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Winter Storm Scenario Generation for Power Grids Based on Historical Generator Outages

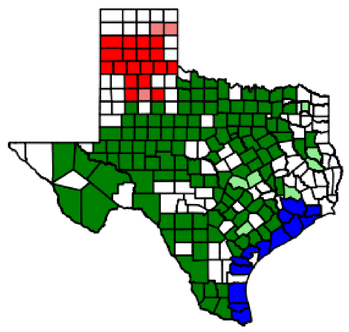
Motivation

In February 2021, the extreme cold temperatures brought on by Winter Storm Uri severely crippled electric power generators across the state of Texas. This work was the first of two completed phases in a research effort. The goal of this part was to simulate the impact of winter storms on generators in a power grid. The goal of the second part was to leverage the simulations to inform generator winterization decision-making via stochastic programming.

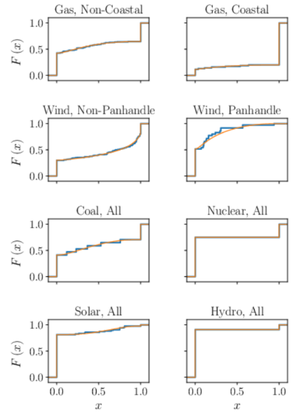
We present an approach to simulation based on max-likelihood estimation of historical generator outage data. The estimated distributions are manipulated to simulate the severity of the storm and each generator's susceptibility to its effects. We also present an application of the simulation to the ACTIVS 2000-bus synthetic grid of Texas.

Approach

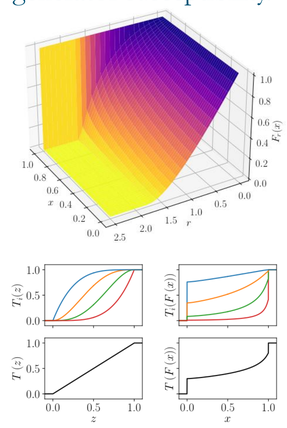
Step 1: Group generators from the outage data by fuel type and geographical region.



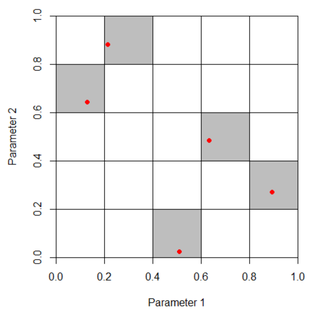
Step 2: For each generation class, compute an estimated distribution of capacity loss.



Step 3: Perturb distributions to simulate storm severity and generator susceptibility.



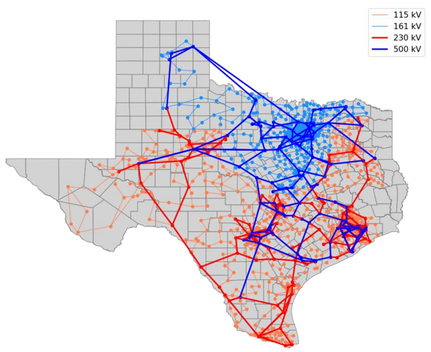
Step 4: Generate scenarios via Latin hypercube sampling of distributions.

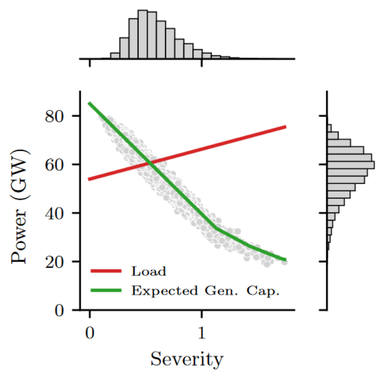


Application

To feed the second, more optimization-focused part of this research effort, we computed mixture distributions of capacity loss via max-likelihood estimation for 8 generator classes using ERCOT data from Winter Storm Uri.

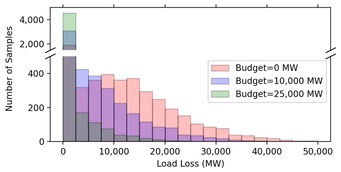
Making some assumptions about the distribution and effect of storm severity, we produced several thousand winter storm scenarios for the ACTIVS 2000-bus synthetic grid of Texas (center) which features 432 online generators. The overall expected effects of these unmitigated scenarios are shown here in the joint plot of storm severity and expected generation capacity (right). Our estimate of overall system load is also provided for reference.

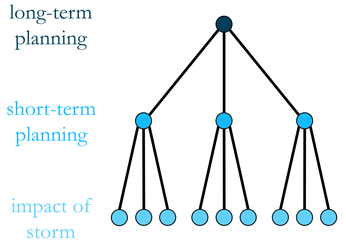




Next Steps

The second part of this research, "Risk-Averse Investment Optimization for Power System Resilience to Winter Storms" (2022TD0125), is also being presented in this session. The work employs two-stage stochastic programming to identify investments that effectively mitigate the worst winter storm scenarios.





Moving forward, our goal is to jointly optimize long- and short-term winterization strategies. We need to adapt our simulation approach to differentiate between information known now about winter storms in general and specific forecasts that only become available prior to a particular imminent storm.

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