JTCM 2024: IEEE PES Distribution Resilience

January 9, 2024

13:30-15:00 EST

https://sagroups.ieee.org/distreswg/

Resilience TF Agenda

- Welcome and Introduction
- DRES Task Force and Working Group
  - Scope of Taskforce – Distribution Resilience Guide
  - Discuss deliverables planned (white paper)
    - Chapters and lead authors
    - Resilience Framework_Outline_SP - Google Docs
  - Progress on Chapters
- Action items and next steps

Resilience Guide Outline

- Seven chapters, sub-sections for each chapters
  - Link T&D_DSC_DResWGTF_Guide_Outline - Google Sheets
  - Sub-groups for each chapters

CHAPTER	LEAD
CHAPTER 1: Literature Review	Masoud Davoudi
CHAPTER 2: Resilience Goal / Objectives	On Hold
CHAPTER 3: High Impact Weather / Storm Event Risk Identification	Ali Bidram
CHAPTER 4: Quantification of Resiliency	Shikhar Pandey
CHAPTER 5: System Modeling and Storm Simulation	Sarmad Hanif
CHAPTER 6: Infrastructure and Operational Improvements for Resilience	Julio Romero
CHAPTER 7: Case Study and Resiliency Study	Gary Huffman

Resilience Definition

- Electric Power Distribution System Definition
  - The capability of electric power distribution systems to deliver electric energy to end-use customers and recover this capability following exposure to high impact low frequency weather events

- Presidential Policy Directive (PPD) 21

"the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."

https://www.energy.gov/ceser/presidential-policy-directive-21#:~:text=Presidential%20Policy%20Directive%2021%20(PPD,functioning%2C%20and%20resilient%20critical%20infrastructure.

Chapter 1: Literature Review

- Goal was to triage papers and communicate to chapter leads what literature would be beneficial for their chapter work
- Remaining papers to be prioritized and categorized by JTCM
- Next steps to convert reviews into text for Chapter 1 Review

62 Papers Identified	
2015-2019	2020-2022
24 Remain	38 Complete

13 Detailed Reviews

Definition	Resilience Goal	Event Modelling	Valuation/ Quant.	System Modelling	Grid Mod.	Climate adaption	Use case / case study
20	25	17	27	18	22	8	22

Chapter 1: Literature Review

- Triaged and selected a total of 64 high relevant references
- Communicated and supported other chapter leads on beneficial resources for their work
- Next steps:
  - convert reviews into text for Chapter 1 Review: 11 done out of total of 18 highly related papers. Goal is delivery by the end of January.
  - critical review of the other chapters to identify similarities with existing references and guide the work as needed: starting after JTCM.

Chapter 2: Resilience Goal / Objectives

On Hold

Chapter 3: High Impact Weather/Storm Event Risk Identification

- Chapter outline:
  - The key factors for identifying the risk of extreme events
  - The specifications and parameters for the development of extreme event scenarios
  - Resources for utilities: FEMA National Risk and Capability Assessment
  - Utility Examples:
    - ComEd
    - SCE

Chapter 3: High Impact Weather/Storm Event Risk Identification Cont.

- Identification of high-impact weather/storm events risk depends on the specification of extreme events of concern based on stakeholders' priorities in a specific geographic area. High-impact weather events include heat waves, freezes, heavy downpours, tornadoes, tropical cyclones, and floods that can have detrimental impacts on distribution systems
  - The key factors for identifying the risk of extreme events
    - The likelihood of the extreme event occurrence in the future (based on historical data of the previous occurrence)
    - The likelihood of severe consequences from extreme events
    - The vulnerable populations, buildings, and infrastructure strategic priorities
    - The dollar values for potential losses
    - The availability of resources and budget constraints to respond in a timely manner
    - The existing utility infrastructure (underground vs overhead)
    - Time of day and year
    - Coincidence of different events
    - Social vulnerability

Chapter 3: High Impact Weather/Storm Event Risk Identification Cont.

- Extreme event risk identification requires the development and study of different scenarios and their associated uncertainties. The development of extreme event scenarios is based on a set of specifications and parameters including :
  - The type of extreme event (i.e., storm, hurricane, earthquake, tornado, etc.)
  - The category (level) of extreme event (e.g., category of a hurricane)
  - The location targeted by the event (e.g., the population of the area)
  - Time (season, month, time of day, etc.)
  - Duration of the event

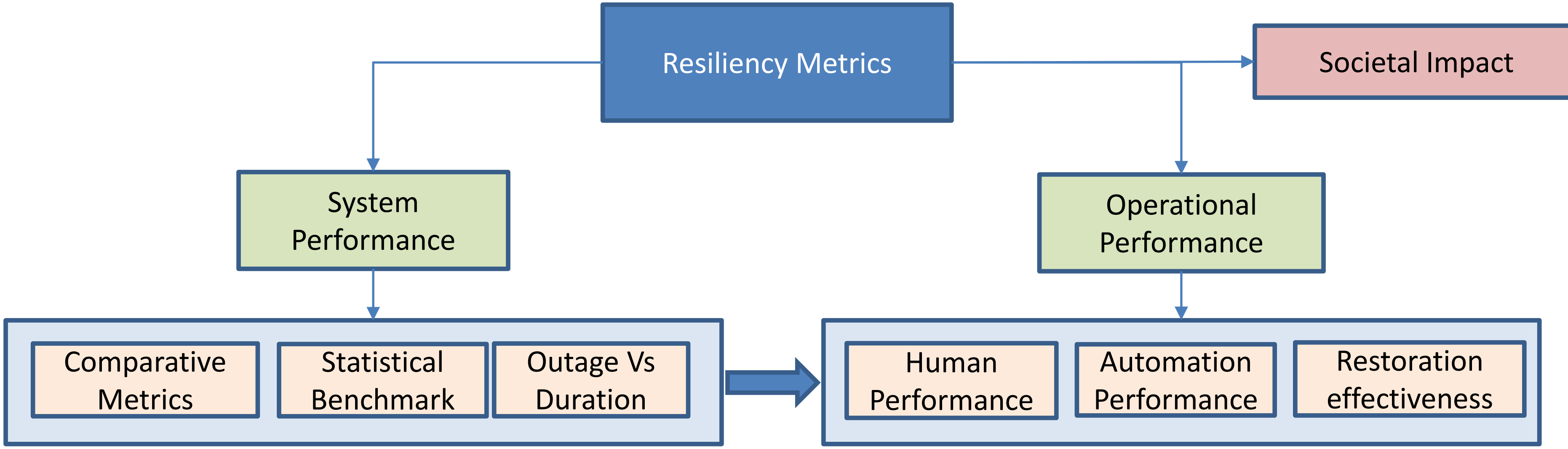
Chapter 4: Quantification of Resiliency

- Chapter outline:
  - Comparative Metric (FPL)
  - Storm Metric – ComEd
    - Work in progress to generalize the metric
    - Include data driven threshold setting

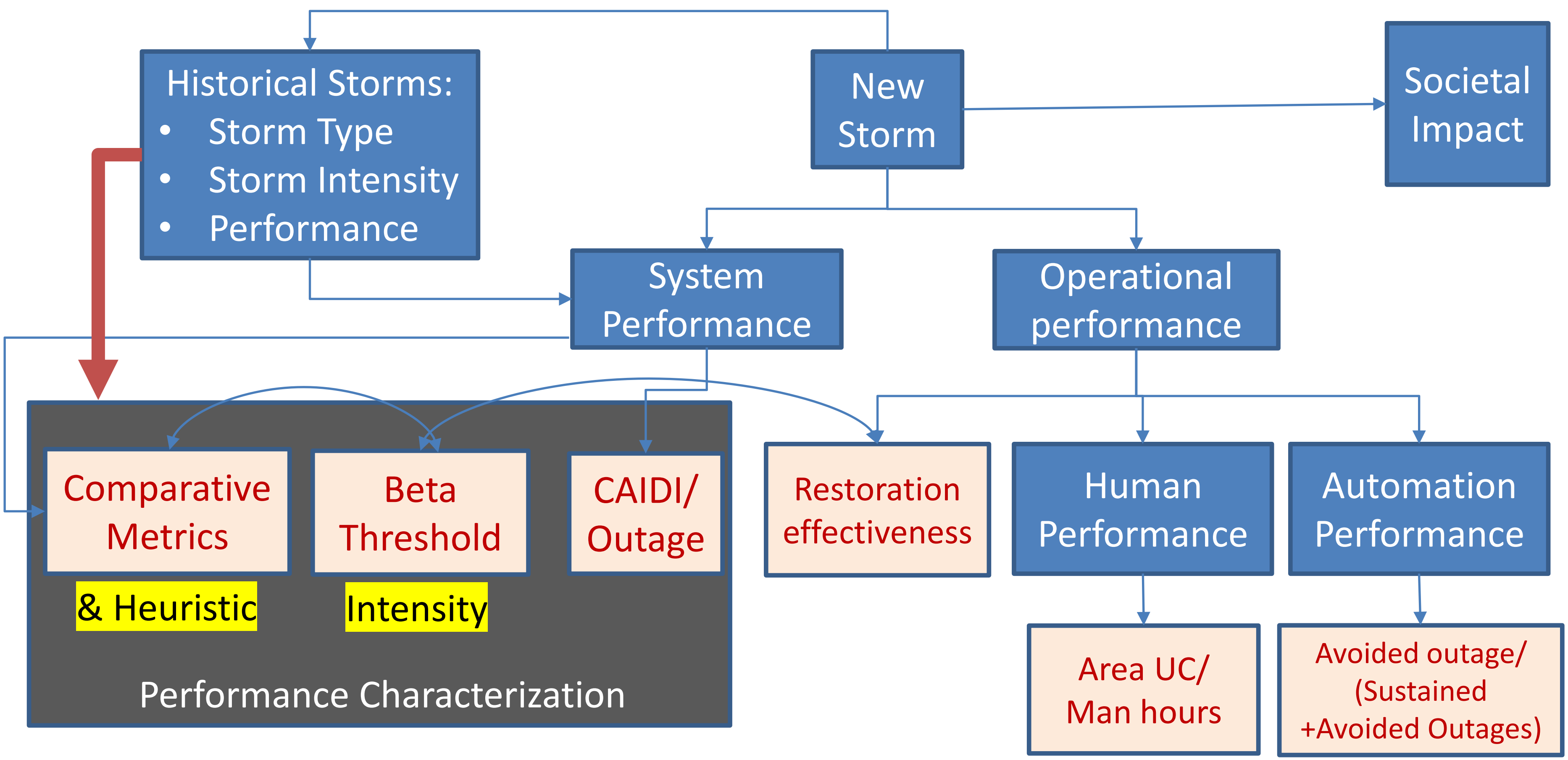
Storm Event: $x = \frac{\sum \text{Customers Without Power for More Than 12 Hours}}{\textit{Sustained CI+ACI Due to Distribution Automation}}$

  - Gray Sky day Metric

Chapter 4: Quantification of Resiliency



Metrics Plan Details

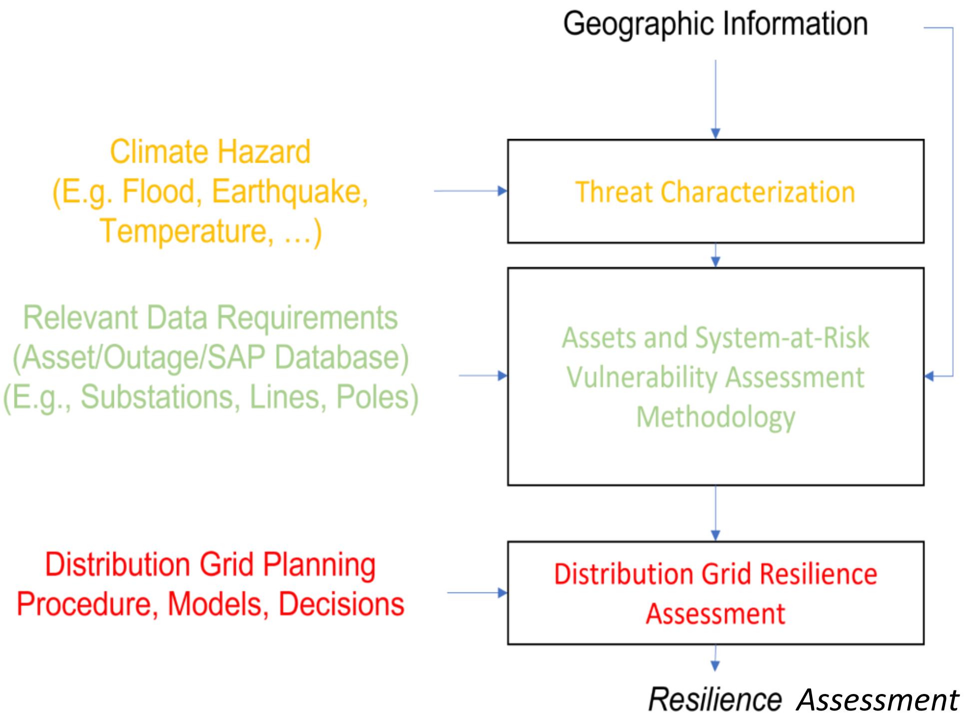


Chapter 5: System Modeling and Storm Simulation

- Goal:
  - Provide overview of methods to determine Assets-at-Risk and System-at-Risk
  - Provide list of relevant Distribution Grid Assets and methods used to quantify their risk due to Resilience Events
- Chapter outline:
  - Hazard Identification
  - Assets-at-Risk to Climate Type
  - Models to Quantify Risk
  - Assets-at-Risk to System-at-Risk Process
  - Examples/Lessons Learned from Utilities

Chapter 5: System Modeling and Storm Simulation Cont.

- The main content of this chapter is shown in green text
- The Threat Characterization part is the input to the chapter (Chapter 3)
- The output of this chapter could be utilized for Resilience Quantification (Chapter 6)



Chapter 5: System Modeling and Storm Simulation Cont.

- Jan-Mid Feb
  - Writing of individual sections of Chapter
- Mid Feb – End March
  - Content combination and improvement
- April
  - Finalizing Content and Submitting for proof reading

Chapter 6: Infrastructure and Operational Improvements for Resilience

- Upgrade infrastructure/assets for wind, ice, snow and flood protection (e.g., installing tree wire, aerial bundled and spacer cable, upgrading crossarms and poles, installing submersible equipment, etc.)
- Vegetation management
- Targeted undergrounding
- Review/update overhead and underground infrastructure design

- Enhanced line inspection programs
- High reliability/resiliency distribution system design (primary loop, primary and secondary selective, etc.)
- Digital/mobile workforce management
- Advanced inspection and damage assessment

- Redundant infrastructure (e.g., backup control center and supply to critical customers, etc.)
- Distribution and DER physical and cyber security standards
- Reinforced buildings and fences
- Shield assets from outside attacks
- Gas insulated and underground substations

- Underground cable replacement
- Protective, switching and volt-VAR equipment replacement
- Pole inspection and replacement

- Spare equipment (e.g., PPE, distribution poles, wires, cables, switches, and distribution transformers)
- Mobile transformers and generators
- Mutual assistance agreements, contractors/service provider agreements and onboarding, staff augmentation, etc.
- System and business recovery/remediation plans and processes (e.g., blackstart, contingency plans, storm restoration, safety, etc.)

- Shielding of T&D control centers, mitigation of radiated threats at substations, mitigation of conducted threats at protection and control equipment

- Distributed generation, energy storage, and microgrids
- Advanced DER monitoring and control
- Non-Wires Alternatives (NWA) and value of DER
- Hosting capacity management and optimization

- Real-time asset monitoring and condition assessment/prioritization
- Predictive/prescriptive asset health assessment via advanced analytics
- Optimal asset upgrade/replacement strategy
- ISO Certification

- Data collection, processing, storage and analysis
- Advanced T&D system modeling, simulation, planning and analysis
- Resiliency analytics
- Performance analytics
- Asset health analytics

- Real-time monitoring and control
- Management and monitoring systems (Advanced Distribution Management Systems – ADMS, Outage Management Systems – OMS, Network Monitoring Systems – NMS, etc.)
- DER and Demand Response Management Systems (DERMS and DRMS)
- Microprocessor-based controllers (voltage regulators, load tap changers, capacitor banks)

- New substations, feeders, line extensions, and feeder ties
- Reconductoring and rephasing
- Phase balancing
- Distribution class series and shunt FACTS devices for power flow control

- Smart protective and switching devices (e.g., smart reclosers/switches, self-resetting interrupters, etc.)
- Advanced reclosing (single-phase reclosing, pulse reclosing, etc.)
- Fault Location, Isolation and Service Restoration (FLISR)
- Substation automation

- Substation and feeder protective devices
- Bidirectional network protectors
- Adaptive protection and control of overcurrent protection devices

- Smart Meters and Advanced Metering Infrastructure (AMI)
- Sensors and advanced meters (voltage, current, power flow, temperature, irradiance, wind speed, fault circuit indicators, PMUs, power quality meters, etc.)
- Power electronics-based volt-VAR control devices (e.g., low-voltage SVCs)

- Remote/virtual operations
- Backup IT systems (Network Operations Center – NOC, Security Operations Center – SOC)
- Substation, feeder and last-mile telecommunications infrastructure

- Advanced inspection techniques (e.g., LIDAR)
- Predictive/prescriptive maintenance via advanced analytics
- Efficiency improvement via digital/mobile workforce solutions

Chapter 6 – Current Status

- Draft currently being developed using the framework provided in the last WG meeting at the 2023 IEEE PES General Meeting in Orlando, FL
- Target date to have the first draft of the chapter ready to share with WG Leadership Team on February 16, 2024, and with WG membership in March
- Approach to write document consists of 1) describing each solution for resilience improvement, 2) explain how it is applied to distribution systems, and 3) present examples of industry experiences and success stories, including references to published articles
- The following slides provide examples of some of the topics being discussed in the document, this is FYI only at this point, WG Leadership Team and members will have the opportunity to provide detailed comments to the first draft once distributed

Chapter 7 – Case Studies

- ComEd
  - Operational Performance
    - Human Performance
    - Automation Performance
    - Restoration Effectiveness
- National Grid
  - Operational Performance
    - Restoration Effectiveness
    - Gray Sky Day
- Duke Energy
  - Operational Performance
    - Restoration Effectiveness
- Florida Power and Light
  - System Performance
    - Comparative Metrics

Action items and next steps

Time frame	Tentative action items	Possible outcome	Work Done
GM 2021-JTCM 2022	Finish Target 1 Start Target 2	○ Identity and build the team ○ Qualitative definition of resilience • Factors affecting resilience of the grid against different disturbances ○ Identify data to be gathered for Targets 1-4	○ Over 60+ organizations engaged ○ Extensive discussion on Reliability vs Resiliency ○ IEEE DRWG team actively involved
JTCM 2022-GM 2022	Finish Target 2 Start Target 3	○ Baseline resilience against different events • Sharing experience of last events ○ Methods to quantify resilience ○ Briefing the important factors from the qualitative study ○ Gathering data on common industry/DOE/utility definitions ○ Gathering data on common tools ○ Gathering data on available research and academia literature	○ 5+ presentations by utilities and industries on Extreme Events ○ Storm Survey sent to DRES and DRWG members ○ Over 15+ responses to the survey ○ 6 entities willing to share outage level data
GM 2022-JTCM 2023	Continue Target 3	○ Build consensus on resilience metrics between the following factors ○ Common tools among utilities ○ Common tools among research ○ Bring a consensus among available data to utilities, data infrastructure, and research methods	○ Guide Outline Prepared – Chapter Leads and volunteers assigned ○ Resilience Definition work-Literature Survey ○ Resilience Metric development work in progress
JTCM 2023-JTCM 2024	Finish Target 3 Start Target 4 TBD	○ Creating a common framework for quantitative metrics of resilience with focus on available data ○ Start risk-benefit analysis of investments on both new infrastructure and gird hardening	○ 6 Quantitative metrics proposed. 4 are developed and Case Studies are being run on them by 4+ Utilities

Link to resilience guide draft

[Resilience Framework Outline SP - Google Docs]

Examples of Resilience Improvement Solutions – Undergrounding (FYI only)

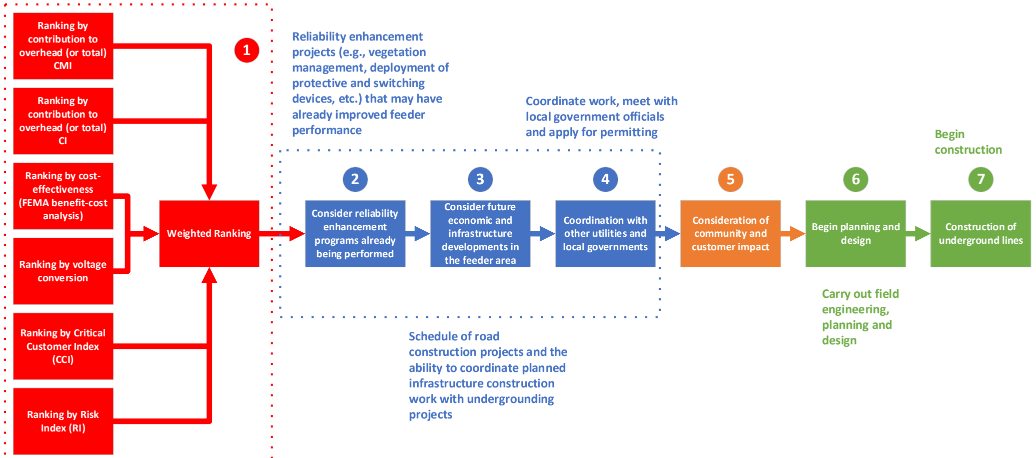
- In general, overhead systems are less costly to install and easier to maintain than underground systems since problems are generally easier to find and repair. However, underground systems are less susceptible to damage from storms, vegetation, and other environmental disturbances
- Undergrounding overhead lines is a solution that is increasingly being used by electric utilities to improve resilience and reliability and address existing and new challenges driven by climate change, such as wildfires and more frequent and severe storms
- Strategic or selective undergrounding is the most popular approach and consists of targeting only selected areas of T&D lines (e.g., primary taps), this is the approach used by Florida IOUs
- Some utilities have decided to target significant parts of their service territory. For instance, Dominion Energy and Wisconsin Public Service have undergrounded 1,800 and 2,000 miles of overhead lines, respectively.

Targeted Underground Projects

	2018	2019	2020	2021
DEF	12 ($3.7 m)	3 ($17.7 m)	205 ($29.4 m)	204 ($65.2 m)
FPL	0	33 ($76 m)	216 ($129 m)	350 ($212.5 m)
Gulf	0	0	0	8 ($5.2 m)
TECO	0	0	1 ($8 m)	520 ($79.5 m)

Source: FPSC

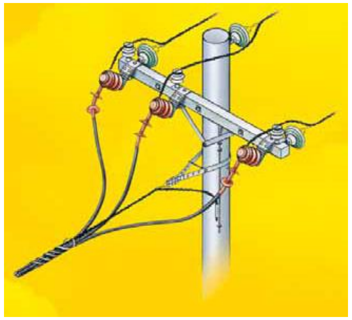
Example of Undergrounding Prioritization Strategy



Ranking feeders using a combination of the individual contribution of feeder CMI, CI, $/CMI, voltage conversion, CCI, and RI using weights to identify which feeders to underground and which portion of selected feeders to underground

Examples of Resilience Improvement Solutions – Aerial Cable (FYI only)

- A feasible alternative to undergrounding that represents a trade off in terms of benefits and costs with respect to overhead and underground construction is the utilization of aerial cable.
  - There are numerous approaches to aerial cable, from tree wire and covered conductor to fully-insulated aerial cable in open wire, spacer or bundled configuration.
  - Fully insulated self-supporting EPR cables assembled into Aerial Bundled Cable (ABC) and supported by a high strength copperweld messenger is being utilized by utilities in the Northeast and overseas as an alternative to undergrounding to improve distribution system reliability and resilience
  - Spacer cable, commonly known as



Source: Hendrix, Okonite and Olex (Nexans)

Chapter 7: Case Study: Storm Resiliency

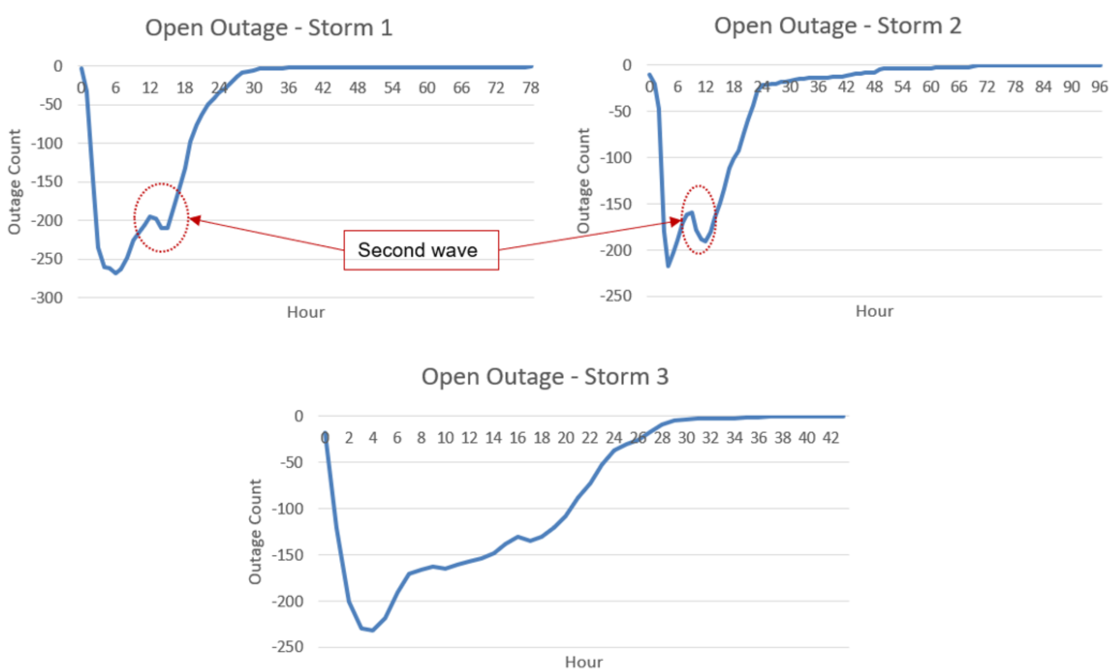
- Storm 1 and 2 and then compare it with Storm 3. Storms 1 and 2 are 1 year apart, with very similar outage count and avoided customer interruption (ACI) count, see Table. In storm 1 during the first 12 hour 93.6% customers were restored whereas in storm 2 only 88% customers were restored. This led to our storm metrics be 4.1% and 8% for the two storms. In both these storms we missed the performance target.

#	Start Storm Date Time	End Storm Date Time	Sustained Outage Count	Sustained Customer Interruption	CAIDI (Min)	Max Otg (HR)	DA ACI	Restored >12Hrs (w/ ACI)	Restored ≤12Hrs (w/ ACI)	Major Causes
Storm 1	6/26/2020 16:53	6/27/2020 18:51	575	57,504	220	75.7	30,537	4.18%	93.60%	HAIL, LIGHTNING, RAIN, WIND
Storm 2	6/20/2021 20:51	6/21/2021 17:34	527	53,156	334	93.1	26,511	8.01%	88.00%	RAIN, TORNADO, WIND
Storm 3	9/7/2021 13:02	9/8/2021 6:13	420	40,946	231	39.4	30,372	3.67%	93.60%	HAIL, LIGHTNING, RAIN, WIND

Chapter 7: Use Cases: Storm Resiliency Cont.

Case Study from :

1. FPL
2. ComEd
3. National Grid
4. Others?



Questions?

Storm Resiliency Definition

- Calculation:
  1) For each storm in a calendar year, calculate the ratio of customers without power for more than 12 hours and total customer interruptions (CI) including customers automatically restored (ACI) through smart switch operations (DA devices), community energy storage, and microgrids (does not include substation reclosing events) – measured in %

$$\textbf{Storm Event: } x = \frac{\sum \text{Customers Without Power for More Than 12 Hours}}{\textit{Sustained CI+ACI Due to Distribution Automation}}$$

  2) Based on number of interruptions (storm outages), categorize each storm event significant, large, medium, or small
  3) Determine if X is greater than or equal to the threshold value (Y) for the category.
  4) If X < Y, storm met expectations. If X >= Y, storm did not meet expectations
- Storm event size
  - Since all storms are not equal, to compare and gauge improvement, storms will be categorized into four categories
    - Significant Storms: Defined as greater than 1500 storm outages
    - Large Storms: Defined as between 701 and 1500 storm outages
    - Medium Storms: Defined as between 251 and 700 storm outages
    - Small Storms: Defined as less than or equal to 250 storm outages
  - For each storm size, the average percentage of customers without power for 12+ hours was calculated annually between 2009 and 2018
  - These annual averages were used to determine the baseline threshold values for each storm size
    - Significant = 24.1% , Large = 9.0%, Medium = 2.8% and Small = 0.8%

Gray Sky Day Definition

- **Gray Sky Days (GSD) Definition:** Includes any calendar day that meets any one of the following weather criteria:
  - >=80˚F average temperature across the system
  - <=0˚F average temperature across the system
  - >=25MPH average sustained wind speeds across the system
  - >=25MPH average one-hour wind gust across the system
  - >=0.75” average rain across the system
  - >=3,000 lightning strokes across the system
- Uses ICC definition of a customer Interruption i.e. applying ICC exclusions such as customer related, planned outages, fire/police requests, alternative retail electric supplier (RES) or utilities outages
- GSD Intensity measures extremity of qualifying weather conditions
- Three color codes (yellow, orange, red) account for average daily temperature, wind speed, rainfall, and lightning strokes
- These color codes can be used to evaluate reliability performance on a given GSD

Yellow

- **Average temperature** between 80 and 85 degrees
- **Average temperature** between 0 and -5 degrees
- **Average sustained wind speed** between 25 and 30 MPH
- **Average of one-hour wind gust** between 25 MPH and 30 MPH
- **Average rainfall** between 0.75” and 1”
- **Lightning stroke count** between 3,000 and 6,000

Orange

- **Average temperature** between 85 and 90 degrees
- **Average temperature** between -5 and -10 degrees
- **Average sustained wind speed** between 30 and 35 MPH
- **Average of one-hour wind gust** between 30 MPH and 35 MPH
- **Average rainfall** between 1” and 1.25”
- **Lightning stroke count** between 6,000 and 10,000

Red

- **Average temperature** greater than 90 degrees
- **Average temperature** less than -10 degrees
- **Average sustained wind speed** >= 35 MPH
- **Average of one-hour wind gust** >= 35 MPH
- **Average rainfall** greater than 1.25”
- **Lightning stroke count** greater than 10,000

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