Parameterized Pole-wire System Analysis with Image Processing

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INTRODUCTION

Power Distribution System (PDS), one of the major components in electric grid, is experiencing serious damages under various natural hazards, such as hurricanes and winter storms. Failure of the structural components under such weather events could lead to the instability of the pole-wire system in the community and cause possible cascading consequences leading to large area blackouts. Therefore, the structural integrity analysis (SIA) is required to evaluate the vulnerability of the PDS to give the agents or agencies an insight of the potential structural damages if a natural hazard was to occur.

In addition, most of current studies model the PDS as a perfect design system without considering the actual condition or construction bias. This study aims to provide a method to model the on-site PDS with point cloud data from LiDAR with high accuracy to capture the practical condition of the system structure. It can be much easier for agents to keep their assets information updated as soon as possible.

MOTIVATION

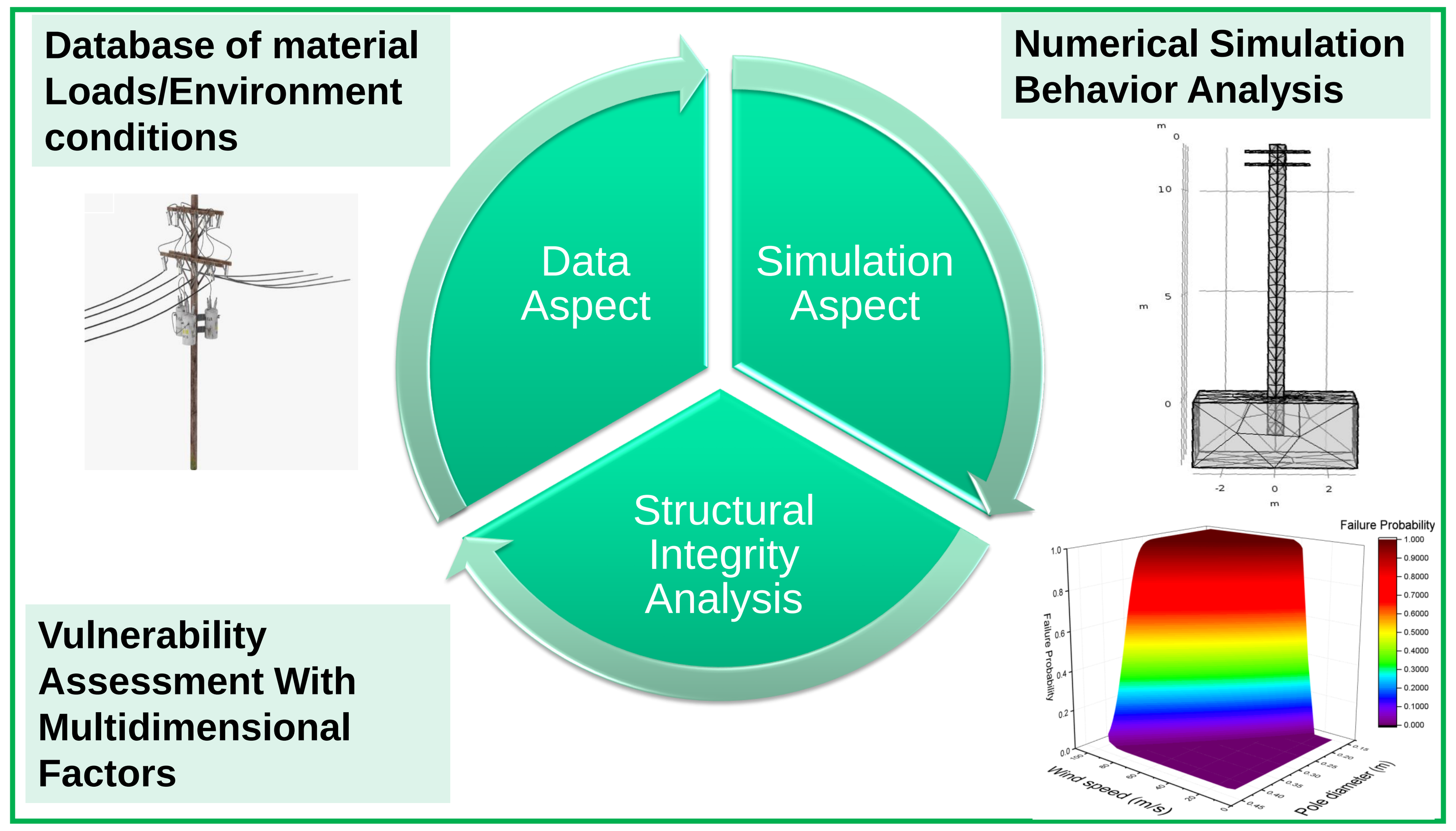

Figure 1 .Concept and Process of SIA cycle

METHODOLOGY

The parameterized pole-wire system model is to assess the vulnerability of the pole-wire system considering on-site condition. Its methodology is displayed in the following figure.

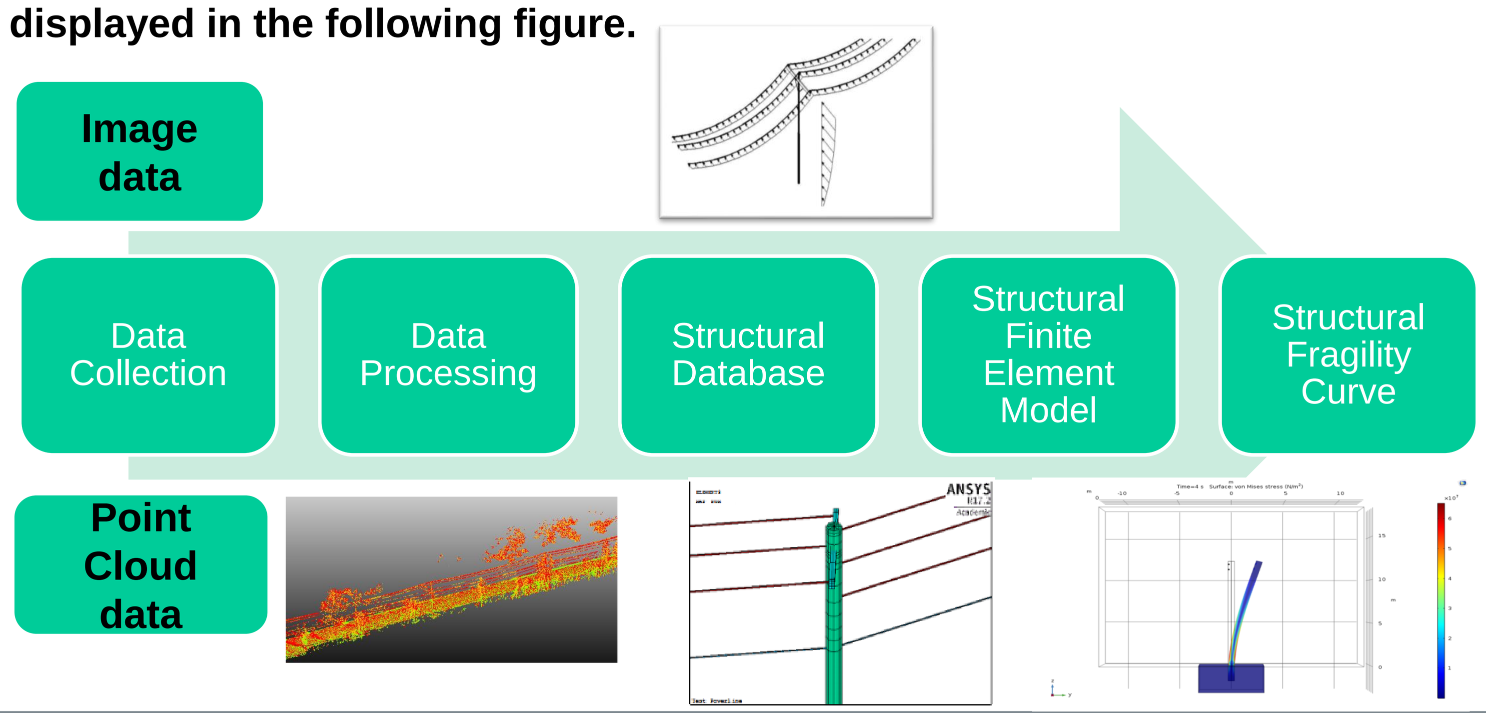

Figure 2.Flowchart of the Parameterized pole-wire system model

DATA PROCESSING

Structural modeling usually follows the engineering design records to model the structure employing finite elements model without reflecting the in-situ structure condition. Using data processing from different sources, real-time structural parameters could be obtained and updated in the structural database. The procedure of data processing is exhibited in Figure 3.

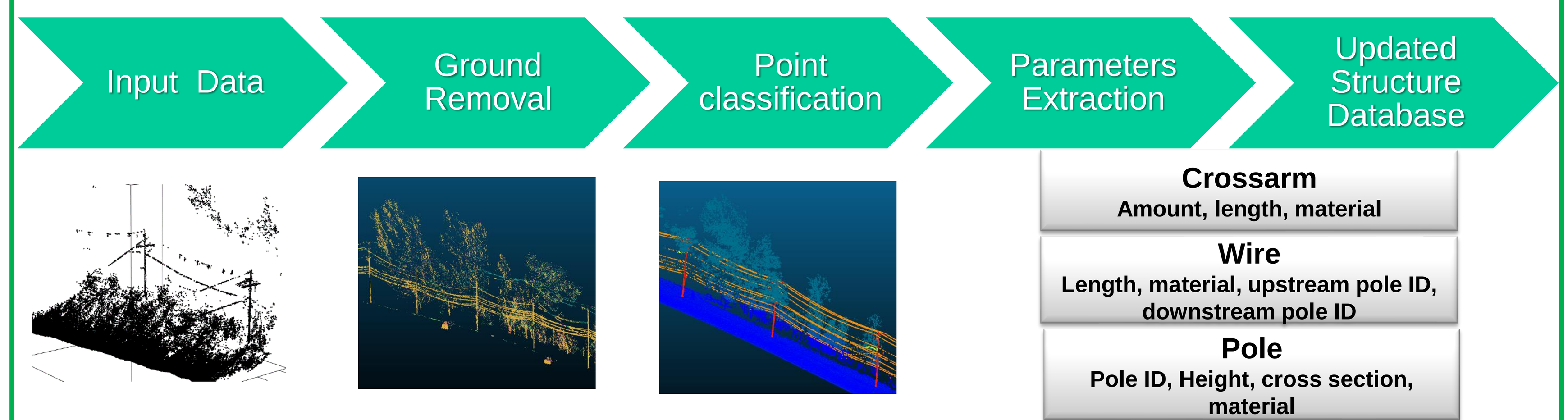

Figure 4. Exhibition of the methodology of DATA PROCESSING

ALGORITHMS IN DATA PROCESSING

In Ground Removal, Cloth simulation filtering (CSF) algorithm is applied in this case which is based on the simulation of a simple physical process in Figure 5. This algorithm has fewer parameters to adjust and is highly adaptive to various landscapes.

In Point Classification, Label Connected Components algorithm is adopted. Its advantage is similar to CSF algorithm which has only 2 parameters to modify. Its results are shown in Figure 5.

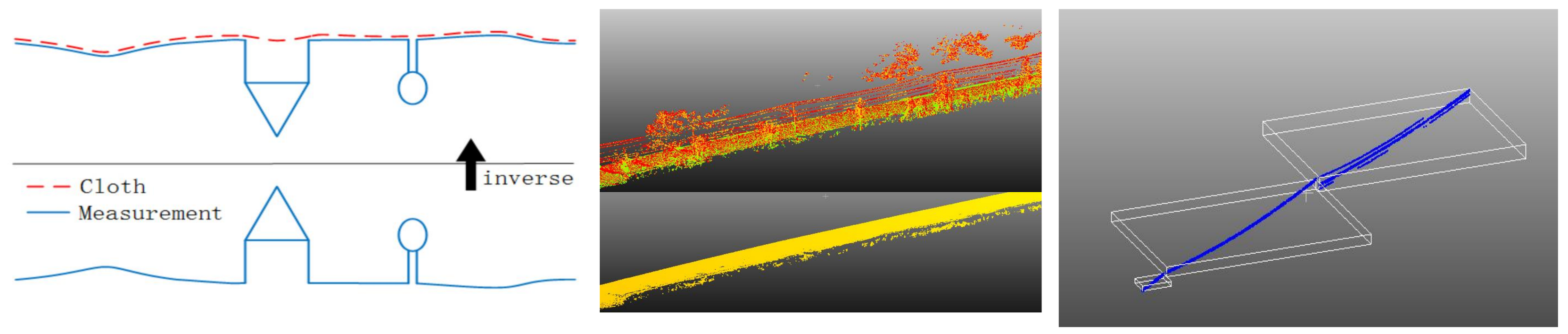

Figure 5. Demonstration of CSF algorithm (Left) and result of ground removal (Middle) and Wire classification (Right)

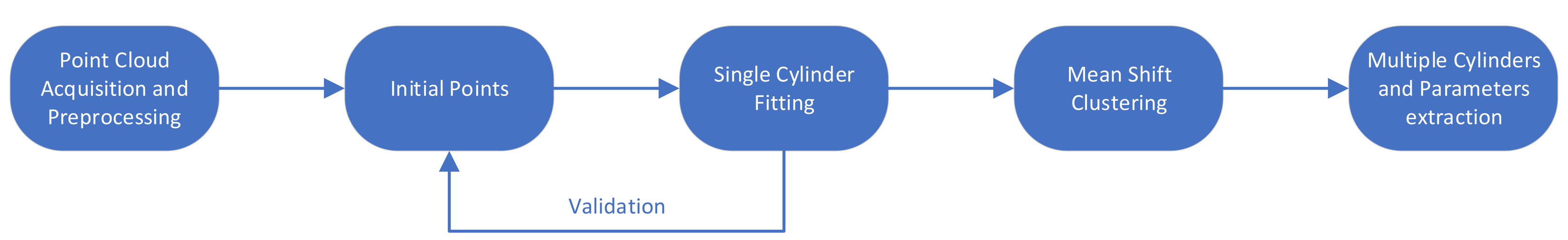

Figure 6. RANSAC algorithm to extract parameters of poles

POLE-WIRE MODEL FRAGILITY ANALYSIS

Most of the damage on the pole-wire system is due to the wind, falling tree branches and ice during the winter. The traditional deterministic structural analysis is displayed as follows with four scenarios in Figure 7. However, uncertainty is accounted in various aspects. An alternative way to evaluate the severity of the damage under these loads is to perform structural reliability analysis.

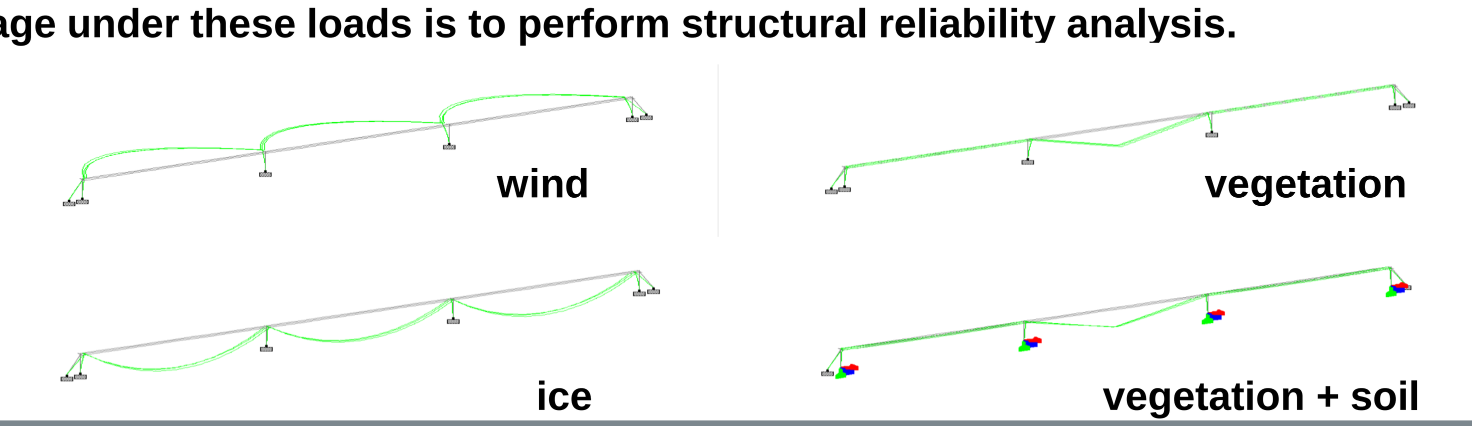

Figure 7. Traditional Deterministic Structural Analysis using ANSYS Software

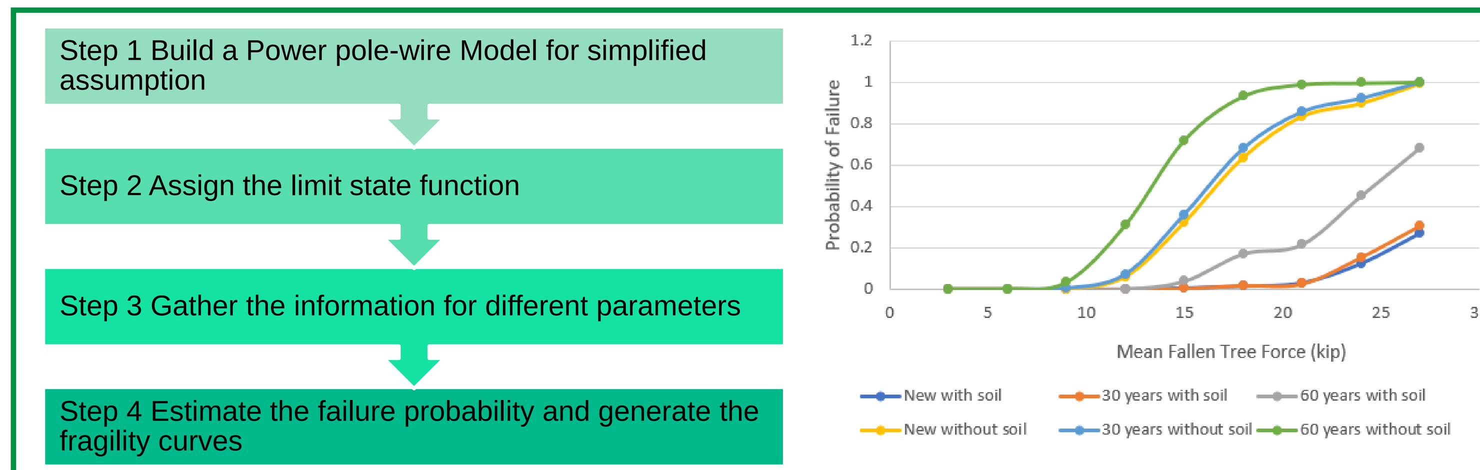

Figure 8. Flowchart of the Fragility curve and Demonstration of the fragility curve

INTEGRATIVE SYSTEM MODELING

Since the computation of the fragility curve for the whole system is very time consuming, an alternative way is to decompose the system into separate subsystems and do the calculation of subsystem fragility curves.

After decomposition of the whole system, sensitivity analysis of the pole-wire Subsystem could be performed as follows:

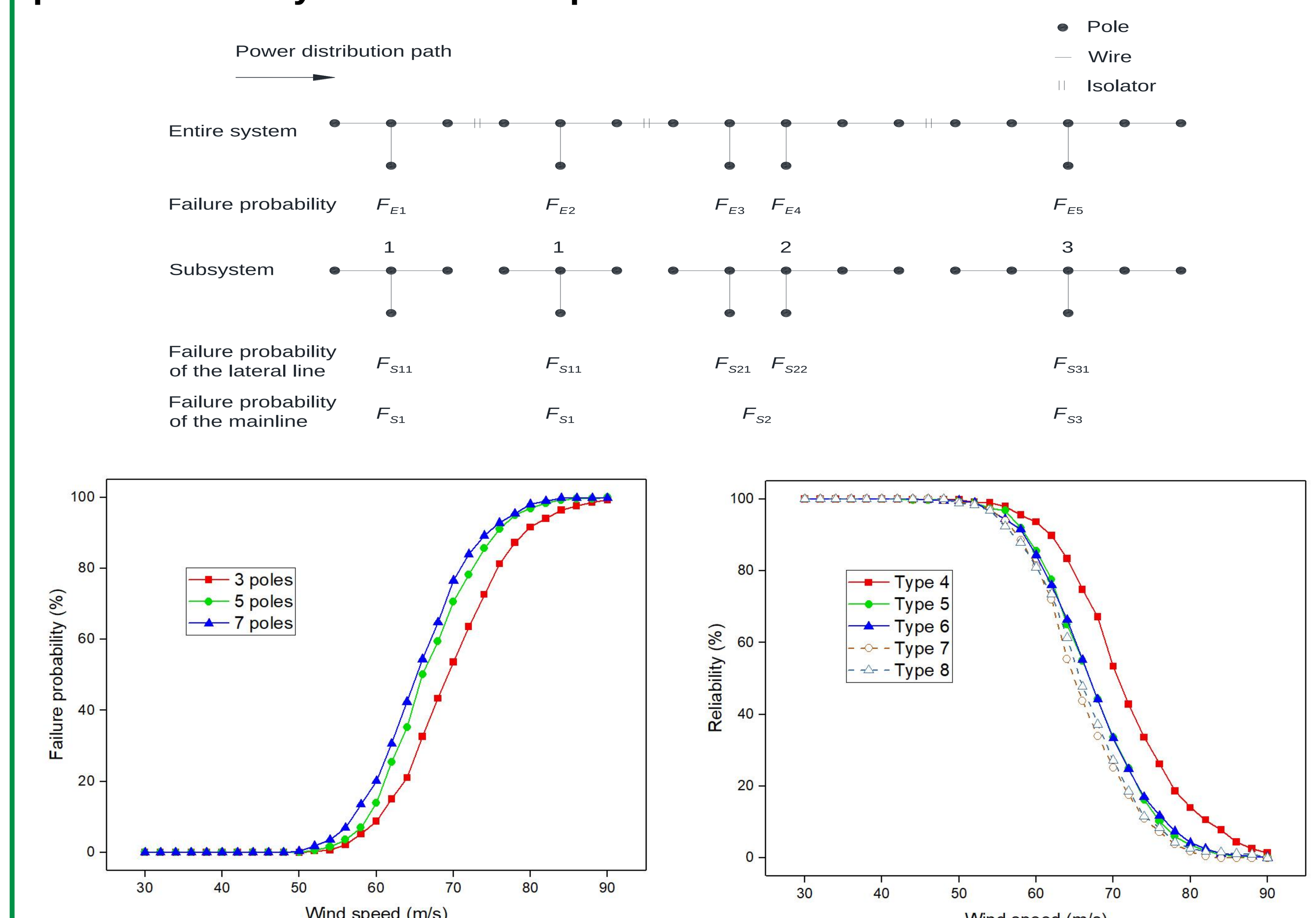

Figure 9, 10 and 11. Demonstration of subsystem (Upper) and Fragility curves of the subsystems with only the mainline (Lower left) and Reliability of the subsystems with the lateral lines(Lower right)

STUDY CONTRIBUTIONS

- Provide an **in-situ and real-time methodology** for extracting the structural parameters for finite element analysis
- Consider **different subsystems** in the pole-wire system to have a more detailed and comprehensive understanding about the effect of subsystems on the whole system
- Reduce **the computation time** using the subsystem approach

ACKNOWLEDGEMENTS & REFERENCES

- Eversource Energy; EverSource Energy Center; CEE Department

- Yuan, H., Zhang, W., Zhu, J., Bagtzoglou, A. (2018) “Resilience Assessment of Overhead Power Distribution System under Strong Winds for Hardening Prioritization”. *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems*, 4(4). https://doi.org/10.1061/AJRUA6.0000988.

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