Metrics for electricity distribution resilience analysis in the Northeast

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Overview

- What are “resilience metrics” and how are they used?
  - Applications
  - Types
- Resilience “performance metrics”
  - Two interpretations
  - Current Northeast regulatory state-of-play
- Projecting and assessing outcomes/effects of resilience measures
  - Two kinds of uncertainty
  - Risk management
- Takeaways

Metrics uses

- In the resilience as well as reliability context, the term “metrics” is used in several contexts:
  - Planning - *Ex ante*
    - Identification of priority/critical zones, circuits, locations, and/or customers for potential resilience measures
    - Development of measures and their *estimated* costs and potential benefits, including reductions in outage frequencies and durations, and avoided utility and customer costs.
  - Reporting and assessment – *Ex post*
    - Storm and storm-related data reporting
    - Project tracking and estimation of actual measure outcomes and effectiveness – “measurement”

Metric types

- In turn, there are several metric types used in one or more of the above activities, particularly for resilience analysis:

1. Indices measuring average distribution system performance including “major storms” – so-called “all-in” versions of standard reliability metrics (in some cases calculated also at the circuit level):
   - SAIDI: System Average Interruption Duration Index
   - SAIFI: System Average Interruption Frequency Index
   - CAIDI: Customer Average Interruption Duration Index
   - CAIFI: Customer Average Interruption Frequency Index

- IEEE Standard 1366 defines “Major Event Day” in statistical terms. Some states use this but also have their own definitions, based on, e. g., numbers or percentages of customers without power, and/or without power for more than a certain duration.

2. Variables or statistics on customer impacts of major storms – calculated at the system and/or circuit level - including
   - CMI: Customer Minutes Interrupted (and CMI/event)
   - Number or % of customers interrupted

Metric types (2)

2., cont.
- CEMIx: (number of) Customers Experiencing Multiple (>x) Interruptions
- CELID: (number of) Customers Experiencing Long-duration Interruptions
- Number and type of critical facilities interrupted
- Customer impacts by socio-demographic categories

3. Infrastructural/ implementation-related, such as
- Number or lines or line-miles or % overhead hardened or undergrounded.
- Project specific progress, costs

4. Utility infrastructure impacts and storm response/restoration activities, such as
- Pole, overhead line, and/or underground line failures (numbers and locations)
- Times to restore X% of customers
- Personnel involved and costs incurred

5. Economic/financial – Avoided customer and utility restoration costs

- Note that while the details vary from state to state, the above and related metrics are essentially *all* that are currently being used in the Northeast.

History

- States have long been using the reliability versions of many of these metrics.
- Some utilities have also used the all-in reliability metrics for resilience planning.
  - Example: Unitil New Hampshire “Storm Resiliency Program,” initiated 2012 – reports indices without and with major storms.
- However, resilience planning *per se* has emerged in the past few years as a semi-distinct activity, although closely connected to others – e. g., vulnerability assessment – and in part subsumed under integrated grid planning (by whatever name).
  - In these initiatives, the question of metrics is receiving new attention.

Resilience “performance” metrics

- In this context, another distinction arises, in *ex post* analysis, between
  - A. Measuring the physical/engineering effects/outcomes of installed resilience measures – e.g., reduced numbers and durations of outages and incidence of customers experiencing repeated/lengthy outages.
  - B. Using metrics of the type described above to establish resilience criteria/targets/standards - extending or akin to reliability standards
- The term *performance metrics* is used (implicitly) to refer to both these applications, but they are different.
  - A. is necessary but not sufficient for B.
- Regulators in several states have highlighted developing such metrics as a priority – somewhat ambiguously.

Regulatory guidance

- Massachusetts Dept. of Public Utilities , in Electric Sector Modernization Planning proceedings – encourages "…discussion and proposals on performance metrics" in 2025.
- Maine PUC 2024 Order in integrated planning proceeding:
  - "…the utilities must propose how to measure the effectiveness of their grid plans…in improving reliability and resiliency and enabling cost-effective achievement of the State's climate and GHG reduction policies. This includes lessons learned and proposed changes to future planning assumptions and methodologies."
- NY PSC: Dec. 2024 order regarding utility Climate Change Resilience Plans:
  - The Commission acknowledges the "…absence of industry standardized resilience performance metrics…"
  - Approves use of outcome measures such as outage frequencies before and after measure installations, while instructing utilities to work with other stakeholders to "..further expand on and improve these" and in the future report on their progress.

Regulatory guidance: Connecticut

- Connecticut has developed the most comprehensive framework for reliability and resilience planning, in a 2017-2022 investigation (although neither of the Conn. IOUs has yet submitted plans pursuant to it).
- But in a 2022 decision it stated
  - "[We] find that there is not yet a uniform modeling tool that can be mandated for assessing [resilience] benefits. Rather, [we] find that EDCs may use a reasonable estimate for expected outage reductions derived from a model or [other] source; however, each EDC must provide all assumptions and inputs used to determine how outage durations are expected to be reduced during various events…."

Availability of information and predictability

- Historically, it has been possible to establish (and enforce) distribution reliability standards because of
  - Relatively stable climate and weather patterns over long periods
  - Long utility experience in dealing with weather-related (and other) short-duration, relatively localized power outages – prevention and remediation.
    - This is an empirically-driven process, involving trial-and-error over a long time.

- For storm hardening and other measures to improve resilience, however:
  - There is a shorter and sparser history of major storms
  - Utilities (and regulators) have less experience with larger storm-hardening projects and their outcomes.

Projecting outcomes and comparing to "actuals"

- As far as data: More extreme weather is a long-term problem, but as in Vermont, utilities and regulators are also addressing *recent* and *current* increases in disruptions caused by storms.
  - Utilities are using both historical data and model projections
- The exact methods/ models/ tools that utilities are using to estimate the physical/ engineering outcomes of resilience measures *ex ante* are not well documented.
- Regardless, there are two major uncertainties involved:
  1) Whether or not assumed extreme weather events – frequency, intensity, locations of major storms – will conform to either recent historical, or projected, patterns.
     - I. e., will the threats that resilience measures are aimed at mitigating actually materialize, and if so, when and how often?
  2) How will resilience projects/measures aimed at preventing or mitigating extreme weather impacts perform in practice – i. e., when extreme weather occurs?

Resilience performance metrics as risk management

- Reliability doesn't seem to be generally seen as a type of risk management, but it is.
- Defining and using resilience performance metrics is too.
- A standard definition:

  Risk = Event X Consequence

- Regarding resilience, "Event" here refers to extreme weather -uncertainty type 1), and "Consequence" to its impacts on the distribution system and customers.
  - Resilience measures are aimed at changing the Consequence(s) – uncertainty type 2)
- More weather, and experience with resilience measures, will reduce but not eliminate both types of uncertainty – it will take a currently-unknowable amount of time for resilience to "converge with" reliability in this sense.

Takeaways

- There is no shortage of resilience metrics in the sense of indices, variables, statistics; they are already being used.
- But there are no generally – or even partially – agreed upon resilience performance metrics in the sense of targets or standards, or procedures for developing them.
- There is no reason to expect that some specific one-size-fits-all set *of either type* is going to be identified, nor is this necessary or appropriate.
  - There are some “objective” metrics that virtually all jurisdictions will use.
  - But individual states have their own infrastructures, resilience-related risks, regulatory environments, and priorities.
    - This is especially the case with standards: These cannot be set purely objectively. E.g., what is the appropriate level of resources to expend on protecting “hard-hit” and/or otherwise vulnerable customers/communities from storm-caused outages?

Some considerations for Vermont in developing resilience metrics

- What data related to the types of resilience metrics described above will utilities need to collect on an ongoing basis that they aren't now?
- What will be the costs of collecting and reporting these data?
  - For small utilities especially, this may be a factor.
- Who will use the information (data and metrics), and for what purposes?
  - Utilities
  - VDPS
  - Other stakeholders
- The needs of these three may not be exactly the same – e. g., what is needed for detailed planning and engineering may be more than what is needed for regulation. They should be delineated early in the development process.

Considerations (2)

- Utilities are using different models and methods to estimate *ex ante* the *ex post* outcomes of potential resilience measures/projects.
  - The Connecticut PURA 2022 decision on this topic provides a reasonable approach to regulatory treatment.
  - How to document the use of proprietary software for this purpose is a legal and policy issue that will need to be addressed.
- Resilience performance metrics will
  - require uncertainty and risk to be explicitly quantified and incorporated, and
  - need to be negotiated between the Department and individual utilities, as with the SQRPs.

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