension. That decreases sag in the left-hand span and increases sag even more in the right-hand span. Photo: Gerhard Biedenbach, LineVision.

PREVENTING ASSET DAMAGE

Plastic elongation

Icing events' impacts can be felt long after the icing event because of damage they inflict on transmission assets. Conductor plastic elongation is an important metric to track. Icing puts excessive mechanical load on, and increases the tension of, a conductor. If that line is stretched beyond its tension limit, it can cause permanent plastic elongation of lines. A conductor that is loaded with excessive weight from icing in the winter will sag more dramatically during the summer.

LineHealth not only tracks the new permanent sags of affected transmission lines and alerts utilities to these changes but also analyzes any reductions to their useful lives. LineHealth calculates estimated residual lifetime of each line by combining any icing event data with previous data on conductor thermal history, loading events, and sag behavior. The software helps enable operators to make condition-based maintenance decisions.

Galloping

When ice begins to build up on a conductor or asymmetrical ice shedding on a line occurs, winds crossing the conductor can act as a source of lift, causing a line to bounce up and down or "gallop." LineAware tracks the frequency, amplitude and duration of the galloping event, and LineHealth monitors conductors to inform operators of the impact to their assets' useful life.

PRIORITIZING HEALTHY LINES

Despite utility operators' best efforts to prevent outages or asset damage, they still need measures in place if an issue arises.

Dynamic line ratings

Although transmission lines sometimes represent areas of vulnerabilities, they can also represent reserves for support. For example, an icing event and subsequent line outage can prompt utilities to implement line prioritization measures to redirect energy flow to other lines, similar to a shoulder lane on the highway. LineVision's LineRate solution helps utilities manage that line prioritization by knowing the true available capacity on other lines in their fleet.

CONCLUSIONS

Utilities in areas prone to icing face huge potential costs in asset maintenance or replacement and risk the loss of power delivery to customers in the middle of inclement weather. For utilities at risk of ice buildup on their assets, LineVision's suite of advanced transmission monitoring technologies provide full visibility into icing events as they occur. The monitoring system identifies ice buildup and alerts asset owners, empowering them to make decisions to prevent damage or loss of service. LineAware and LineHealth allow owners to identify and mitigate potential failures while icing is occurring and to assess for damage after icing passes.

Reach out to LineVision to learn more about strategies for de-icing your lines with advanced transmission monitoring.
Contact LineVision at info@linevisioninc.com or visit www.linevisioninc.com.

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