Microgrids for Tropical Storm-Prone Areas

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Resilience Training for the Southeast
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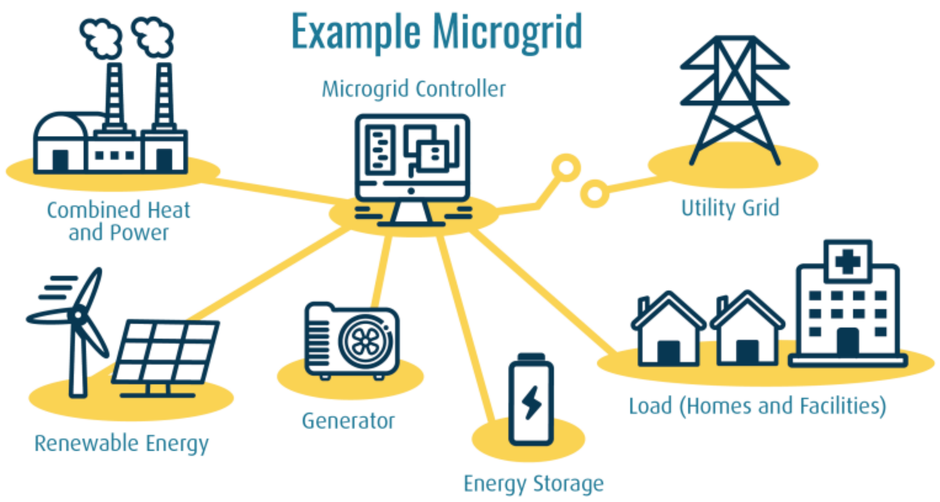
Microgrids

Definition

“A group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode”.

Source: Dan Ton and Merrill Smith, U.S. Department of Energy, “The U.S. Department of Energy’s Microgrid Initiative,” 2012. https://www.energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy%27s%20Microgrid%20Initiative.pdf



Source: NASEO Microgrid State Working group. https://www.naseo.org/issues/electricity/microgrids

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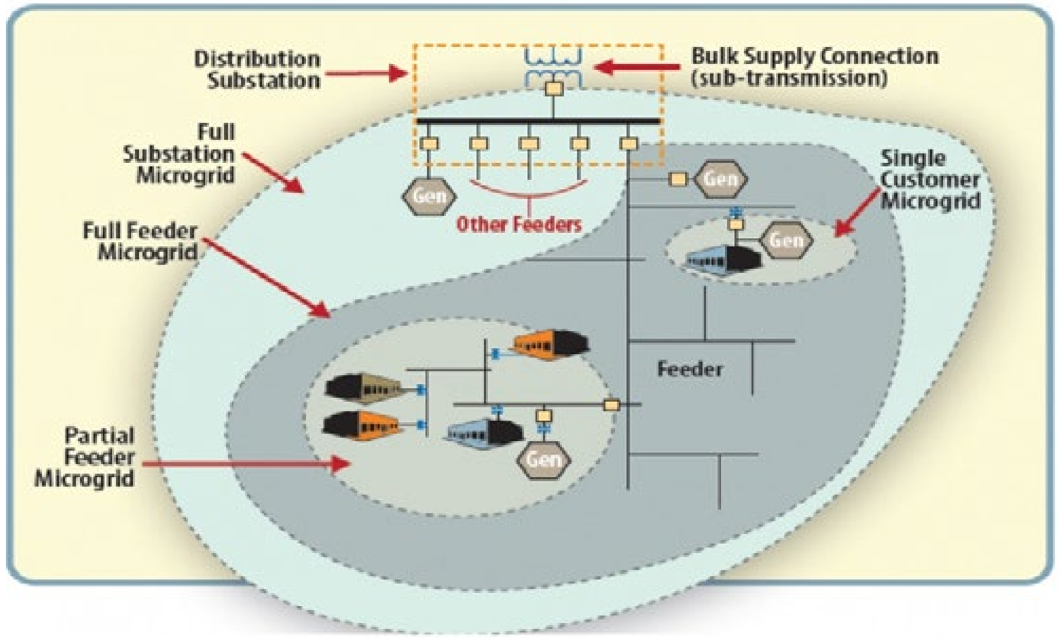
Types of Microgrids

3 types

- **Building-level:** single facility microgrid with one or multiple DERs operating behind the meter and owned by the same customer.
- **Campus-level:** multiple-facility microgrid with DERs owned by the same customer. The microgrid may include its own internal network and multiple meters.
- **Community-level:** multiple-facility microgrid with DERs owned by multiple entities. Implies operation across rights-of-way, which is forbidden in many jurisdictions. In practice, these type of microgrids are owned and operated by public utilities.



Source: NARUC and NASEO – joint publication, "User Objectives and Design Approaches for Microgrids: Options for Delivering Reliability and Resilience, Clean Energy, Energy Savings, and Other Priorities" (2021). https://pubs.naruc.org/pub/E1F332D4-155D-0A36-31CB-889ABED753D5

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Customer Owned Microgrids

Customer Owned Microgrid Resilience

Function, design and applications

- In building or campus-level microgrids, resilience is included as a design requirement to serve critical functions of their users.
- Resilience is one among other microgrid design objectives (*e.g.,* energy savings or peak shaving) included in a techno-economic feasibility study.
- Resilient design does not depend on a particular set of outage events. Instead, it is a function of the critical energy needs of a specific infrastructure.
- Examples of critical infrastructure include hospitals, shelters, fire stations, and public service offices.

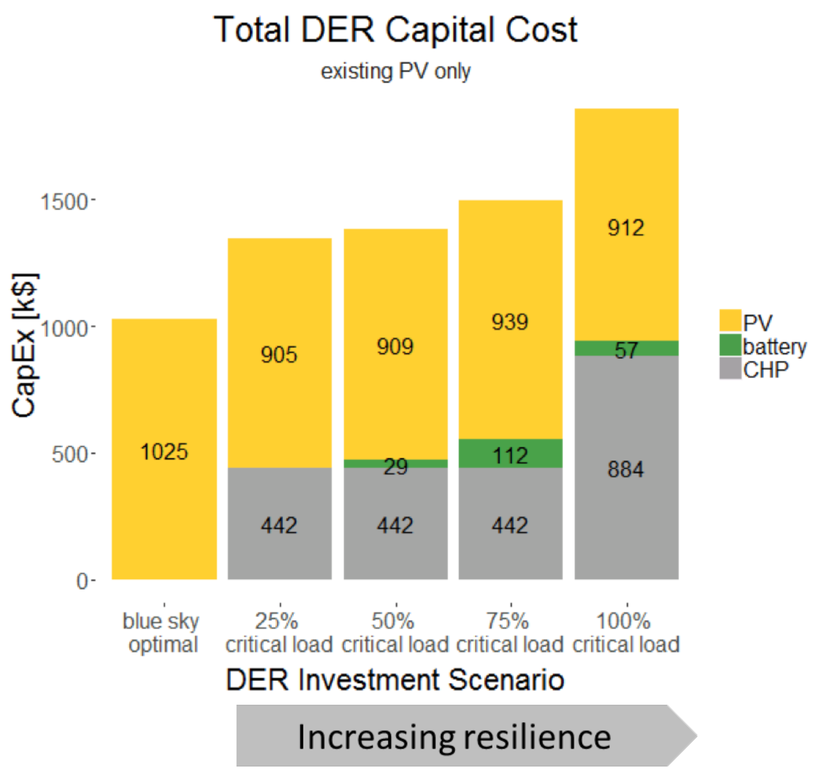
Critical load definition

- Critical load is the key element of the resilient design. It can be defined in two ways:
  - *Backup energy*: The microgrid design and operation must always guarantee that the required level of energy (kWh) can be delivered in islanded mode.
  - *Critical load curve:* The microgrid design must ensure that a load curve, including temporal power characteristics (such as peak and ramps), can be supplied in islanded mode.

Example: Building-level Microgrid Design

Public Building (North Carolina)

- A building-level microgrid was designed in NC, under the *DOE Better Buildings Initiative,* to serve both electricity and heating needs.
- The critical load, defined as percentage of the total load curve, must be supplied for 4 consecutive days in islanded mode.
- Investments in DERs increase with the resilience target, *i.e.*, with the percentage of load that is considered critical to the system (holding the system size constant).
- Combined heat and power, as a flexible asset for both electricity and heating supply, is able to provide multi-energy backup power. It is a key solution for high resilience scenarios.



Source: "Save Money and Build Resilience with Distributed Energy Technologies," Better Buildings Initiative webinar, Feb 2020. https://betterbuildingssolutioncenter.energy.gov/webinars/save-money-and-build-resilience-distributed-energy-technologies

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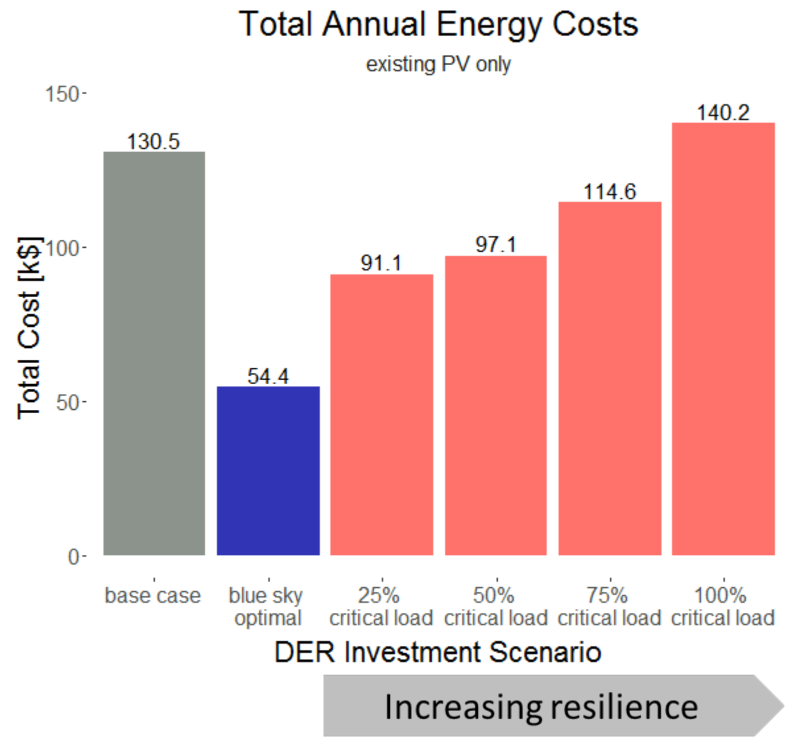
Example: Building-level Microgrid Costs

Public Building (North Carolina)

- As resilience requirements increase, higher DER capacities are installed beyond what would be the economic optimal infrastructure, i.e., the capacity needed under blue-sky (regular operation) conditions.
- The DER capacity added for resilience purposes leads to lower incremental returns, increasing the total microgrid operational costs in comparison with the blue-sky scenario.
- When critical load represents more than 75% of the energy consumption, the total microgrid energy operation costs are higher than the energy operation in the base case (without a microgrid installation).



Source: "Save Money and Build Resilience with Distributed Energy Technologies," Better Buildings Initiative webinar, Feb 2020. https://betterbuildingssolutioncenter.energy.gov/webinars/save-money-and-build-resilience-distributed-energy-technologies

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Takeaways: Customer Owned Microgrid

Summary

- In customer owned microgrids, resilience is a function of the critical multi-energy (not only electricity) needs of a specific infrastructure.
- High resilience targets often increase microgrid investment costs.
- High resilience targets also increase microgrid operation costs. With traditional revenue streams, resilient microgrids may not be economically viable.
- Policies and regulations can encourage microgrid-resilient infrastructure and mechanisms to increase microgrid revenue streams.

Policy and regulatory instruments

- **Blue-sky DER compensation** mechanisms can indirectly incent flexible generation and storage. With small additional investments, these assets can be operated as a microgrid in gray-sky (natural disaster) conditions.
- **Microgrid tariffs** can directly create specific revenue streams for resilience infrastructure.*
- **Pilot projects** can help demonstrate economic feasibility of microgrids in different contexts and test impacts of different revenue streams.

*California and Hawaii have microgrid services tariffs in place to expediently integrate resilient and renewable energy into the grid. https://www.hawaiianelectric.com/about-us/our-vision-and-commitment/resilience/microgrid-services-tariff

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Microgrid Pilot Programs

- Resilience Center Pilot Grant Program, Wisconsin
  - Launched by: Public Service Commission of Wisconsin's Office of Energy Innovation
  - Description: The program focused on pre-disaster mitigation through critical infrastructure microgrids and other resilient building strategies by studying the feasibility of the deployment of DERs.

Source: https://apps.psc.wi.gov/ERF/ERFview/viewdoc.aspx?docid=414483

- Town Center Distributed Energy Resources Microgrid program, New Jersey
  - Launched by: New Jersey Board of Public Utilities
  - Description: Created after Superstorm Sandy, the program incentivized microgrids in critical facilities, within a municipal boundary, capable of providing essential municipal services and shelter for the public during and after an emergency situation.

Source: https://www.nj.gov/bpu/pdf/energy/Phase%20II%20TCDER%20Microgrid%20Incentive%20Program%20Application%202-19-20.pdf

Utility Owned Microgrids

Utility Owned Microgrids Resilience

A proactive planning problem

- How can utilities have the necessary resources on the ground to mitigate the effect of extreme events?
- How can utilities make **risk informed** decisions when planning for investments in DERs and microgrids?
- Resilience valuation of DERs and microgrids is about exploring the trade-offs between economic costs and system risk.

Utility Planning: Reliability vs Resilience

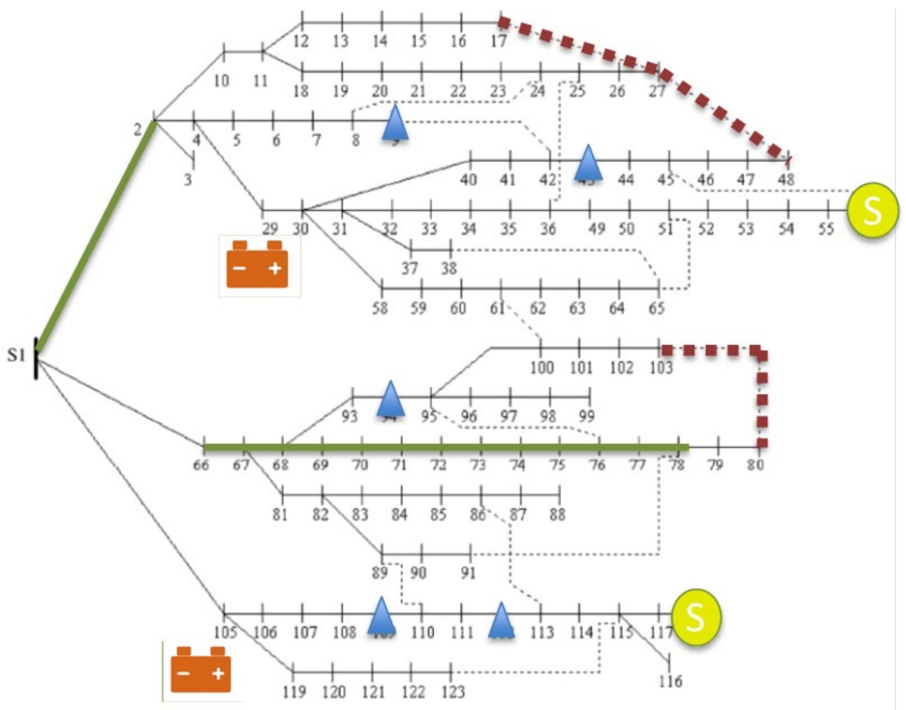
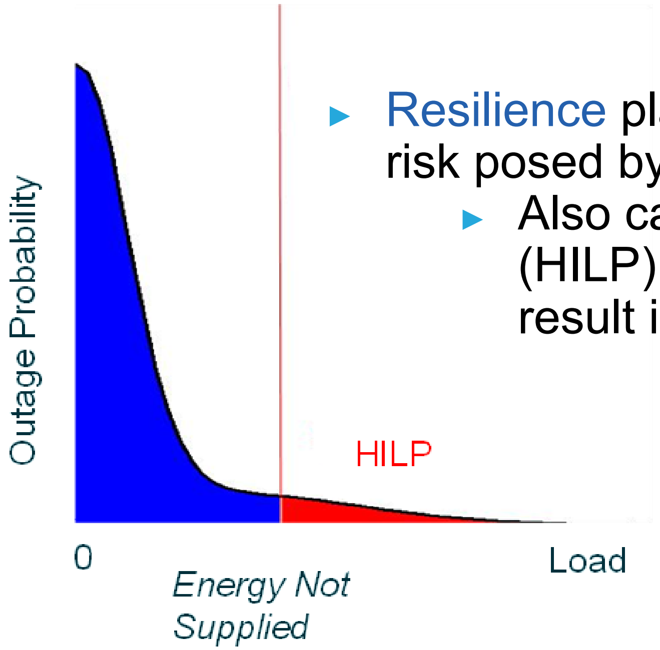


Illustration of the potential grid upgrade candidates in a distribution grid, including new connections to the transmission, reconductoring, ties to adjacent feeders, storage and microgrids, etc.

- Reliability planning is about mitigating outages caused by routine events.
  - Expected value of interruptions, captured by metrics such as SAIDI and SAIFI.



- Resilience planning is about controlling the risk posed by extreme events.
  - Also called High Impact Low Probability (HILP), *i.e.* rare catastrophic events that result in major outages.

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Risk Mitigation in Utility Planning

Advanced resilience planning should consider:

- Investment costs of new upgrades.
- Expected cost of outages associated with routine events, measured under **reliability** performance metrics.
- **Value-at-risk** of economic losses associated with the cost of outages caused by extreme events, such as storms.
- Outage costs can be estimated based on the economic value of loss of load.

Reliability
Expected value of the outages
(Routine events)

Resilience
Conditional value at risk of outage costs
(HILP events)

Minimize

$$(1-\lambda)(\text{UpgradeCosts} + \text{E}[\text{cost}]) + \lambda\,\text{CVaR}[\text{cost}]$$

- The Risk Aversion (λ) parameter captures the “cost vs risk” decision of the planner:
  - If λ=0, the planning objective is risk-neutral, focused on costs and neglecting resilience.
  - If λ=1, the planning objective becomes extremely risk-averse and maximizes resilience.

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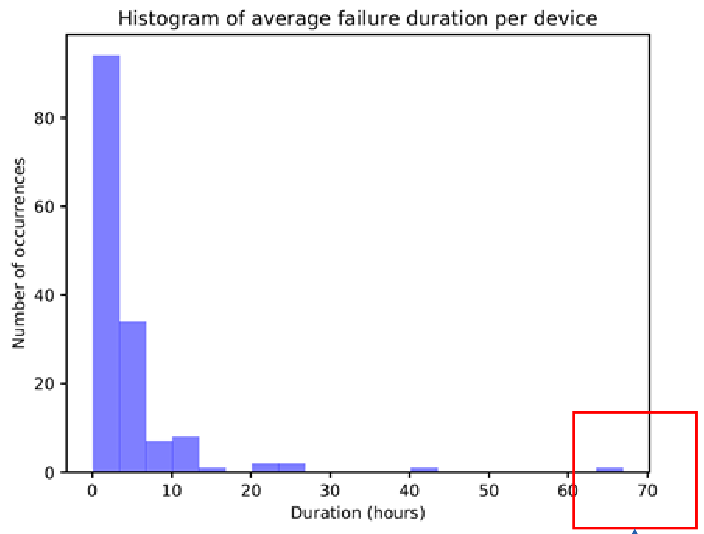
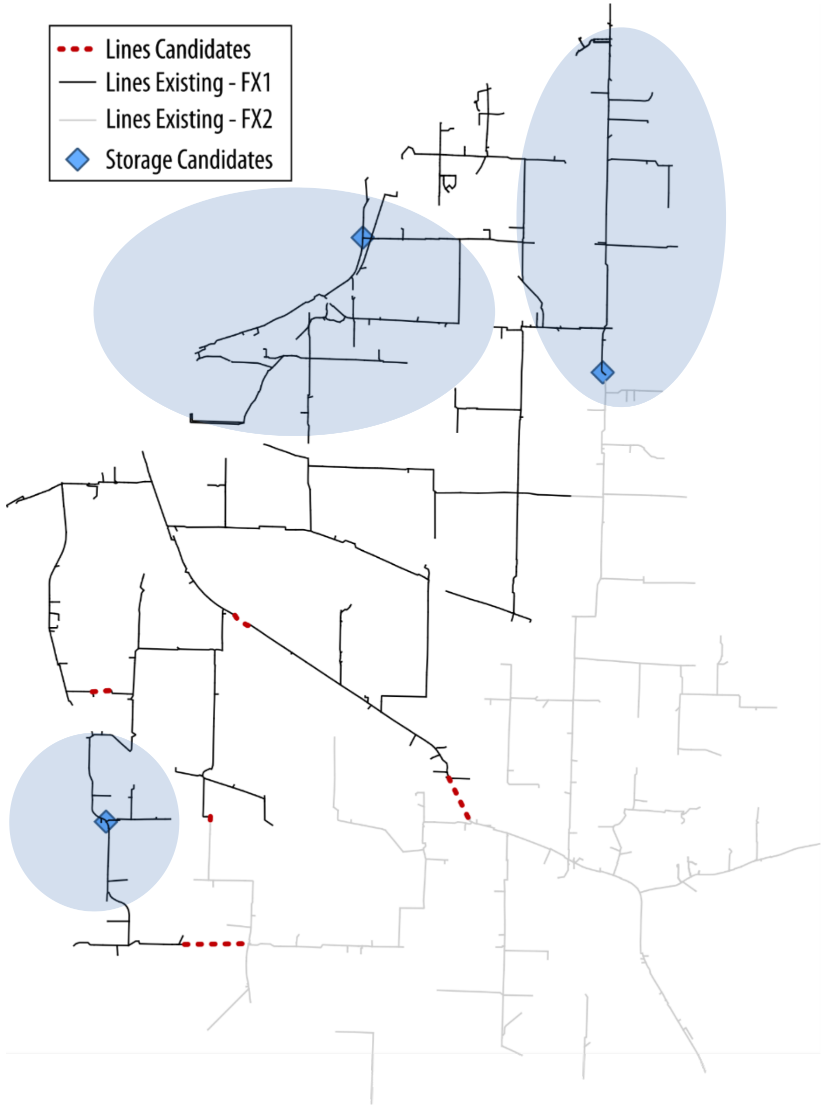
Resilience Valuation Case

Valuation of resilience feeder upgrades

- Gather historic outage data, including for extreme events;
- Add scenarios of extreme events and their likelihood; and
- Evaluate different investment solutions for different levels of risk aversion.



Summer storm in August 2020



ComEd's Reliability Program Feeder with different proposed upgrades, including 3 potential storage projects with potential islanding capabilities.

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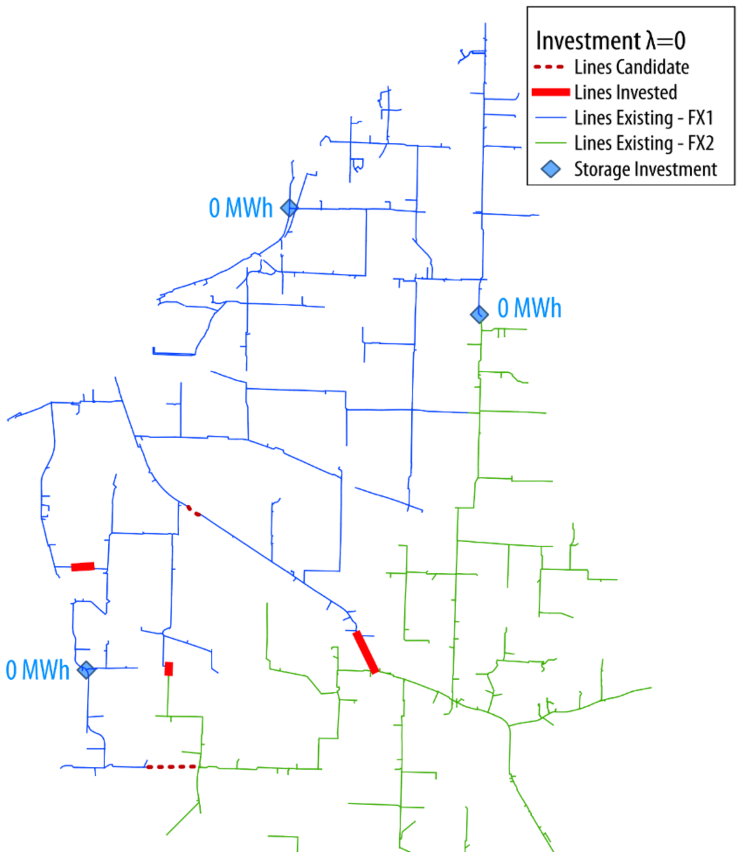
Resilience Valuation Case

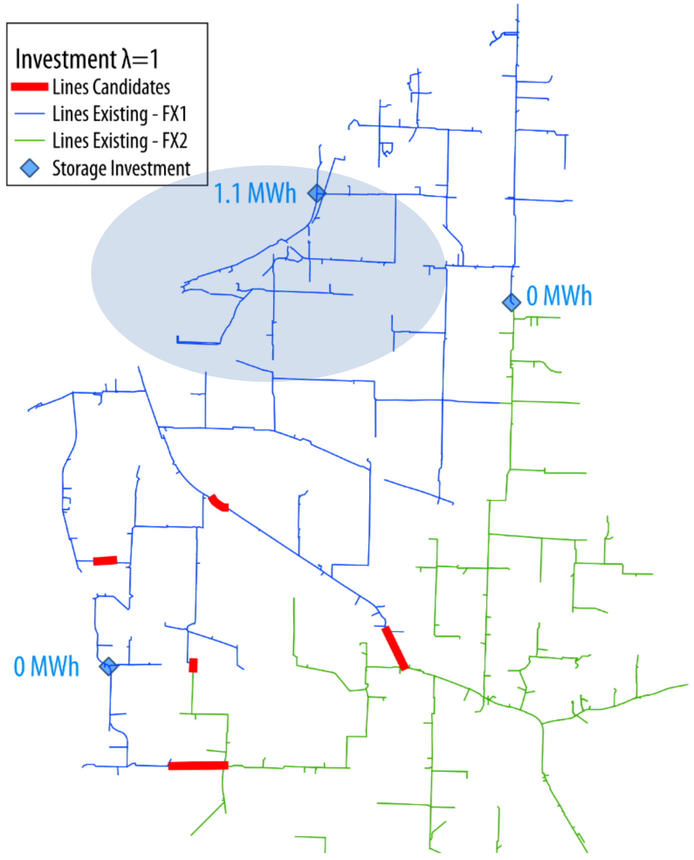
Planning Solutions

- The inclusion of DERs and microgrids in the distribution grid planning solution is a function of the risk aversion policy.
- Both planning solutions are optimal from the economic perspective. However, they comprise different risk aversion criteria.
- The additional 2 lines + the battery project can be seen as a risk "premium" to protect against a potential \$2.6B loss.



Risk neutral plan (λ=0)

- 3 new line interconnections.
- System Risk Cost (CVaR): \$2.6B



Risk averse plan (λ=1)

- 5 new line interconnections
- 1 MW battery (+islanding capability)
- System Risk Cost (CVaR): \$1.0M

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Cost of Outages in Resilience Valuation

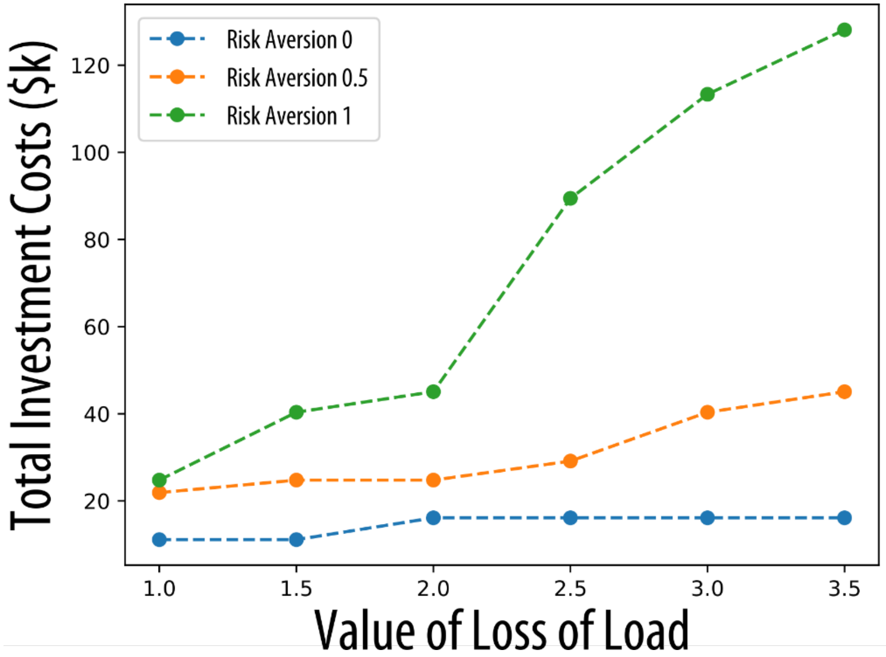
Value of Loss Load – Sensitivity Analysis

- An accurate estimation of the costs of service interruption, and the corresponding value of loss of load, are critical pieces of the "cost vs risk" analysis.

- The economic cost of outages determines the resilience value of distribution system upgrades, including DERs and microgrids.

- Econometric models such as the Interruption Cost Estimate (ICE) tool can be used to estimate the cost of outages.*

* Source: https://icecalculator.com



Optimal investment costs to upgrade ComEd's Reliability Program Feeder (shown in previous slides). Upgrade costs for different levels of risk aversion are presented as a function of the value of loss of load ($/kWh).

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Takeaways: Utility Owned Microgrid

Summary

- In utility-owned microgrids, resilience is the ability to control the risk posed by extreme weather events, such as storms.
- Microgrids can be part of a proactive distribution grid planning strategy, guided by accurate risk assessment methodologies.
- The resilience value of microgrids is a function of:
    - The risk aversion policy embedded in the distribution grid planning process and
    - The economic costs of long-duration outages to customers and society.

Policy and regulatory insights

- Distribution grid planning processes can include risk assessment methodologies to accurately capture the resilience value of microgrids.
- Utility microgrid investments can be regulated under a "cost vs risk" framework with transparent risk aversion policies.
- Regulator guidance on estimating the economic cost of outages is key to determining the value of resilience assets, such as microgrids.

Contact

https://www.energy.gov/gdo/grid-deployment-office

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