#lse4unme

NASPI State Estimation Tutorial
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San Mateo, California
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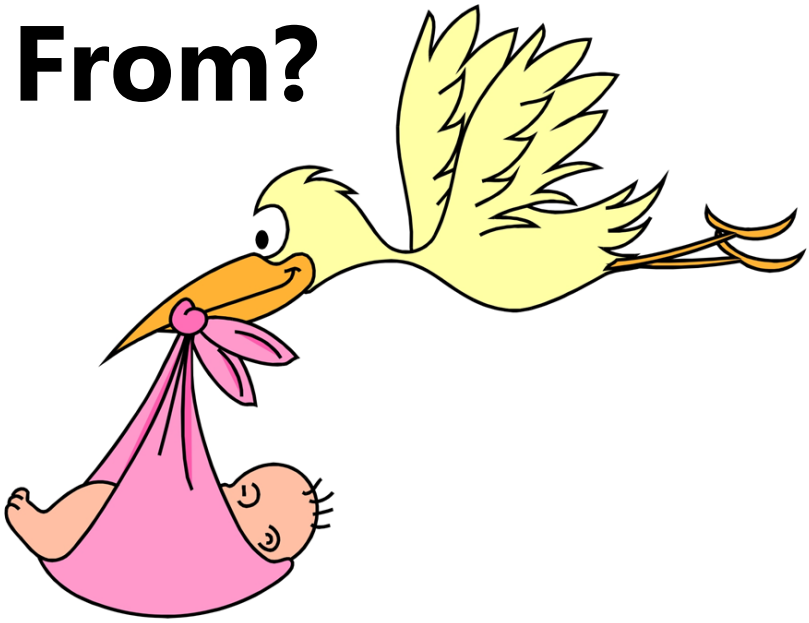
What I'd Like for You to Take Home

- Appreciation beyond the mathematics
  - **Understand**:
    - Purpose of linear state estimation
    - Current industry landscape (without naming names)
    - Challenges & potential use cases

Where Do State Estimators Come From?



- Misconception of purpose
  - "SE gives me my base case!!"
  - True, but narrow
- Operator's Load Flow drove adoption of state estimation
  - Raw SCADA data yielded poor initial condition for power flow
- State estimation was/is just a form of data conditioning designed to provide high fidelity information to network apps.

Purpose of LSE

- Also has misconception of purpose
  - "I already have a state estimator!!"
  - "LSE won't give me a base case so its useless!!"
  - "LSE is backup EMS."
- LSE provides a front end data conditioning for [certain classes of] synchrophasor network apps by:
  1. **Reducing errors**
  2. **Extending observability**
  3. **Increasing signal availability**
  4. **Network contextualization of PMU data**

Both sides of the story

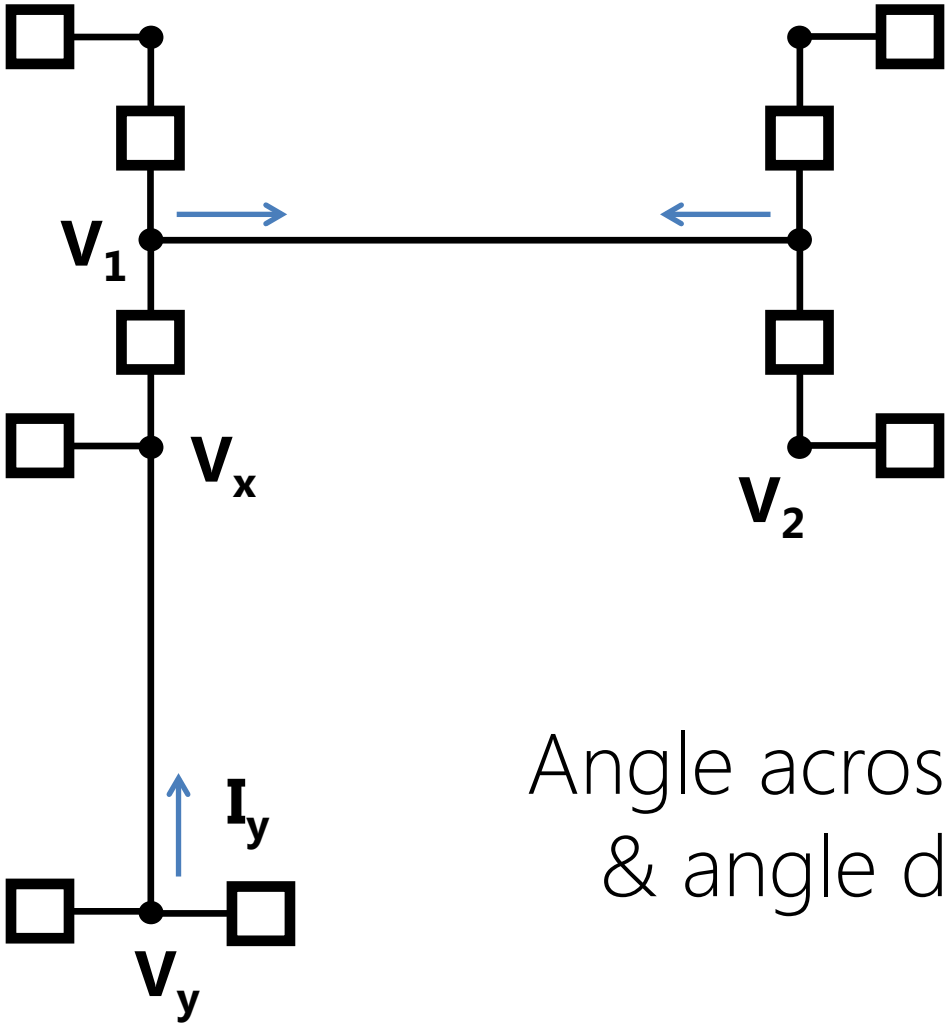
Traditional State Estimation

- Circa 1970
- Non-linear, iterative
- V_{mag}, I_{mag}, P, Q (scalars)
- Non-synchronized (SCADA)
- Solves (at best) in seconds
  - But minutes is more representative of the norm
- No dynamics
- Mainstream by 1990s
- **Feeds network apps**

Linear State Estimation

- Circa 1980
- Linear
- **V**, **I** (complex)
- GPS time synchronized
- Solves at frame rate
- Tracks dynamics
- Trending now
- **Feeds network apps**

Example Network App



If $\mathbf{Line_{1\text{-}2}}$ is open, how to tell breaker closing angle?

- Substitute $\mathbf{V_1}$ with $\mathbf{V_x}$
- Compute $\mathbf{V_x}$ with $\mathbf{V_y}$ & $\mathbf{I_y}$

Similar concept would apply to any two angle deltas across the transmission network.

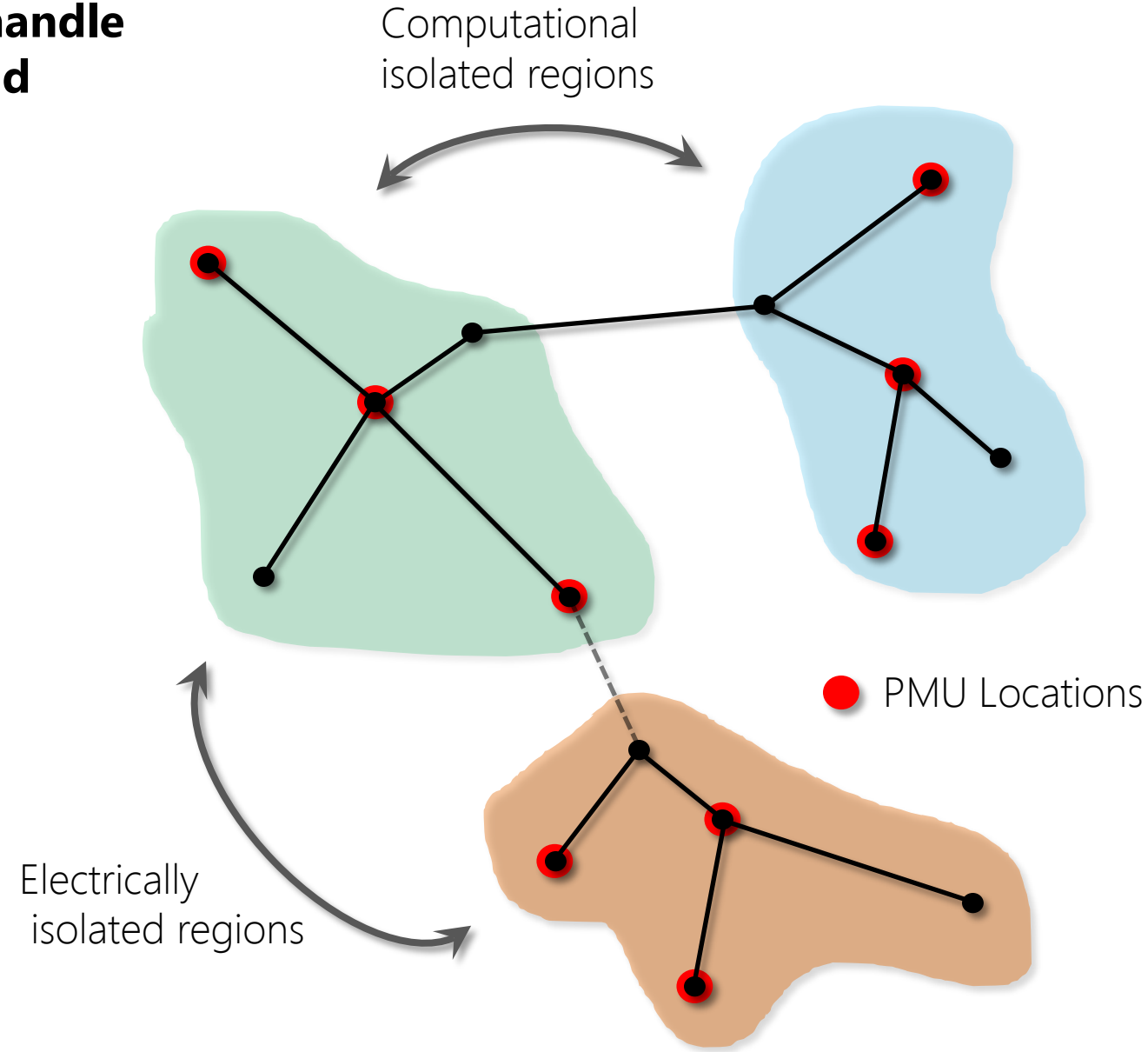
Angle across breaker & angle differences

LSE can breezily handle computational and physical islands

PMU footprints are often sparse and non-uniform *(computational isolated measurement regions)*

PMU monitoring of system restoration (black start) events would benefit from LSE *(electrically isolated measurement regions)*

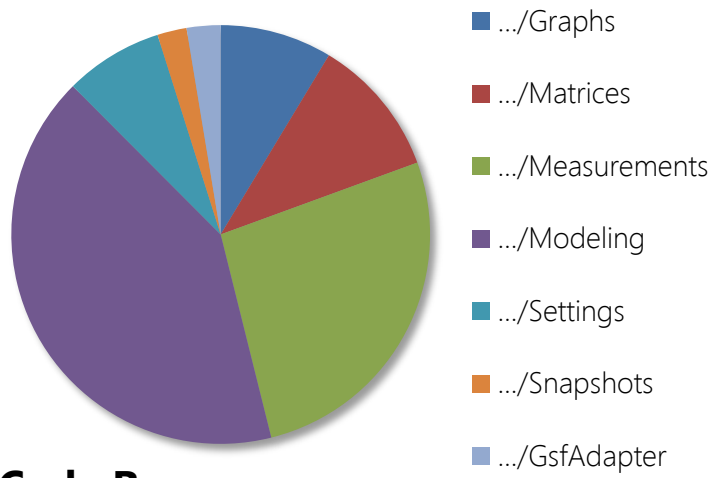
- Synchronized monitoring of islands
- Could know voltage magnitude and angle on far end of line before connecting two islands



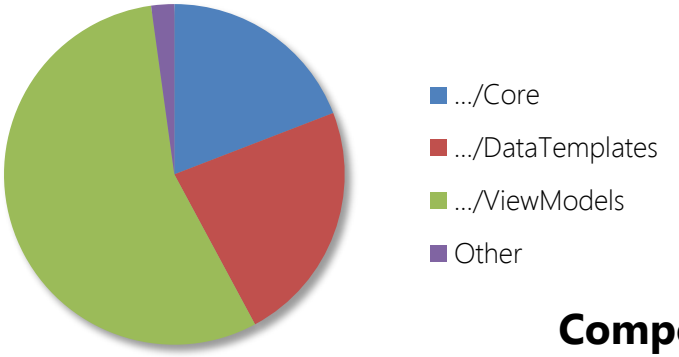
Challenges

- Perception
- Modeling & Integration
- Telemetry
- Computation Time
- Fragmentation?

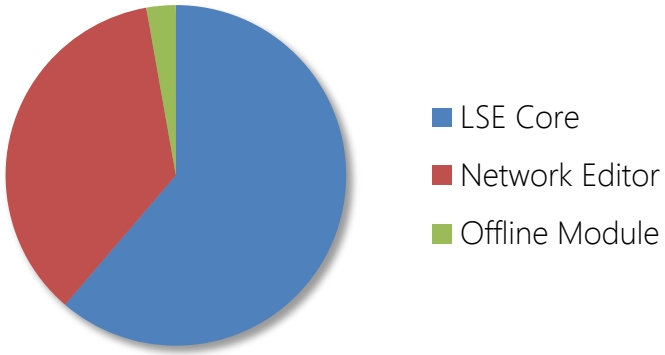
LSE Code Base



Network Editor Code Base



Component Totals



Trying not to reinvent the wheel…

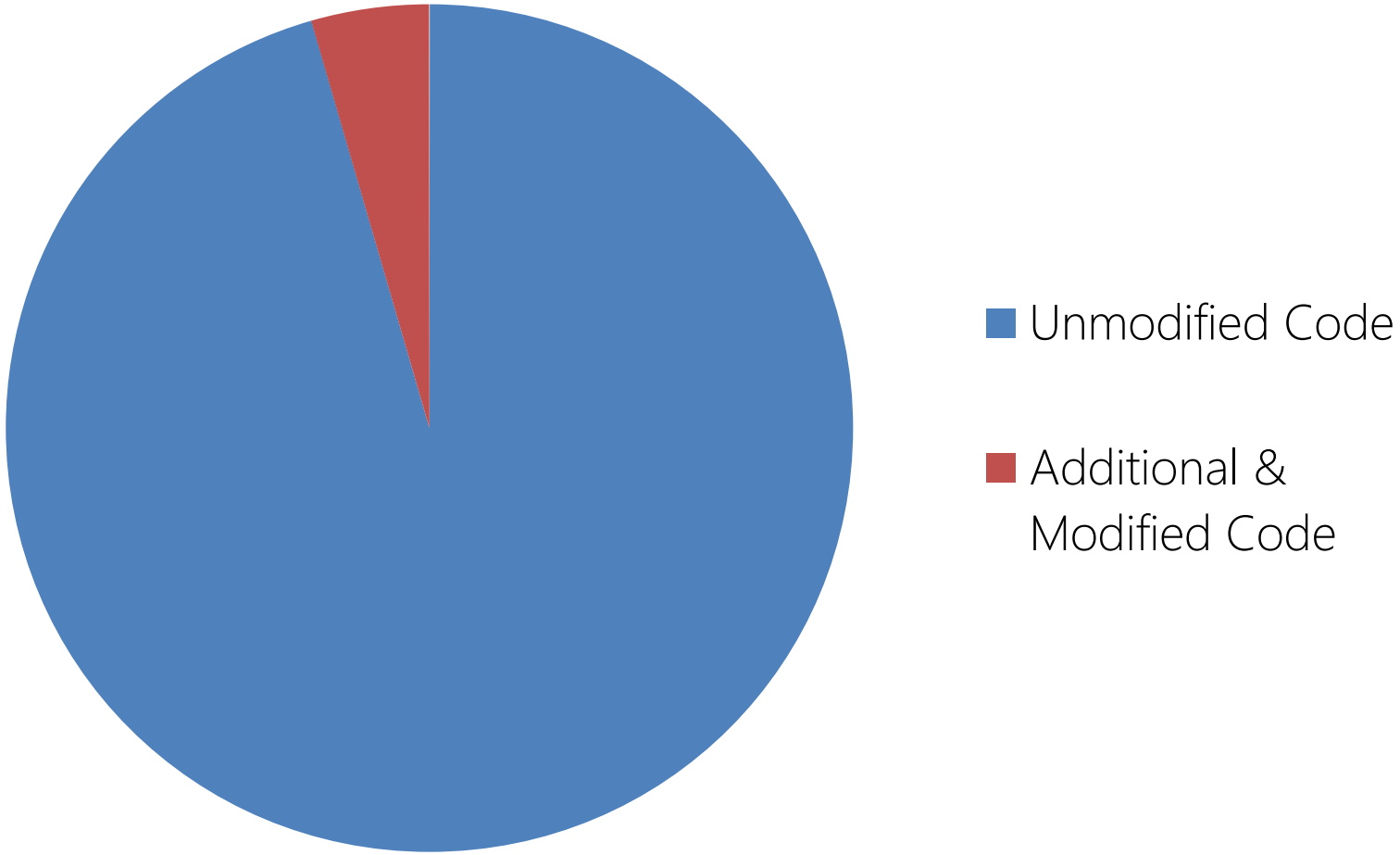
Additional features or functionality for this type of technology shouldn't require entirely different projects to implement…

Desiring a different solver?
- *modify the source code!*

Expecting differet network element extensions?
- *modify the source code!*

Not open to openPDC?
- *modify the source code!*

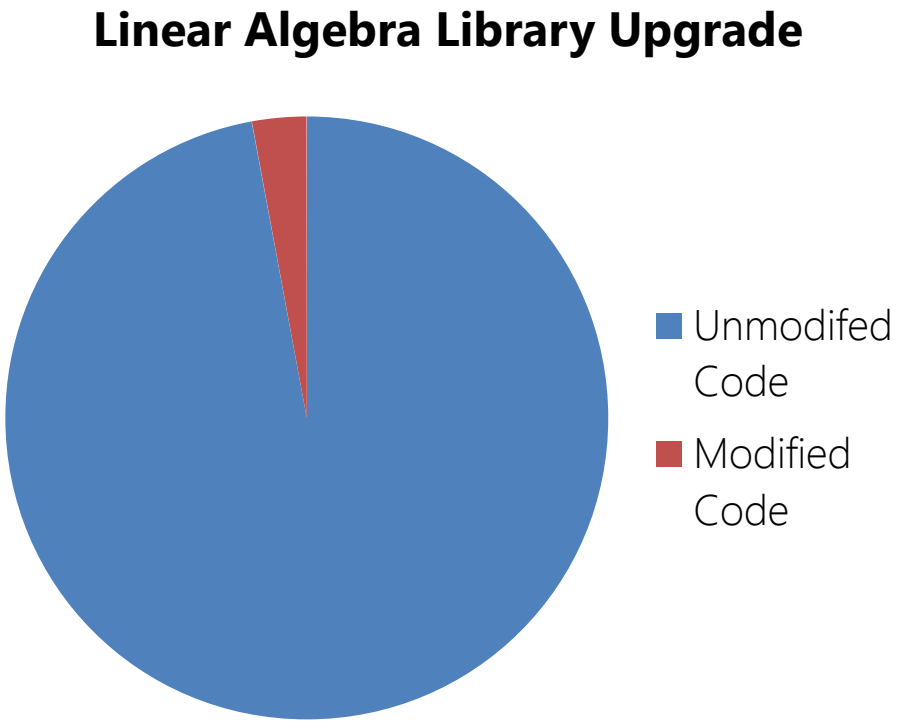
Inclusion of Positive Sequence LSE and Sequence Components Calculator



Keepin’ it Real (Time)

Addressing computation time

- Processing at frame rate is computationally expensive
- Majority of CPU time is matrix multiplication
- Trying and migrating to different linear algebra packages to improve computation time
- Experience: migrated from **Extreme Optimizations** to **Math.NET** achieved orders of magnitude improvements to computation time.
- Very minor changes to code base and less than 1 working day of time

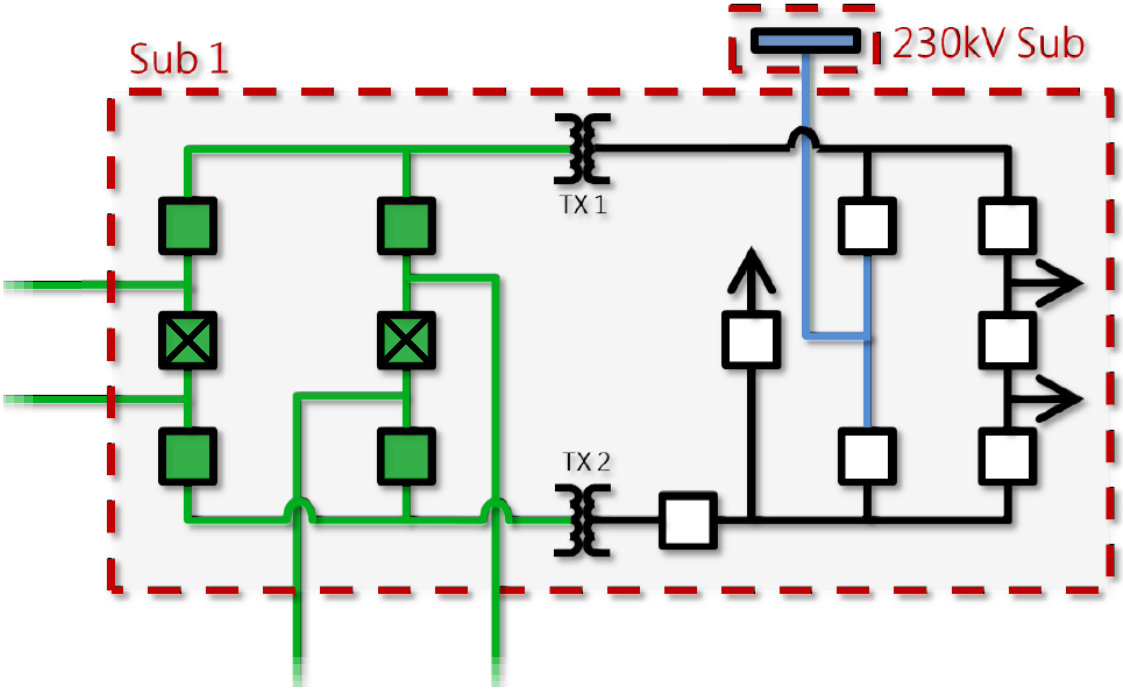


Lack of Breaker Status Telemetry

Breaker statuses key for accurate topology processing, especially at frame rate.

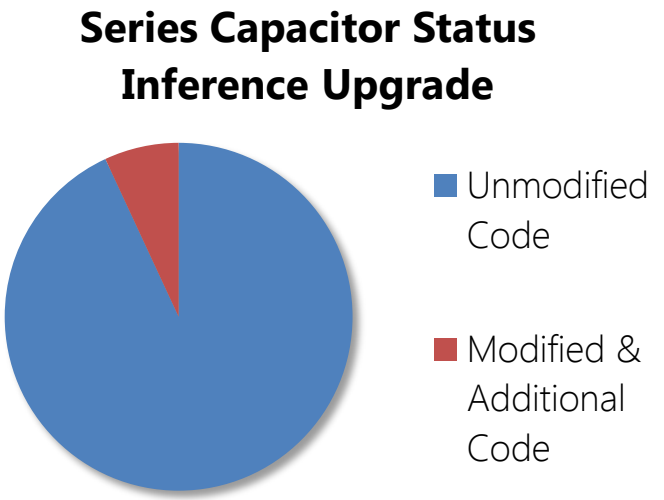
Breaker statuses can be brought in via a digital word in the C37.118 PMU stream. However, availability of this type of telemetry can be limited. Future PMU installations can be standardized to address this issue.

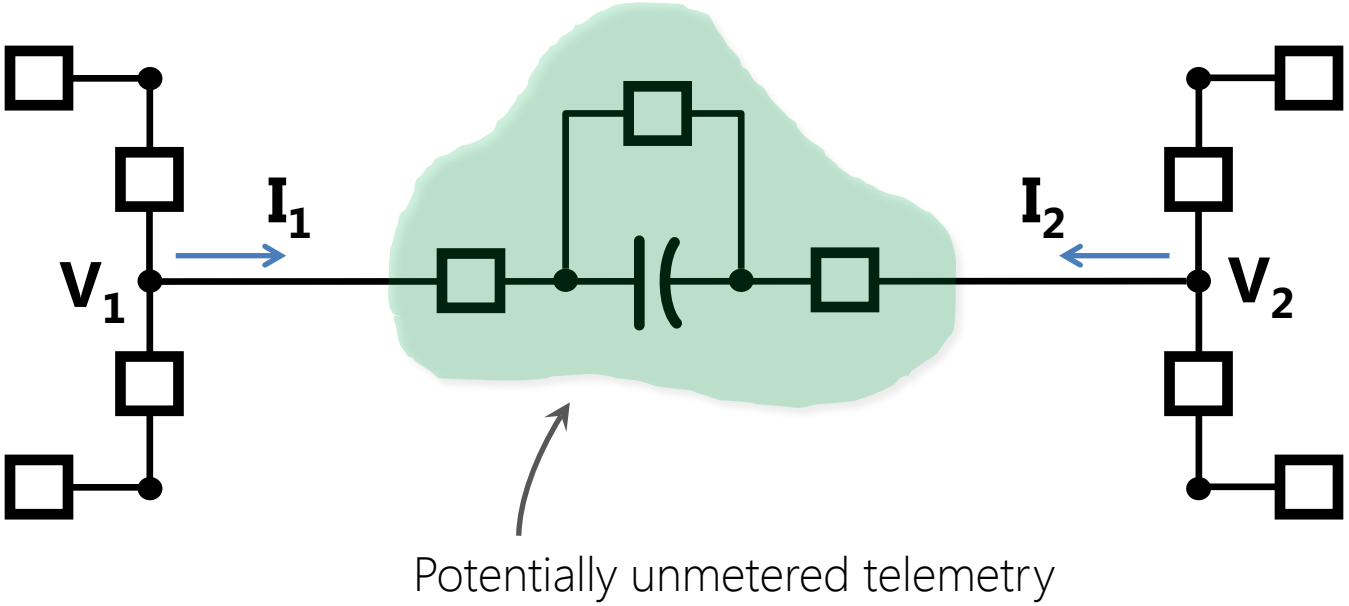
LSE can be supplemented with breaker statuses from SCADA via ICCP. While signal availability is not an issue, these are not time synchronized and LSE output temporally close to breaker status change could have incorrect topology information.



Series Compensator Status Inference

- Total **Z** needed for LSE
  - Breaker telemetry and/or series compensator telemetry may not be available.
  - Can infer status of series compensators by calculating total line reactance





Some Potential Eventualities…

- Inevitable PMU proliferation?
- Scenarios where network apps driven more by synchrophasors than SCADA?
- Line between PMU & SCADA blurs? Data is just data…
- Classes of network apps with classes of data quality requirements

Summary

- LSE in a nutshell
  - Data conditioning for network apps
    - Bias & noise reduction
    - Extended observability
    - Observation redundancy
    - Network model contextualization

- Need for unified conversation and greater collaboration *(I know, but I can dream can't I?!)*
- LSE will key, foundational component of future data systems
- No one size fits all for data conditioning solutions

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