NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

How NERC measures and tracks resilience of the BPS

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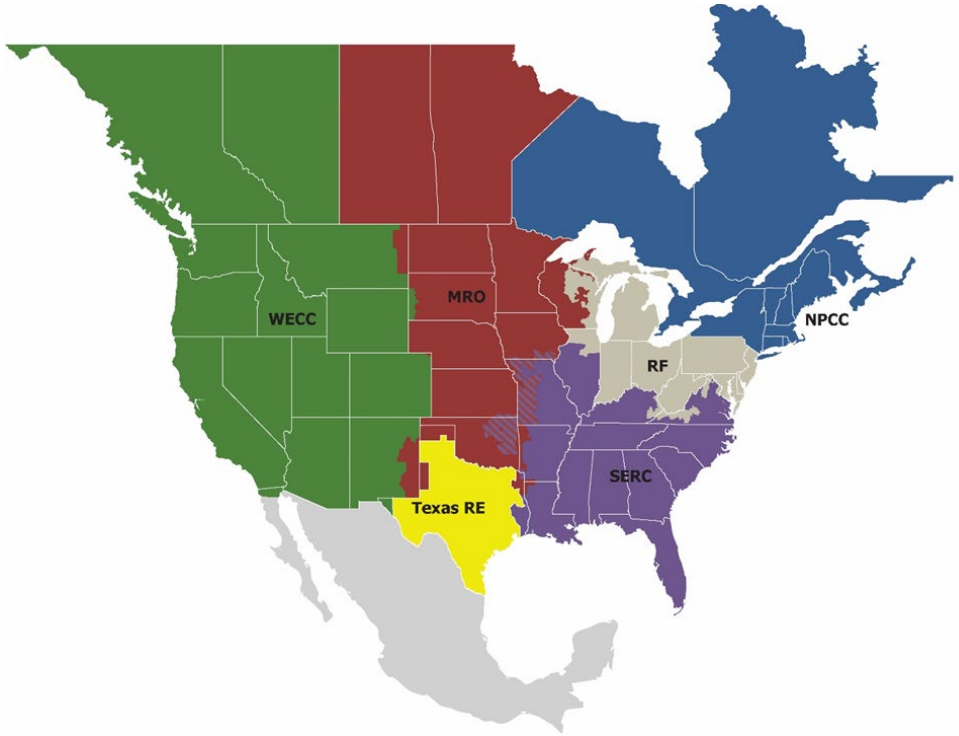
RELIABILITY | RESILIENCE | SECURITY




Outline

- NERC as a part of the Electric Reliability Organization (ERO) Enterprise
- Extreme weather is the top cause that tests grid resilience
- Large weather events on transmission system
- Metrics to track resilience and restoration during and after extreme weather
  - Hurricane Ida (2021) as a major transmission and generation event
- How we started: Resilience events on distribution system (CDW 2021)

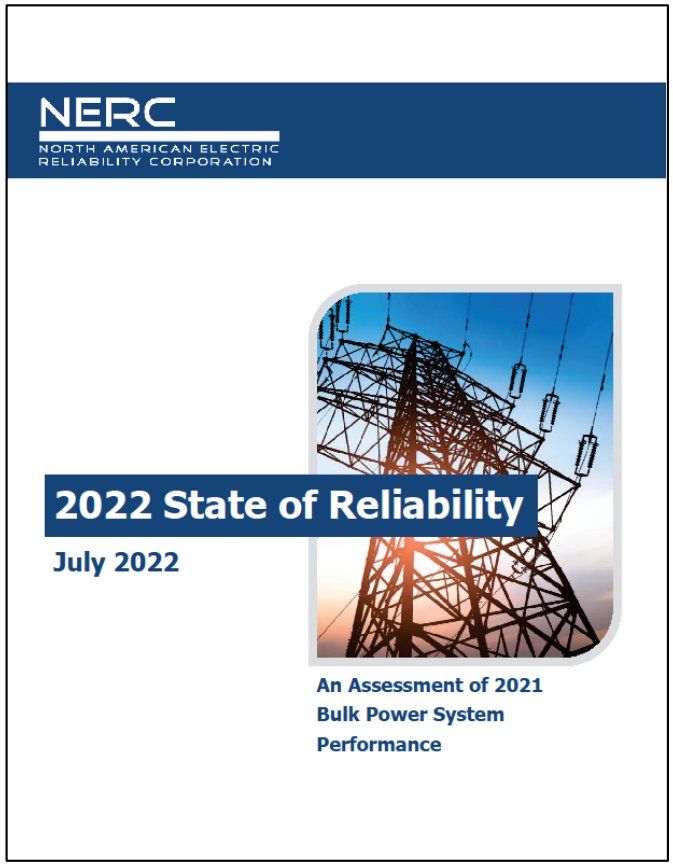
Electric Reliability Organization



- 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 days are determined by combined impact from transmission, generation, and load losses
- 2021
  - All caused by extreme weather
    - February Cold weather event (6 days)
    - Heat Dome
    - Thunderstorms
    - December tornadoes
    - Hurricane Nicholas
- 2017-2021
  - All caused by extreme weather
    - February Cold weather event (5 days)
    - Hurricanes
    - Winter storms



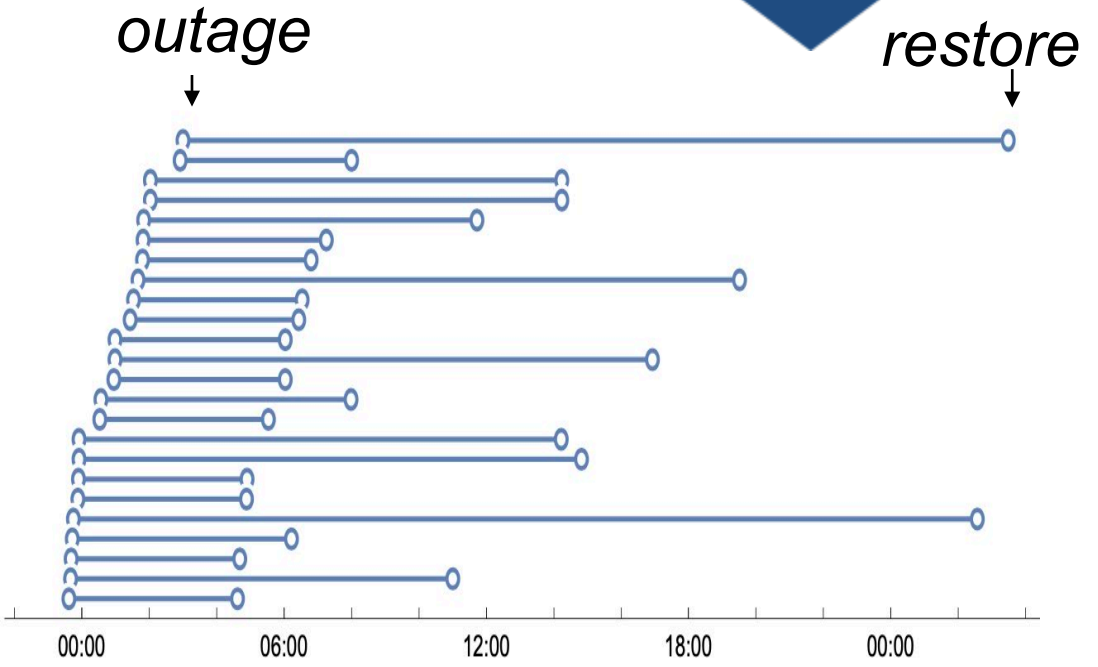
Transmission Outage and Events

- Transmission owners (TO) report automatic outages in NERC TADS (Transmission Availability Data System) and outage events (TO-specific)
- To identify large transmission events that typically involve multiple utilities, we developed an algorithm* to group outages from the same interconnection

*Impact of Extreme Weather on North American Transmission System Outages | IEEE Conference Publication | IEEE Xplore

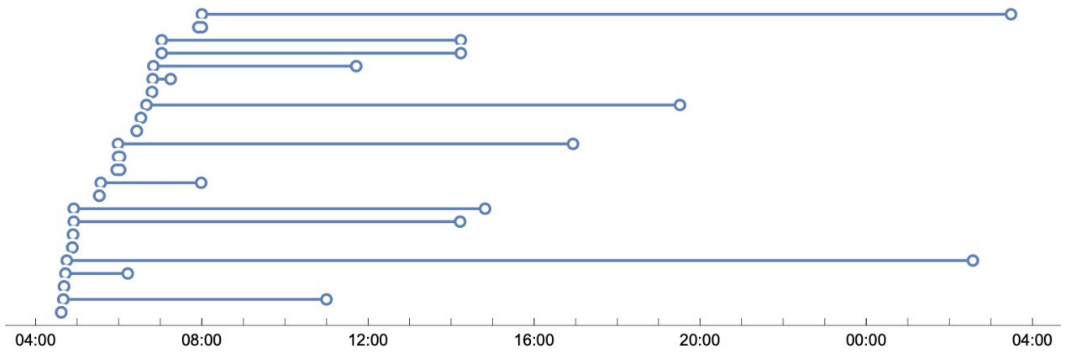
Transmission Events are Output of the Grouping Algorithm

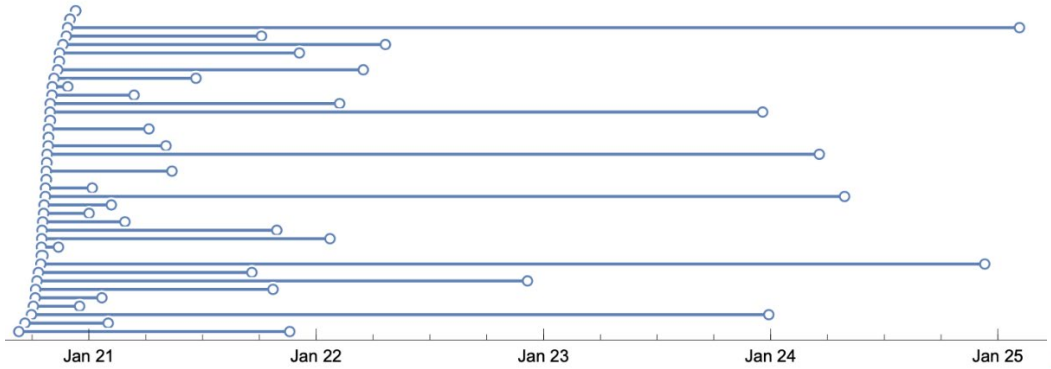
- Events are characterized by
  bunching (outages in close succession) and overlapping accumulation of outages in time.
- An event with at least one outage initiated by a weather-related cause is defined as a weather-related event.
- Large Events: Events with 20 or more outages

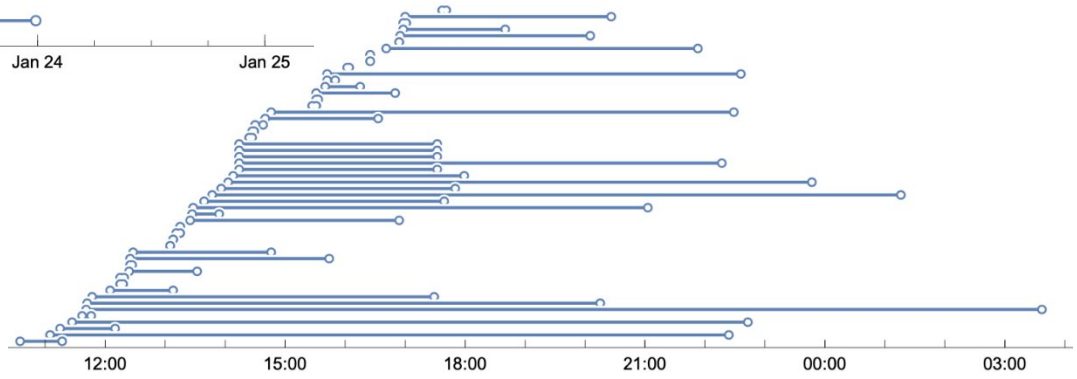


outage bunching and overlapping

Examples of Transmission Events Extracted from TADS

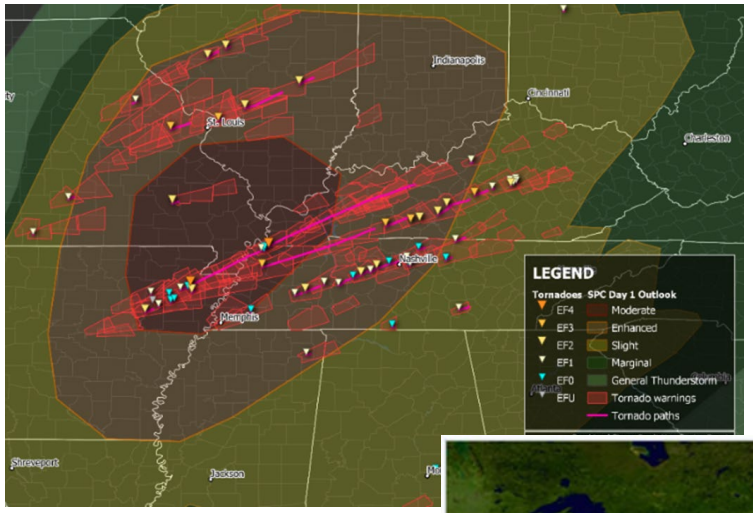


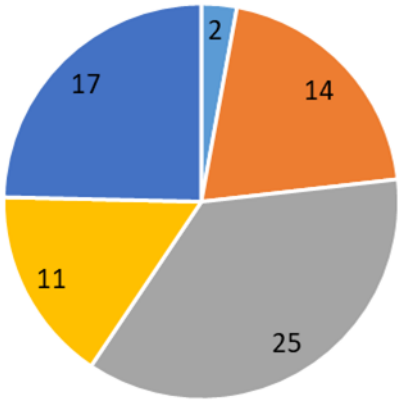


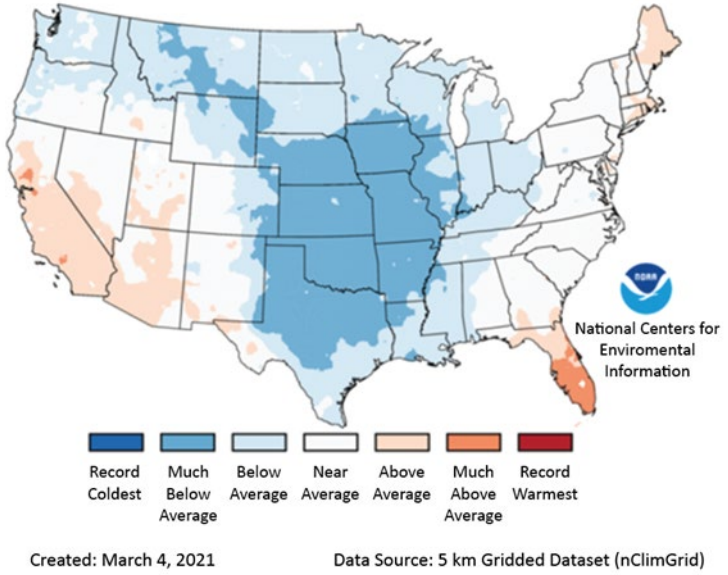


Large Weather-Related Transmission Events

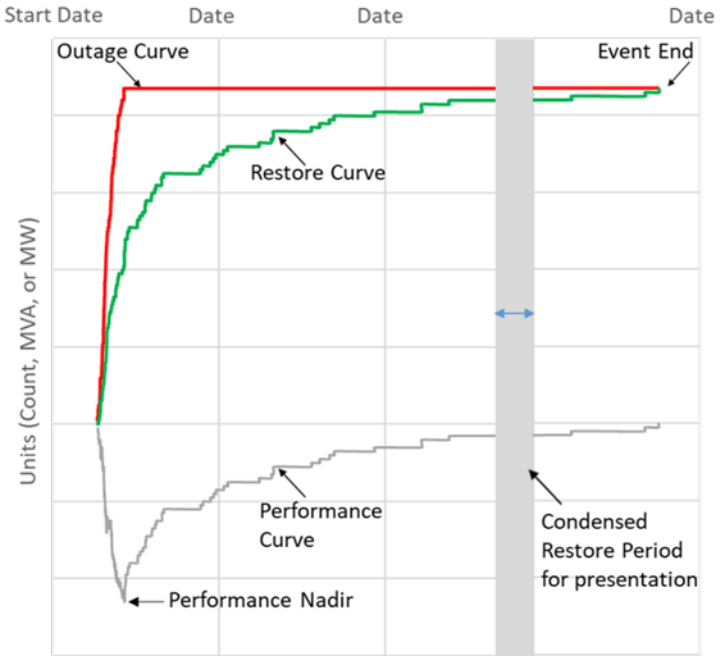
- 70 large events for 2016-2021
- 69 are weather related!







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.

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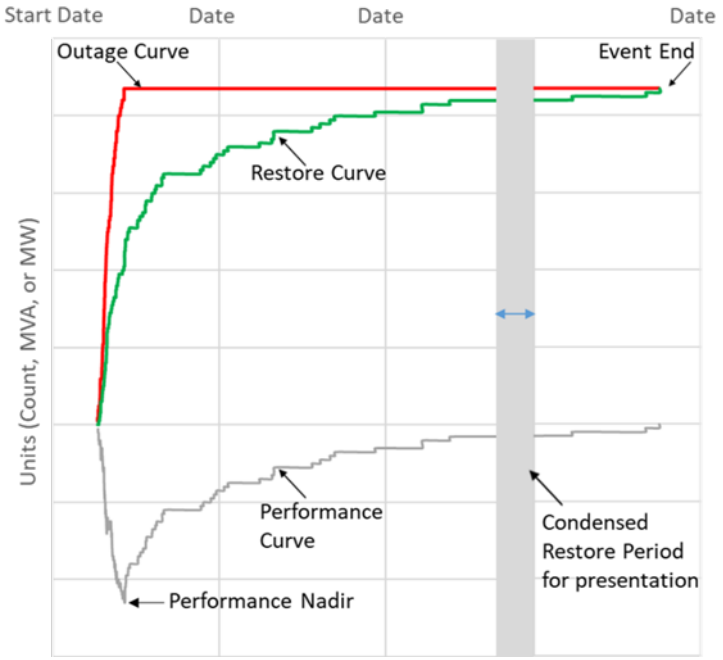

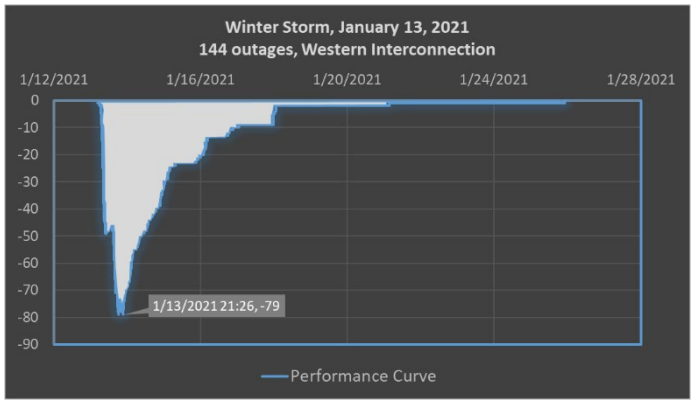

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Attributes/Abilities of Resilient Power System and Resilience Metrics

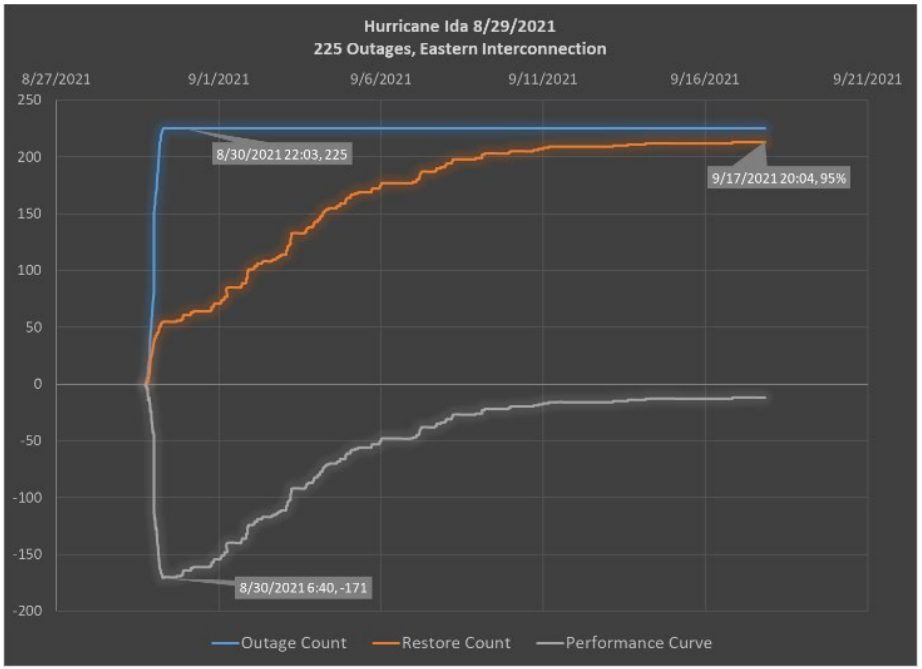
Attributes

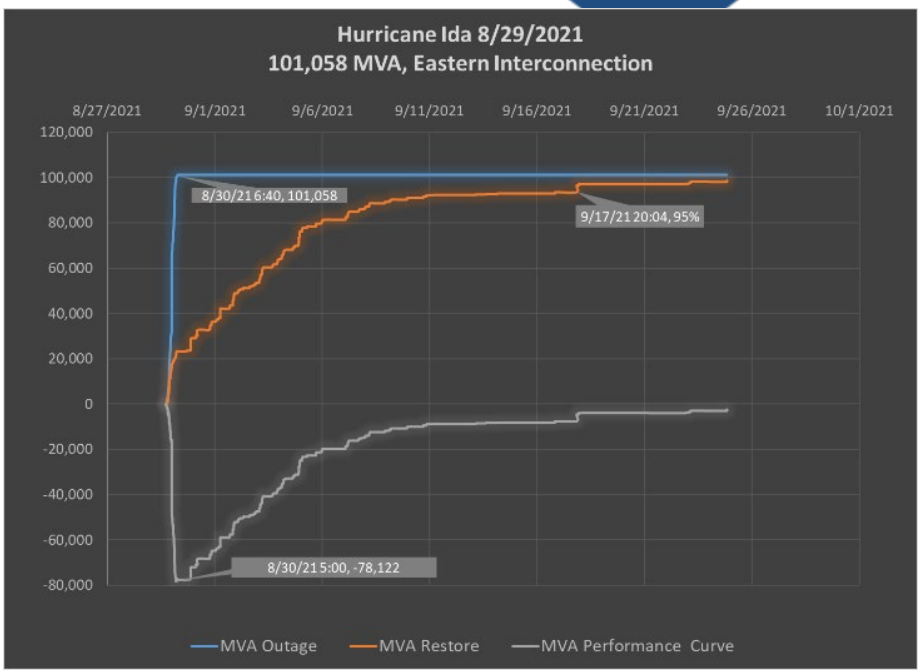
- Anticipate and plan
- Absorb and withstand
- Adapt and protect against
- Recover and reduce the duration/magnitude

Metrics

- Event Size (Outages or MVA)
- Outage process duration
- Outage rate
- Time to first restore
- Most degraded state (Max Simultaneous outages)
- Total element-days (MVA-days) lost
- Restore rate
- Event duration
- Time to critical restoration level (95% of elements or 95% of MVA)

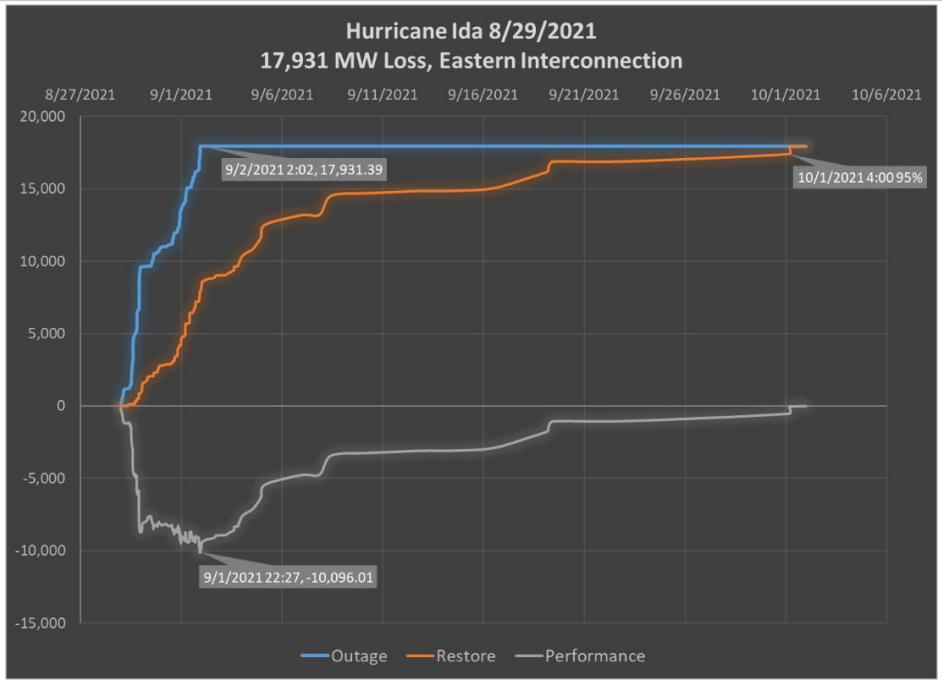
Hurricane Ida: Largest Transmission Event of 2021





- Outage process: 13 hours; 17 outages per hour or ~7,700 MVA per hour
- 225 automatic outages: 4 transformer outages and 221 ac circuit outages (12 TOs)
- Most degraded state (171 elements and 78,000+ MVA out), stayed there 1 minute
- Time to first restore 47 minutes
- Total losses: 1300 element-days and 641,500 MVA-days
- Total event duration 124 days; 95% outages and MVA restored after 19 days (15% of total duration)

Hurricane Ida: Large Generation Event of 2021



- Outage process: 96 hours; 1.3 outages per hour or ~187 MW per hour
- 73 conventional generation units
- Most degraded state (49 units and 10,000 MW out), stayed there 19 minutes
- Time to first restore 9.5 hours
- Total event duration 44 days; 95% outages restored after 33 days (97% of total duration)

Statistics for Resilience Metrics for Large Weather Events on Transmission System

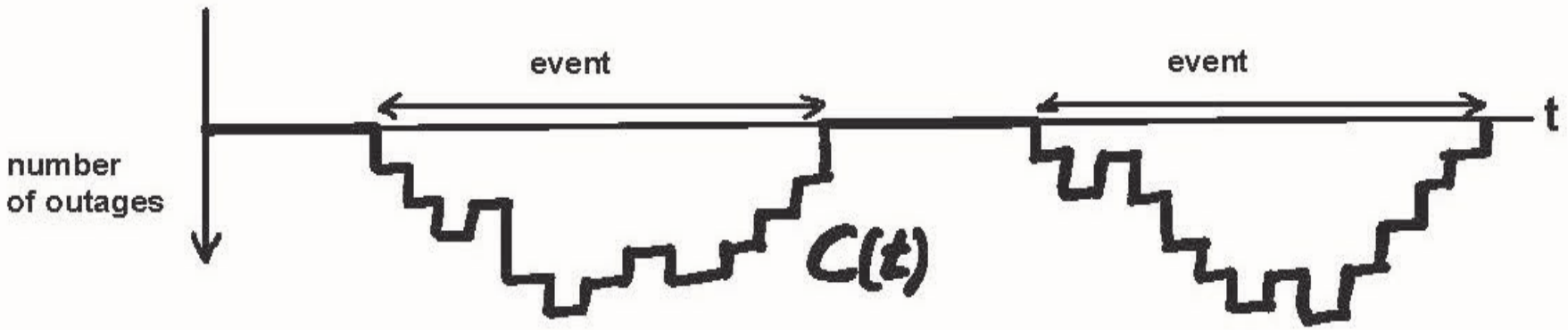
Process	Resilience Metrics	Mean	Std Dev	Median
Outage process	Event size (# outages)	45	50	27
	# generations	31	37	21
	Miles affected	1175	1173	850
	MVA affected	17165	18514	10769
	TADS elem affected	39	43	25
	Outage process duration Hrs	6	5	5
	Outage rate (elem/Hr)	7	4	6
	Outage rate (MVA/Hr)	3008	2765	2220
Restore process	Restore Process Duration Days	14.5	33.1	4.6
	Time to First Restore Minutes	46	51	31
	Time to restore 95% outages Days	3.9	5.4	2.3
	Time to restore 95% MVA Days	4.2	6.3	2.2
	% Event Duration to Restore 95%outages	58%	31%	63%
	% Event Duration to Restore 95% MVA	58%	33%	61%
Performance process	EventDuration Days	14.6	33.1	4.6
	Max Elemements Out	27	28	17
	Max MVA Out	9724	10721	6283
	Element-Days Lost	59	104	18.7
	MVA-Days Lost	21394	39499	5535

References

- Report (nerc.com) NERC 2022 State of Reliability, An Assessment of 2021 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)
- Report (nerc.com) NERC's Reliability Issues Steering Committee Report on Resilience
- N.K. Carrington I. Dobson, Z. Wang, Extracting resilience metrics from distribution utility data using outage and restore process statistics, IEEE Transactions on Power Systems, vol. 36, no. 2, November 2021, pp. 5814-5823. https://iandobson.ece.iastate.edu/PAPERS/carringtonPS21.pdf

Resilience Events on Distribution System (Ian Dobson et al. 2021)

- Distribution outages reported by one distribution utility
- Each outage records start and finish times to the nearest minute and number of customers out
- **Resilience curve C(t)**: negative of cumulative number of outages (or number of customers) as a function of time t.
- An **event** is the resilience curve dropping below zero and then returning to zero as outages occur and are restored.



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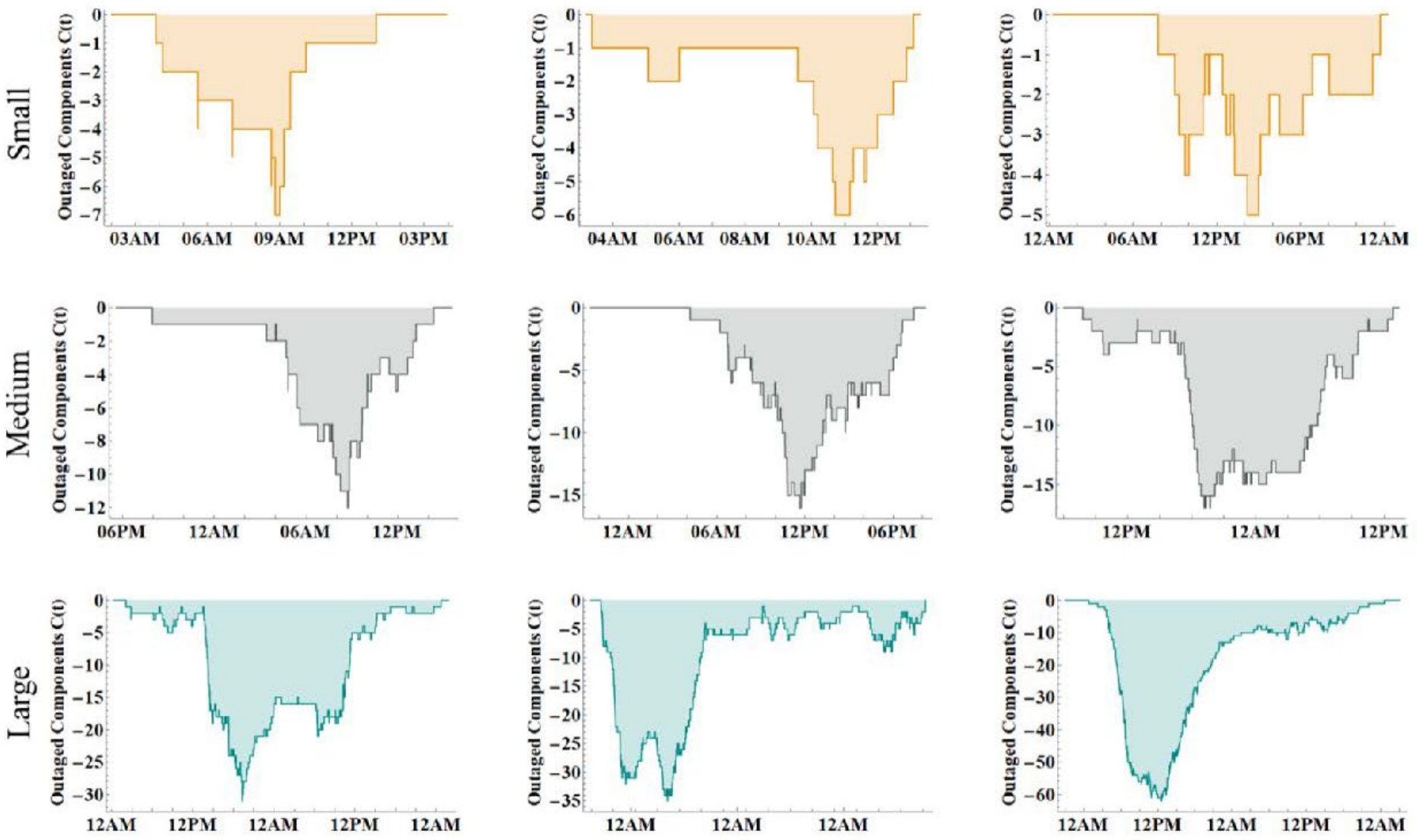
Distribution Resilience Events (Ian Dobson et al. 2021)



Questions and Answers