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Generator Outage Identification Using Synchrophasor Measurements

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MOTIVATION & FRAMEWORK

Unplanned and undetected generator outages

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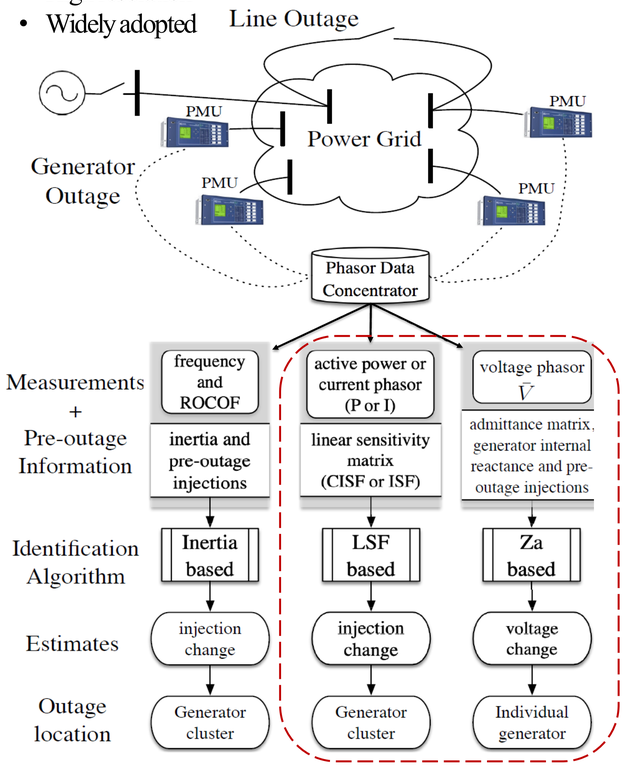
Instability, cascading outages, major blackouts

Goal: A framework of fast, accurate identification algorithms given limited information and motoring devices

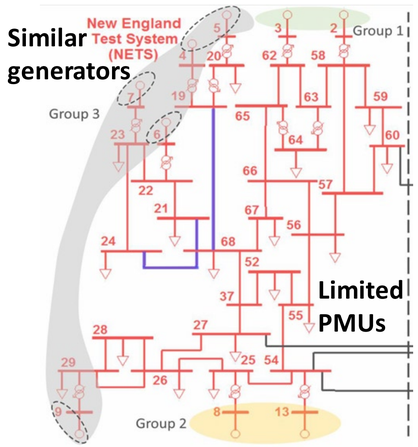
- Multiple model-based identification algorithms
- State-of-the-art devices: phasor measurement units (**PMU**s):
  - GPS time synchronized
  - High resolution
  - Widely adopted



THE LSF-BASED METHOD

The LSF-based method identifies the cluster with the largest estimated injection change as the outage source.

INDISTINGUISHABLE



- **Fast**
- **Versatile**
- **Accurate**
- **Bonus Pg estimate**

Cluster generators together based on QR decomposition results of the LSFs.

The inverse problem

NOT INVERTIBLE

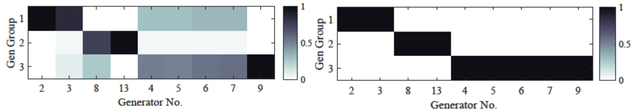
$$\Delta \boldsymbol{I}_l = \boldsymbol{A}_l \Delta \boldsymbol{I}_g \qquad \Delta \tilde{\boldsymbol{I}} = \tilde{\boldsymbol{A}}_l^{-1} \Delta \boldsymbol{I}_l$$

Clustering + Inverse

$= \boldsymbol{A}_l$ ← Estimated changes (Cluster)

$= \tilde{\boldsymbol{A}}_l^{-1}$ ← Approximate LSFs ← Observed (PMU)

Best bet (largest cluster injection change)



the original LSFs

the approximate LSFs (only representatives)

THE Za-BASED METHOD

The Za-based method compares simulated voltage changes to the observed.

hypothesis testing **A lot of model info required!**

$$\Delta \boldsymbol{V}^{(i)} = \boldsymbol{Z}_a \begin{bmatrix} 0 \\ \frac{jX_i}{Z_a(i,i) - jX_i} I_{g,i} \\ 0 \end{bmatrix}$$

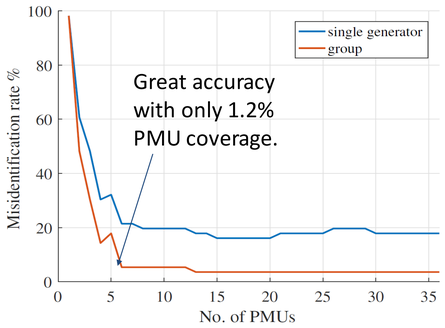
Pre-outage injection

Expected changes **(Hypothetical)** — Augmented system impedance matrix — Generator subtransient reactance

$$g^* = \arg\min_i |\Delta \boldsymbol{V}_m^{(g_o)} - \Delta \boldsymbol{V}_{pmu}^{(i)}|$$

Outage originating Generator — **Expected** changes — **Observed** changes (PMU)

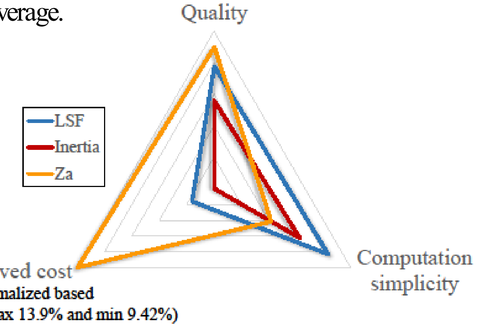
Best bet (smallest voltage difference error)



Great precision and accuracy given so limited data!

CASE STUDIES

Find a **good compromise** to identify outages quickly and accurately with good localization precision given limited PMU coverage.



Method	Localization precision	Accuracy	Injection loss estimation error	Models required
Inertia	cluster (lowest)	100%	high (>40%)	H, Pg
LSF	cluster	100%	low (<5%)	LSFs
Za	generator (highest)	<100%	n/a	Y, X'', Ig

CONCLUSION

A framework consisting of multiple model-based algorithms for generator outage identification was proposed.

- using different types of PMU measurements
- implemented in a complementary fashion with great efficiency and accuracy
- appropriate for utility control centers

Given data availability and the above trade-offs, operators can choose which algorithms to implement. Based on overall performance, we would suggest LSF> Za > inertia-based method.