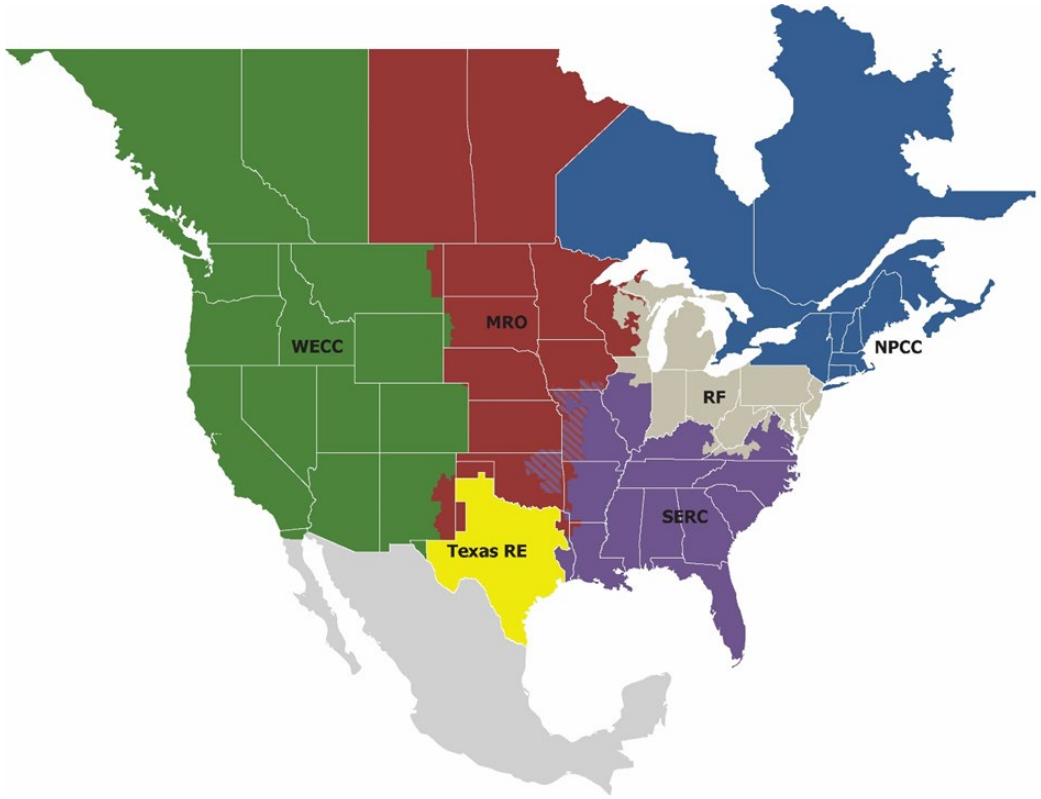
NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

How NERC Measures and Tracks Resilience of the BPS

Maria Kachadurian, Principal Analyst
ESIG Forecasting and Markets Workshop
Weather, Extreme Events and Resilience Panel
June 26, 2025

Electric Reliability Organization

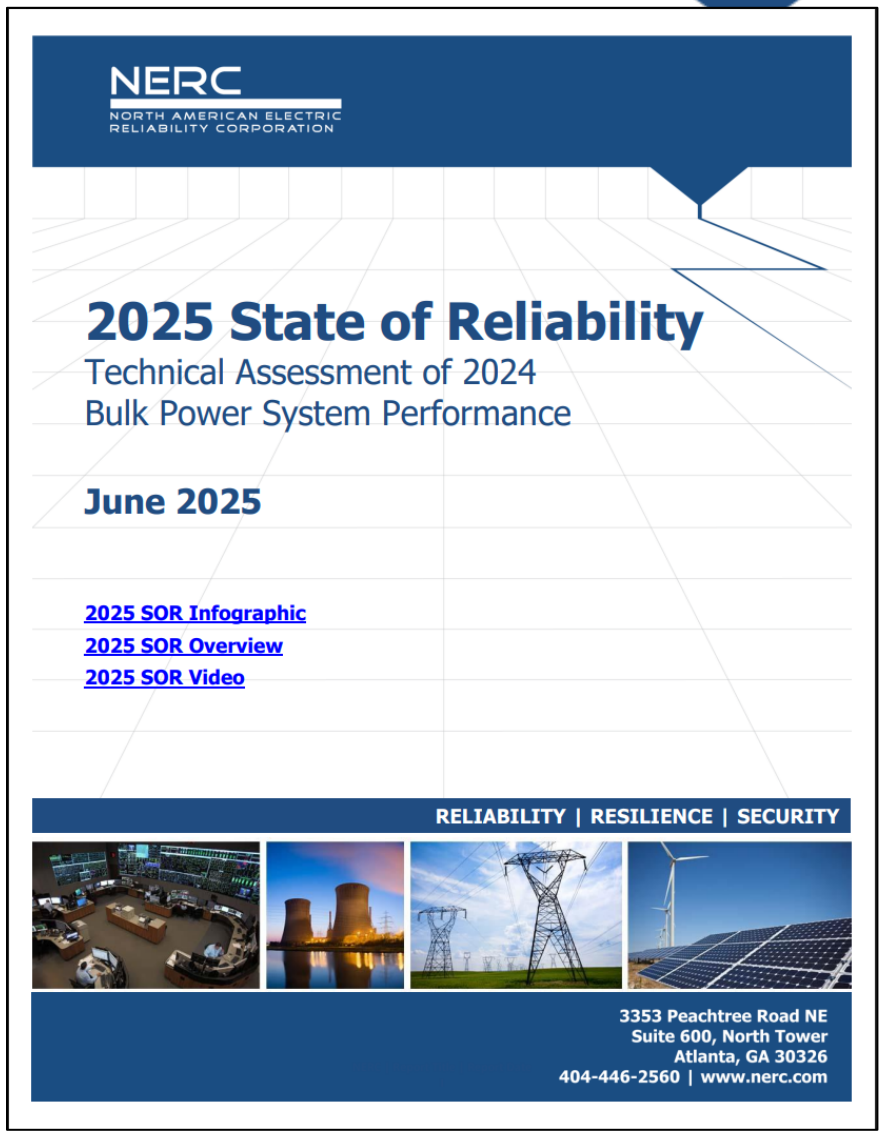


- The vision for the ERO Enterprise, which is comprised of the North American Electric Reliability Corporation (NERC) and the six Regional Entities, is a highly reliable and secure North American bulk power system (BPS). Our mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid.

- NERC collects transmission and generation outage and inventory data in TADS and GADS

North American BPS: Top 10 Extreme Days

- Top extreme days are determined by the combined impact of transmission, generation, and load loss
- 2024 Top 10 Extreme Days
  - All caused by extreme weather
    - Hurricane Helene
    - Winter Storm (6 days)
    - Hurricane Beryl
    - Severe Storms, Tornadoes
- 2020–2024 Top 10 Extreme Days
  - All caused by extreme weather
    - Winter storms (Uri, Elliott and January 2024 storm)
    - Hurricanes (Helene, Florence and Laura)
    - Severe Storms, Derecho



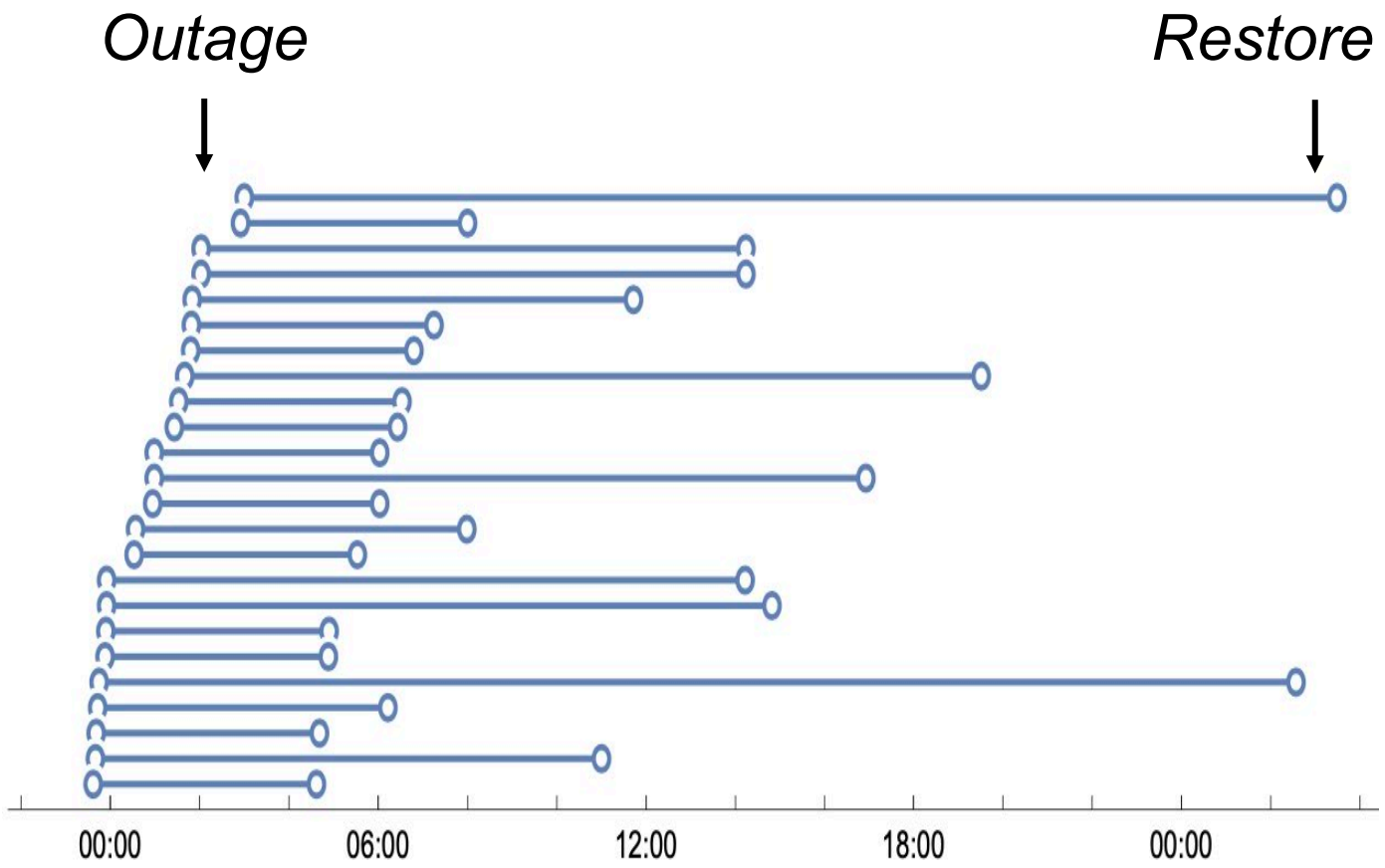
Transmission Outages and Events

- Transmission owners (TO) report automatic outages and events in NERC TADS (Transmission Availability Data System)
  - Single outages that are related and occur within one minute of each other are assigned as an event.
- To identify large transmission events that involve multiple utilities and span across large geographical areas, NERC developed an algorithm[1] that groups outages from the same interconnection

[1] Impact of Extreme Weather on North American Transmission System Outages | IEEE Conference Publication | IEEE Xplore

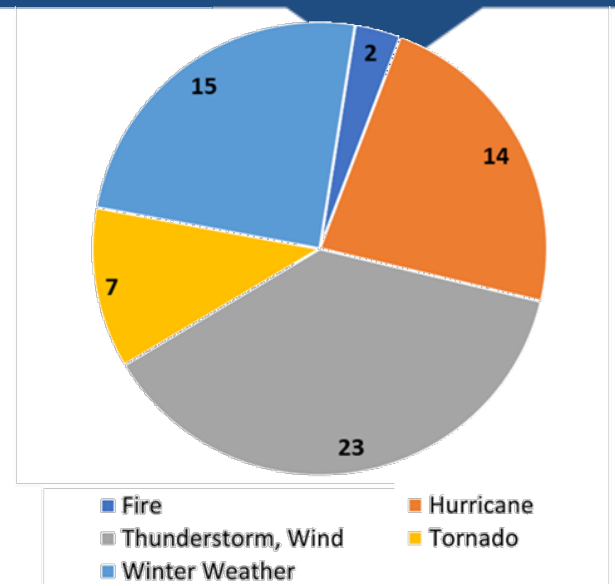
Transmission Events are Output of the Grouping Algorithm

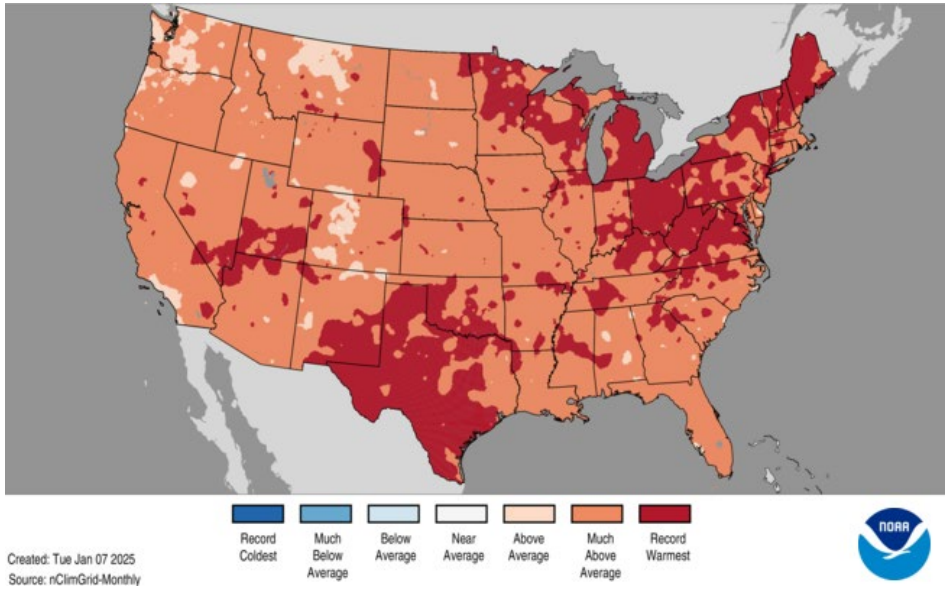
- Events are characterized by clustering (outages in close succession) and an overlapping accumulation of outages over time
- An event with at least one outage initiated by a weather-related cause is defined as a weather-related event
- Large Events: Events with 20 or more outages

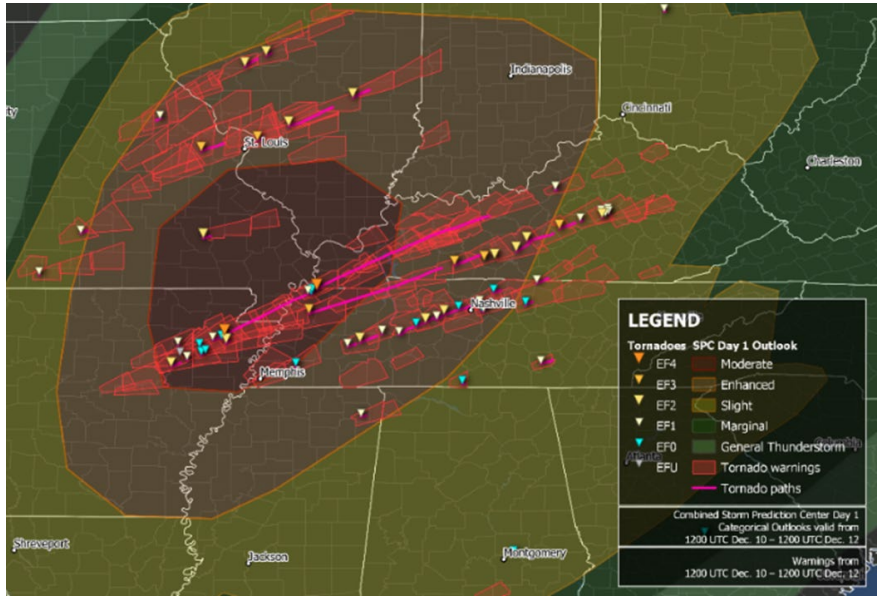


Large Weather-Related Transmission Events

- 2020–2024:
  - 62 large events identified
  - 61 are weather related[1]
- 2015–2024:
  - 115 large events identified
  - 114 are weather related[1]







[1]*A large event in 2023 (SERC region) with 30 outages was caused by bird contamination; the event duration was 2.5 days.*

Attributes/Abilities of Resilient Power System and Resilience Metrics

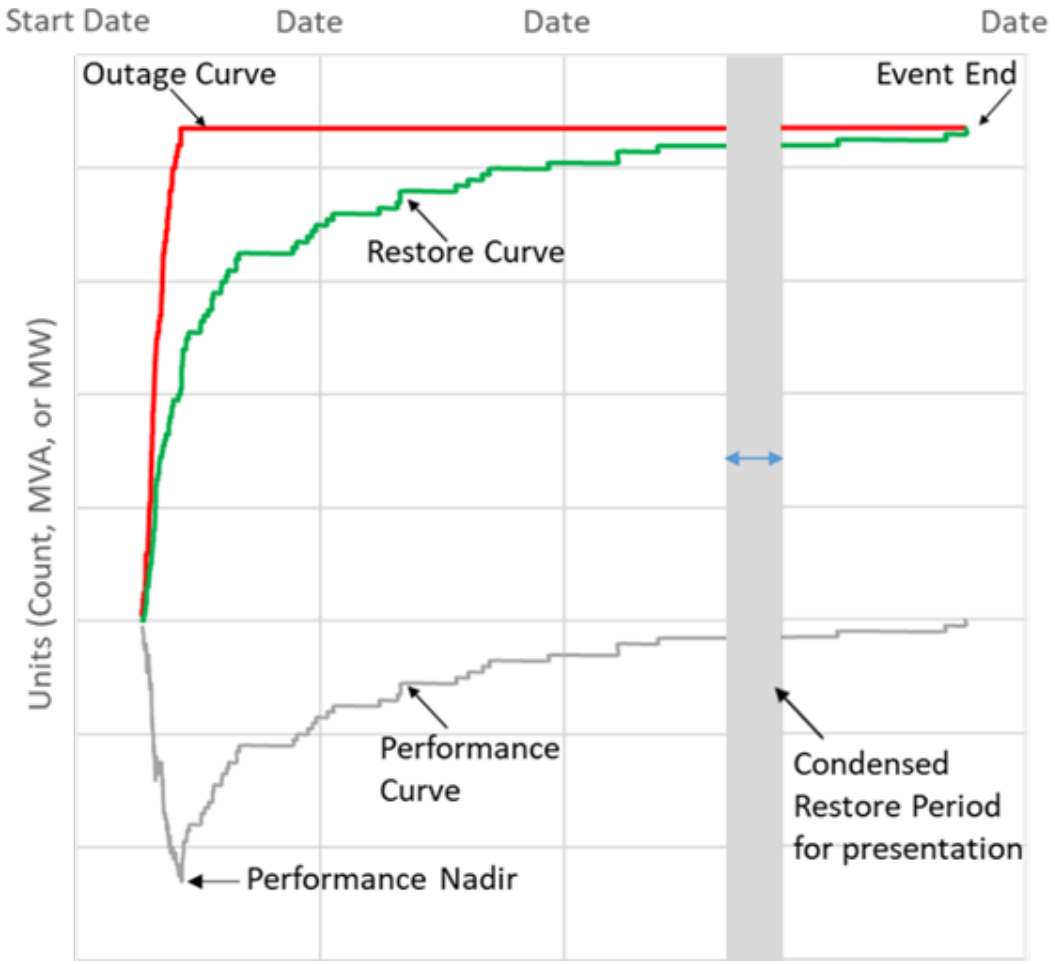
Attributes

- Anticipate and plan
- Absorb and withstand
- Adapt and protect against
- Recover and reduce duration/magnitude

Metrics

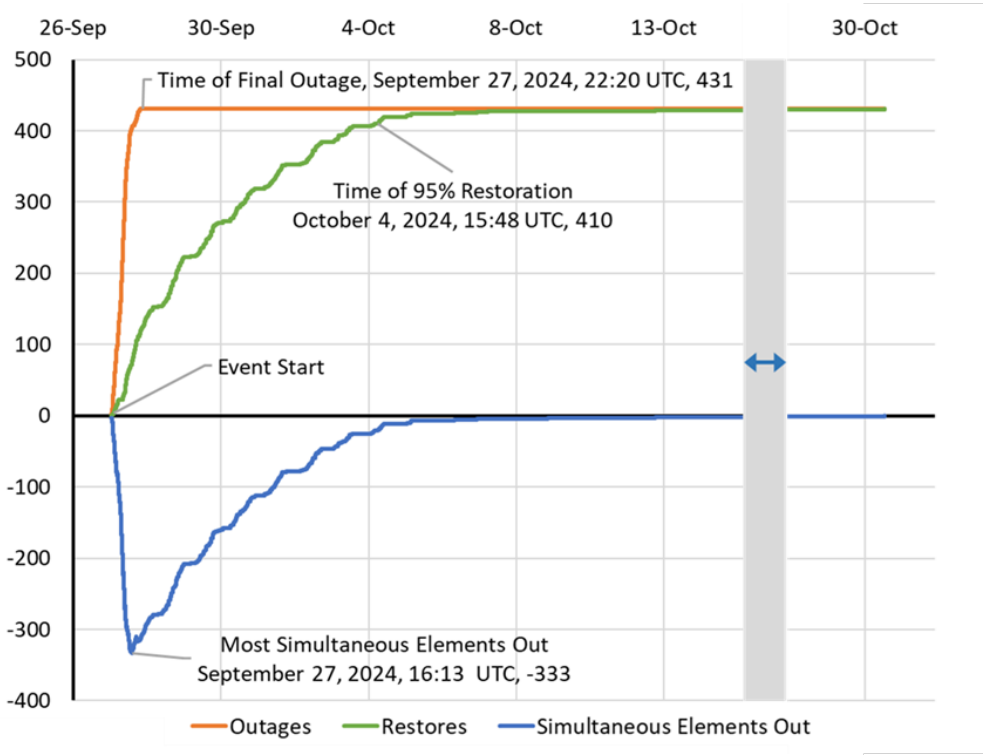
- Event Size (Outages or MVA)
- Outage Process Duration
- Outage Rate
- Time to First Restore
- Most degraded state (Maximum Simultaneous Outages)
- Total Element-Days (MVA-days) Lost
- Restore Rate
- Event Duration
- Time to Functional Transmission Restoration (95% of elements or 95% of MVA)

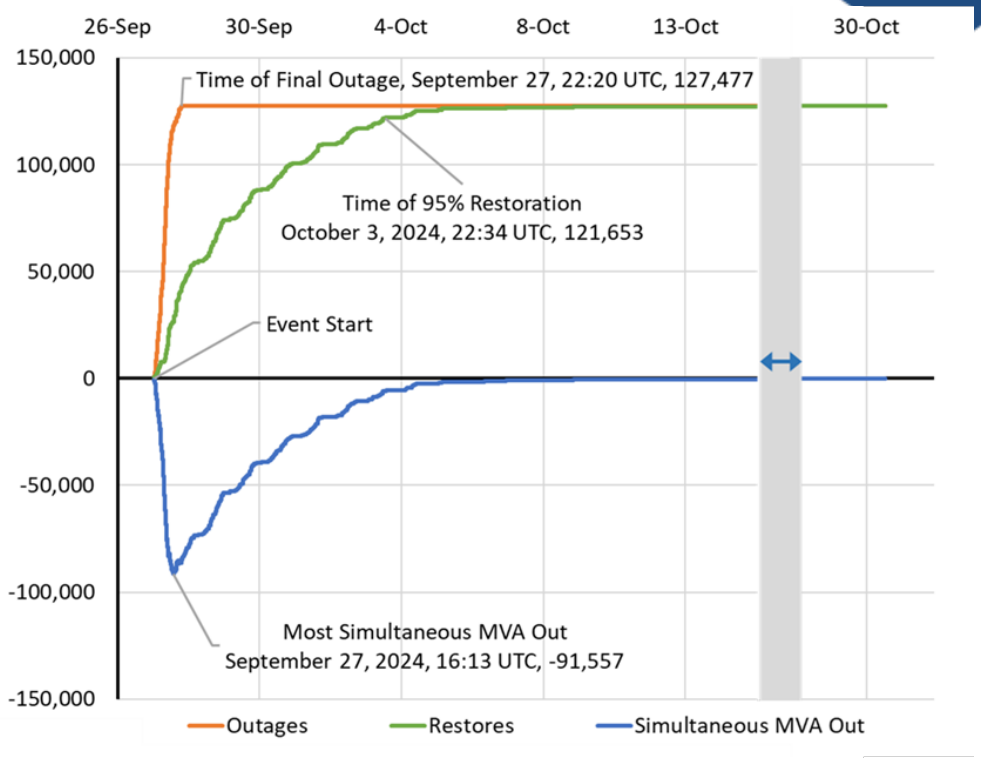
Outage, Restore, and Performance Curves for an Event



- Outage process O(t) counts the cumulative number of outages by time t
- Restore process R(t) counts the cumulative number of restores by time t
- Performance process P(t)=R(t)-O(t) is the negative number of outaged elements at time t
- The three curves are used to calculated several metrics that quantify resilience of the system against this event

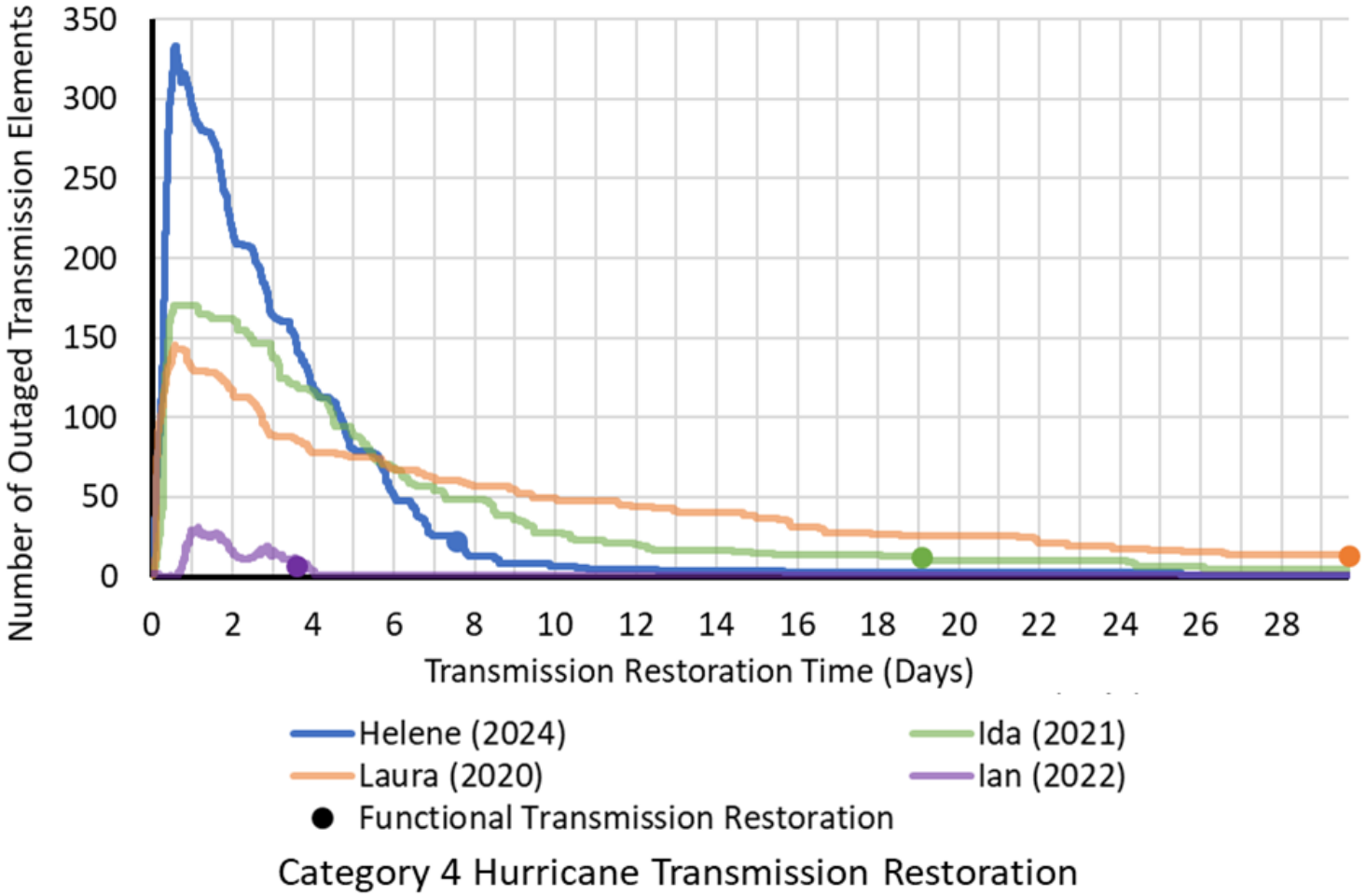
Hurricane Helene: Largest Transmission Event of 2024





- Outage process: 20 hours; 21 outages per hour or ~6,348 MVA per hour
- Automatic outages: 431 total; 9 transformer outages and 422 ac circuit outages (20 TOs)
- Most degraded state (333 elements and 91,557 MVA out), stayed there 7 minutes
- Time to First Restore 18 minutes
- Total losses: 1,140 element-days and 288,329 MVA-days
- Total event duration 33.4 days; 95% outages and MVA restored after 7.6 days (22% of total duration)

Performance Curves: Category 4 Hurricanes, 2020–2024



Category 4 Hurricane Transmission Restoration

- Performance Curves can be used for storm comparisons
- Hurricane Helene - largest Category 4 Hurricane
- Functional Transmission Restoration:
  - Hurricane Helene – 7.6 days
  - Average for 2020–2024 Category 4 hurricanes – 15 days
  - Average for all 2020–2024 hurricanes (Categories 1–4) – 9 days

Observations and Conclusions

- In 2020-2024, all large transmission events except one were weather-related. This confirms that extreme weather is a major risk to resilience of the transmission BPS.
- Hurricanes cause the largest, longest, and most impactful events on the transmission system
- Typically, the most degraded state during a large transmission event occurs relatively soon after the event start, and the system remains in this state for only a few minutes
- The restore process starts quickly after the event start progresses quickly, and then slows down
- The 95% restoration level is reached much faster relative to the event duration.
- Time to Functional Transmission Restoration is decreasing over time
- Next steps:
  - Identify ways to improve storm comparisons (incorporate weather covariates)
  - Develop generation version of resilience analysis

References

- NERC 2025 State of Reliability, An Assessment of 2024 Bulk Power System Performance
- Impact of Extreme Weather on North American Transmission System Outages | IEEE Conference Publication | IEEE Xplore
- Assessing Transmission Resilience during Extreme Weather with Outage and Restore Processes | IEEE Conference Publication | IEEE Xplore
- Resilience Framework, Methods, and Metrics for the Electricity Sector (TR83) (ieee-pes.org)
- NERC Reliability Issues Steering Committee Report on Resilience

Questions and Answers