

Importance of High-Resolution Data in Power Transmission Vulnerability

INTRODUCTION

- Catastrophe (CAT) Modeling probabilistically studies natural disasters and their consequences.
- Modeling these rare events with more than historical data is key to understanding and fortifying community resilience, the preparedness level of a collective to mitigate risks related to extreme events and recover functionality within a given period [1].
- This study investigates the importance of detailed powerline modeling in assessing the functionality of a power network under hurricane wind conditions. In particular, the sensitivity of the network functionality to different choices in terms of the level of detail in the fragility model is quantified.

METHODOLOGY

The analysis incorporates two distinct tower types and evaluates the impact of four wind directions on network functionality. The towers and their fragilities are taken from the literature, and parametrized to four wind directions of 0 degrees, 30 degrees, 60 degrees, and 90 degrees with respect to the conductor cables. Spatial correlation across tower failures is accounted for in the sampling of the tower damage state, for a given probability of failure.



Figure 1: Raster data of Hurricane Ian's Three Second Sustained Wind Speed

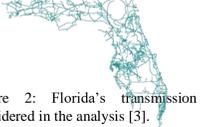


Figure 2: Florida's transmission lines considered in the analysis [3].

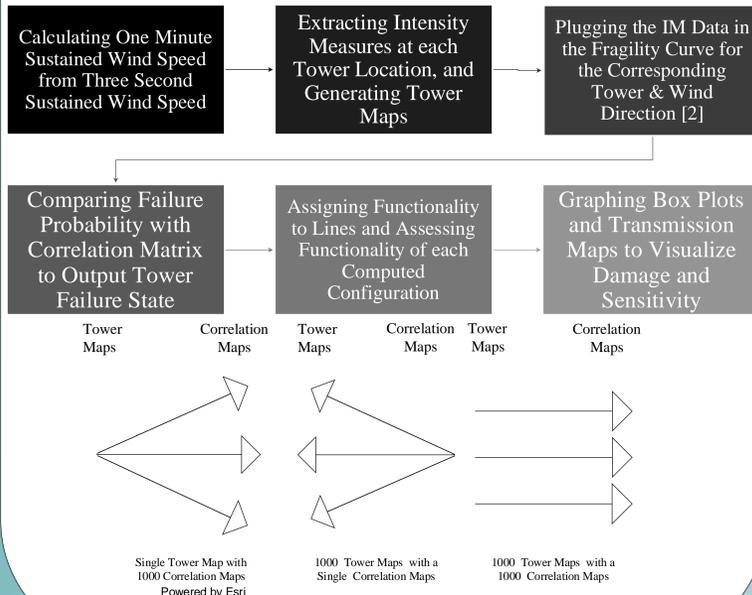


Figure 3: Network Visualization for the Match-Ups between the Correlation Matrices and the Randomly Generated Tower Maps

ANALYSIS

- The contribution of a power line to the functionality of the transmission system is quantified as the product of line length and voltage.
- Each line is modeled as a series system, so the failure of any tower along a line results in the complete removal of that line from the functionality calculation.
- The total network functionality is computed as the sum of the contributions of all active lines, normalized by the value obtained under ordinary conditions.

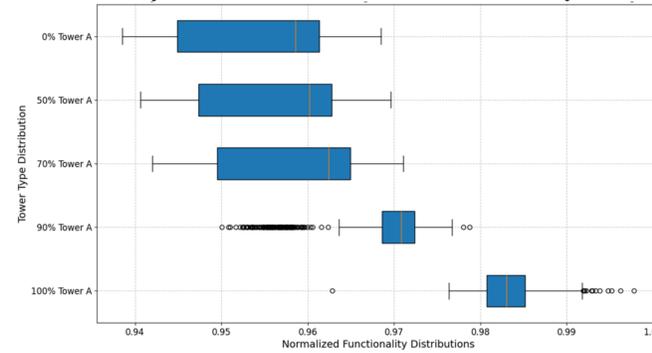


Figure 4: Functionality Distributions for Different Percentages of Towers A and B with 30 Degree Wind Assignment

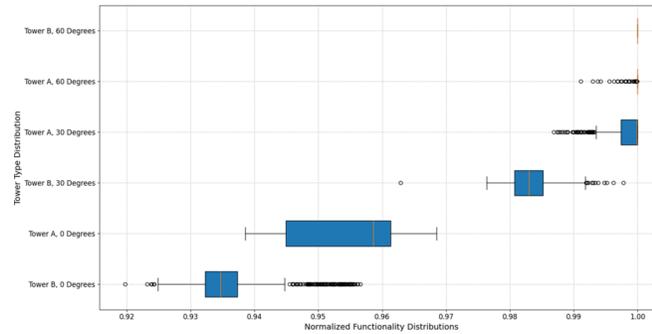


Figure 5: Functionality Distributions for Towers A and B with 0, 30, and 60 Degree Wind Assignment.

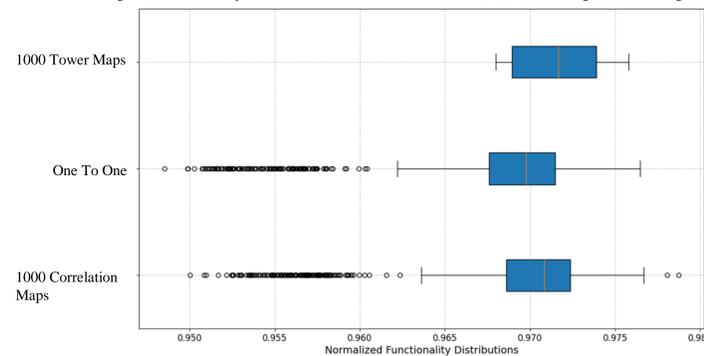


Figure 6: Functionality Distributions for Three Model Scenarios

- In a mixed tower network, the incorporation of different percentages of the towers greatly shifts the total network functionality to that of the functionality of a network consisting of only one tower.
- Furthermore, wind direction emerged as a key factor influencing tower failure patterns, underscoring the importance of accounting for directional loading effects in structural design and mitigation planning.
- The One-to-One scenario having a higher variation than the other two scenarios means the variations accounted for in the correlation matrices are significantly more important than possible variations in the tower distribution.

SIGNIFICANCE

- Results reveal a significant impact of tower type specification and wind directionality on network functionality.
- The study of the One-To-One model is one of four combinations of tower maps and correlation maps that yield insignificantly different variations in the tower network functionality.

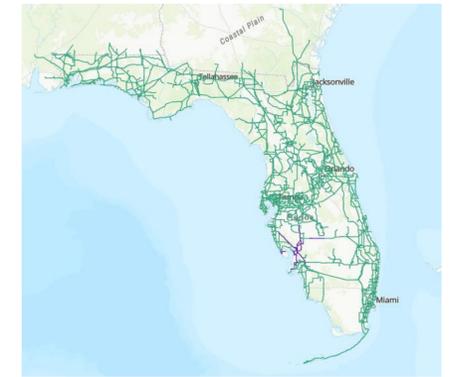


Figure 7: Sample of Tower A with 30 Degree Wind Direction Entire Network Assignment Failure States.

CONCLUSIONS

- These findings emphasize the necessity of capturing variability unaccounted for in tower fragilities in tower characteristics across the network to understand and improve the resilience of power systems in hurricane-prone regions.
- This work contributes to advancing power system risk assessment methodologies and supports decision-making for infrastructure design and management under extreme climatic conditions.

FURTHER STUDY

- Implementing a variability study for wind direction, where the wind direction is chosen based on the correlation maps, creating more alike conditions for neighboring towers.

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REFERENCES

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