MARCH 2021 COLORADO WINTER STORM: A GRID OPERATIONS PERSPECTIVE
WHITE PAPER

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WEATHER BACKGROUND MARCH 13 AND 14, 2021

Over the weekend of March 13th and 14th 2021, the Denver area and its suburbs were subjected to a winter storm that measured more than two feet of accumulation. The heavy snow started in the afternoon on Saturday the 13th, in some areas the snow lessened, plus ground temperatures above 32 degrees Fahrenheit allowed some melting, but quickly led to refreezing and heavy accumulation overnight that lasted well into Sunday. By early Sunday morning, between 10 and 17 inches of snow were already reported in the Fort Collins and Wellington areas, with around two feet in the foothills of Larimer County. The heavy, wet snow had accumulated on trees and powerlines, producing scattered power outages. Early Sunday morning the storm moved South across Greeley and into the entire Denver Metro area. The important factor for utilities in the area was that the earlier ice and heavy wet snow were joined by extreme winds causing blizzard conditions. The National Weather Service recorded, snowfall measurements of one to two inches per hour and more importantly sustained winds reaching 20-30mph and gusts of 40mph, in some locations creating extremely treacherous visibility and road conditions for utility vehicles to travel (Summary, 2021).

WINTER WEATHER RISKS TO A UTILITY

Accumulation on power lines can pose significant issues for utilities and their restoration crews. When combined with high winds, the threat can become serious. Crews working near these lines risk being struck by nearby collapsing vegetation, but the greatest safety risk is simply moving personnel and material. Vehicle travel away from the major highways can be treacherous for utility crews with ice under layers of snow. The Denver area event even caused outages from private vehicles colliding with power poles. Without material and personnel prepositioning the sustained outages can be prolonged.

High winds may cause ice laden lines to gallop, and if the wind is significant, the galloping lines may collide causing faults, downed lines, possible equipment damage and sustained power outages.

According to Xcel Energy's outage map, as of Sunday the 14th at 10 pm, 24,871 customers were without power in northern Colorado, mostly around Greeley. More than 600 people worked Sunday to restore the power, said Hollie Velasquez Horvath, senior director of state affairs and community relations at Xcel Energy. The heavy snow as well as high winds displaced powerlines, snapped utility poles and damaged the arms that connect the powerlines to the poles, she said (Schmelzer, 2021). In comparison only 500 customers in the Denver Metro area remained without power by 10 pm Sunday.

No cost estimates have been made public yet from the March 13 and 14th event, however, a single 3-day event, studied by the Federal Emergency Management Agency (FEMA) in 2008, estimated damage and loss of function costs of $1.33 million in 2007 dollars (Loss, 2021). Understanding the issue of ice accumulation can be extremely helpful for transmission and distribution system operators and help them take advantage of the value provided by asset specific snow, ice and wind forecasts.

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PROBLEMS DUE TO ICE ACCUMULATION ON THE ELECTRICAL GRID:

- Combined impacts of ice on generation and power lines can force load shedding, impacting hundreds to thousands of households and critical businesses in need of electricity, heat and water.
- Increased component fatigue from snow, ice and wind loads can cost millions in infrastructure replacement.
- Utility personnel out of position and unable to travel can cause understaffing in control centers, as well as, personnel and material shortages for restoration crews.
- Increased labor and material costs, as well as, lost revenue associated with sustained outages.
- The most worrisome is the safety risk to employees and the public due to ice shedding, flashover events, fallen or at-risk vegetation, downed structures and vehicle travel.

OBJECTIVE

The intent of this March 13-14, 2021 winter storm review is to help utility industry professionals have a better understanding of the types of ice accumulation to transmission and distribution assets and to clearly understand the weather patterns and conditions that lead to icing. Understanding the different types of ice accumulation will allow for more informed business decisions. Then we will show how increased awareness of asset specific forecasts, and customized alerts, has helped with preparedness and optimized restoration.

FORECAST METHODS

There are multiple forecasting methods. Publicly available forecasts such as television and the National Weather Services can bring awareness to precipitation based icing and freezing fog. However, they are targeted to predict just ice accumulation on surfaces and roadways, and lean toward more populated areas. Forecasts from private and commercial sources, continue to improve and new ensemble model forecasts are more accurate and can target ice accumulation forecasts at electrical conductor heights. Additionally, alerts can be issued to provide advance notice of impactful events. Larger utilities may have meteorologists on staff who can perform a deeper analysis of weather patterns and conditions to deliver a more asset specific impact forecast. This can be especially valuable for in-cloud icing events in elevated terrain areas, or localized extreme wind events. However, not all utilities have this luxury.

TYPES OF ICE ACCUMULATION, RELATED WEATHER CONDITIONS, PROPERTIES

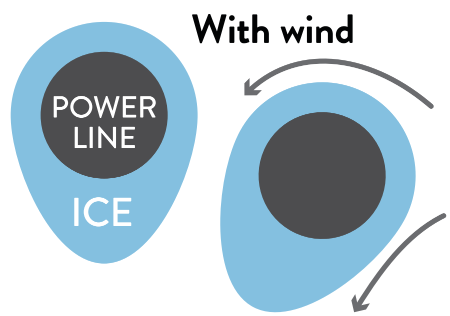
PRECIPITATION BASED ICING

- Freezing drizzle
- Freezing rain
- Wet snow

Freezing drizzle and freezing rain occur when supercooled water droplets fall onto the surface of an object (electric conductor, structure, or tree limb) with a temperature below freezing. In the case of freezing rain, light precipitation events over a long duration, greater than 6 hours, are much more concerning than heavier precipitation events, with moderate to heavy freezing rain. One reason being the heavier event usually lasts a short period of time and the rate of precipitation is such that adequate time for ice formation and accretion is inhibited.

Wind speed during an event of 10 mph or higher is an important factor in the ice accretion process. Higher wind speeds will generate larger accumulations of ice. The wind speed is essential to ice formation because it dissipates the surface heat and heat from UV radiation. Ice can still occur at low wind speeds, but the accumulation will be less.

The wind speed plays a second role. In the absence of significant wind, ice forms on power lines in a teardrop shape. During events with significant wind, power lines oriented perpendicular to the mean wind direction will accumulate more ice in an airfoil, or aircraft wing shape and when the load is great enough and winds strong enough, the ice accumulation shape can promote lift and the lines can begin to gallop. Galloping can cause wires to eventually touch, resulting in a fault, or even prolonged power outage if faults keep occurring. The increased movement can also cause cross-arms to break bringing powerlines to the ground (King-homan, 2021).



The time of day is also important, there is a marked drop in ice accumulation from noon to 6 pm due to solar radiation effects. Events before or after these hours are more likely to be significant.

Wet snow can cause ice accumulation on equipment because it is made up of partially melted snow crystals which can stick to the surface and freeze upon contact. A wet snow icing event followed by a cold snap with very low temperatures can cause strong accretion of ice that can persist for an extended period of time (days).

Precipitation based icing is the best understood type of icing by the lay person and it is also the most frequently forecast type of icing by local TV and National Weather Service sources. Precipitation based icing results in a glaze type of icing. The ice accumulation that occurs from precipitation events is generally clear in color and has the highest density of the icing types. The rate of accumulation is dependent on the following:

- Wet bulb temperature
- Wind speed / stronger winds = more ice
- Rate of precipitation

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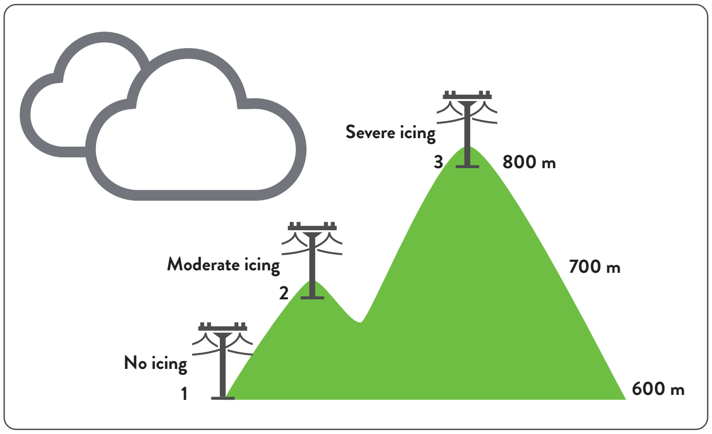

IN-CLOUD ICING

- Impacts transmission lines in mountainous terrain
- Most likely to cause long term, dense, ice load events
- Transmission structures susceptible to channeled high force winds
- Investigation and repair complicated by remoteness and weather hazards

In-cloud icing occurs when super-cooled water droplets in the cloud come in contact with a surface (transmission conductor or structure) and freeze on impact. Not only is in-cloud icing the most common type of icing on transmission lines in higher elevations, it also has the most significant impact with pro-longed events lasting over 24 hours, and significant ice accumulation is possible. In-cloud icing is dependent on the height of the cloud base.

In-cloud icing is the most complex type of icing because it can result in a combination of ice accumulation.

- Glaze
- Hard rime

In the first category, in-cloud and precipitation-based icing can occur at the same time resulting in a heavy glaze ice accumulation. In the case of rime icing, accumulation is dependent on the water droplet size, wind speed and atmospheric moisture content. Forecasts for in-cloud icing are challenging and typically come from private sources.

FREEZING FOG/MIST

- Usually results in light ice accumulation
- Often not well forecasted
- Prolonged events can occur causing bigger issues

As with in-cloud icing, accumulation of ice occurs in freezing fog or mist when super-cooled, tiny water droplets come in contact with a surface that has a surface temperature below freezing. This form of icing can occur with air temperatures well below freezing. It can also occur when air temperatures are above freezing but the surface is below freezing.

Icing from freezing fog and mist results in a soft rime accumulation which has the lowest density of the ice types and often has a frosty appearance. This type of icing is more common in the central and northeast United States in the mid to late winter. One common scenario when freezing fog occurs is when an arctic cold front with shallow, dense air undercuts a warmer, moist airmass in place causing lift, clouds and in some cases, even freezing mist/fog. Another example would be when a warmer, moist airmass is transported into a region with snow cover. Cooling occurs, the airmass becomes saturated and fog develops. At that point the tiny water droplets of fog can freeze onto the cold, surrounding surfaces.

Long duration events, greater than six hours, are critical. Events lasting 1-2 days should be of greater concern. Wind is again important primarily because it causes a greater mass horizontal flux of water droplets to the equipment or wire increasing accumulation. If the freezing fog event lasts a day or more the ice accumulation could become great enough to trigger galloping in the right wind conditions. Even on overcast days the ground absorbs solar radiation which can raise temperatures a few degrees which could warm conductors. Therefore, these events are more impactful if there is snow cover and if the temp is below 30 degrees during the event.

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UTILITY EXPERIENCES AND ACTIONS FROM MARCH 10 - 14

Indji Systems investigated this Colorado storm with a utility customer and it proved the value of asset specific forecasts alerts that can help electrical system supervisors and operators to pinpoint the areas of greatest concern for their service territory and make proactive operational decisions. Hourly updated asset specific forecasts already provided several days advance notice of a significant snow event. But, during the very early hours of Thursday morning the 11th the operations team started to get alerts for assets that were expected to accumulate ice above .21 inches at conductor height combined with forecasted wind speeds up to 24.6 mph, and above .21 inches and exceeding 22.5 mph for assets near Greeley. Their custom alert thresholds were set to automatically alarm for a combination of ice accumulation greater than .2 inches and wind speeds above 15 mph. The alerts, which started 48-60 hours in advance predicted these conditions to last from 4 pm MST on Saturday the 13th until 7 am MST on Sunday the 14th, and subsequent forecast alerts extended these conditions until late afternoon on the 14th. This precipitation-based icing was accompanied by heavy wet snow that was forecasted to exceed 16 inches in some substation locations, and as we know it exceeded two feet in many locations by Monday the 15th.

The utility asset specific forecast alerts allowed management to schedule extra control center personnel to be on-hand to handle the potential volume of momentary and sustained outages from Friday evening through Sunday. They were even prepared to offer nearby hotel rooms for operators during their rest period. Outage response crews and material were prepositioned to minimize travel delays and improve both safety and restoration time. In severe, prolonged events, the advance notice could even be used to muster resources from nearby utilities not expected to take the brunt of the storm.

CONCLUSIONS

Icing to power lines can grow to become more serious during a longer duration event and can become a critical problem when these heavy ice and snow loads are combined with extreme wind events. Asset specific advanced awareness and alerting of these events will increase preparedness and aid in mitigation efforts to reduce the impact the event has on operations. Consider the following actions that could take place:

- Awareness of expected significant events could lead to faster and more informed decisions by transmission and distribution operators to help mitigate faults, avoid damage to equipment and prevent sustained outages.
- Smarter response planning including material and labor scheduling through awareness of the event duration and total impact.
- Improved safety awareness by prepositioning, minimizing travel and determining the vegetation ice load threat.
- Fine-tuning of power forecast and scheduling of supplemental generation to account for increased consumer demand (system load) at a time when availability issues may arise from ice damage and related outages.
- Forensic analysis of these events can help system engineers better understand at-risk infrastructure and plan for methods to reduce the impact of ice related damage in the future.

Forecasts from commercial providers continue to improve in this area. Industry stakeholders can expect and should require continued improvements in the area of ice forecasting accuracy and advanced alerting of events to help mitigate the impact to operations.

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