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

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Abstract

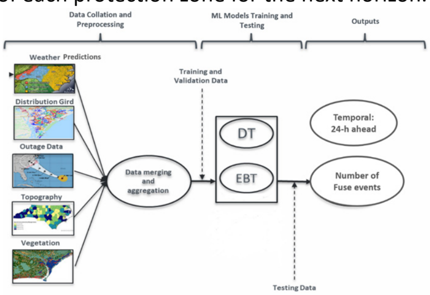
Distribution system resilience enhancement is an important topic to ensure customers have access to power supply during extreme events. In fact, certain weather-related extreme events can be predicted ahead of time. Therefore, it is important to investigate how to predict grid outages using extreme weather forecasts, and how outage predictions can be incorporated into distribution system resilience enhancement. In this paper, a preventative scheduling model for distribution systems is proposed. The model targets at allocating resources, especially mobile responsive resources such as mobile backup generators and mobile energy storage systems, to prepare for an extreme event in the day-ahead context. To achieve efficient resource allocation and scheduling, a machine learning-based outage prediction module is developed to predict vulnerable or risky segments of the distribution system based on historical operating records and extreme weather event forecast. By integrating the outage prediction results into the scheduling model, optimal resource allocation can be derived to help distribution systems prepare for an upcoming event and improve resilience performance. A real distribution feeder in North Carolina, U.S. is used in the case study to validate the proposed approach.

Outage Prediction with Machine Learning

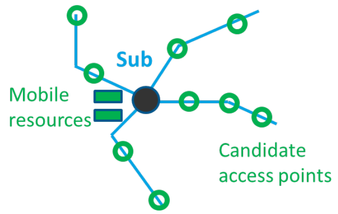
- Predict outages associated with each protection zone for the next time horizon (e.g., 24 hours).
- Provide an indication of the physically affected sections of each protection zone for the next horizon.

- Weather features include: 1) max/min relative humidity (in %); 2) wind speed and direction; 3) max/min temperature
- The complete dataset includes 16 extreme event data for training and 2 event data for validation.
- Two machine learning models, namely decision tree (DT) and ensemble boosted tree (EBT), are implemented.

Metric	DT	EBT
RMSE	0.3504	0. 3421
R^2 Score	0.79	0.83
NMAE	5.96%	5.37%



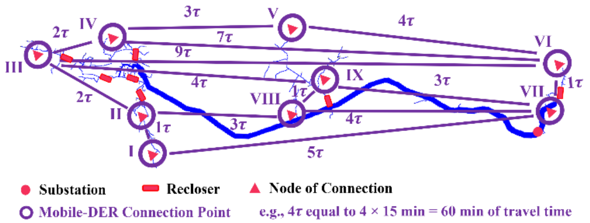
Forecast-based Preventative Scheduling (FPS) Model with Mobile DERs



Objective function:	Maximizing system resilience while minimizing resource allocation costs
Constraints:	Distribution power flow constraints
	DER operating constraints
	Outage prediction constraints
	Mobile responsive resource constraints
	Logistic constraints

Integrating Mobile DER Constraints

- Three types of mobile resources are considered. Mobile generator and BESS can generate electricity. Mobile transformer can restore the connection between critical node and the grid.
- Mobile DERs are constrained by both their inherit operating boundaries such as rated power, power factor, and runtime, and by the transportation network constraints such as travel time from one location to another.

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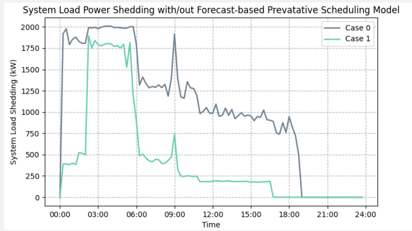
           [11,  9,  9, 13, 20, 11,  9,  0,  1],    VIII
           [12, 10,  8, 12, 19, 10,  8,  1,  0]     IX
           ]
```

e.g., 4 means 4τ, and equal to 4 × 15 min = 60 min of travel time

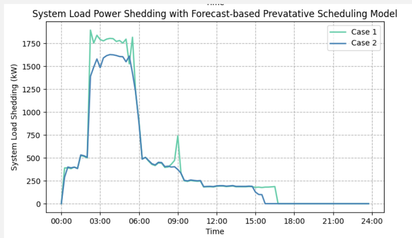
Simulation Results

Case	Description
0	No outage forecast, no mobile DER dispatch.
1	Consider outage forecast, no mobile DER dispatch.
2	Consider outage forecast and mobile DER dispatch.

➢ FPS without mobile DER deployment



➢ FPS with mobile DER deployment



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

➢ Mobile DER dispatch

Mobile DER	Dispatch	Departure	Arrival
Generator	II -> III	00:15	00:45
	III -> I	04:00	04:45
BESS	IX -> IV	00:15	01:45
	IV -> V	03:15	04:00
	V -> IV	06:00	06:45
Transformer	I -> IX	01:45	03:00
	IX -> VII	04:30	05:15

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