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ComEd Post-Storm Distribution Reliability and Maintenance Inspections

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SUMMARY

Storms are a common feature of life in northern Illinois. These volatile events can come in the form of tornadoes, blizzards, and derechos, among others. In the aftermath of destructive weather, ComEd seeks to identify and mitigate latent damage on its infrastructure. It is the responsibility of ComEd's Grid Analytics team to create and execute an effective post-storm patrol process to locate and remediate this damage to ComEd facilities before subsequent outages interrupt our customers' service. In the past, the list of locations identified as requiring inspection was generated by members of ComEd's Emergency Response Organization based on distribution circuits that experienced a lockout during a given storm event and circuits that had a mid-circuit recloser operation. This procedure did not account for weather. ComEd's Grid Analytics team's newly-established process for determining post-storm inspection locations include weather datasets such as wind speed, lightning density, and NWS preliminary LSRs. The intent of the new procedure is target areas with a high probability of damage to increase the damage find rate in the wake of storms.

KEYWORDS

Reliability, Severe Weather, Inspections, Preventative Maintenance, Analytics

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1 RELEVENT ACRONYMS

NWS – National Weather Service
LSR – Local Storm Report
FAA – Federal Aviation Administration
DOD – Department of Defense
ASOS – Automated Surface Observing Systems
AWOS – Automated Weather Observing Systems
KMZ – Keyhole Markup Language
DC – Direct Current
FALLS – Fault Analysis and Lightning Location System
SPC – Storm Prediction Center
SWOP – Significant Weather Observation Program
GIS – Geographic Information System
NCEP – National Centers for Environmental Prediction
NARR – North American Regional Reanalysis

2 INTRODUCTION

Storms are known for leaving destruction in their wake including damage to homes, hampered travel, and power outages. These outages impact the U.S. economy to the tune of $20 billion to $55 billion annually [1]. When storms traverse a utility's electrical grid, they can also leave latent damage on overhead equipment that could cause future outages when said equipment fails. It is the duty of ComEd's Grid Analytics team to create and execute an effective post-storm inspection process to locate and remediate this damage to our facilities before it interrupts customers' service. Historically the post-storm procedure only used outage data in selecting inspection locations; only circuits that experienced a lockout during a given storm event and circuits that had a mid-circuit recloser operation were put on the inspection list. Grid Analytics hypothesized that incorporating weather data as opposed to outage data would produce a higher damage find rate following storm events. Several sources were considered for use, including data from the NWS/FAA/DOD ASOS/AWOS, lightning density, and NWS LSRs. On certain occasions with very localized damage (like tornadoes), the local Chicago NWS office also publishes KMZ files of damage paths when they complete their surveys. The team is able to overlay those paths with geographic representations of our system and tell maintenance inspectors exactly where to go to look for damage.

3 WEATHER DATASETS

Each storm that impacts the ComEd service territory is different. These unique events mean that datasets for post-storm analytics must be chosen on a case-by-case basis. This section describes several weather datasets that are considered when performing inspection location selection. Some storms require the use of more datasets than others, and there are times when certain datasets are not applicable at all (i.e. tornado paths do not exist when no tornado occurred).

2.1 Wind Observations from ASOS/AWOS Stations

Wind is often a main outage driver during a storm event, whether it causes damage directly to equipment or impacts nearby trees that interact with utility infrastructure. ComEd gathers observational data from ASOS/AWOS stations, which are situated at various airports in and around the service territory. These stations use sensors to record automated observations at various intervals and report them to the public.

Figure 1: Photo of an ASOS station in Peoria, IL (not one of the stations ComEd uses, but a good example of what they look like) (Source: Wikipedia)

ComEd presently uses the following ASOS/AWOS stations; note that several are outside of the service territory but are closest to some customers:

Site	Station Name	Airport	Network
SFY	Savanna	Tri-Township Airport, Savanna, IL	AWOS
MLI	Moline	Quad Cities International Airport, Moline, IL	ASOS
FEP	Freeport	Albertus Airport, Freeport, IL	AWOS
SQI	Sterling/Rock Falls	Whiteside County/Jos H Bittorf Field, Rock Falls, IL	AWOS
RFD	Rockford	Chicago/Rockford International Airport, Rockford, IL	ASOS
RPJ	Rochelle	Rochelle Municipal Airport/Koritz Field, Rochelle, IL	AWOS
DKB	DeKalb	DeKalb Taylor Municipal Airport, DeKalb, IL	AWOS
VYS	Peru	Illinois Valley Regional-Walter A Duncan Field, Peru, IL	AWOS
UGN	Waukegan	Waukegan National Airport, Waukegan, IL	ASOS

PWK	Palwaukee	Chicago Executive Airport, Wheeling, IL	ASOS
ARR	Chicago/Aurora	Aurora Municipal Airport, Aurora, IL	ASOS
C09	Morris-Washburn	Morris Municipal Airport-James R. Wasburn Field, Morris, IL	AWOS
JOT	Joliet	Joliet Regional Airport, Joliet, IL	AWOS
LOT	Romeoville/Chi	Lewis University Airport, Romeoville, IL	AWOS
DPA	Chicago/DuPage	DuPage Airport, West Chicago, IL	ASOS
ORD	Chicago O'Hare	Chicago O'Hare International Airport, Chicago, IL	ASOS
MDW	Chicago	Chicago Midway International Airport, Chicago, IL	ASOS
IGQ	Chicago/Lansing	Lansing Municipal Airport, Lansing, IL	AWOS
IKK	Kankakee	Greater Kankakee Airport, Kankakee, IL	AWOS
PNT	Pontiac	Pontiac Municipal Airport, Pontiac, IL	AWOS
C75	Lacon	Marshall County Airport, Lacon, IL	AWOS
CWI	Clinton	Clinton Municipal Airport, Clinton, IA	AWOS
EFT	Monroe	Monroe Municipal Airport, Monroe, WI	AWOS

Table 1: List of ASOS/AWOS stations from which ComEd's Grid Analytics team collects data

ASOS wind observations are collected as follows: per the ASOS User's Guide [2], "the rotating cup anemometer and the simple wind vane are the principal indicators of wind speed and direction." The older incarnation of this system, which is still used at some stations, "consists of a cup-driven DC generator with an output calibrated in knots and a vane coupled to an indicator by means of a DC synchro-system." The newer system, which is the current standard, uses "electro-magnetic signals generated by the rotating cup and wind vane are directly converted into reportable values by ASOS." The observation height is currently federally mandated to be sited at 10 meters (32.8 feet). Most ASOS wind sensor heights are either at 27 feet or 33 feet depending on site-specific requirements. Wind speed measurements are reported once every minute are based on a two-minute average that is updated every five seconds. Wind gusts are reported only when the reporting observer or the ASOS algorithm detect certain conditions. Wind direction is reported once per minute and is a two-minute average of five-second average wind directions. The direction is reported to the nearest ten-degree increment and is relative to true north.

Figure 2: Image of Vaisala's WINDCAP Ultrasonic Wind Sensor WMT700 Series; this is a wind sensor used in certain ASOS stations from 2017 onward (Source: Vaisala)

In the post-storm inspection process, maximum wind gust observations at each station are matched geographically with their closest locations within the territory. Geographic areas are then ranked from highest wind gust experienced to lowest when determining risk scores associated with post-storm inspection locations.

2.2 Lightning Density

Lightning strikes have the potential to cause massive damage to electrical infrastructure. Within ComEd's service territory, approximately 330,000 lightning strokes occur each year.

ComEd's Grid Analytics team uses the FALLS software from Vaisala to detect and catalogue lightning strokes along with information on stroke polarity and intensity. These locations can then be correlated with geographic areas and equipment features around the service territory. In storms with lightning activity, geographic areas with the most significant lightning density are risk scored higher than areas with lower or no lightning density when selecting post-storm inspection locations.

3.3 NWS LSRs

LSRs are reports of weather information that the NWS deems credible and publishes. The LSRs socialized by the SPC have a number of sources, most of which are external to the SPC. These reports can come from weather spotters, local officials, news media, the public, etc. and generally contain information about hail size, wind gust magnitude or damage, tornadoes, snowfall amounts, rainfall amounts, and more. The local SPC office conducts some sanitization of the reports and they are then redistributed to the public. They remain preliminary until they are certified locally and nationally (after which they end up in the NWS Storm Events Database). Because these reports come from such a wide variety of sources, the measurement techniques are variable. For example, weather spotters might have their own equipment for measuring winds or rainfall and as such can occasionally report actual measurements. The general public, however, might post pictures of downed trees on social media; although not a measurement, these photos indirectly give us information about the wind (e.g. Beaufort Wind Scale, as shown in "Tips for Estimating Wind Speeds for SWOP Observers" [3]). Although these reports are not nearly as standardized as ASOS/AWOS observations, they can provide a “boots on the ground” perspective that exclusively stationary observing equipment cannot.

When using LSRs, the team takes several variables in the dataset into consideration. First, the availability of the types of LSRs are assessed. Usually wind observations are most closely related with damage, but occasionally things like hail and flooding are also relevant. Sometimes only wind observations that include a magnitude are used, occasionally narrowed down further to observations that were actually measured as opposed to estimated. In other cases, the team uses reports that reference particular types of damage such as downed trees, building damage, etc. After the set/subset of reports are selected, the next important variables of consideration are latitude and longitude. The presence and accuracy of the geographic locations of the reports are just as important (if not more important) than the actual measurements. The coordinates allow the reports to be associated with a geographic area or even the nearest circuits. In a weather event where wind was a significant driver of outages, the LSRs tend to be a valuable source on which to rely because they can significantly focus post-storm efforts onto the circuits that are in areas where damage and/or high wind observations were present.

2.4 Damage Paths

Extreme events like tornadoes are often particularly destructive and highly localized. The NWS Chicago office publicly posts tornado track or wind damage swath GIS files following their field surveys. These geographic representations are invaluable to post-storm inspection location selection. The Grid Analytics team can overlay these paths with circuits to pinpoint areas with the highest likelihood of damage. Historically damage find rates have increased threefold when using this method.

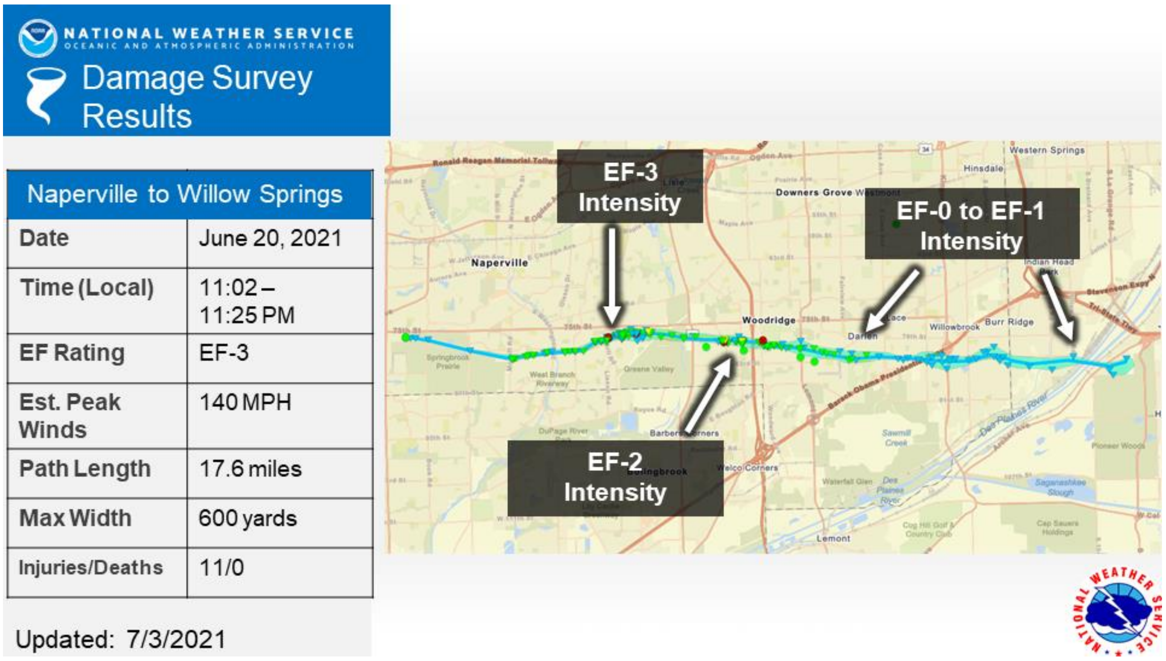

Figure 3: Example of a tornadic event with damage paths (Source: NWS)

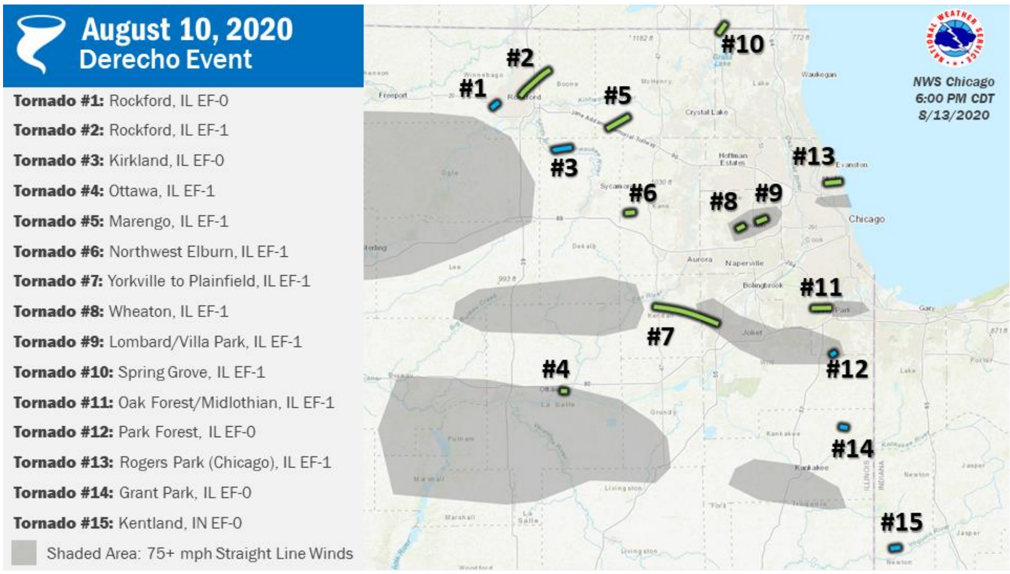

Figure 4: Example of event with tornado paths and wind swaths (Source: NWS)

2.5 Other Considerations

In certain events, datasets and calculations not mentioned in the previous sections need to be incorporated. For example, during winter storms, ice accretion can be a damage multiplier on overhead equipment. Unfortunately, radial ice accretion is not a measured variable reported by the NWS. In extreme icing cases, ice accretion must be estimated using ASOS/AWOS temperature and precipitation data.

$$R_{\mathrm{eq}} = \frac{1}{\rho_i \pi} \sum_{j=1}^{N} [(P_j \rho_0)^2 + (3.6 V_j W_j)^2]^{1/2}, \qquad (3)$$

where R_{eq} is the uniform radial ice thickness (mm), N is the number of hours of freezing precipitation, ρ_i is the density of ice (=0.9 g cm^{-3}), ρ_0 is the density of water (=1.0 g cm^{-3}), P is the precipitation rate (mm h^{-1}), V is the wind speed (m s^{-1}), and W is the liquid water content ($W_j = 0.067P^{0.846}{}_j$).

Figure 4 : Estimated radial ice accretion equation [4]

In other cases, vegetation density datasets might be available for select areas. For storms with high winds, these datasets can be overlaid to further enhance inspection location selection. These datasets are not present comprehensively across the territory, so they only apply in some cases.

4 RESULTS

When all applicable datasets are compiled, the interpretation process can begin. The ComEd service territory is segmented by an internally-defined mapping grid. This grid is used to geographically risk score portions of their territory based on exposure to the weather conditions in the selected datasets.

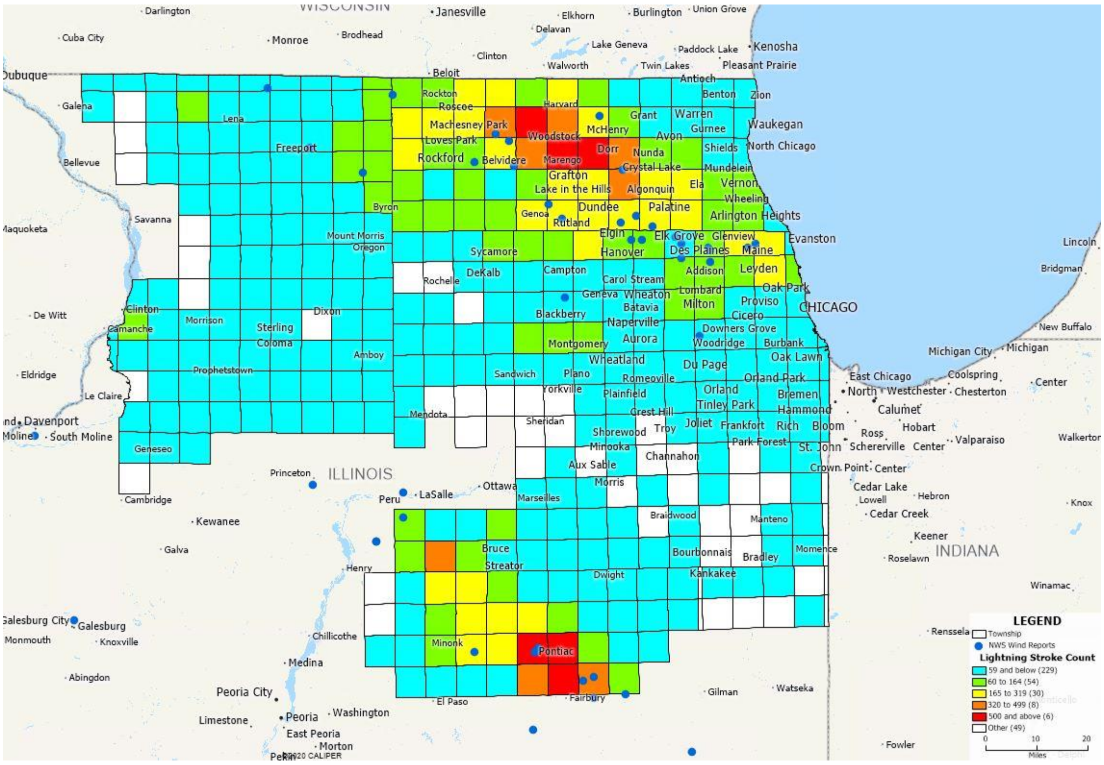

Figure 5: Example of gridded lightning density data with NWS storm reports overlaid

Once geographic areas are risk scored, the circuits with overhead exposure in those areas are queried and prioritized based on factors like customer counts, reliability history, and age of infrastructure. These criteria often vary by storm. After prioritization is complete, the selected circuits are inspected and damage is submitted for repair.

The new method has only been in place for a few storms, but an improvement in damage find rate is already evident. Comparing damage find rate for one storm in June of 2022 to all storms in 2019, the new process yields a higher find rate in 78% of cases. Find rates increased as much as 138% with an average increase of 21% per storm.

Storm ID	Find Rate (Damaged Equipment per Inspection)
2019 Storm 1	2.00
2019 Storm 2	1.34
2019 Storm 3	2.03
2019 Storm 4	3.50
2019 Storm 5	1.87
2019 Storm 6	2.18
2019 Storm 7	0.95
2019 Storm 8	1.12
2019 Storm 9	0.90
2022 Storm	2.15

Table 2: Damage find rates in post-storm inspections; new method was used in 2022, old method was used in 2019

5 CONCLUSION

ComEd's Grid Analytics team has sought to continuously improve the post-storm inspection process and will continue to do so. The use of weather data is crucial to understanding damage trends on electric infrastructure and this process is no exception. In the future, the team hopes to incorporate additional sources of information, such as historic radar reflectivity, NCEP'S NARR, and utility-owned weather stations.

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