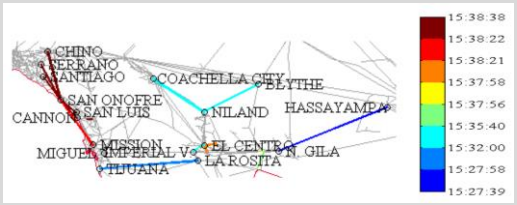
Research 1: Failure Cascade Prediction in Power Grids

Motivation

Large Blackout due to **Failure Cascade**

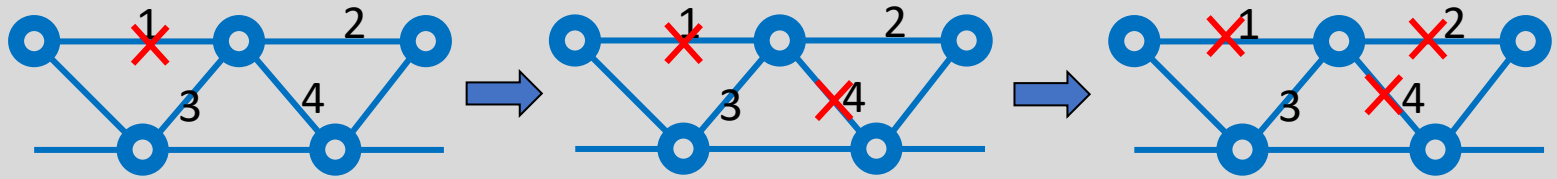


Q: Can we **predict** it in early stage?

Contributions

1) Influence model to capture failure cascade
2) 3-step learning framework to learn the influence model
3) Evaluation on real systems over: failure size, final state, failure time, time cost, etc.
4) Critical component identification

Influence Model



Pair-wise influence: $A_{14} = \begin{bmatrix} 0.9 & 0.1 \\ 0.2 & 0.8 \end{bmatrix}$ **Influence Weight**: D_{12}, D_{42}

Modeling failure cascade:

$$\tilde{s}_j[t+1] = \sum_{i=1}^{N} \boldsymbol{D}_{ij}(\mathbf{A}_{ij}^{(11)} s_i[t] + \mathbf{A}_{ij}^{(21)}(1 - s_i[t]))$$

$$\hat{s}_j[t+1] = 1\{\tilde{s}_j[t+1] \geq \varepsilon_j\}$$

[Parameters: $\{\boldsymbol{A}, \boldsymbol{D}, \vec{\boldsymbol{\varepsilon}}\}$ **]**

Learning Framework

$\boldsymbol{A}$: Monte-Carlo

↓

$\boldsymbol{D}$: Min. MSE $\|s[t] - \tilde{s}[t]\|^2$

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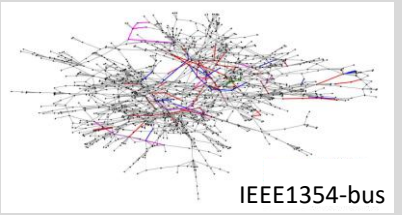
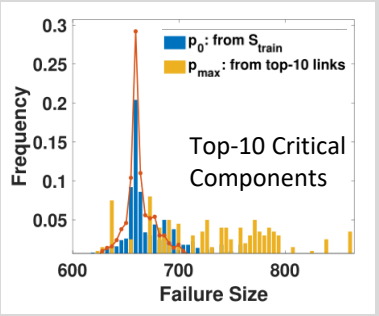
$\vec{\boldsymbol{\varepsilon}}$: Nearest Neighbor

Advantage:
- Fully parallelizable
- $\boldsymbol{A}$ and $\boldsymbol{D}$ interpretable

Experiments





Metric	Result
Failure Size	<3% error
Final State	<9% error
Failure Time	<1.5 units
Time Cost	1/872 of flow cal.

Connection to Industrial Research:
1) Framework extended to data flow network & power-comm network
2) ML experience in time series prediction over large datasets

X. Wu, D. Wu and E. Modiano, "Predicting Failure Cascades in Large Scale Power Systems via the Influence Model Framework," in *IEEE Transactions on Power Systems*, vol. 36, no. 5, pp. 4778-4790, Sept. 2021, doi: 10.1109/TPWRS.2021.3068409.