A customer-focused framework for electric system resilience

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May 2018

Full report: **https://gridprogress.files.wordpress.com/2018/05/customer-focused-resilience-final-050118.pdf**

Reliability and resilience are inseparable

- Reliability and resilience are so deeply intertwined that they are functionally inseparable.
  - **Reliability** = operational security (short term) and resource adequacy (long-term)
  - **Resilience** = "the ability to withstand and reduce the magnitude and/or duration of disruptive events, which includes the capability to anticipate, absorb, adapt to and/or rapidly recover from an event." (162 FERC ¶61,012) – up to and after the outage occurs
  - Many resiliency measures enhance reliability (and vice versa).
- In practice, FERC, NERC and RCs have been doing BPS resilience under the reliability umbrella – so we must continue treating reliability and resilience as joint in effort and outcome.

What's the goal?

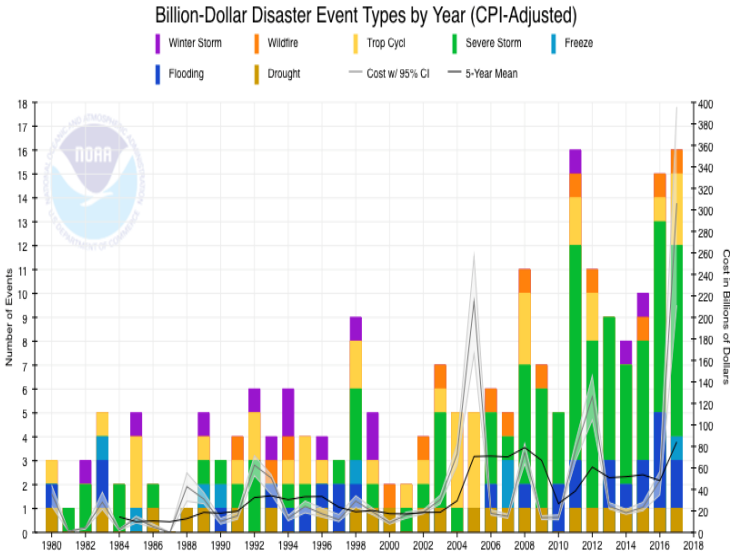
What's the problem we're trying to solve?

- Resilience and reliability for generation is different from the grid is different from resilience and reliability from customers' perspective.
- We should prioritize reliability and resilience (R&R) for customers, not just for generation
- Customer-centric benchmarks for R&R are:
  - Outage frequency
  - Outage duration
  - Outage magnitude
  - Outage survivability

Key points about power system outages

1) Most outages are caused by distribution-level problems (94%), not generation or fuel supply (way below 1%), and by routine rather than huge events
2) Major disasters harm transmission, generation or fuel as they harm distribution
3) Some threats are increasing: routine and severe weather, cyber & physical attack. Some are being addressed: GMD, EMP, new surprises…
4) Some questions related to the evolving fuel mix are being studied through standard reliability assessments of grid changes: fuel security, loss of inertia, risks and opportunities of DERs and microgrids

Major disaster events are getting worse over time



Source: NOAA 2018

Threat-agnostic measures to improve R&R

Preparation for outage

Response to outage

Planning

- System design
- Asset design
- System models
- Threat characterization
- Vulnerability assessment
- Reliability standards
- Interconnection requirements

Hardening & Damage Prevention

- Asset redesign
- Asset configuration
- Undergrounding
- T&D O&M
- T&D tree trimming
- Situational awareness
- Generation fleet diversity
- Fuel contracts
- Cyber-security
- Secure communications networks
- Physical security
- Grid modernization – transmission automation, distribution automation, advanced meters, synchrophasors
- Emergency drills
- Emergency planning

System Recovery

- Spare equipment
- Mutual assistance
- Black-start
- Damage assessment
- Incident management
- Outage management system

Survivability

- Backup generators, distributed generation
- Storage, microgrid
- Energy efficiency
- Distribution management system
- Graceful failure (commands, system)
- Urgent service

Outage

How to evaluate R&R measures?

- Estimate the impact of each measure's ability to reduce the probability or level of outage frequency, magnitude and duration or upon its ability to improve customer survivability.
- Adjust the cost of the measure to reflect its co-benefits (if any) beyond R&R impacts – e.g., T&D O&M has system capital and efficiency benefits, energy efficiency has customer bill-saving, comfort and emissions benefits.
- Then calculate dollar per R&R impact.

[yes, these would not be easy to estimate but it's worth thinking about…]

Context for R&R costs

- Society, customers and utilities have limited budgets for energy. R&R expenditures for electricity have an opportunity cost – if we increase total electric costs for R&R, customers can afford less electricity, or R&R crowds out other electricity inputs (including other effective R&R measures).
- We currently plan for reliability on a deterministic basis (N-1), and make reliability standards mandatory – i.e., reliability has infinite value.
- But many R&R measures have diminishing marginal returns (particularly incremental generation capacity above a reasonable G + DR + EE + storage reserve margin).
- So we should look for the set of R&R measures that offer the biggest customer-centric R&R and survivability impact per $, not just look at the measures that are within your jurisdiction.

High and low value R&R measures:

	High Value		Low Value
Grid operator, reliability coordinator	Interconnection rules Schedule coordination Fuel coordination Emergency planning and drills System & asset models Situational awareness		Generation capacity payments
T&D, Genco Capital	Distribution pole hardening Additional transmission paths and loops Back-up communications Transmission automation Distribution automation	T&D undergrounding Generator weatherization	Coal & nuclear subsidies
T&D, Genco O&M	Tree trimming Cyber security & secure communications networks Physical security Mutual assistance Strategic spare equipment & mobile substations Situational awareness, system monitoring, PMUs Emergency planning and drills Outage management system		Fuel supply guarantees
Customer	Distributed generation, back-up generators Emergency supplies More efficient building shells Community critical infrastructure hardening	Insurance Distributed storage	

Customer-centric R&R value

- If most outages arise from routine distribution and transmission events, then R&R measures that address T&D will benefit customers more immediately than resilience for generation.
- R&R and survivability measures that are effective against multiple high-probability threats (such as tree-trimming, O&M, energy efficiency, critical spares, smart DG inverters) will benefit customers more, and more often, than measures that address narrow-scope, low-probability threats.
- Other high-value R&R measures – physical & cyber-security, mutual assistance, distributed gen & storage, emergency drills, T&D automation, some T&D hardening, elec-gas coordination.