Basic picture

- Direct state measurements (e.g. via PMU) at some buses
- Not enough for complete observability
  - Because of incomplete deployment in local grid
  - Because of interactions with neighboring parts of grid
- Goal: Check for fingerprint of significant events
  - Efficient computation via linearized model
  - Filter to avoid excessive solver work
- Steady state for now; transient in future
Status

- Previous report (March call)
  - Basic method for diagnosing 1-2 lines
  - Initial accuracy results on IEEE 57-Bus network
- New progress
  - Diagnose line failure or substation reconfiguration
  - Tests with noise
  - Tests larger network (2393-bus Polish network)
Revised framework

- Measure change in voltage $E\Delta v$
- Model change in voltage under contingency satisfies

$$
\begin{bmatrix}
A & U \\
V^T & D
\end{bmatrix}
\begin{bmatrix}
\delta v \\
\lambda
\end{bmatrix}
= 
\begin{bmatrix}
0
\end{bmatrix}
$$

where $A$ is a previously-factored Jacobian.

- Note $\delta v = A^{-1}(r - U\lambda)$, so

$$
\|E\Delta v - E\delta v\| \geq \min_{\gamma} \|E\Delta v - EA^{-1}(r - U\gamma)\|
$$

Use this bound to filter out implausible contingencies

- Rank plausible contingencies by $\|\Delta v - \delta v\|$
Grid Event Fingerprints and PMUs

Accuracy: Line Failures
Grid Event Fingerprints and PMUs

Accuracy: Line Failures

The graph shows the accuracy of line failures with different test strategies. The x-axis represents the rank of the test, and the y-axis represents the fraction of tests. There are three test strategies: All, Sparse, and Single. The graph indicates that the fraction of tests increases as the rank increases, with the 'All' strategy performing the best.
Accuracy: Line Failures (noisy)
Accuracy: Substation reconfiguration

![Graph showing the accuracy of reconfiguration tests with different ranks and fraction of tests.](image-url)
Accuracy: Substation reconfiguration (noisy)
Filtering effectiveness

![Graph showing filtering effectiveness with different line filtering methods: All, Sparse, and Single. The x-axis represents the fraction of failure scenarios, and the y-axis represents the fraction of lines filtered. Different line styles indicate different filtering methods.](image-url)
## Timings: Polish network (2393 bus, \( \approx 3000 \) lines)

<table>
<thead>
<tr>
<th>Line</th>
<th>FLiER (s)</th>
<th>Solution rank / # t’s computed</th>
<th>FLiER n.f. (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1502, 917)</td>
<td>0.36</td>
<td>1/2</td>
<td>53.89</td>
</tr>
<tr>
<td>(1502, 1482)</td>
<td>0.028</td>
<td>1/2</td>
<td>62.94</td>
</tr>
<tr>
<td>(557, 556)</td>
<td>0.31</td>
<td>1/4</td>
<td>67.49</td>
</tr>
<tr>
<td>(2346, 2341)</td>
<td>16.83</td>
<td>23/878</td>
<td>66.79</td>
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<tr>
<td>(909, 1155)</td>
<td>0.29</td>
<td>1/2</td>
<td>67.15</td>
</tr>
<tr>
<td>(644, 629)</td>
<td>0.37</td>
<td>1/7</td>
<td>66.77</td>
</tr>
<tr>
<td>(591, 737)</td>
<td>0.35</td>
<td>1/6</td>
<td>66.88</td>
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<tr>
<td>(559, 542)</td>
<td>0.50</td>
<td>1/12</td>
<td>66.62</td>
</tr>
<tr>
<td>(378, 336)</td>
<td>0.36</td>
<td>1/6</td>
<td>67.13</td>
</tr>
<tr>
<td>(101, 94)</td>
<td>0.28</td>
<td>1/2</td>
<td>66.92</td>
</tr>
</tbody>
</table>
FLiER: Practical Topology Error Correction Using Sparse PMUs
Submitted to IEEE TPS, in review
http://arxiv.org/abs/1409.6644