Improving data quality in PSE&G's synchrophasor network

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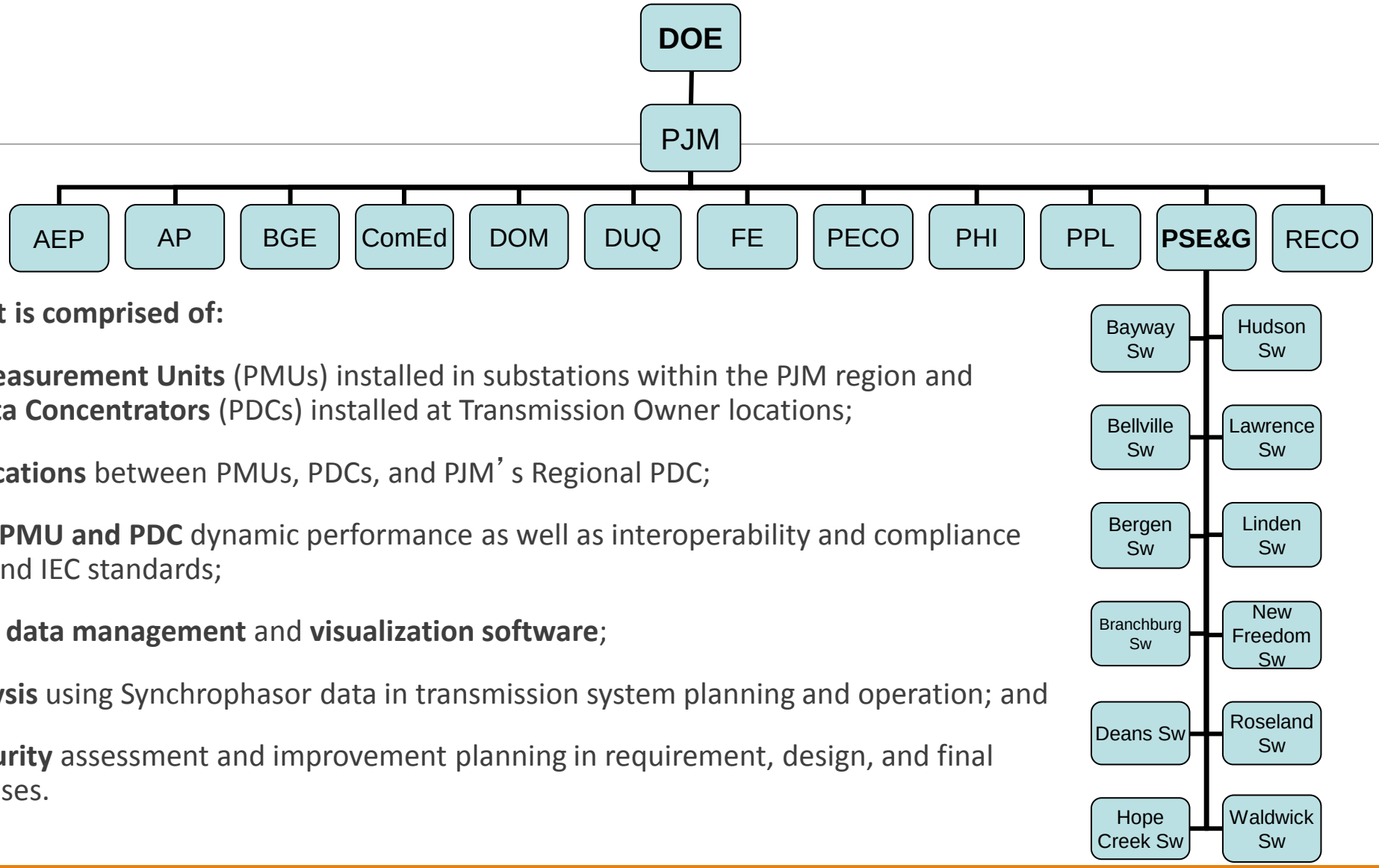
Synchrophasors at PSE&G

PJM SynchroPhasor Project ~Circa 2008



The project is comprised of:

Phasor Measurement Units (PMUs) installed in substations within the PJM region and **Phasor Data Concentrators** (PDCs) installed at Transmission Owner locations;

Communications between PMUs, PDCs, and PJM's Regional PDC;

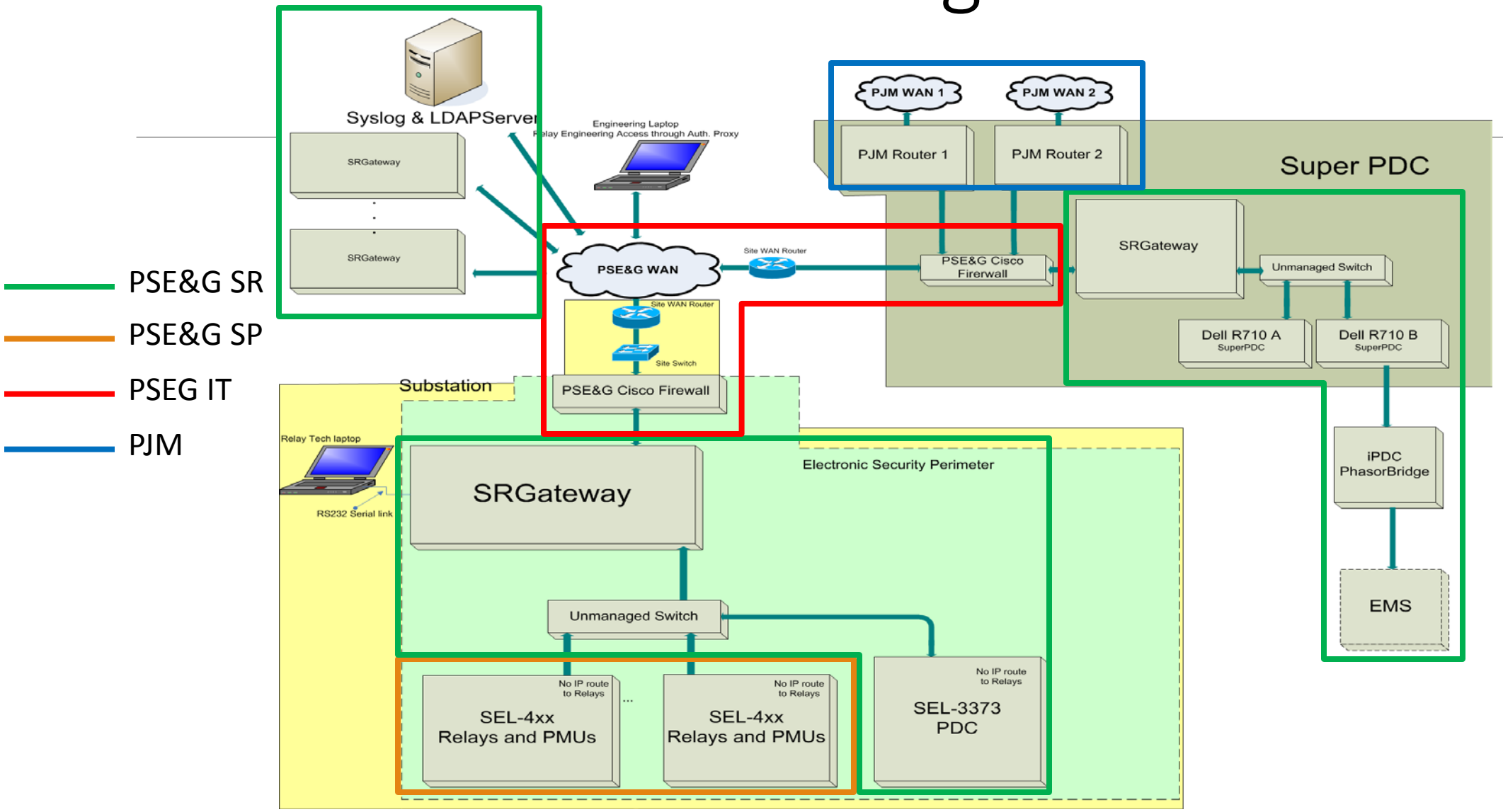
Testing of PMU and PDC dynamic performance as well as interoperability and compliance with IEEE and IEC standards;

Integrated **data management** and **visualization software**;

Data analysis using Synchrophasor data in transmission system planning and operation; and

Cyber security assessment and improvement planning in requirement, design, and final testing phases.

Block Diagram



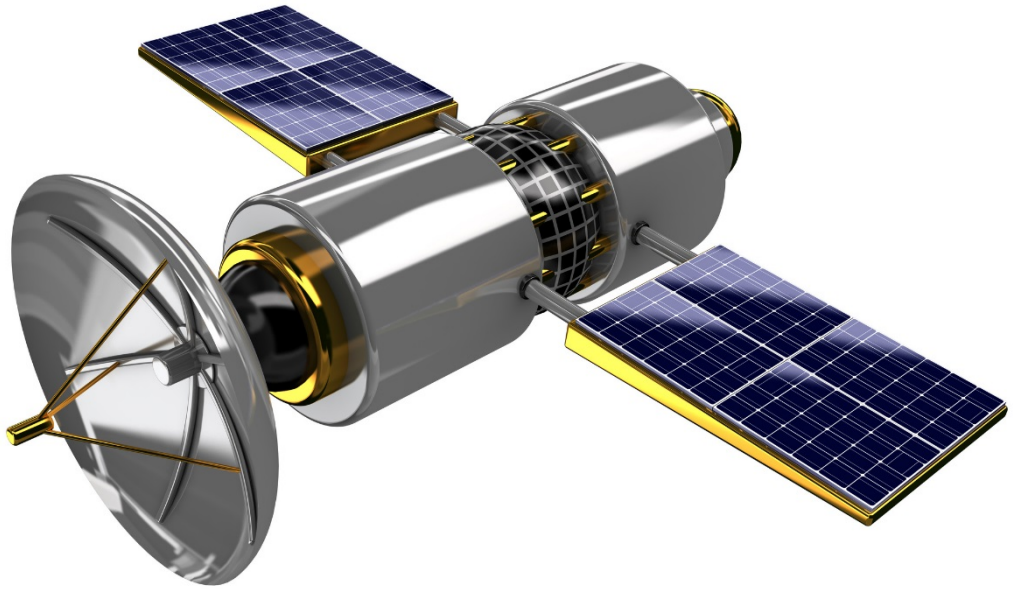
PJM Goals

- PJM Phasor Data Quality Task Force (Sept 2013)
  - Improve phasor data quality
- Weekly and monthly reporting on data quality and latency
  - Catalyst for much of PSE&G's data quality improvement
- Data quality targets
  - 99%, increasing to 99.5% in the new year
- Latency targets
  - Soft target of 500ms end to end
- Planned outage reporting
  - Increased difficulty when using relays as PMUs, work could be done by other departments

Data quality challenges

GPS Clock Errors

- Errors related to satellite synchronization
- Often caused by inclement weather (unavoidable)
- May be the result of poor antenna placement or wiring
- Leap second
  - Adjustments for UTC time due to irregularities in earth's rotation
  - Clocks, PMUs, and PDC must handle the repeated/skipped UTC second correctly

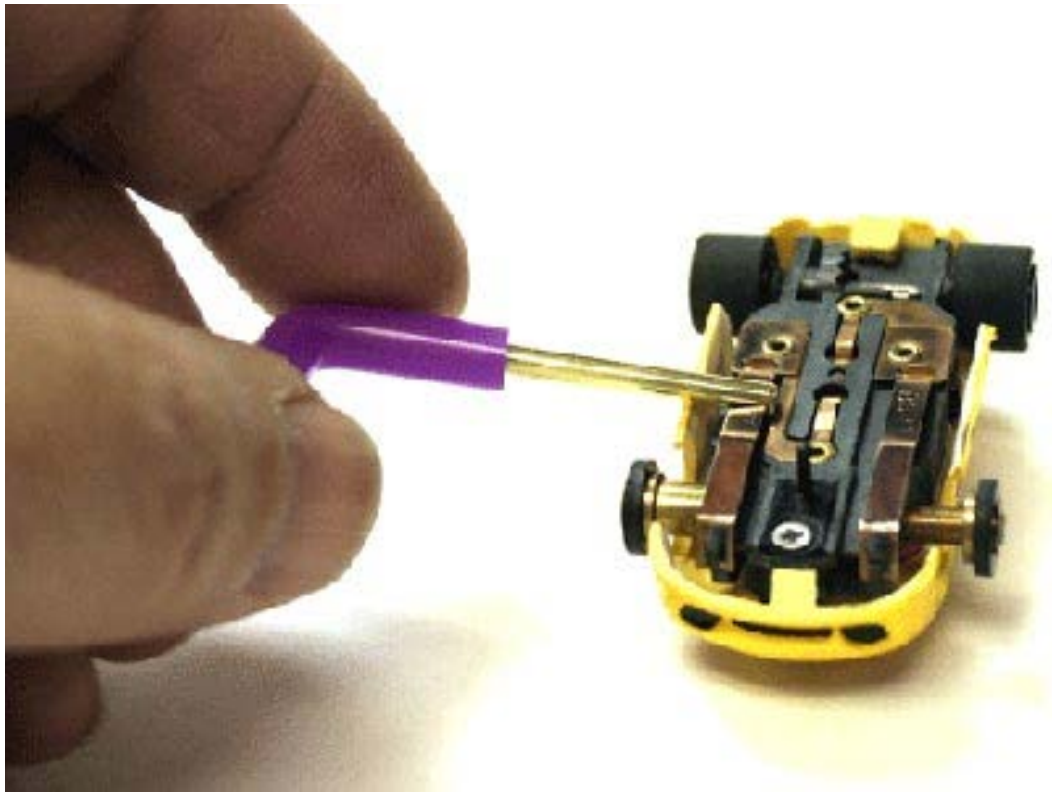


Network Issues

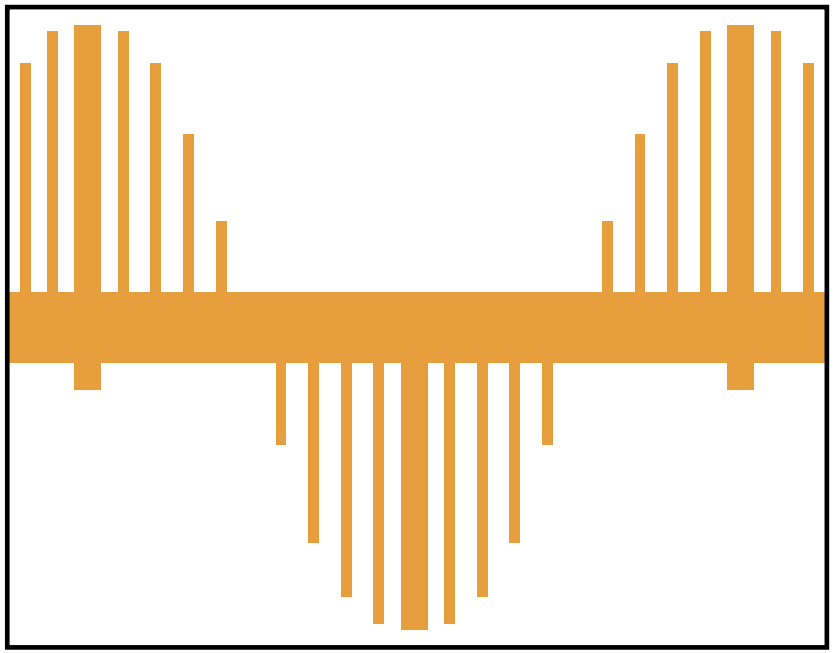
- Broken connections (intermittent or otherwise)
- Selecting appropriate latency targets
  - PJM's "soft" end-to-end latency target
- Trouble achieving latency targets
  - At station and super PDC levels
- Dropped data packets
  - PMU error or high latency?
- Data quality vs. latency trade-offs
  - Increased wait periods to raise data quality, or lower wait periods to lower latency?

Latency, Data Quality, and Wait Periods

- PDC's use wait periods to enforce latency targets
- If data from a source device is not received within the wait period, it "misses the train" and is marked as invalid when the PDC outputs data
- Late data is NOT passed to higher level PDCs, even when it is finally received
- If wait period is too long, the entire subset of data the PDC is concentrating may "miss the train" at the higher level PDC
- There is a need to "tune" the wait periods for the optimal trade-off between latency and data quality

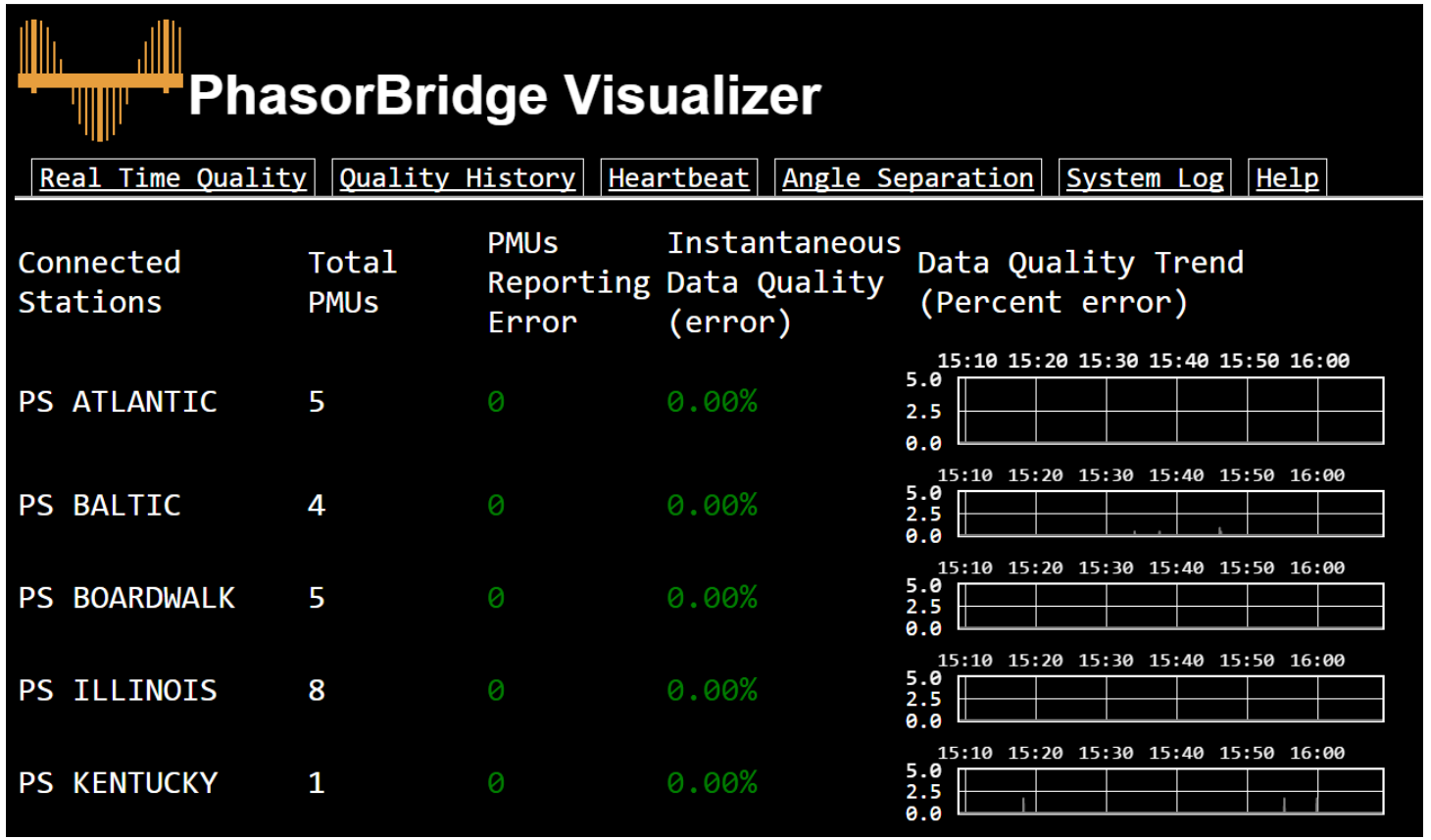


Solution: Monitoring

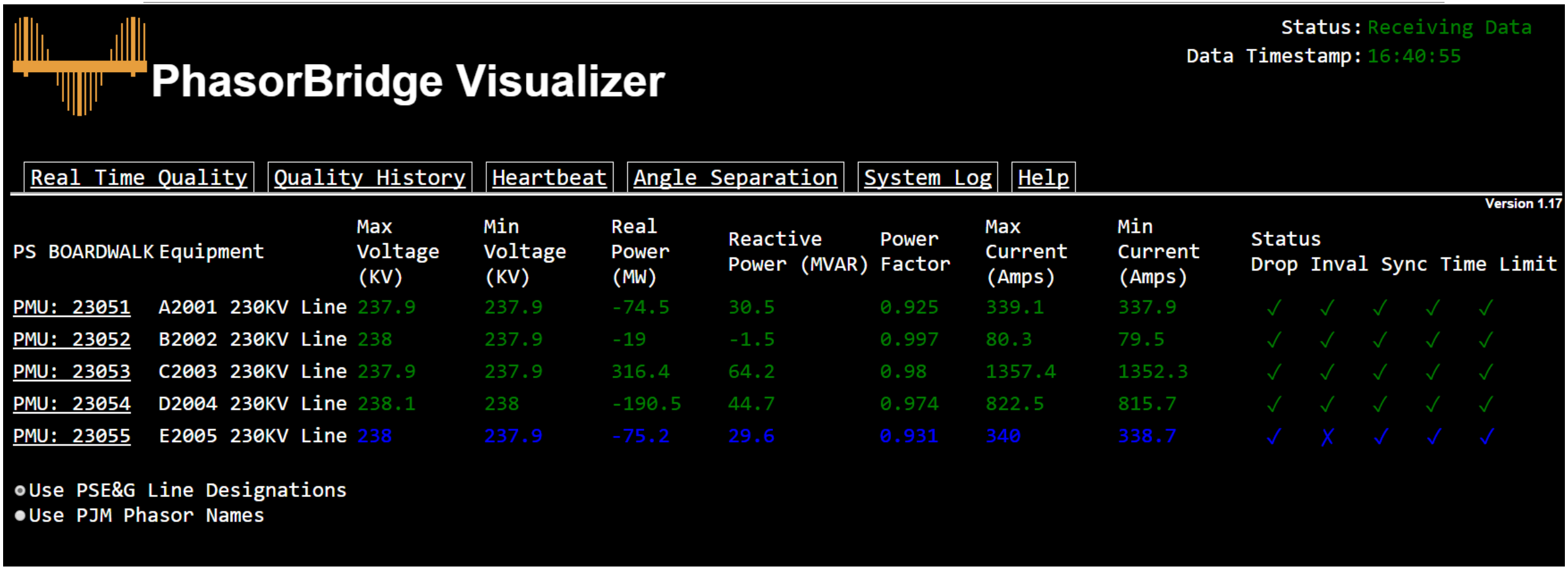


PSE&G PhasorBridge

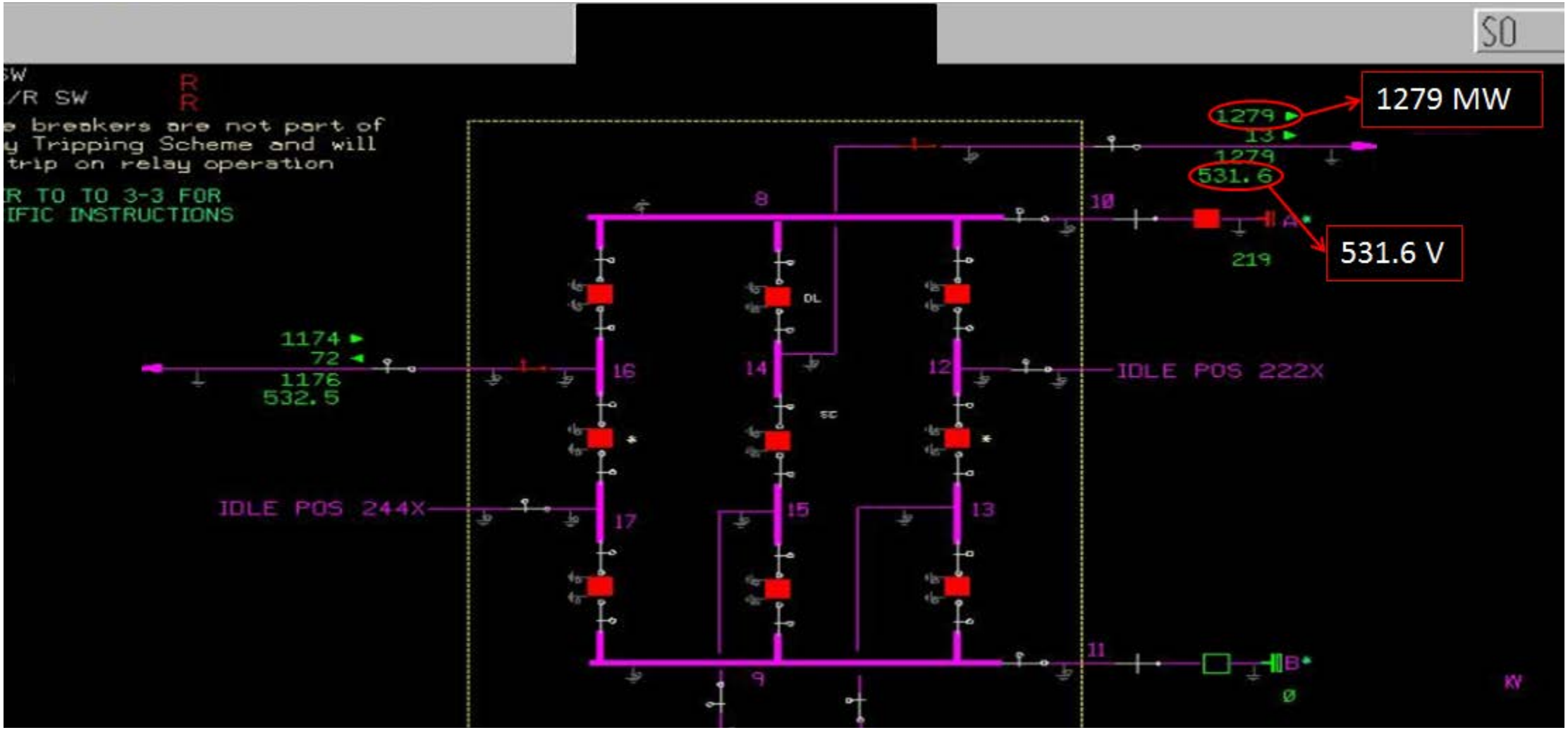
- In house tool to monitor synchrophasor network health
- Generate quality statistics to help diagnose issues
- Display real-time data in SCADA-like format
- Automatic alerting for issues
- Single point of contact for synchrophasor data



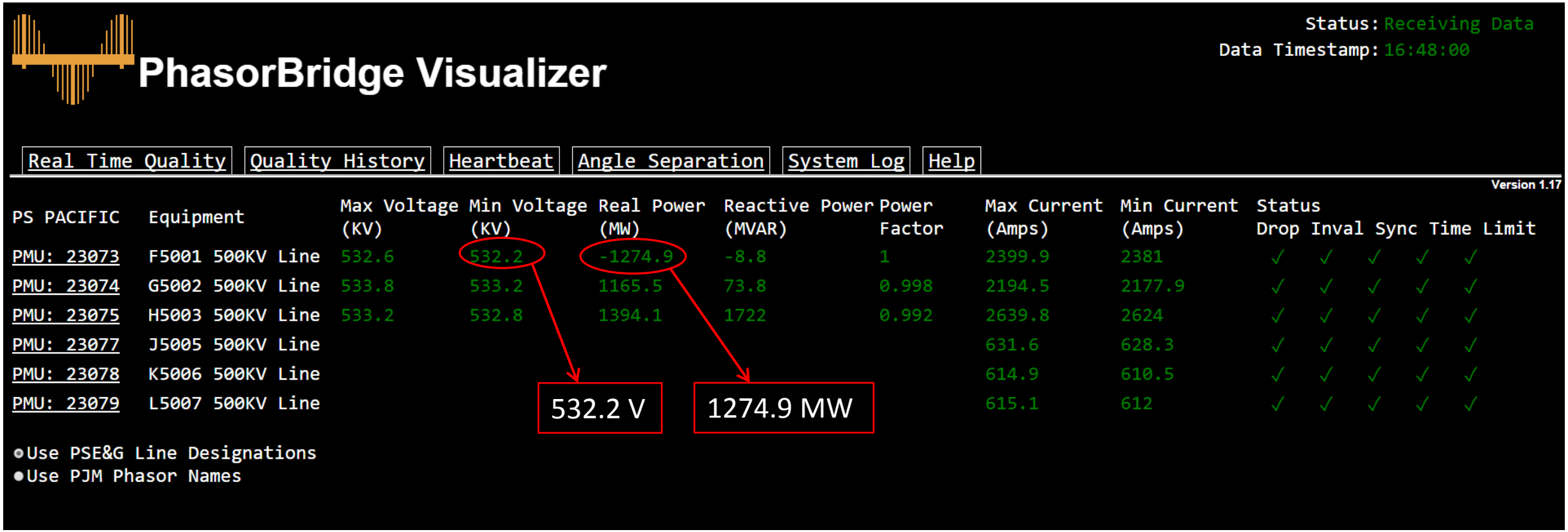
Viewing Synchrophasor Data



EMS – RTU View

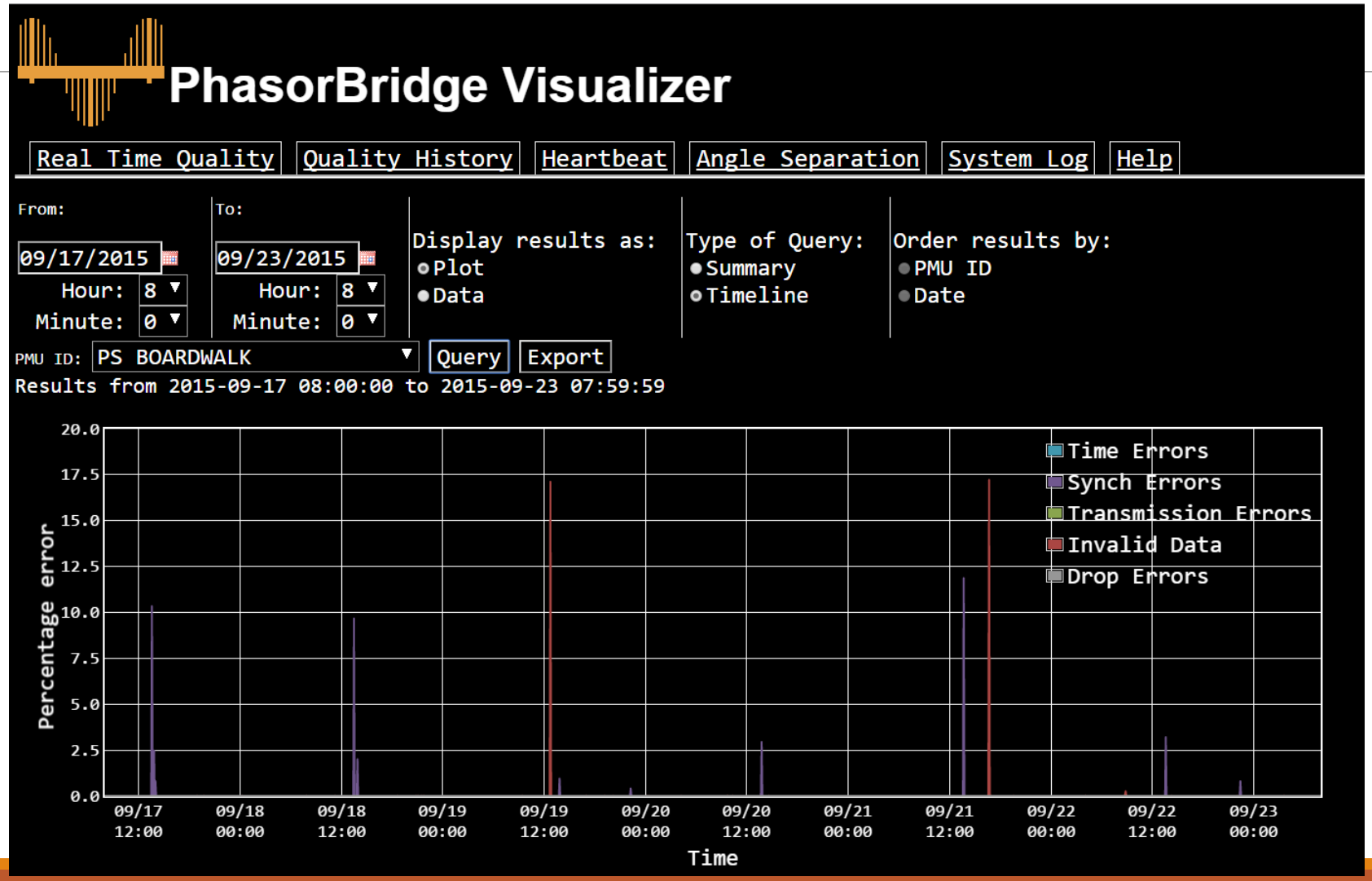

1279 MW
531.6 V
1279
13
1279
531.6
219
1174
72
1176
532.5
IDLE POS 222X
IDLE POS 244X
DL
SC
breakers are not part of
Tripping Scheme and will
trip on relay operation
R TO TO 3-3 FOR
IFIC INSTRUCTIONS

Phasor Data View

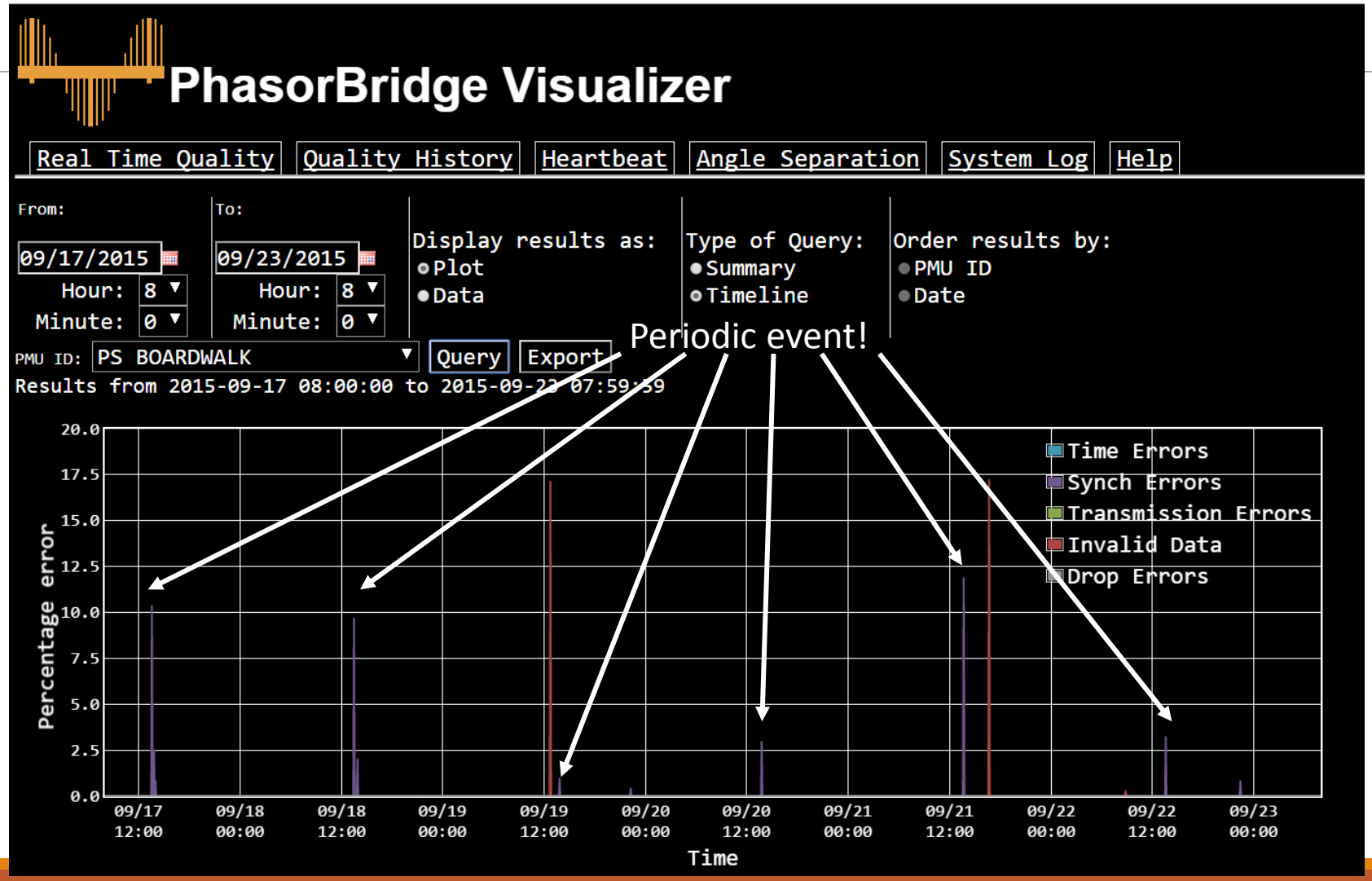


EMS View	Phasor View
531.6 kV	532.2 kV
1279 MW	1274.9 MW

Identifying data quality trends



Identifying data quality trends



Alerting for outages

- Automated alerting
- Alert conditions:
  - Sustained data outage (due to any error type)
  - Sustained station “Heartbeat” loss
- Alerts received as email and text messages
- Select alerts received by Network Operations

Logistic and other challenges

Procedural and organizational issues

- Who manages the synchrophasor equipment?
  - PMUs (relays) – System Protection and Relay division
  - Network – Corporate IT
  - PDCs, SRGateways, and PhasorBridge – SR
- Who can go on site when necessary (possibly into secure areas)?
  - On-site troubleshooting and setup - LTS
- If using existing equipment (relays, network equipment), what additional requirements are there?
  - NERC CIP for relays, firewalls
- Synchrophasor placement?

Regulatory issues (NERC CIP)

- Additional requirements for relays as PMUs
  - Two-factor access to relays
  - Log of access
  - Extended log retention
  - Password management

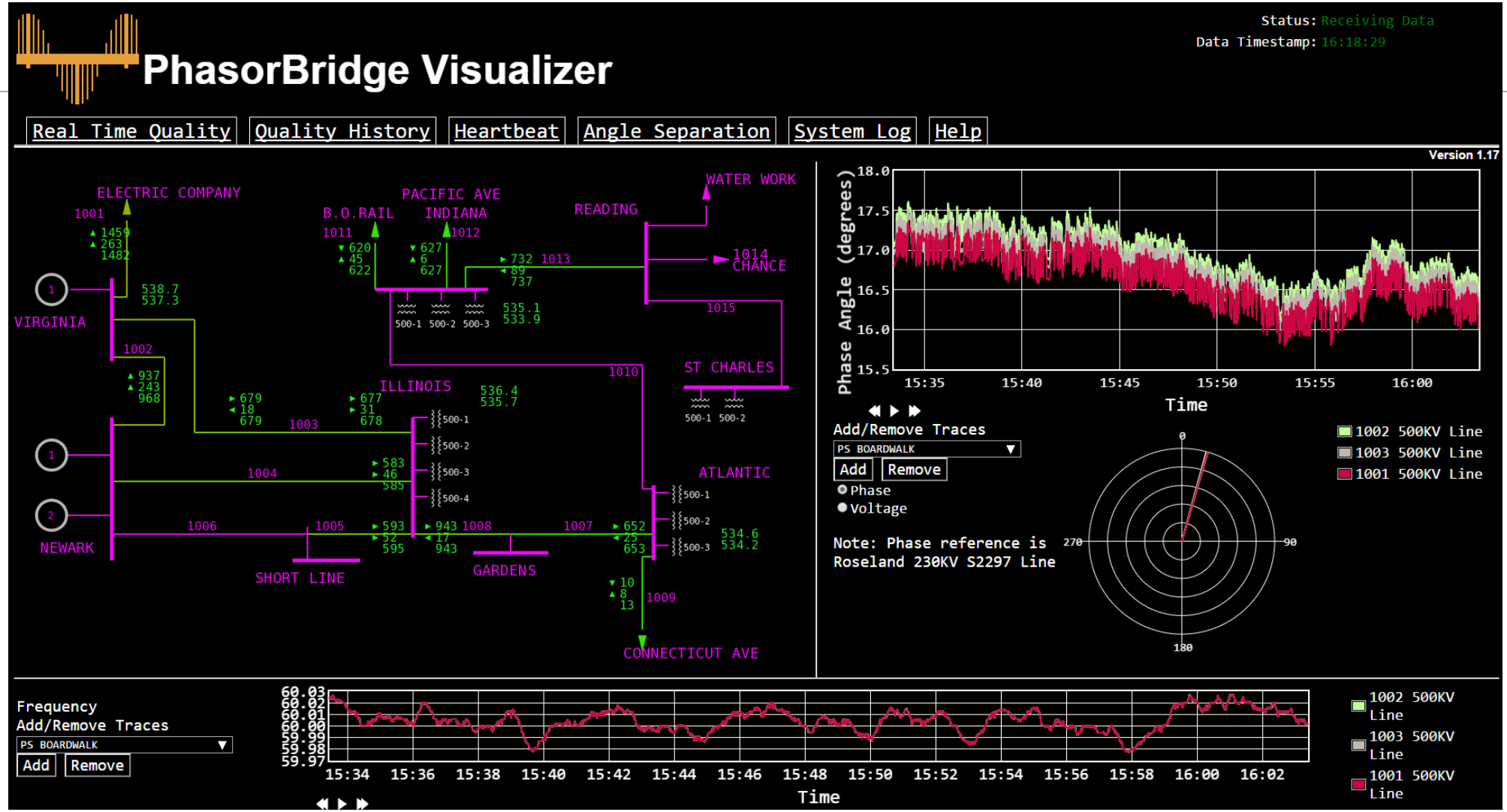
Moving forward

- Synchrophasors in the control room
  - Use PMU data in real-time monitoring – real-time phase angle difference monitoring
  - Use PMU data in state estimation – PMU data as alternative data sources
  - Use PMU data in post event analysis – PMU data retention
- Increased coverage in the future
  - Funding and maintenance requirements
  - RTU replacement project in PSE&G
  - Fibre optic network project in PSE&G

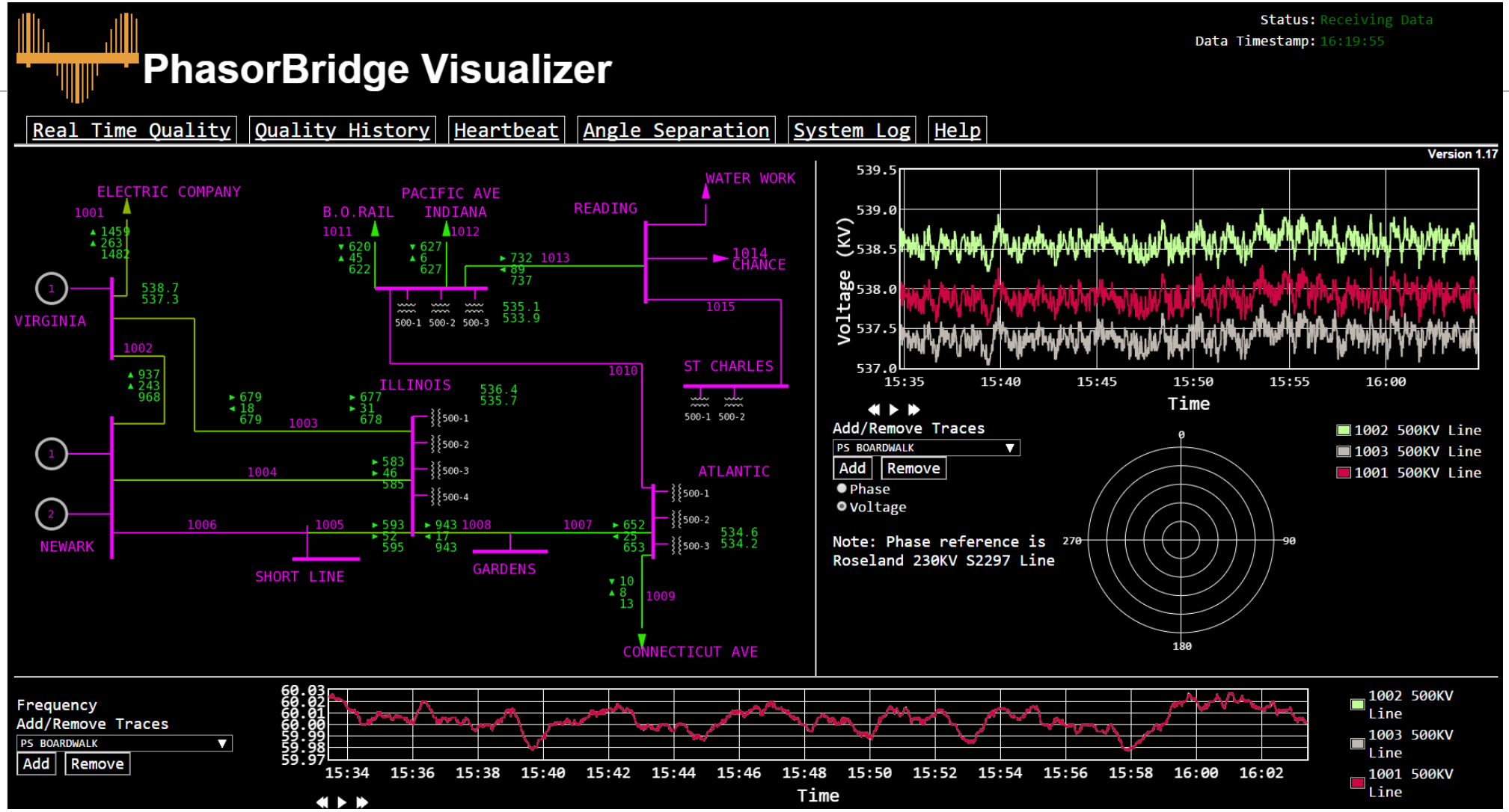
Moving forward

- Adoption of newer standards
  - E.g. lost time quality bits during data concentration in 2005 version of IEEE standard
- Changing PJM requirements
  - Increasing data quality targets, additional applications
  - Data retention?
- Changing regulatory requirements
  - NERC CIP v5 and beyond

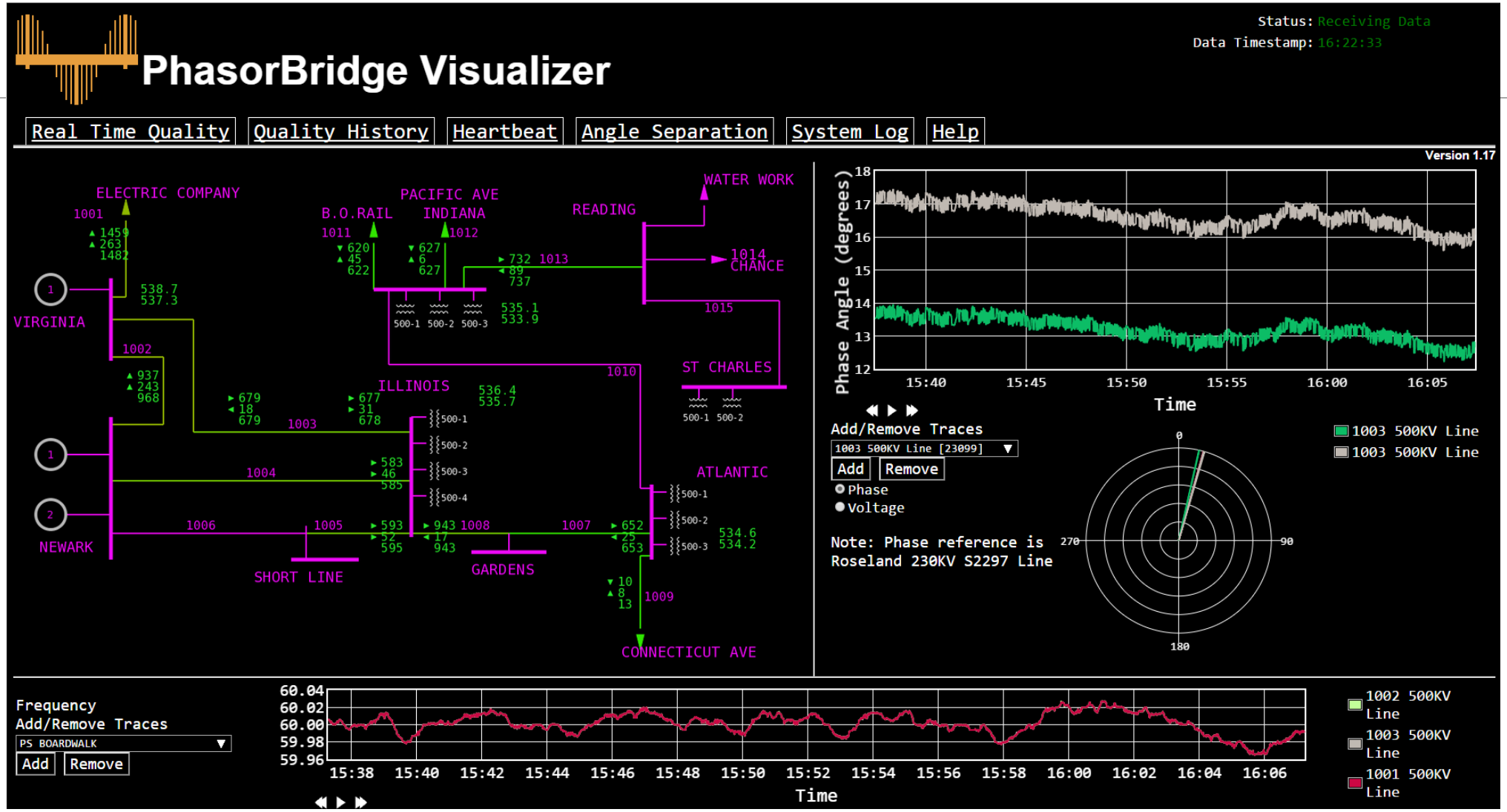
Single station (Phase)



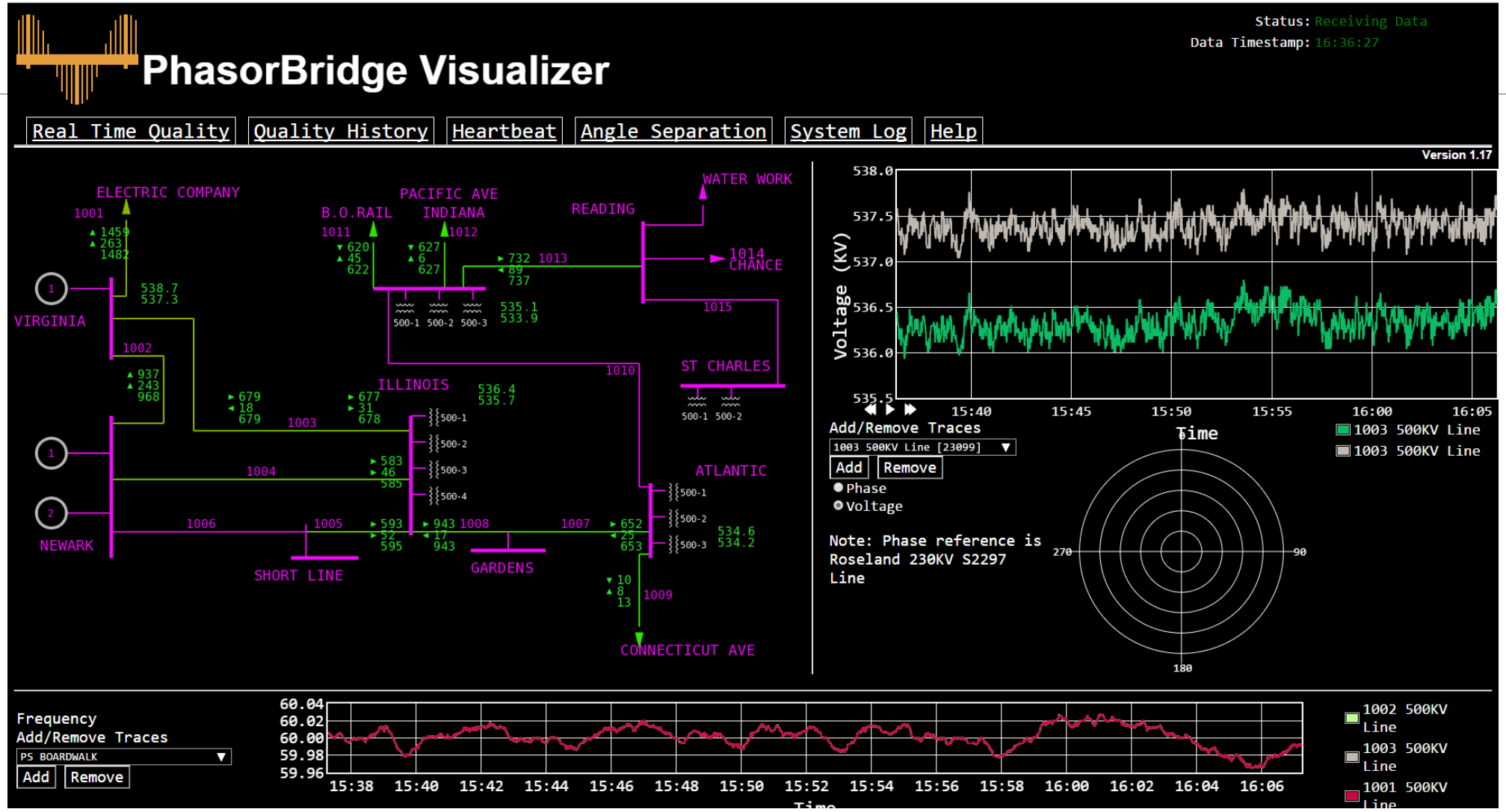
Single station (Voltage)



Two Ends Of One Line (Phase)



Two Ends Of One Line (Voltage)



Phasor Angle Separation

Power Angle Equation:

$$P = \frac{V_1 V_2}{X} \sin\delta$$

For the 1001 line, the positive-sequence reactance is: 26.25Ω

$$\delta = sin^{-1}\left(\frac{PX}{V_1 V_2}\right) = sin^{-1}\left(\frac{679 \times 26.25}{537.3 \times 536.4}\right) = 3.55°$$

The calculated voltage angle difference matches with the PMU angle difference value

Questions?