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Outage Forecast-based Preventative Scheduling Model for Distribution System Resilience Enhancement

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- Background
  - Growing integration of distributed energy resources (DERs) helps mitigate service interruptions during grid disturbances.
  - For certain extreme events such as hurricane and flood, it is possible to get a pretty good prediction of the event propagation hours or days ahead. It is possible to allocate resources such as backup generators to the vulnerable segments to improve resilience.
  - Key questions to be addressed:
    - How to efficiently map the extreme event prediction to grid outage prediction.
    - What measures can be taken to allocate assets to prepare for the outage event.
- Proposed Approach
  - Machine learning based method to predict vulnerable grid assets in day-ahead context.
  - Forecast-based preventative scheduling (FPS) model to allocate responsive DERs.
- Objective
  - Generate the optimal resource allocation scheme based on credible outage predictions to improve distribution system resilience.

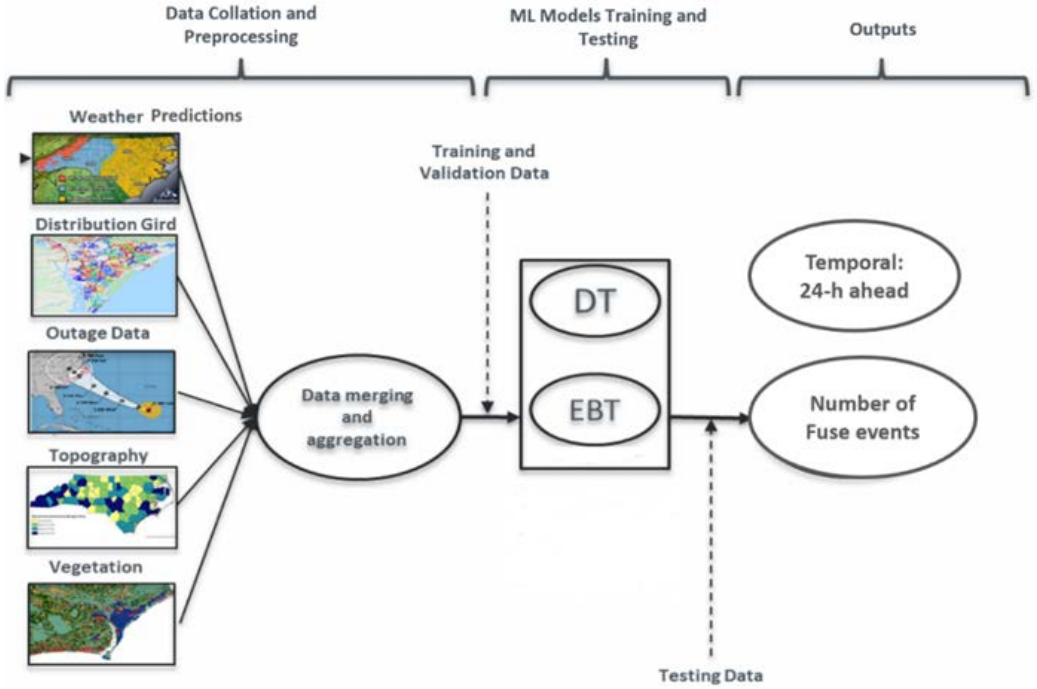
Outage Prediction with Machine Learning

Data collection and feature selection

- 10 years historical data of 25 substations are collected and processed.
- The following weather features are used: 1) max/min relative humidity (in %); 2) wind speed and direction; 3) max/min temperature.
- The complete dataset includes 18 extreme weather events and contains 22,050 records. Among these 18 events, 16 will be used for model training and 2 will be used for validation.

Machine learning models

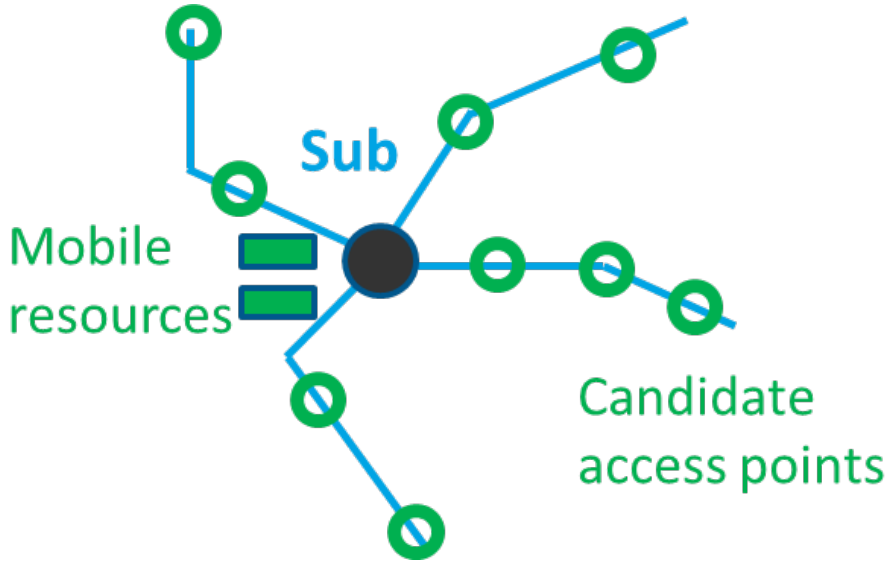
- Two machine learning models, namely decision tree (DT) and ensemble boosted tree (EBT), are implemented.
- DT is fitted with any historical data that is relevant to the problem domain and the true value we want the model to learn to predict.
- EBT combines several DTs to produce better predictive performance. We fit consecutive trees and at every step, the goal is to solve for net error from the prior tree.



FPS Model with Mobile Responsive Resources

Mobile Resource Modeling

- Three types of mobile resources are considered.
- Mobile generator and BESS can be used to generate electricity. Mobile transformer can restore the connection between critical node and the grid.



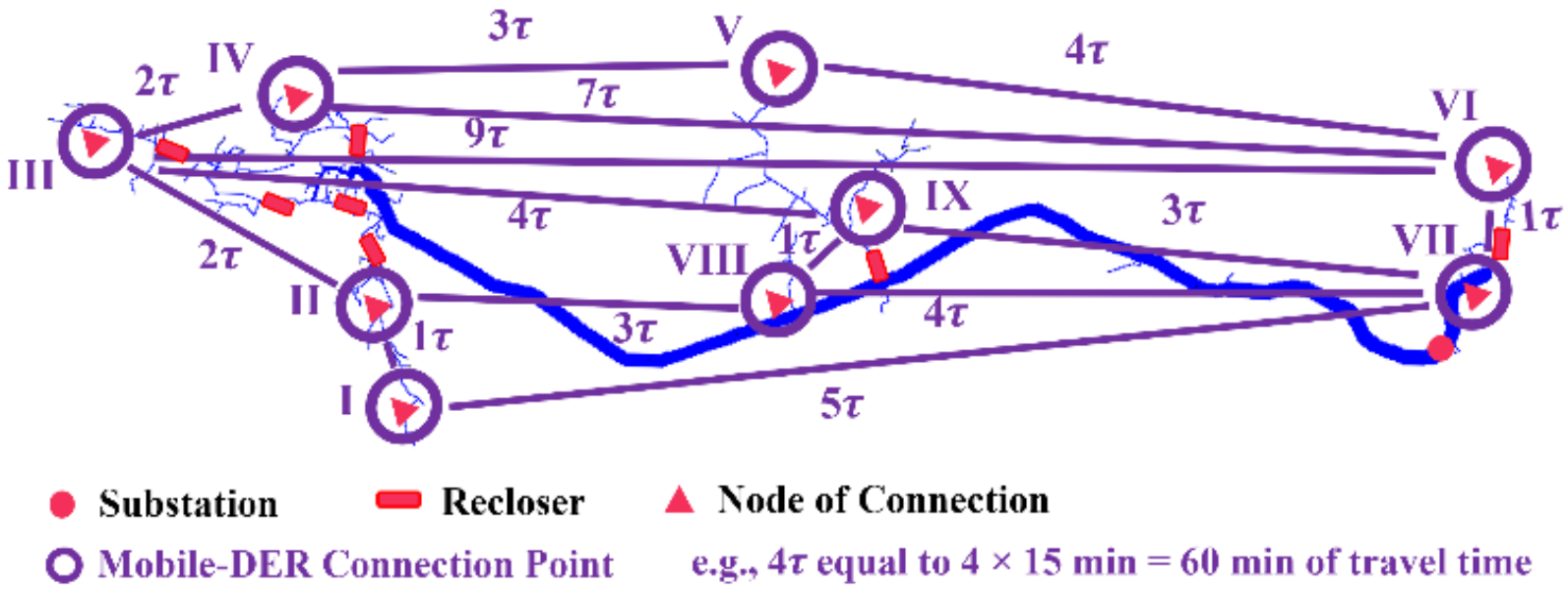
	Capability	Constraints
Mobile generator	Power generation	Capacity; Fuel; Rating power
Mobile BESS	Power generation or consumption	Capacity; Stage-of-charge; Rating power
Mobile transformer	Connection	Capacity

The FPS model includes an objective function to maximize distribution system resilience while minimizing resource allocation costs.

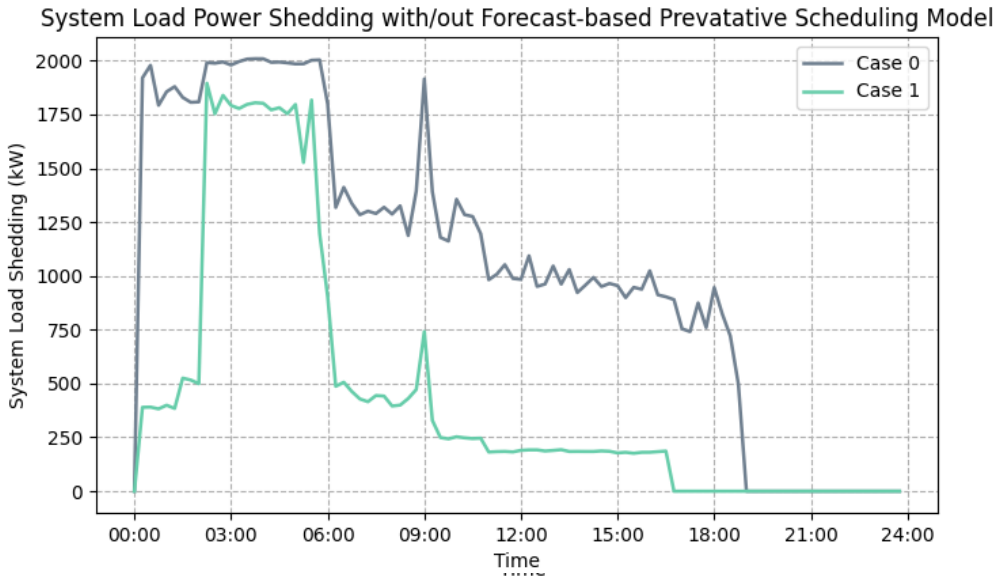
Simulation Setup

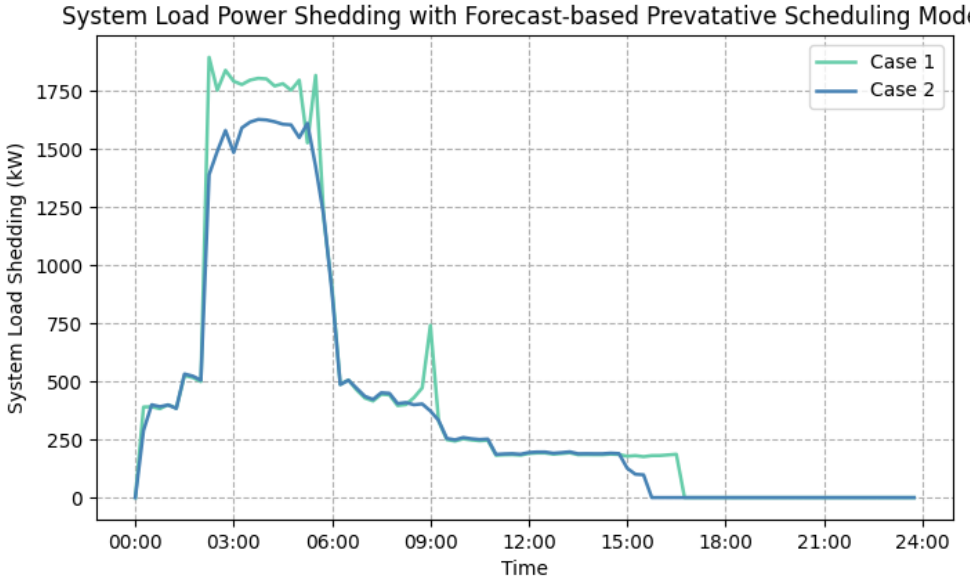
- **Test system**: A real system in North Carolina, U.S., with 1484 nodes and peak load of 3.97MW.
- **Outage prediction**: 7 reclosers with day-ahead outage prediction results.
- **Timeframe**: The simulation timeframe is 24-hour with 15-minute time-resolution.
- **Transportation network**: A simplified network with 9 nodes (access points) is employed to accommodate mobile DER allocation.

- Case 0: FPS without outage forecast information, no mobile DER dispatch.
- Case 1: FPS with outage forecast information, no mobile DER dispatch.
- Case 2: FPS with outage forecast information and mobile DER dispatch.



Simulation Results





Time slot	Mobile generator	Mobile BESS	Mobile Transformer
1	II	IX	I
2	II → III	IX → IV	I
3	II → III	IX → IV	I
4	III	IX → IV	I
5	III	IX → IV	I
6	III	IX → IV	I
7	III	IX → IV	I
8	III	IV	I→ IX
9	III	IV	I→ IX

	Case 0	Case 1	Case 2
Energy shortage (kWh)	25311	10547	9442
Maximum load shed (kW)	2009	1895	1628

Conclusions/Recommendations

- We developed a preventative scheduling model for distribution systems to improve resilience performance leveraging mobile DER dispatch and machine learning based outage prediction.
- Simulation using real-world feeder model and data validates the importance of considering outage information into preventative scheduling.
- Integrating multisource data (e.g., weather forecast, traffic conditions) into resilience planning and restoration strategy is our next task.

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