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Enhancing Informed Decision-Making: Valuing System Upgrades through Resilience Curves

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SUMMARY

The allocation of budgets to competing distribution system upgrades and risk mitigation measures can be a complex process, as these upgrades often target different metrics such as reliability, capacity, and asset robustness. To address this challenge, this paper proposes a novel approach to valuing system upgrades using resilience curves. By considering the contribution of geo-special and time domain segmentation to the resilience curve, utilities can make more informed decisions, prioritize projects, and optimize budget allocation.

KEYWORDS

Resilience, reliability, capacity, investment, decision-making

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INTRODUCTION

Recently introduced, the Infrastructure Investment and Jobs Act (IIJA) [1] confirms a significant push to strengthen electric grid resilience, allocating more than $47B for resilience, including cybersecurity. Unsurprisingly, resilience building comes at a considerable cost and requires meticulous analysis to identify the most cost-effective actions, ensuring the system's ability to perform in a deterministic and measurable manner.

While scoping system improvement projects is relatively straightforward, quantifying the return on newly invested capital (RONIC), especially concerning system performance under extreme events for resilience, becomes a complex, data-driven task. Without resilience RONIC, utilities may inefficiently deploy limited capital, and regulators may struggle to approve capital spend proposals without fully grasping the grid's performance and societal benefits at various cost levels.

To make informed decisions about capital deployment, utility executives often lack comprehensive information when considering system improvements that directly or indirectly impact resilience. This limitation arises from the disjointed nature of traditional planning processes, where different parts of the organization focus on various functions and system levels, such as asset management and system operations, and transmission and distribution.

However, assessment of upgrade initiatives as mutually dependent and/or complementary in investment terms offers a better approach. Evaluating the added value of investment proposals by observing the entire system's performance with and without them allows for a more holistic decision-making process. With an understanding the expected RONIC with respect to the entire system performance, decision makers are better positioned to make the right investment choices.

METHODOLOGY

The proposed approach groups network upgrades into geo-special segment groups, capturing all related proposed upgrades within a specific geographical area. A base resilience curve is established with all proposed upgrades in place, and the distribution power flow model is used to assess the system's response to extreme events, determining the loss of load/assets and system restoration to form the system resilience curve [2]. By sequentially removing network upgrades corresponding to each segment group, utilities can ascertain the added value of each group to the overall resilience curve, providing insights into the potential losses in the absence of specific upgrades.

Proposed upgrades are geo-specially nested based on circuit topology. For the purpose of this paper, an example with three distribution circuits and various segment groups of proposed pole hardening upgrades is evaluated for added value; overhead solution is compared with underground solution.

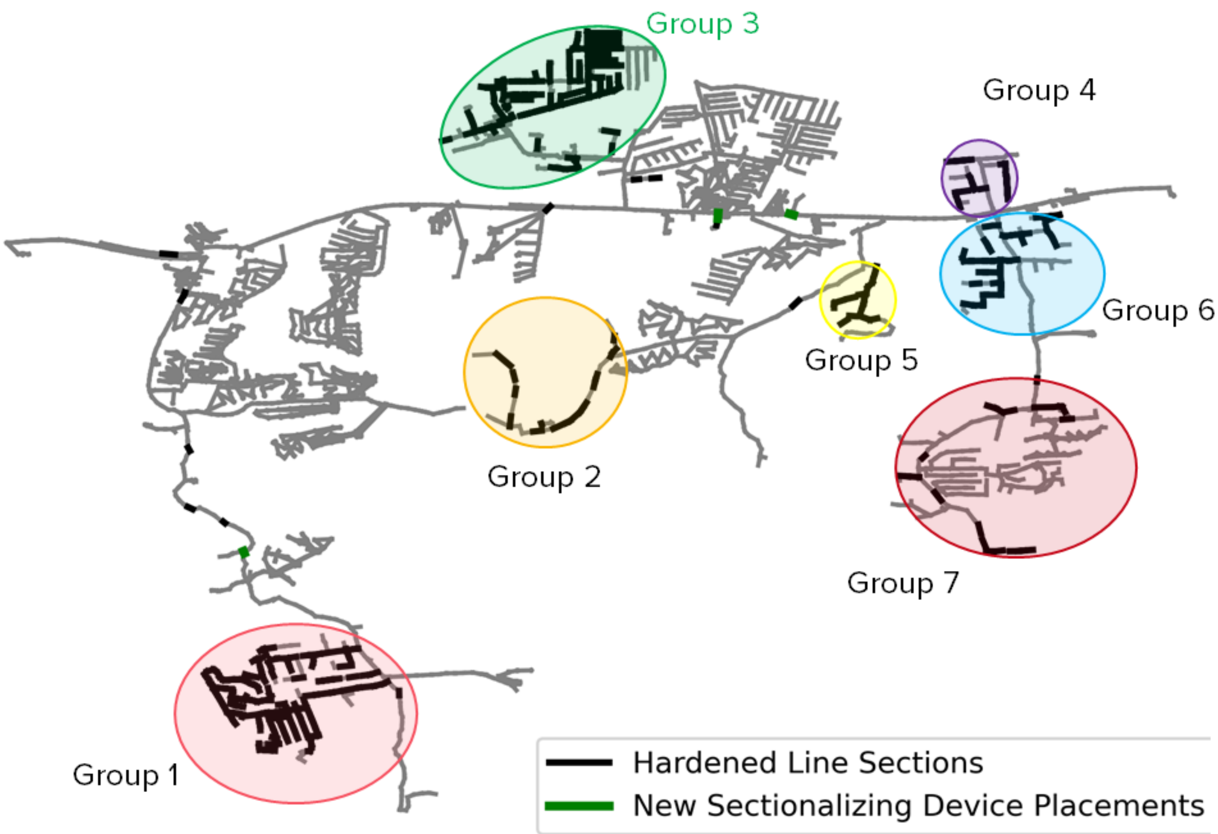

Figure 1. Network Upgrades Grouping

A wind loading risk model has been developed for each distribution pole in the study area, taking into account various factors such as pole type, height, the conductors it carries, conductor spans, and the presence of equipment like service transformers, regulators, and capacitors. Additionally, the model considers any 3rd party equipment, such as communication cables. Subsequently, each pole is assigned to a specific distribution line segment. However, this mapping process can be challenging due to inconsistencies in the GIS, often necessitating the use of analytics methods to accurately map distribution poles to their respective line sections.

The study area is exposed to a range of extreme event conditions that influence the probability of pole failure. When a pole fails, the protection zone it serves is taken out of service. In cases where transfer switches are in place, simulations allow for load transfers to occur, provided that thermal and voltage limits are not violated. This simulation process helps create a resilience curve, which depicts the percentage of power served (or kW loss) over time.

RESULTS

The overall resilience curve was generated by considering all upgrades in place. To determine the added value of each group upgrade, we sequentially removed one group upgrades at a time and evaluated the resulting resilience curve degradation, forming the group added value resilience curve. Figure 2 presents the calculated resilience curve contributions, offering valuable insights to enhance the decision-making process. From the resilience curve, we extracted various attributes, such as expected kWh loss, outage accumulation rate, the number of customers without power after specific intervals (24, 48, and 72 hours), and the time to first and last restored customer. We valued the expected energy loss for each group by assigning monetary weights based on the customer mix and the number of sensitive customers.

Additionally, a benefit-cost analysis was performed to evaluate the overhead versus underground solutions. Understanding the trade-offs between these options is crucial for decision-makers, especially considering the solution lifespan—60 years for overhead and 30 years for underground—and the limited ability to override the decision during the asset's life. Figure 3 illustrates this comparison. The spread between the overhead and underground benefit-to-cost ratio serves as a key indicator for deciding which option to pursue eventually. A smaller spread indicates a more attractive underground solution.

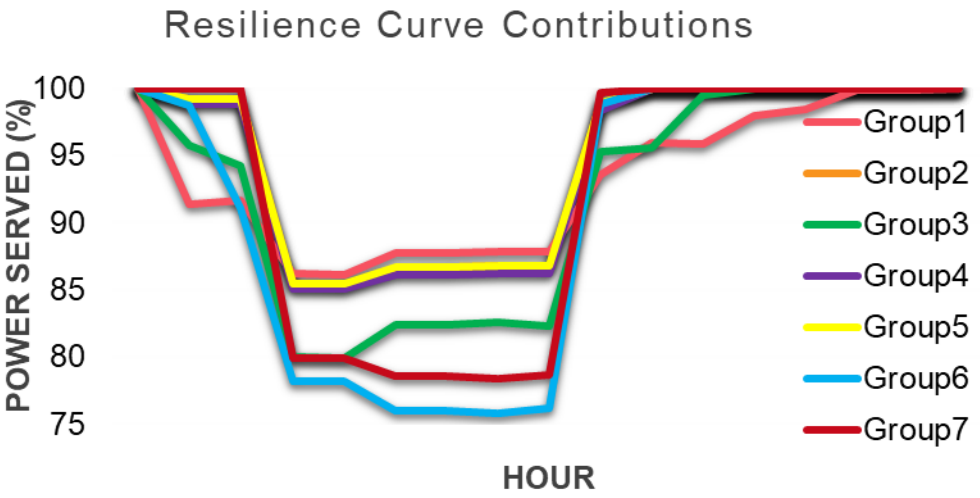

Figure 2. Resilience Curve Added Value for each Network Upgrade Group

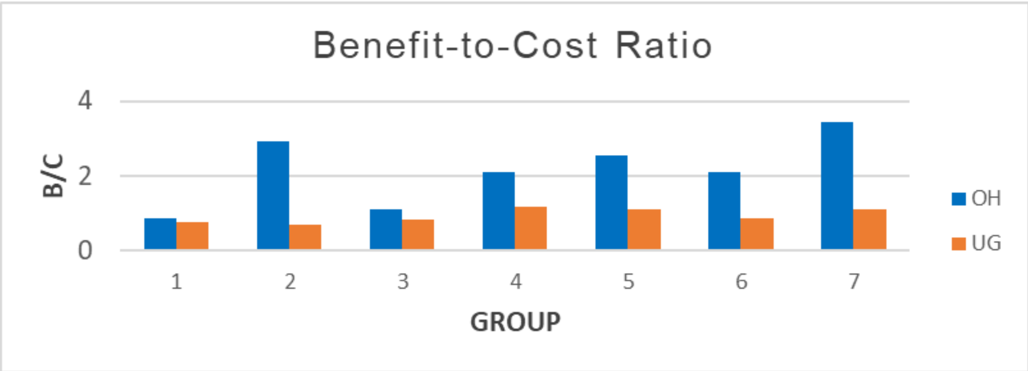

Figure 3. Underground vs. Overhead Benefit-Cost Ratio

PERFORMANCE

The speed of the analysis is influenced by several factors, including the size of the planning area, the severity of extreme events, and the number of segment groups. Regardless, the performance is notably satisfactory. Even for severe weather events, such as a category 4 hurricane, the analysis takes approximately 20 minutes per segment group on a standard desktop machine.

For further improvement in analysis speed, high-performance machines equipped with multi-core processors and ample RAM memory can be utilized. These advanced hardware configurations can significantly enhance the efficiency of the analysis process.

CONCLUSION

The valuation of network upgrades in terms of resilience proves to be a valuable and essential tool for informed decision-making, especially when upgrade costs exceed available budgets. With the implementation of the proposed approach, utilities can strategically allocate capital in a geo-special manner, pinpointing segment groups that warrant investment and areas where it may not be necessary. Ultimately, this method empowers utilities to make prudent choices and strengthen the overall resilience of their distribution systems.

BIBLIOGRAPHY

[1] Infrastructure Investment and Jobs Act (IIJA): Funding for USDA Broadband, Watershed, and Bioproduct Programs" (Electra number 144 October 1992 pages 107-125)

[2] S. Ma, S. Li, Z. Wang and F. Qiu, "Resilience-Oriented Design of Distribution Systems," in IEEE Transactions on Power Systems, vol. 34, no. 4, pp. 2880-2891, July 2019