PJM Synchrophasor Data Quality

NASPI DQ Workshop, March 2016
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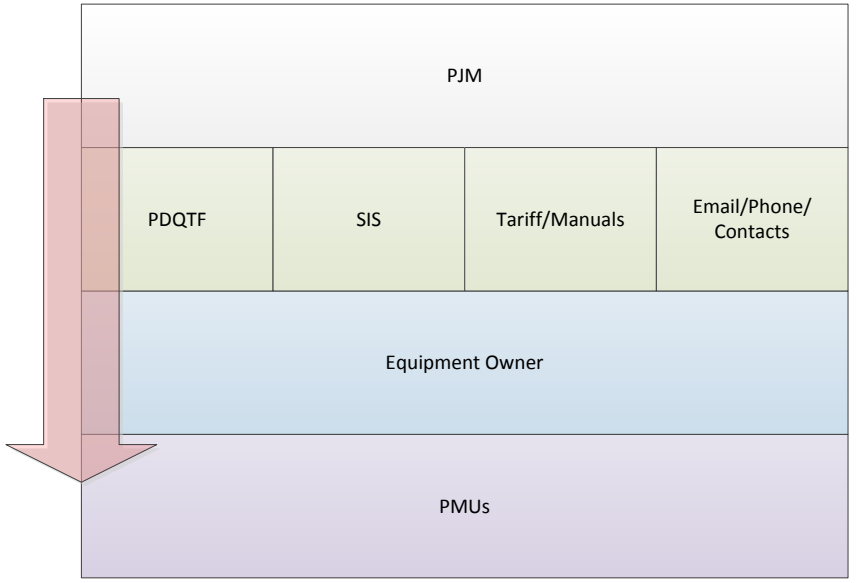
Shaun Murphy

PJM Phasor Data Quality Theory

1. Our members, equipment owners, carry the most significant burden of infrastructure development and maintenance. Therefore PJM's responsibility is to support, enable and inform.
   A. Provide intelligence that is high-value, condensed, and time-saving, derived from the exceptionally large volume of synchrophasor data.
   B. Set data quality goals that are value orientated based on actual application requirements and use cases.
   C. Act as a host wherever intelligence, experience and contacts are mutually beneficial among the PJM family.

PJM's Relation to PMUs



PJM Synchrophasor Performance Metrics from 2/1/2016 to 3/1/2016 – Outage Compensated

Summary PMU Error Rate and Latency Metrics for Each TO

TO	Total Error %	Drop Error %	Data Invalid %	Transmission Error %	Synch Error %	Time Error %	Average Latency	Min Latency	Max Latency
Apple	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	67	0	3861
Tomato	0.032%	0.001%	0.015%	0.000%	0.016%	0.000%	169	72	4065
Bean	0.046%	0.003%	0.044%	0.000%	0.000%	0.000%	210	99	4015
Garlic	0.214%	0.001%	0.177%	0.000%	0.035%	0.000%	149	121	4093
Brussel	0.415%	0.029%	0.385%	0.000%	0.001%	0.000%	210	59	2111
Pepper	0.505%	0.000%	0.000%	0.505%	0.000%	0.000%	141	75	3627
Lettuce	1.569%	1.512%	0.000%	0.000%	0.057%	0.000%	1243	682	4047
Parsley	1.731%	1.606%	0.000%	0.125%	0.000%	0.000%	1088	1045	4124
Daisy	6.323%	0.466%	5.837%	0.000%	0.018%	0.001%	1168	223	4125
Potato	9.364%	0.000%	9.363%	0.000%	0.000%	0.000%	310	137	4062
Basil	22.281%	0.000%	22.245%	0.000%	0.036%	0.000%	30	10	3981
Berry	33.338%	0.002%	33.335%	0.000%	0.000%	0.000%	3184	3013	4098
PJM Total	2.455%	0.757%	1.642%	0.033%	0.023%	0.000%	745	466	3750

The grid above summarizes aggregate average error rates for the month for all PMUs at each TO. Error rates for all PMUs are highlighted on a green-yellow-red gradient scale relative to absolute Error %.
A similar highlighting scheme is used for latency, using a threshold of 500 milliseconds.
Detailed grids showing this data at the substation level and the PMU level are provided late in this document.

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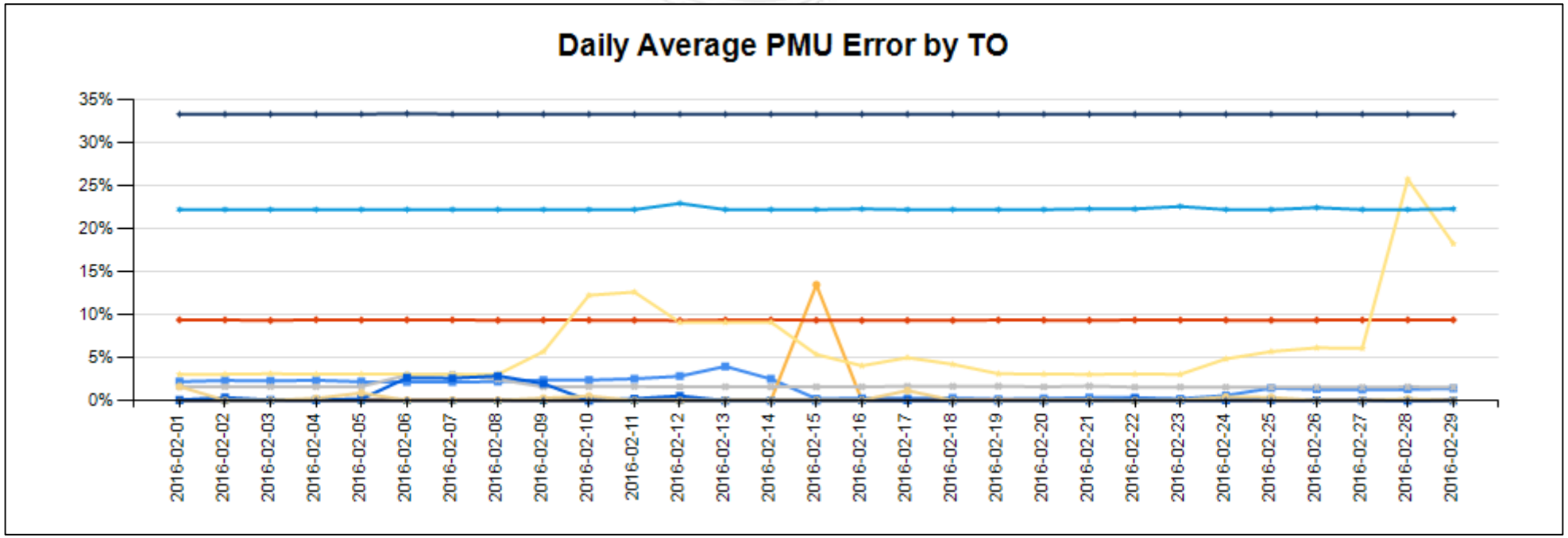
Reporting



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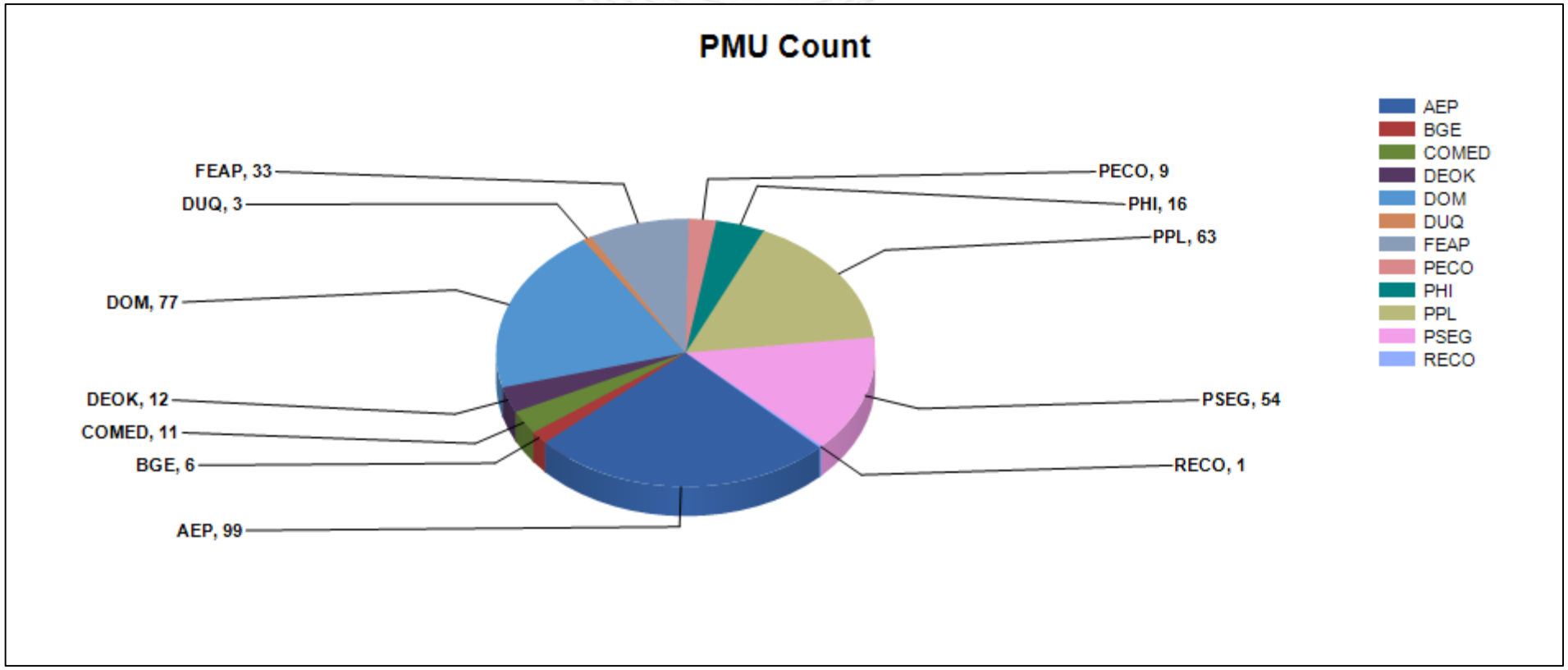
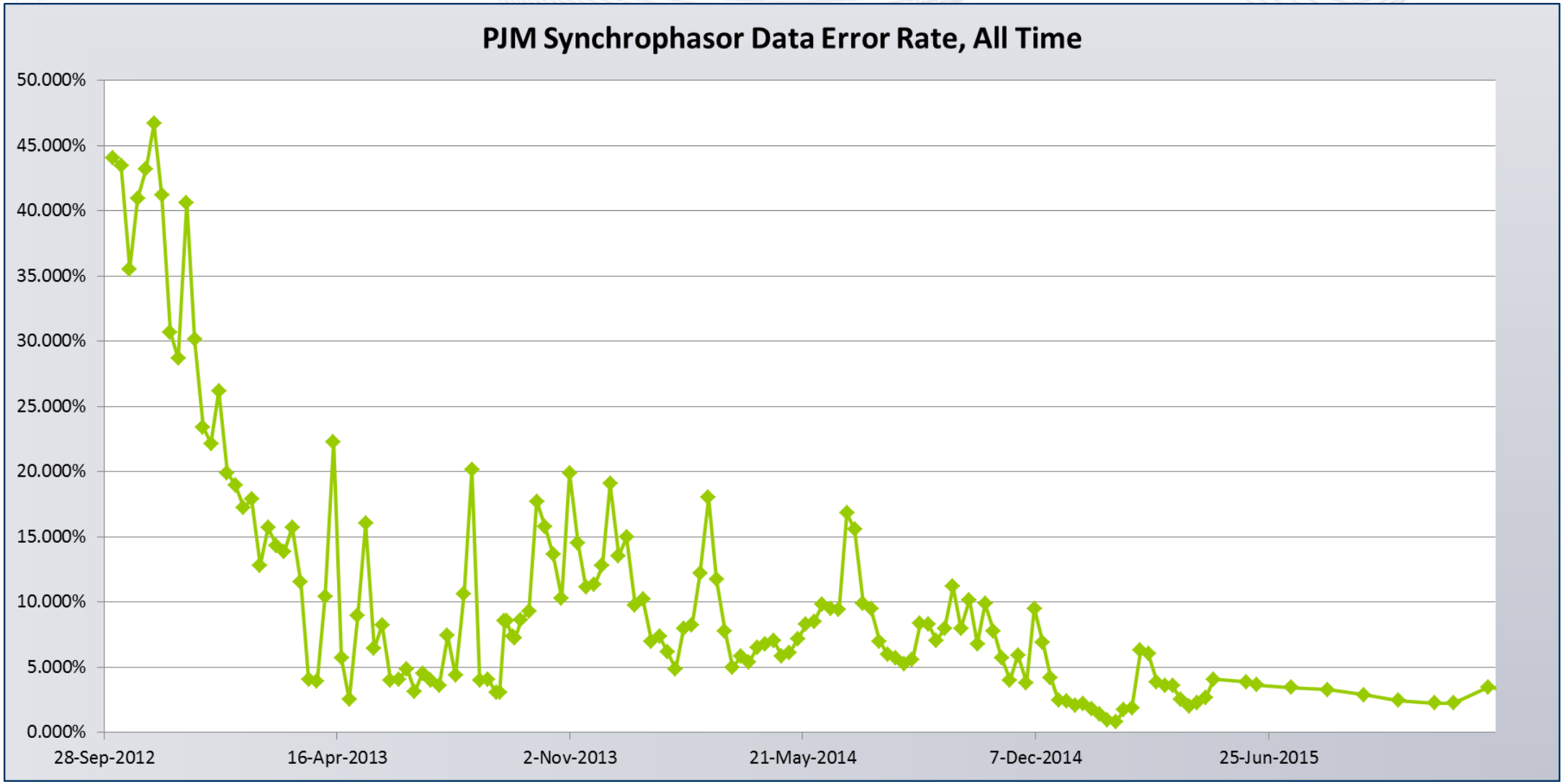
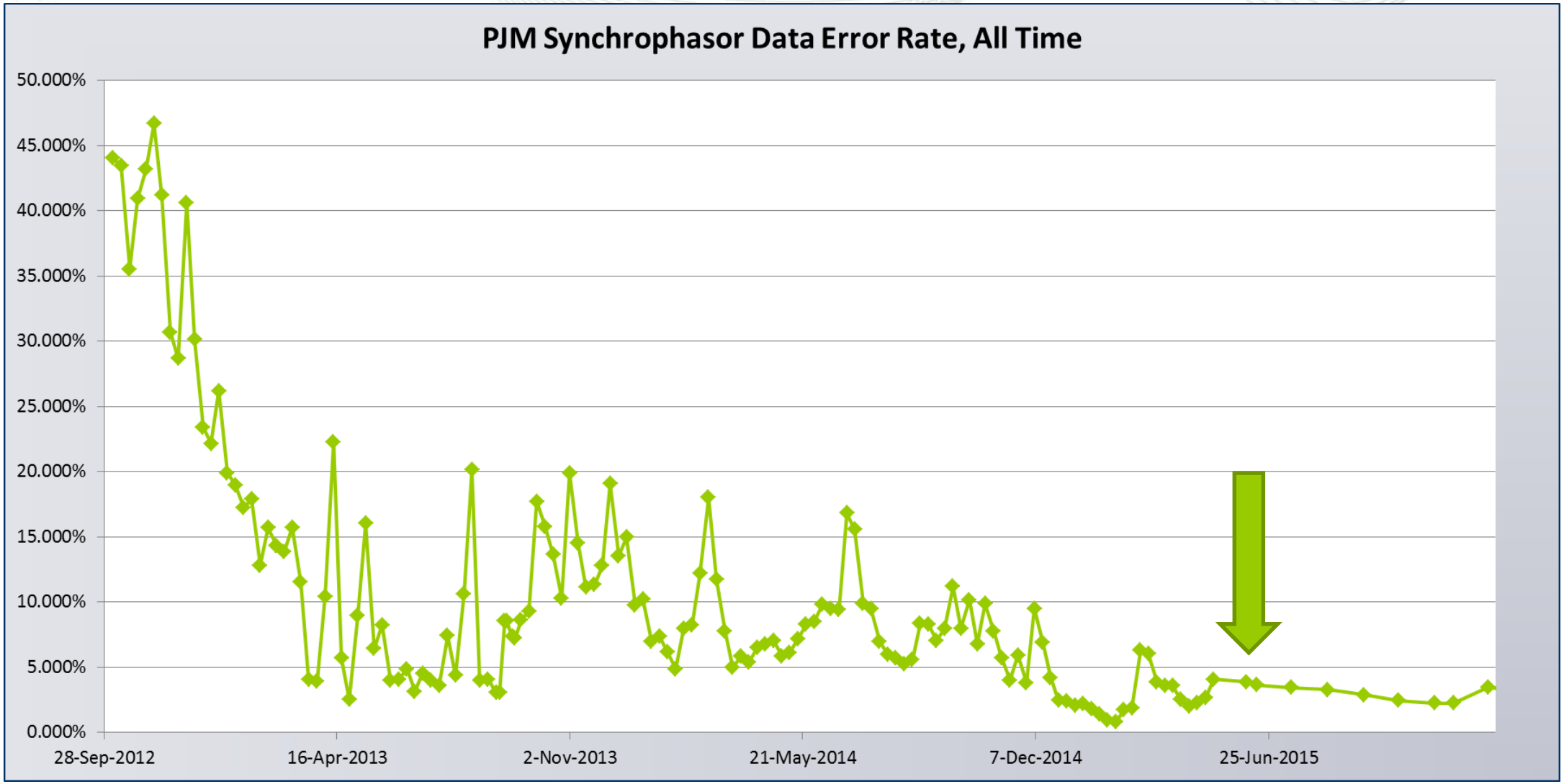


Synchrophasor Data Quality Goals, 2015

- Facing considerable data quality challenges, at the end of 2014 PJM met with TOs to set individual synchrophasor EOY 2015 data quality goals. Most parties agreed to accept the challenge.
- Manual 01 states synchrophasor data quality requirement is +/- 0.2%, or the level the PJM Phasor Data Quality Task Force has set.
- The +/-0.2% threshold is a threshold originally proposed years ago during an earlier phase of synchrophasor research and investigation.


PJM Synchrophasor Data Error Rate, All Time
50.000%
45.000%
40.000%
35.000%
30.000%
25.000%
20.000%
15.000%
10.000%
5.000%
0.000%
28-Sep-2012
16-Apr-2013
2-Nov-2013
21-May-2014
7-Dec-2014
25-Jun-2015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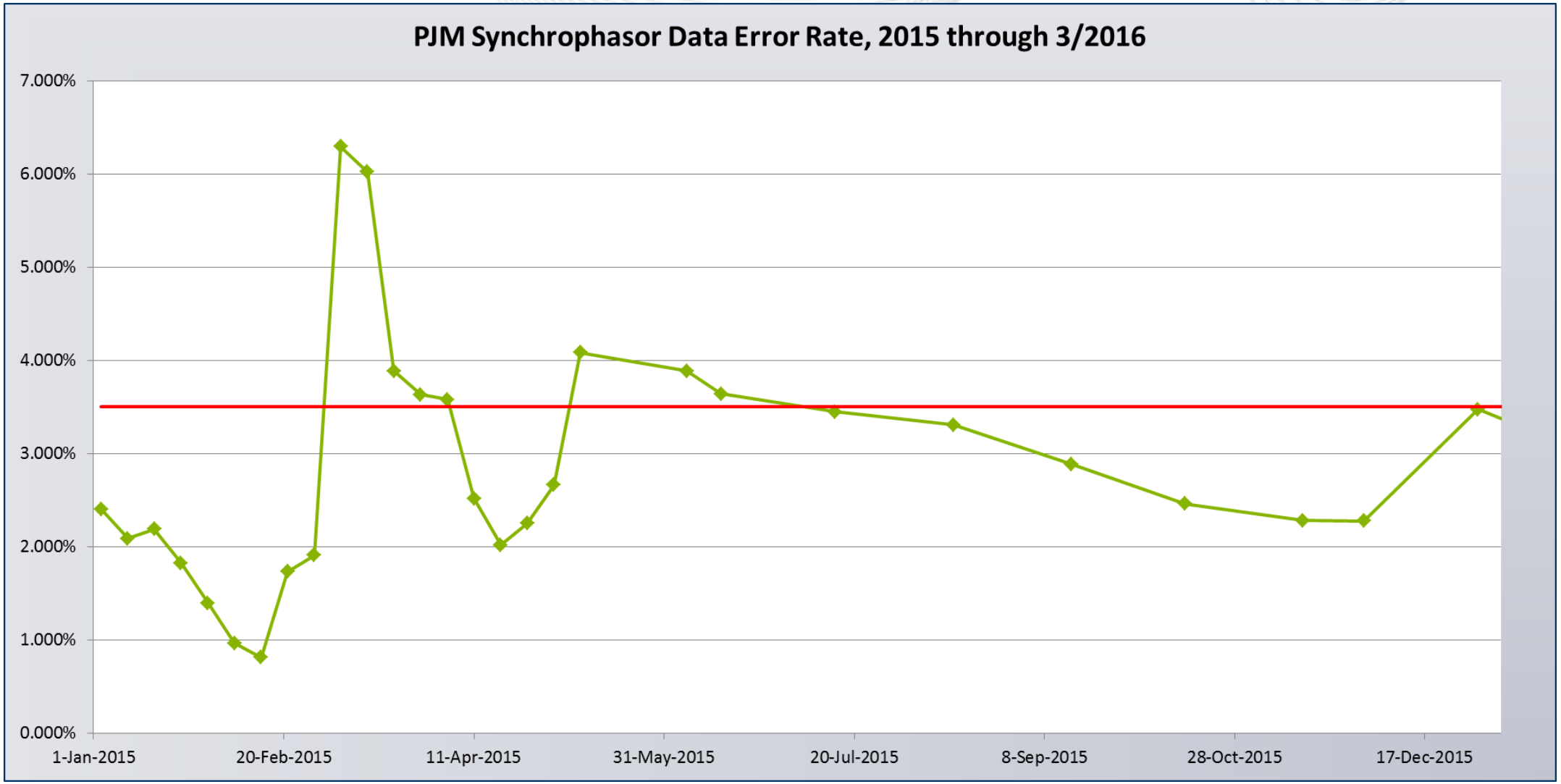

PJM Synchrophasor Data Error Rate, 2015 through 3/2016
7.000%
6.000%
5.000%
4.000%
3.000%
2.000%
1.000%
0.000%
1-Jan-2015
20-Feb-2015
11-Apr-2015
31-May-2015
20-Jul-2015
8-Sep-2015
28-Oct-2015
17-Dec-2015

Synchrophasor Data Quality Goals

Plans for progress, 2016:

- For highest value for effort, focus attention on specific situations that regularly, over a three month rolling average, feature an error rate worse than ±0.5%.
- All companies will continue to be monitored and are encouraged to meet the ±0.2% goal.
- Move beyond looking at data quality, and evaluate data *accuracy*.

Beyond Quality, Into Accuracy

Signal Type	Value
Status	0x0000 (Good Data)
Voltage	0 V / -120 Degree
Current	271.602 A / -1.66576 Degree
Frequency	65.536 Hz / 0 Hz/s

- STAT word is zero – indicating good.
- Voltage is zero, -120, default value.
- Frequency hasn't changed from 65.536 Hz for days.

In standard reporting, this PMU data would be categorized as non-error because of dependency on the STAT word derived quality.

Data Accuracy

Initial Check

- Good C37.118 Status Word
- Good Latency
- Planned Outage

Value Based Check

- Signal Within Expected Range

Model Based Check

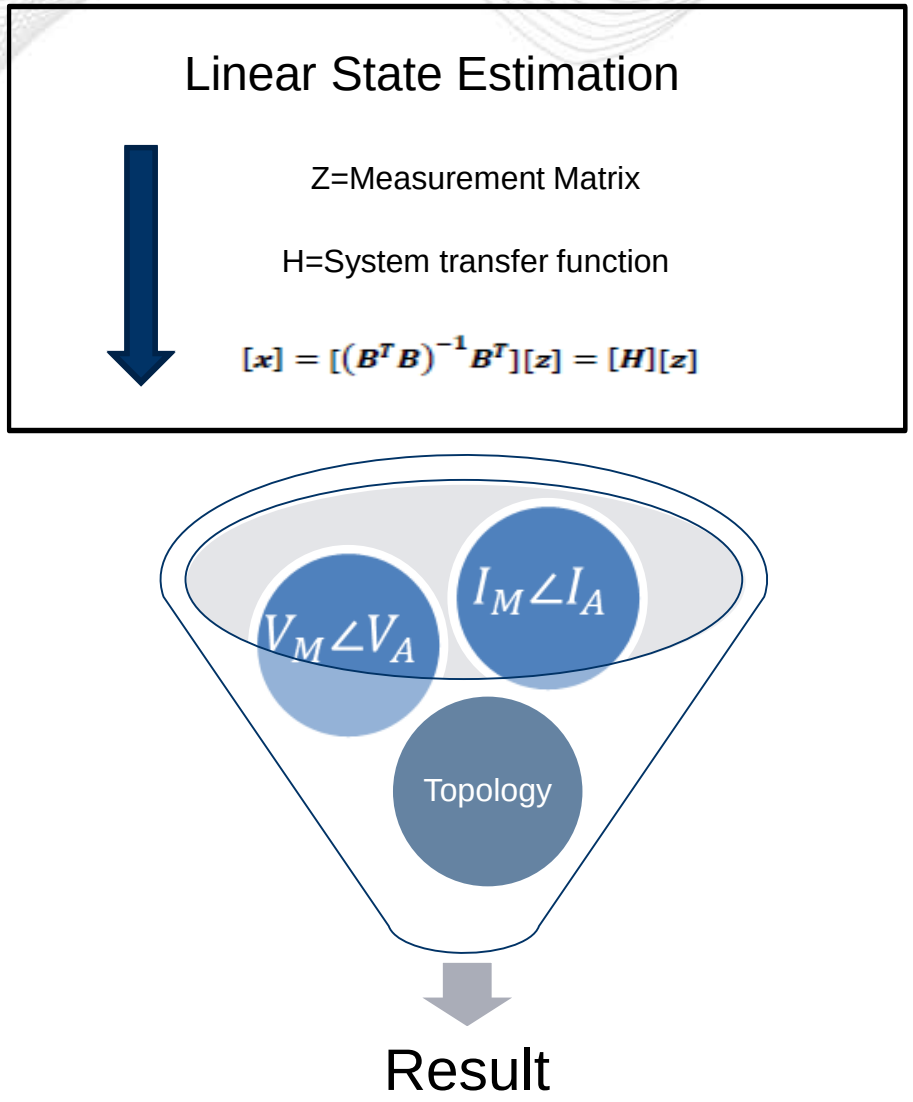
- Signal Fits to System Model (LSE)

Value Based Check

- Voltages
  - Between 0.7 and 1.3 Per Unit
- Currents
  - Less than 100 Per Unit
  - *Less than branch load dump limit*
- Frequencies
  - *Between under and over protection settings*

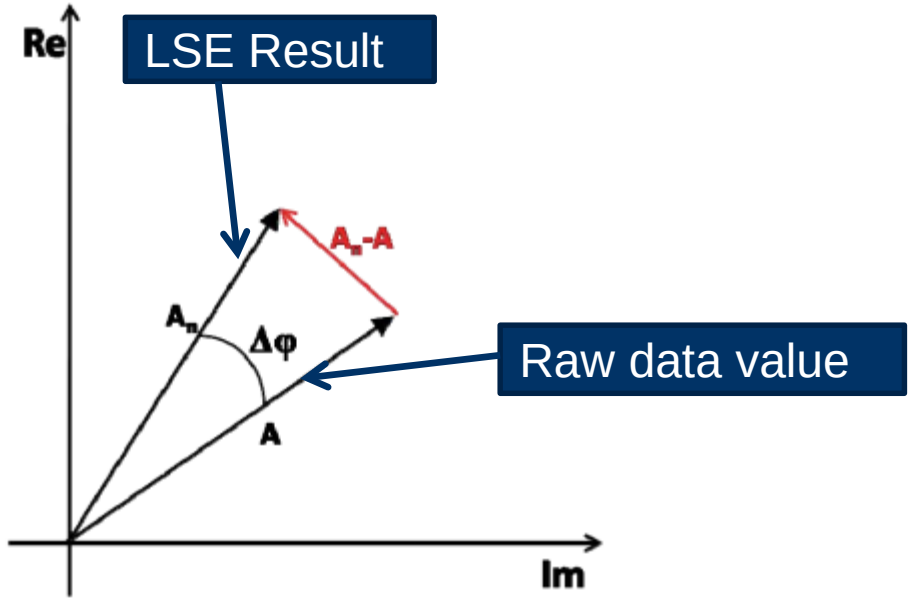
Model Based Check

- Linear State Estimation combines:
  - PMU Voltages
  - PMU Currents
  - Topology
  - Impedance



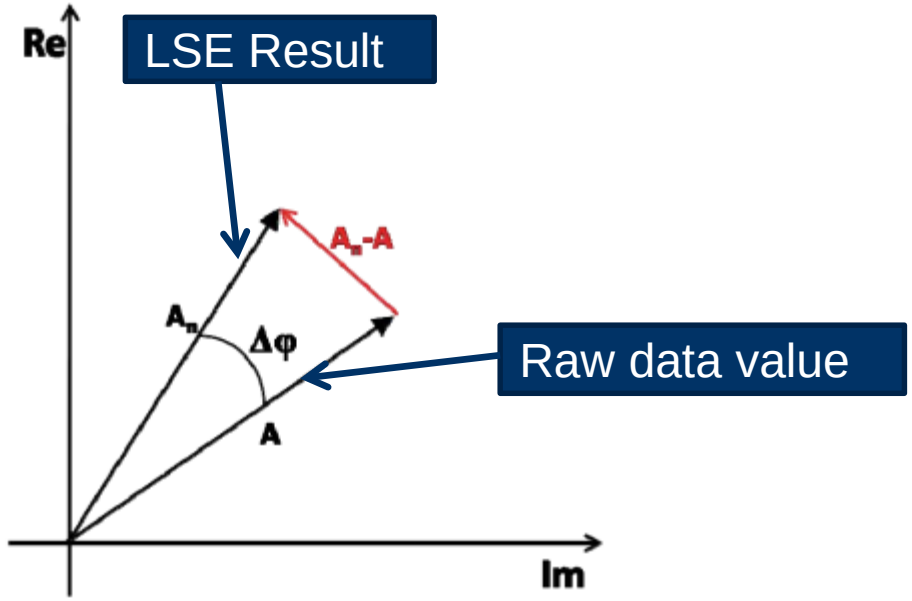
Linear State Estimation Improves Data Quality

1. Process and arrange input data
2. Calculate State Estimate
3. Calculate residual between raw value and LSE result



Linear State Estimation Improves Data Quality

1. Process and arrange input data
2. Calculate State Estimate
3. Calculate residual between raw value and LSE result
4. Remove signal with largest residual, return to step 1

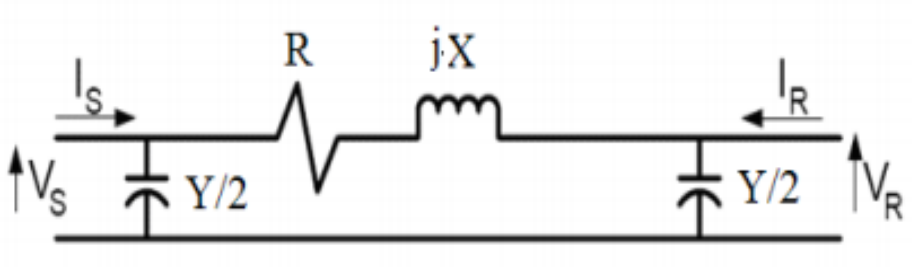


Linear State Estimation Approach

- Systematically remove PMU data with the highest residual value until the maximum residual is under a given tolerance (25%)
- Preserves quality of the system state
- Catalog bad data occurrences and share with PMU owner

Adding Model Validation

- LSE applies PMU data to our model and finds the state
- Current setup identifies large errors in data quality
- Model validation heavily impacts this analysis. Quantifying data quality at a higher degree of accuracy requires a highly-accurate model.



*High residuals may be the result of an inaccurate model

Plans for the future…

- Model Validation
- Apply data to a time-based SE model
- Utilize a filter-based approach to state estimation
- Adding more information to our model will improve data quality detection