SUBSTATION HARDENING FOR ELECTRICITY RESILIENCY

To: North Carolina Utilities Commission

Executive Summary

This brief outlines a potential solution for infrastructure improvements of energy systems in southeastern North Carolina. In 2018, Hurricane Florence caused millions of consumers to lose power due to heavy rain, extensive flooding, and high winds. One of the largest sources of outages came from flooded substations. Although other options for electrical reform were considered, based on a cost analysis and case studies, hardening of North Carolina's electrical infrastructure with substation elevation is a feasible and deliverable strategy for the near-future to mitigate future outages in the case of extreme weather events like Florence.

Background

Heavy rainfalls and powerful winds of Hurricane Florence devastated North Carolina from September 13 to September 17, 2018 (Winsor, 2018). Through the course of this storm, over 2 million customers of North Carolina utilities' customers were without power (Cope, 2019). One of the largest contributors to these power outages was flooding. Due to the extreme rainfalls, high flood levels paired with strong winds caused damage to many parts of the power system infrastructure including power lines and poles. However, approximately 64 flooded substations were found to be more impactful on customer outages due to their position in the supply of power from the generation source to consumer (Kuckro, 2018). Substations also played a critical role in outages during Hurricane Matthew in 2016. This would suggest that improvements to substations could have an outsized impact on preventing future outages in the face of extreme weather events.

Long Island & Houston Case Studies

New York and Texas have both suffered electrical systems failures and resultant power outages due to devastating hurricanes via Superstorm Sandy in 2012 and Hurricane Harvey in 2017, respectively. Areas impacted by storms in both states chose to harden (i.e. make physical alterations to reduce susceptibility of contact flood water and sensitive equipment) their electrical infrastructures though substation elevation (Costa and McAllister, 2017, Walton, 2018).

In New York, National Grid worked in conjunction with other utilities to identify proactive approaches to mitigate extensive substation flooding as seen during Sandy (Costa and McAllister, 2017, Yates et al., 2014). Multiple utilities acted to elevate transformers above flood levels as a result of data analysis following the storm (Walton, 2018). Utilities have reported reduced outage numbers in the case of other extreme weather like blizzards (The Associated Press, 2016).

2 MILLION+

North Carolinians without power

64

substations damaged

$760 MILLION

in total damages to Duke Energy's infrastructure

Texas utilities took a similar approach following Harvey. Entergy, one of Texas' largest energy suppliers, had 17 substations flooded during the storm (Entergy Newsroom, 2018). The utility decided to elevate control houses and critical equipment at substations above the historic flood levels. They also joined industry groups and task forces to plan ways to more efficiently transport and supply mobile substations and transformers during recovery efforts.

In both states, utilities considered other mitigations efforts, such as the undergrounding of power lines. Both New York and Texas utilities found hardening through substation elevation to be the best short term solution for grid resiliency in the face of extreme weather events.

Proposed Solution

Based on an analysis of North Carolina's electricity infrastructure over the past ten years, hardening at least 20 substations is a necessity to ensure the future reliability of the state's power system. Hardening substations includes raising substation equipment above potential flood levels as well as replacing and installing stronger waterproof materials. It is likely that more substations should be hardened, however, due to a lack of comprehensive data the exact number that would be cost effective is unclear.

The cost of hardening substations is significant: over $32 million for the proposed improvements. However, the benefit of substation hardening is a proven solution for areas that are likely to flood. Substations are significantly more difficult and costly to repair for the utilities leading to long outages for many customers. Based on a preliminary economic analysis, the hardening of the substations would likely be cost effective over their lifetime. For example, substation hardening would have likely reduced Duke Energy's reported approximate damages of 557 Million from Hurricane Florence (Downey 2018) by several million dollars. Moreover, it would have reduced the costs to electric cooperatives as well as the economic costs to electricity consumers.

Costs	
Cost Assumptions	
Substation Improvement	$ 2,250,000.00
Number of Substations	20
Interest Rate	2.5%
Discount Rate	7%
Payment Period	20 years
Results	
Total Cost	$ (45,000,000.00)
Annualized Payment	$ (2,886,620.79)
NPV of Cost	$ (32,721,564.93)

See Appendix for a detailed explanation as well as a more detailed cost analysis.

Conclusion

Significant work is necessary to improve the reliability and resiliency of North Carolina's electricity grid in the face of future extreme weather events. North Carolinians have the opportunity to learn from the experience of Hurricane Florence and implement proactive solutions before the next weather event strikes. Many future solutions are necessary to mitigate weather related power outages including better data analysis methods and undergrounding. However, in the near term, substation hardening is an easily implemented solution with proven results.

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Understanding Natural and Human Initiation and Transmission of Cascading Hazards (UNHITCH)

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Appendix

The costs of substation hardening were calculated by first finding an approximate cost of making the improvements to the substation. This average cost was calculated based on New York State's substation improvements which cost $72 million to replace 32 substations or about 2.25 million per substation (Crichton, 2013). Then we assumed that we would replace around 20 substations. This number was decided after an initial news analysis to determine how many substations were critically damaged. The total cost of the investment was calculated and then assumed that the payments would be made over a 20 year period with a 2.5% interest rate on the payments. The net present value of these payments was then calculated using a conservative 7% discount rate. The results are presented in the table above.

An additional analysis of the potential benefits of substation hardening was conducted. The analysis used average economic costs associated with different electricity consumers from the Lawrence Berkeley National Laboratory (2015). In the analysis, it was assumed that approximately 1,500 residential customers could be served by a single substation (Chelan County Power), however, this number fluctuates depending on the specific substation. Further, the analysis assumed that the customers were without power for a total of 4 days which is consistent with the most affected areas from Hurricane Florence. Hypothetical scenarios were then created to determine the approximate cost the substation hardening could avoid. Below are the results.

Scenario	Assumptions	Cost
1	Only residential customers on all 20 substations	$6.1 M
2	Only residential customers on 19 substations, 10 small commercial or idndustrial customers on 1 substation	$6.4 M
3	Only residential customers on 19 substations, 1 large commercial or indstrial customer on 1 substation	$6.9 M

Note: The results were not included in the brief's main body due to several limitations in the analysis. The main limitation includes the lack of data regarding the relevant substations and how many and what types of customers they serve. However, the results were included here as they demonstrate the potential benefits of substation hardening. It should be noted that these estimate cost savings do no include the savings from less repairs and maintenance due to extreme weather events.

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