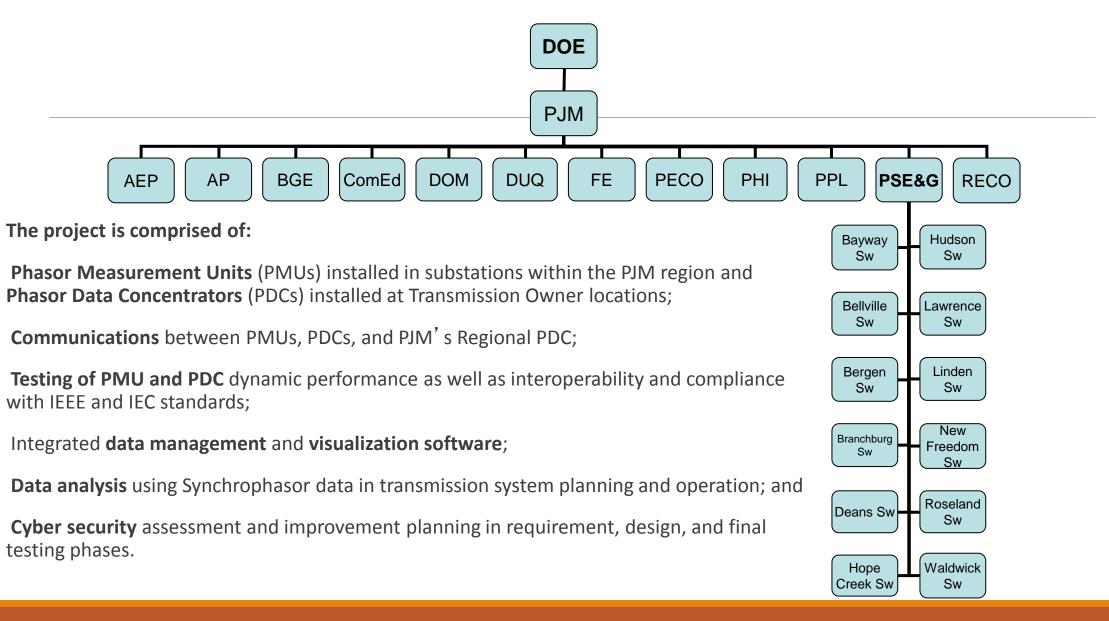
# Improving data quality in PSE&G's synchrophasor network

PING YE PHD- PSE&G

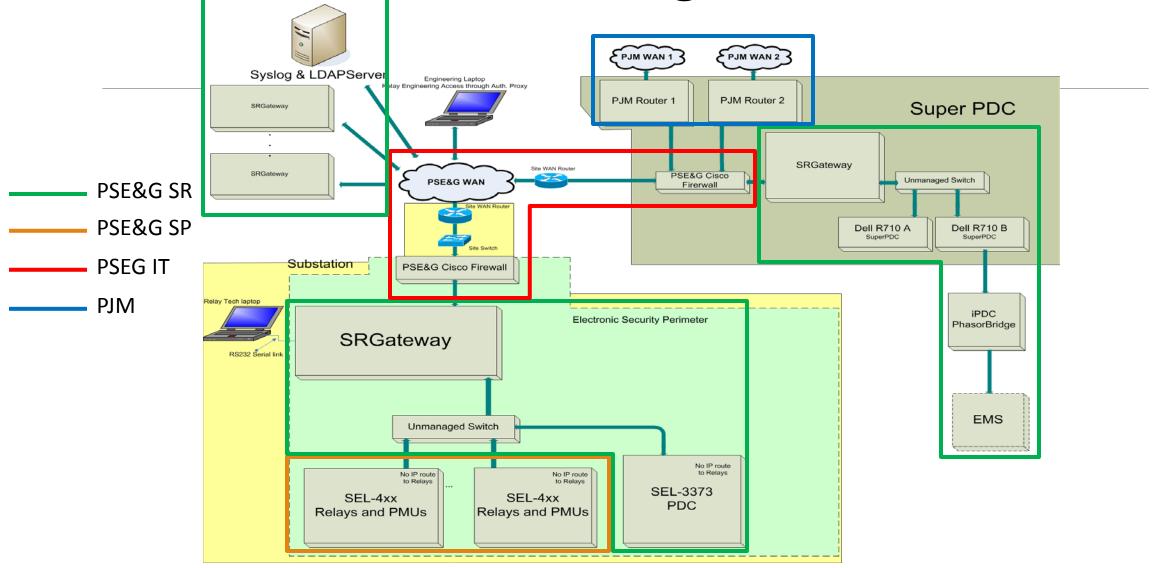
ZACHARY HARDING - PSE&G (IBRIDGE)

# Synchrophasors at PSE&G

#### PJM SynchroPhasor Project ~Circa 2008



### **Block Diagram**



### PJM Goals

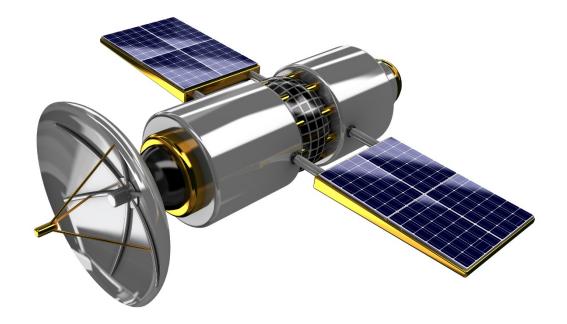


- PJM Phasor Data Quality Task Force (Sept 2013)
  - Improve phasor data quality
- Weekly and monthly reporting on data quality and latency
  - Catalyst for much of PSE&G's data quality improvement
- Data quality targets
  - 99%, increasing to 99.5% in the new year
- Latency targets
  - Soft target of 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



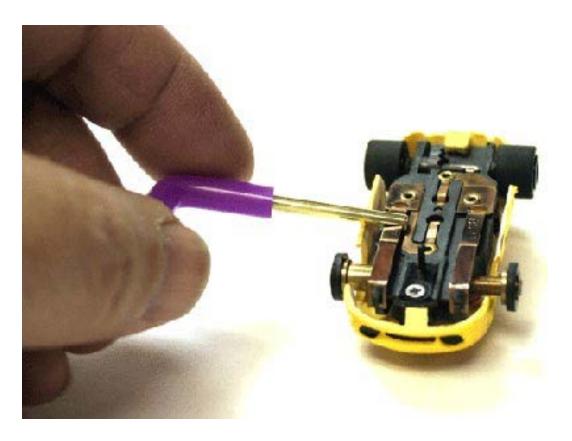
### Network Issues



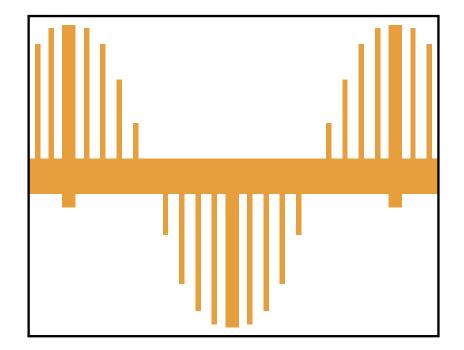
- •Broken connections (intermittent or otherwise)
- •Selecting appropriate latency targets
  - PJM's "soft" end-to-end latency target
- •Trouble achieving latency targets
  - At station and super PDC levels
- •Dropped data packets
  - PMU error or high latency?
- •Data quality vs. latency trade-offs
  - 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 SCADAlike format
- Automatic alerting for issues
- •Single point of contact for synchrophasor data

PhasorBridge Visualizer    Real Time Quality  Quality History  Heartbeat  Angle Separation  System Log  Help										
Connected Stations	Total PMUs	PMUs Reporting Error	Instantaneou Data Quality (error)	Data Quality Irend						
PS ATLANTIC	5	0	0.00%	15:10 15:20 15:30 15:40 15:50 16:00 5.0 2.5 0.0						
PS BALTIC	4	0	0.00%	15:10 15:20 15:30 15:40 15:50 16:00 5.0 2.5 0.0						
PS BOARDWALK	5	0	0.00%	15:10 15:20 15:30 15:40 15:50 16:00 5.0 2.5 0.0						
PS ILLINOIS	8	0	0.00%	15:10  15:20  15:30  15:40  15:50  16:00    5.0						
PS KENTUCKY	1	0	0.00%	15:10 15:20 15:30 15:40 15:50 16:00 5.0 2.5 0.0						

### Viewing Synchrophasor Data



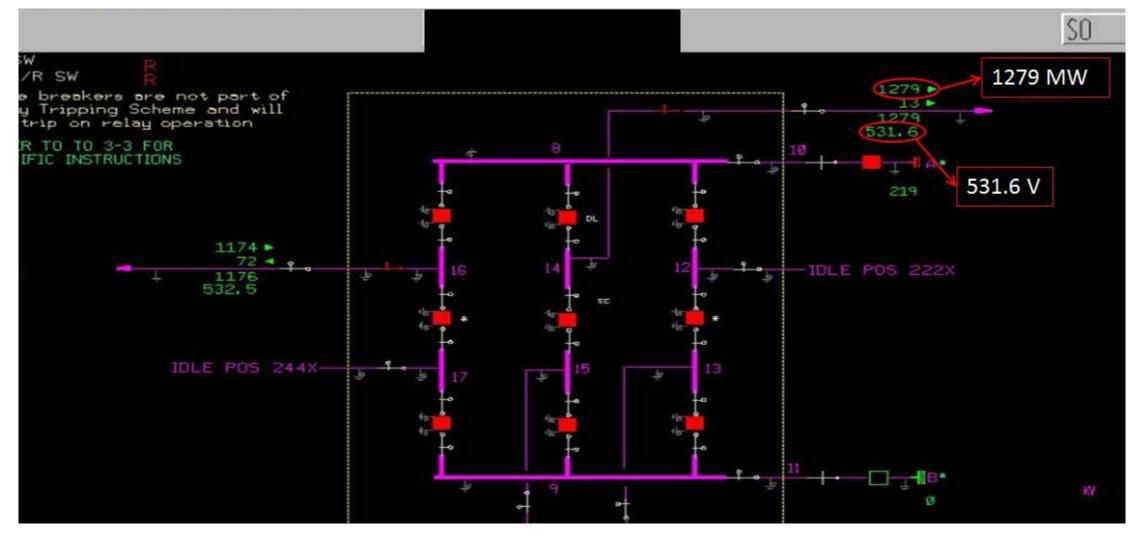
PhasorBridge Visualizer

Status: Receiving Data Data Timestamp: 16:40:55

Real Time	Quality Qualit	<u>y History</u>	<u>Heartbeat</u>	Angle S	Separation S	System Lo	g <u>Help</u>				
PS BOARDWAL	<equipment< th=""><th>Max Voltage (KV)</th><th>Min Voltage (KV)</th><th>Real Power (MW)</th><th>Reactive Power (MVAR)</th><th>Power Factor</th><th>Max Current (Amps)</th><th>Min Current (Amps)</th><th>Statu Drop</th><th>Sync</th><th>Version 1.17 e Limit</th></equipment<>	Max Voltage (KV)	Min Voltage (KV)	Real Power (MW)	Reactive Power (MVAR)	Power Factor	Max Current (Amps)	Min Current (Amps)	Statu Drop	Sync	Version 1.17 e Limit
PMU: 23051	A2001 230KV Line	237.9	237.9	-74.5	30.5	0.925	339.1	337.9			(
PMU: 23052	B2002 230KV Line	238	237.9	-19	-1.5	0.997	80.3	79.5			(
PMU: 23053	C2003 230KV Line	237.9	237.9	316.4	64.2	0.98	1357.4	1352.3			(
PMU: 23054	D2004 230KV Line	238.1	238	-190.5	44.7	0.974	822.5	815.7			/
PMU: 23055	E2005 230KV Line										/

•Use PSE&G Line Designations •Use PJM Phasor Names

### EMS – RTU View



### Phasor Data View

### PhasorBridge Visualizer

Status: Receiving Data Data Timestamp: 16:48:00

Real Time	Quality Quality	<u>History</u> Heartb	eat Angle Sepa	ration System	Log Help						
PS PACIFIC	Equipment	Max Voltage Min V (KV) (KV)	oltage Real Powe (MW)	r Reactive Power (MVAR)	Power Factor	Max Current (Amps)	Min Current (Amps)		Sync	Time	Version 1.17 Limit
PMU: 23073	F5001 500KV Line	532.6 532.2	-1274.9	-8.8		2399.9	2381				
PMU: 23074	G5002 500KV Line	533.8 533.2	1165.5	73.8	0.998	2194.5	2177.9				
PMU: 23075	H5003 500KV Line	533.2 532.8	1394.1	1722	0.992	2639.8	2624				
PMU: 23077	J5005 500KV Line					631.6	628.3				
PMU: 23078	K5006 500KV Line		<u> </u>	<u> </u>		614.9	610.5				
PMU: 23079	L5007 500KV Line		532.2 V	1274.9 MW		615.1	612				
●Use PSE&G ●Use PJM Ph	Line Designations asor Names										

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

### Identifying data quality trends

## PhasorBridge Visualizer

'	<b>  </b>   '				5							
<u>Rea</u>	l Tin	ıe Qu	ality	Quality	History	Heartbeat	Angle S	Separati	on Syst	em Log	<u>Help</u>	
Ho Minu MU ID:	PS E	8 ▼ 0 ▼ 30ARD1/		ur: 8 ▼ te: 0 ▼	●Plot ●Data	results as: Export 9-23 07:59:59	•Summary •Timeli	y	Order res ● PMU ID ● Date	sults by:		
20	.0									<b>Tim</b>	e Errors	
17	.5					1				Syn	ch Errors	
, 15	.0									Tra	nsmission	Errors
ror										<b>Inv</b> a	alid Data	
15 12 12	.5								1	Dro	p Errors	
		1										
enta √	.5—											
Percentage	.0											
	.5											
0	.0 09/ 12:		09/18 00:00	09/18 12:00		09/19 09/2 12:00 00:0	0 12:00	09/21 00:00	09/21 12:00	09/22 00:00	09/22 12:00	09/23 00:00
							Time					

### Identifying data quality trends

#### PhasorBridge Visualizer Real Time Quality Quality History Heartbeat Angle Separation System Log Help From: To: Display results as: Type of Query: Order results by: 09/23/2015 09/17/2015 🔳 • Plot • PMU ID Summary Hour: 8 🔻 Hour: 8 T • Data • Timeline Date Minute: 0 🔻 Minute: 0 🔻 Periodic event! Query Export PMU ID: PS BOARDWALK $\nabla$ Results from 2015-09-17 08:00:00 to 2015-09-22 07:59:59 20.0 Time Errors 17.5 Synch Errors Transmission Errors 15.0 ٥r Invalid Data 12.5 · Drop Errors Dercentage 2.5 0.0 09/17 09/18 09/18 09/19 09/19 09/20 09/20 09/21 09/21 09/22 09/22 09/23 12:00 00:00 12:00 00:00 12:00 00:00 12:00 00:00 12:00 00:00 12:00 00:00

Time

### 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



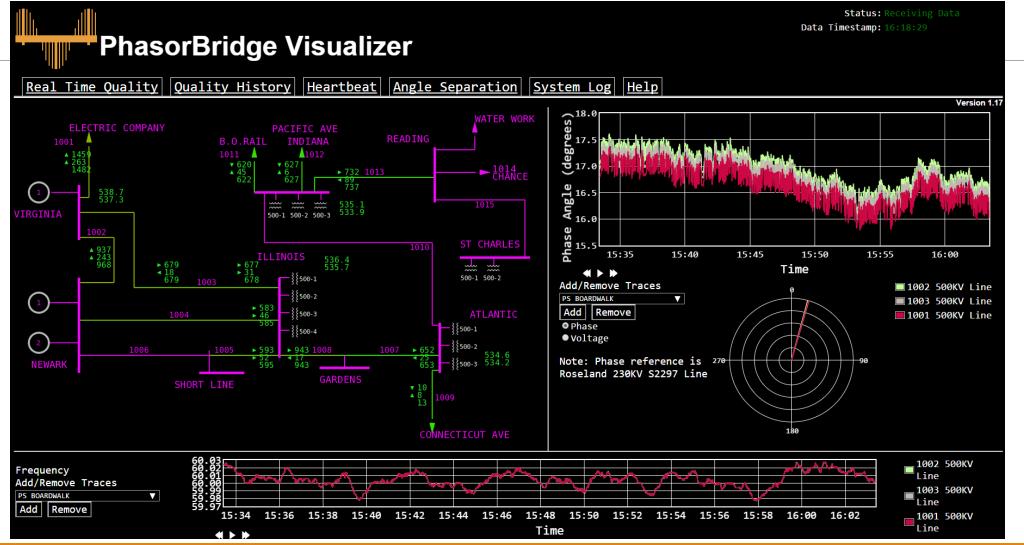
#### Adoption of newer standards

• E.g. lost time quality bits during data concentration in 2005 version of IEEE standard

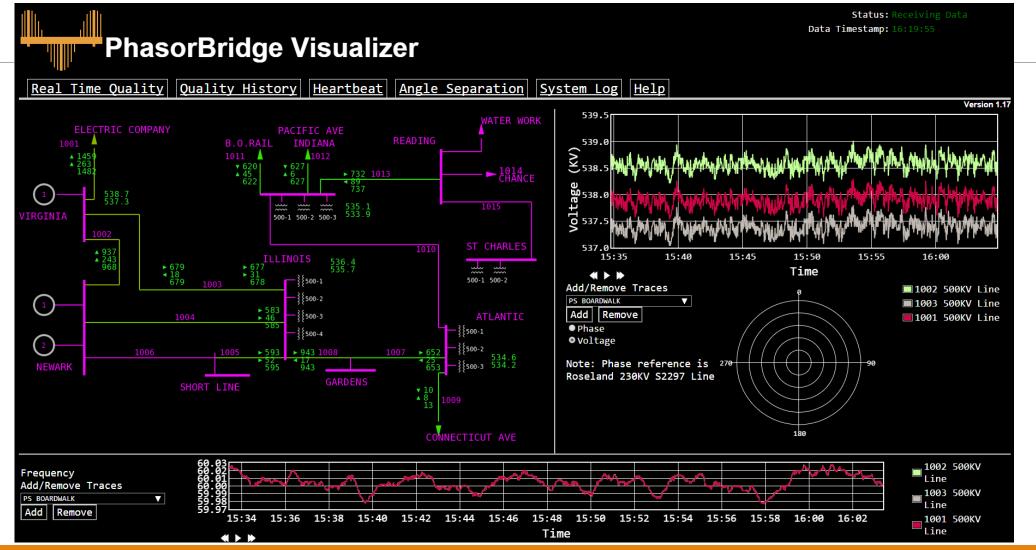
#### •Changing PJM requirements

- Increasing data quality targets, additional applications
- Data retention?
- •Changing regulatory requirements
  - NERC CIP v5 and beyond

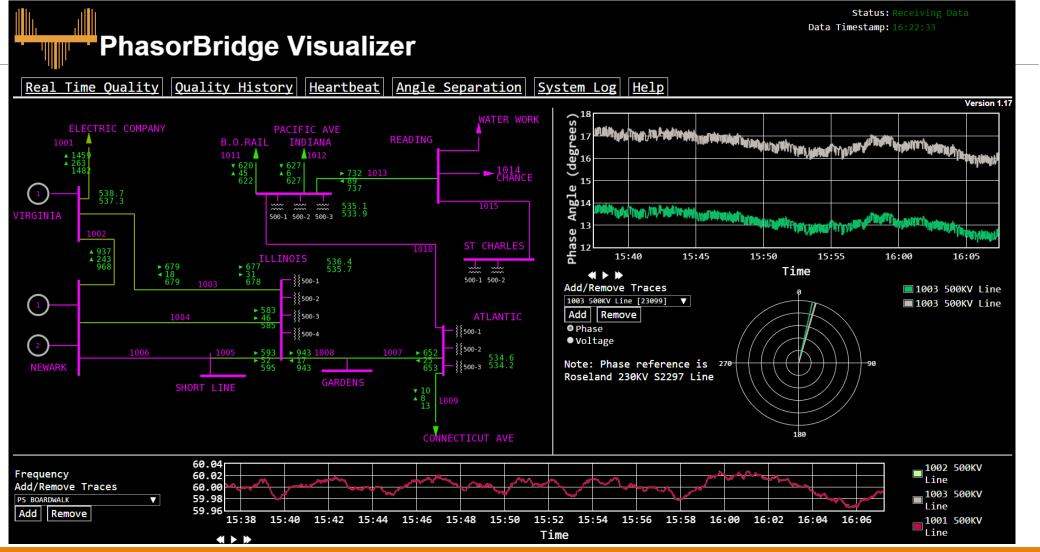
### Single station (Phase)



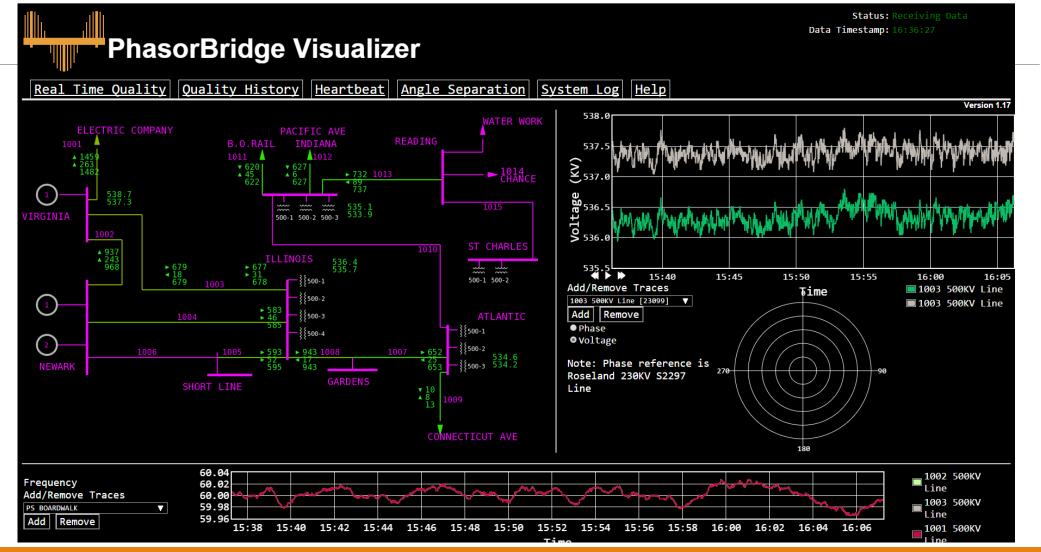
### Single station (Voltage)



### 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:  $26.25\Omega$ 

$$\delta = \sin^{-1}\left(\frac{PX}{V_1V_2}\right) = \sin^{-1}\left(\frac{679 \times 26.25}{537.3 \times 536.4}\right) = 3.55^{\circ}$$

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

## Questions?