



# Grid Software Solutions

Built –in Data Quality

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**Imagination at work.**

# Data Quality in WAMS

- Addressing **data accuracy** and **data availability** issues requires evaluating the **end-to-end system**.
- Need to look at each component dataflow chain:
  - Detect data quality issues close to its source.
  - Preserve & communicate this information to downstream applications.

**PMUs:** Data Quality Status flags in C37.118 stream (GPS Lock, Data Error)

**PDCs:** Monitor and track latency, dropped communications, etc.

**Historians:** Preserve data integrity when archiving data.

**Applications:** Data quality needs and tolerance is application dependent.



**IMPORTANT: LEAVE THE DATA QUALITY HANDLING TO THE APPLICATIONS**

# PDC Processing



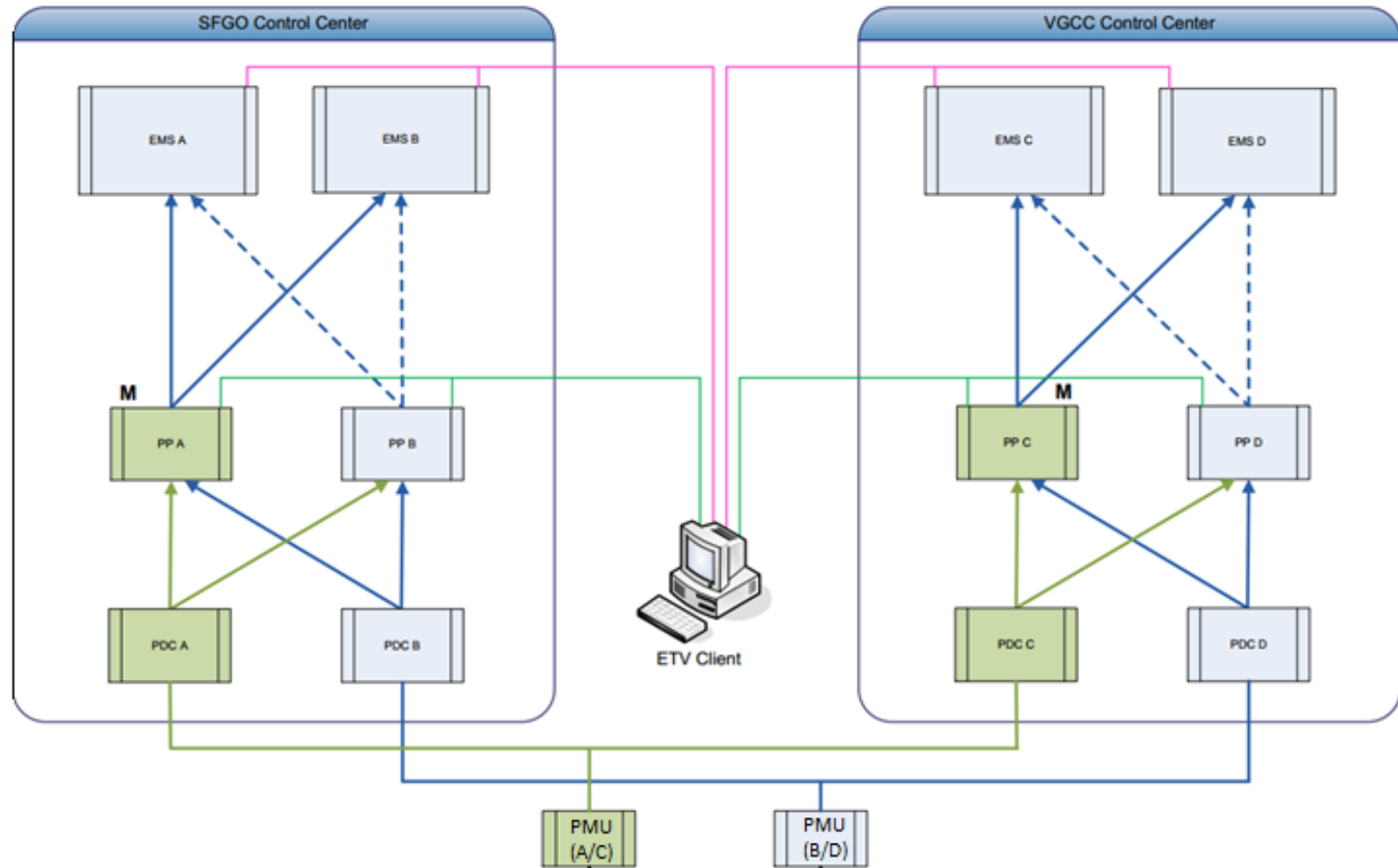
# PDC Processing

- Preserve the integrity of the incoming data stream.
- Support a redundant architecture.
  - **Duplicate Data:**  
For example, data sent through redundant communication paths.
  - **Redundant Data:**  
Data sent by alternate devices.
  - PDC selects data either based on first-arrived or validity
- Monitor incoming data quality statistics (live & historical)



# WAMS System Architecture at PG&E

PG&E SynchroPhasor  
Data Flow Overview



Architecture Supports both Redundant and Duplicate Data



# e-terraphasorpoint PDC

## Statistics and Monitoring Details











- Live **Stream** Statistics
  - Mean/Max/Min frame latency
  - Percentage Time Quality errors (C37.118 MSG\_TQ)
  - Percentage Missing data frames
  - Last Valid data frame

Input Stream Statistics							
							Search: <input type="text"/>
Stream ID	Status	Max Latency	Min Latency	Avg Latency	% Time Quality Errors	Last Valid Data Frame	Missed Frames
60		4215.0	4117.0	4163.0	0.0	Tue Feb 16 13:59:59 PST 2016	0.0
61		4215.0	4117.0	4163.0	0.0	Tue Feb 16 13:59:59 PST 2016	0.0
62		4226.0	4117.0	4163.0	0.0	Tue Feb 16 13:59:59 PST 2016	0.0
63		4215.0	4117.0	4163.0	0.0	Tue Feb 16 13:59:59 PST 2016	0.0
64		4215.0	4117.0	4163.0	0.0	Tue Feb 16 13:59:59 PST 2016	0.0
65		4215.0	4117.0	4163.0	0.0	Tue Feb 16 13:59:59 PST 2016	0.0
66		4215.0	4117.0	4163.0	0.0	Tue Feb 16 13:59:59 PST 2016	0.0
67		4226.0	4117.0	4163.0	0.0	Tue Feb 16 13:59:59 PST 2016	0.0
2000		81.0	11.0	12.0	0.0	Tue Feb 16 14:00:03 PST 2016	0.0
2001		401.0	17.0	187.0	0.0	Tue Feb 16 14:00:03 PST 2016	19.833334

# e-terraphasorpoint PDC

## Statistics and Monitoring Details

- Live **PMU** Statistics (1 minute rolling data)
  - Percentage of GPS Lock
  - Percentage of Valid data
  - Percentage of Data Error
  - Percentage of Missing data

PMU ID	Status	Station Name	% GPS Lock	% Data Valid	% Data Error	% Missing Data	Stream ID
60		Pmu1	100.0	100.0	0.0	0.0	60
61		Pmu2	100.0	100.0	100.0	0.0	60
62		Pmu3	100.0	67.889	0.0	0.0	60
63		Pmu4	100.0	67.889	32.111	0.0	60
64		Pmu5	68.444	100.0	0.0	0.0	60
65		Pmu6	100.0	100.0	0.0	0.0	60
66		Pmu7	100.0	100.0	0.0	0.0	60
67		Pmu8	100.0	100.0	0.0	0.0	60
2000		UFC	100.0	100.0	0.0	0.0	2000
2001		UFMG	100.0	80.083	0.0	19.917	2001



# Applications





# Application Level Data Handling

- Some common data conditioning based on heuristics:
  - **Utilize PMU data quality status** info from the field.
  - **Reasonability Range Checks** e.g.
    - Voltage less than 30% of nominal (user-configurable).
    - Frequency deviation more than 30 Hz.
  - **Derived values** (such as freq, MW, MVAR) are flagged accordingly, e.g.
    - Invalid voltage phasor implies derived frequency is suspect.

*Note: Invalid data is (1) flagged as suspect in operator UIs, (2) handled as applicable to downstream applications.*

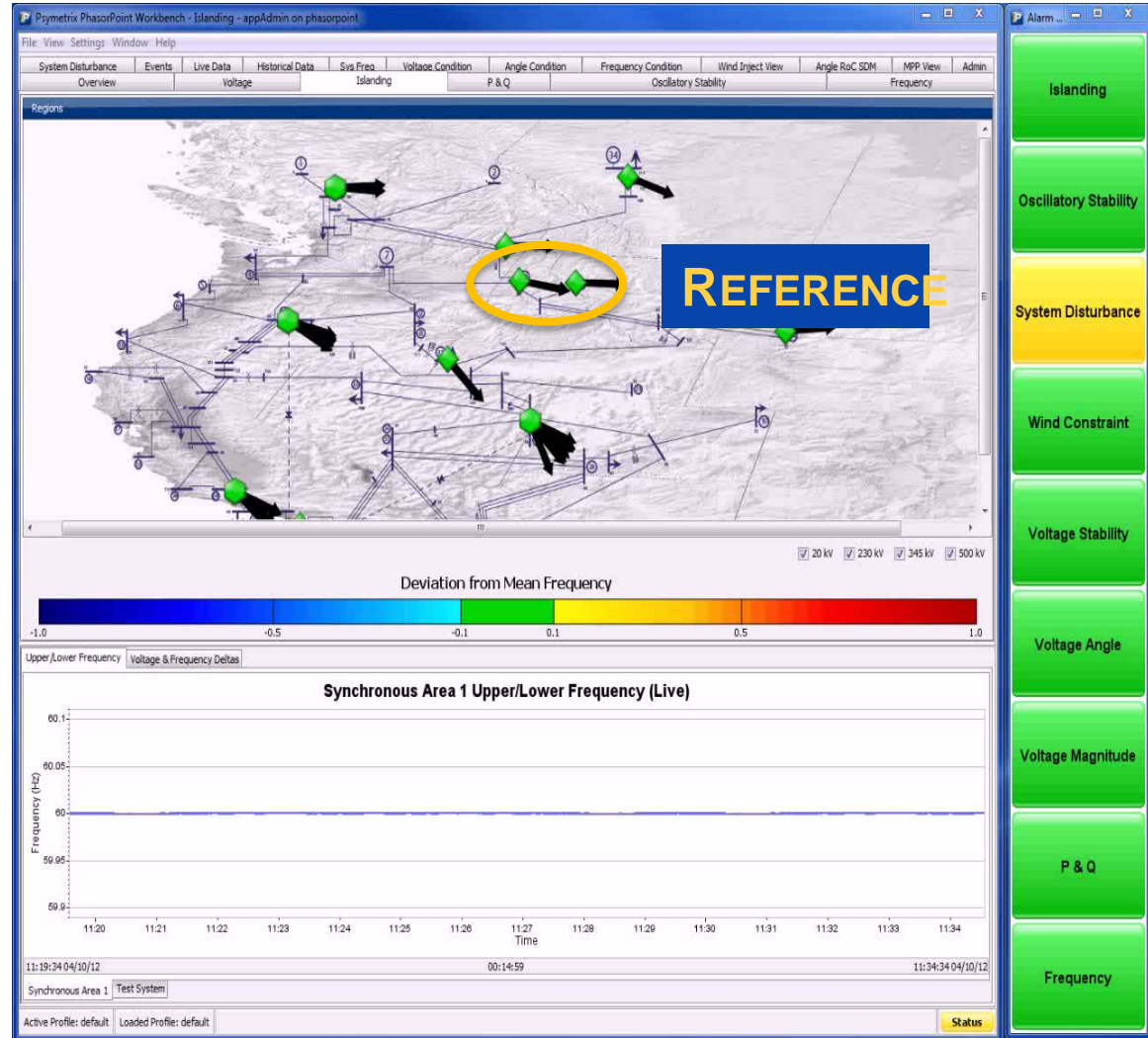
 **IMPORTANT: DATA QUALITY NEEDS ARE APPLICATION SPECIFIC.**

# Example: Reference Angle

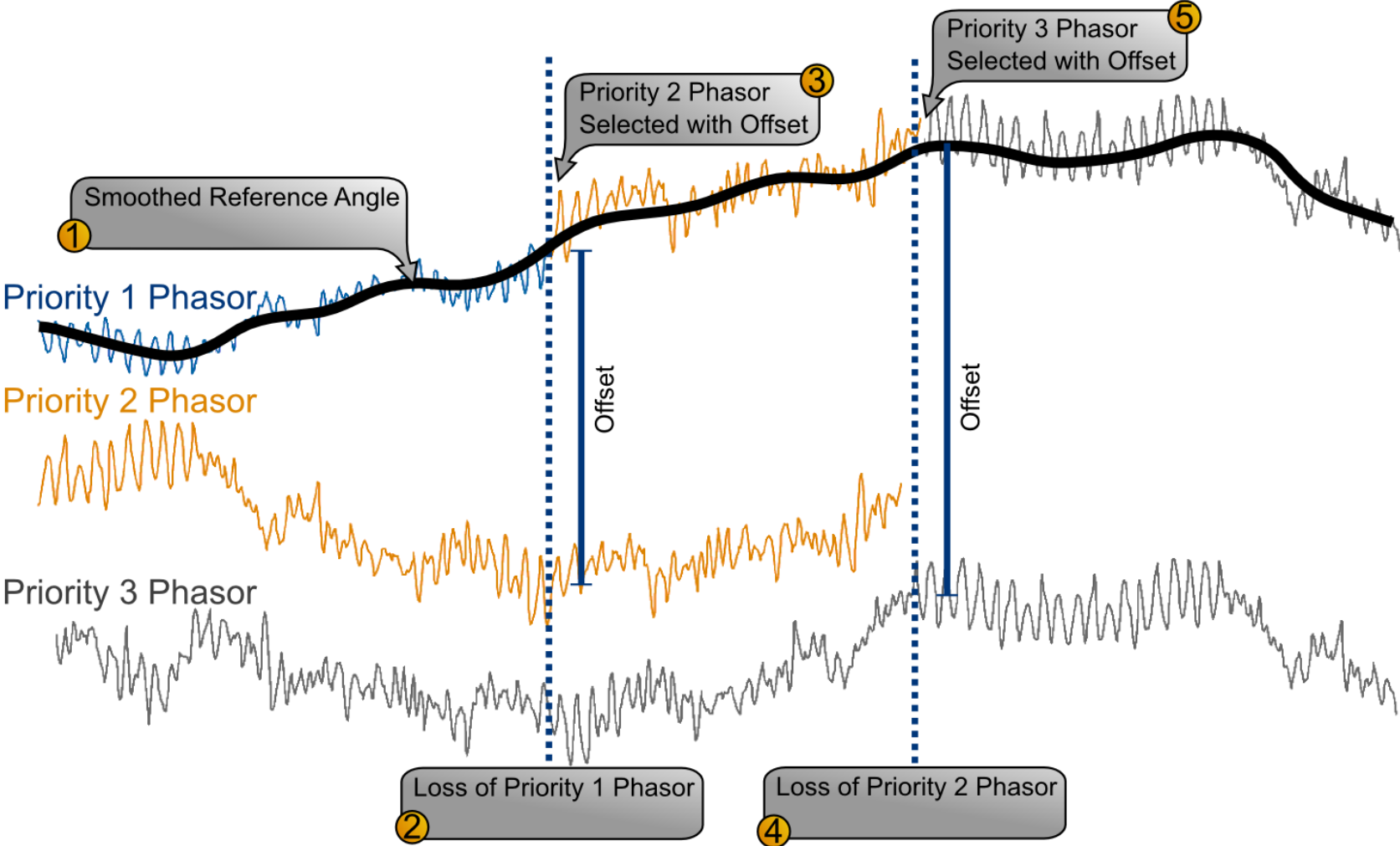


# Reference Handling in Operator Displays

- Operators are used to having the reference angle as 0 degrees.
- Need to ensure the reference is always available  
⇒ **Ref. Priority List**



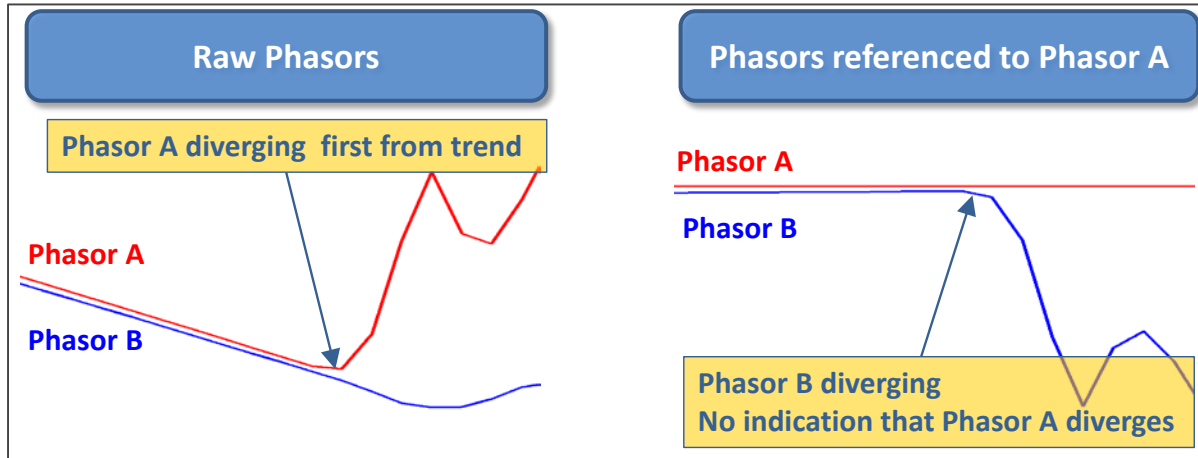
# Angle Reference Processing



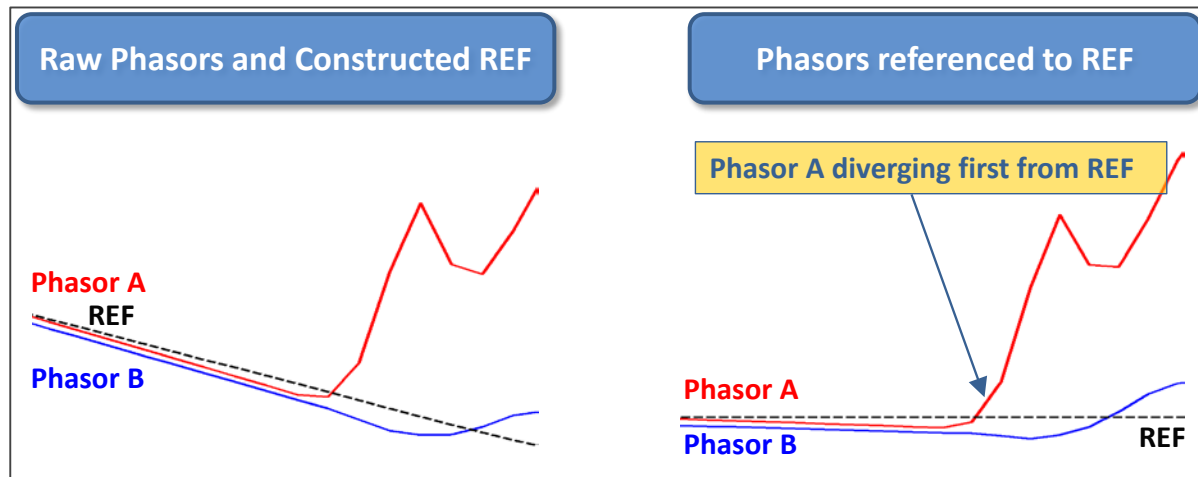
# Event Detection

## *Impact of Reference Selection on Analytical Results*

**WRONG**



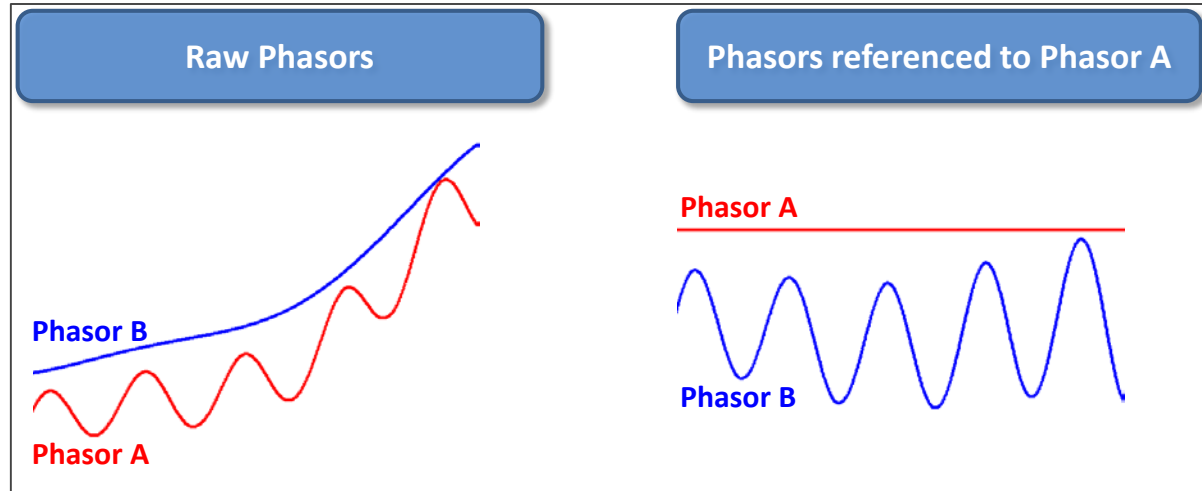
**CORRECT**



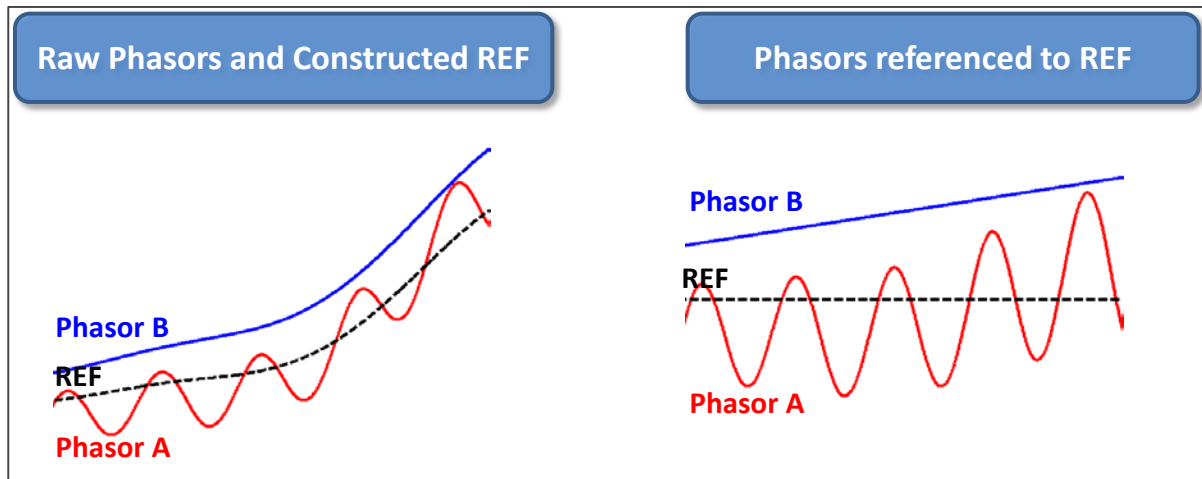
# Oscillation Monitoring

## *Impact of Reference Selection on Analytical Results*

**WRONG**



**CORRECT**



# BUILT IN DATA HANDLING: SOME APPLICATION EXAMPLES



# Data Handling in Oscillation Monitoring

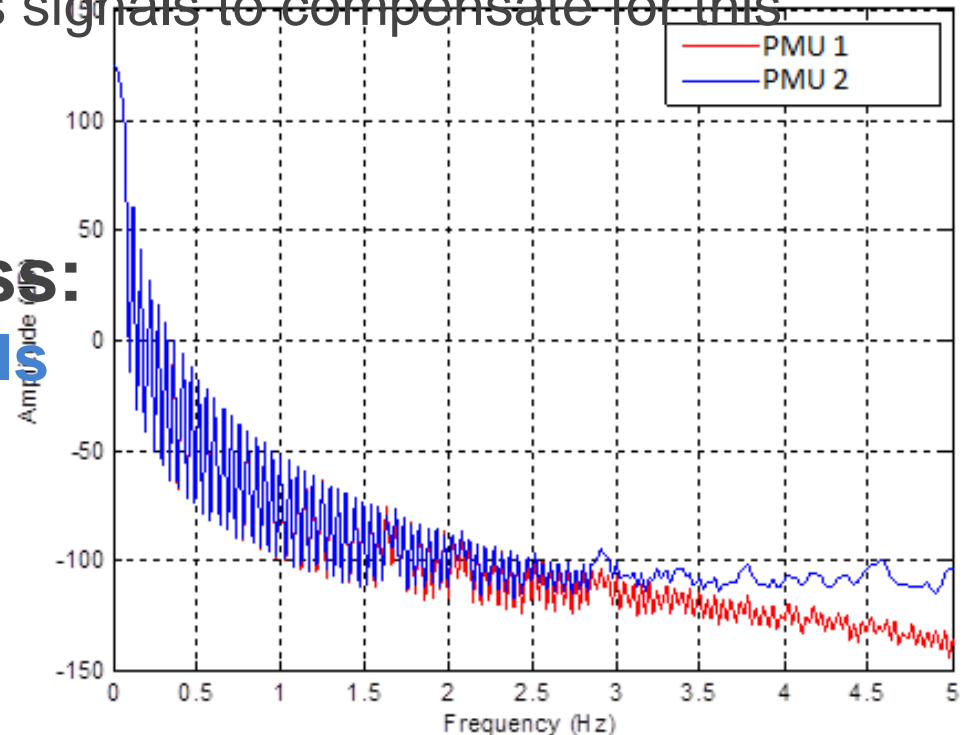
- **Data Gap Tolerance:**

- Expect **at least 90-95% data availability** over the processing window before the signal is not used.
- PMUs with **different dynamic characteristics** will impact OSM results (especially mode amplitudes) - **NO LONGER AN ISSUE.**

⇒ **SOLUTION:** Pre-process signals to compensate for this difference.

- **Signal Loss Robustness:**

- Processes **multiple signals** simultaneously.
- Algorithm can function in the absence of signals.





# Data Handling for Hybrid State Estimation

**Pre-Processing:** Down-sample PMU data to 1 sample/second (i.e. SCADA scan rates).

Focus is on **data completeness** than **precise time alignment** with SCADA data.

Several different down-sampling approaches supported by PDC:

- Pick the **most complete data frame** within the second.
- Data **averaged** within the second.
- **Low-pass filtering** using moving time window.

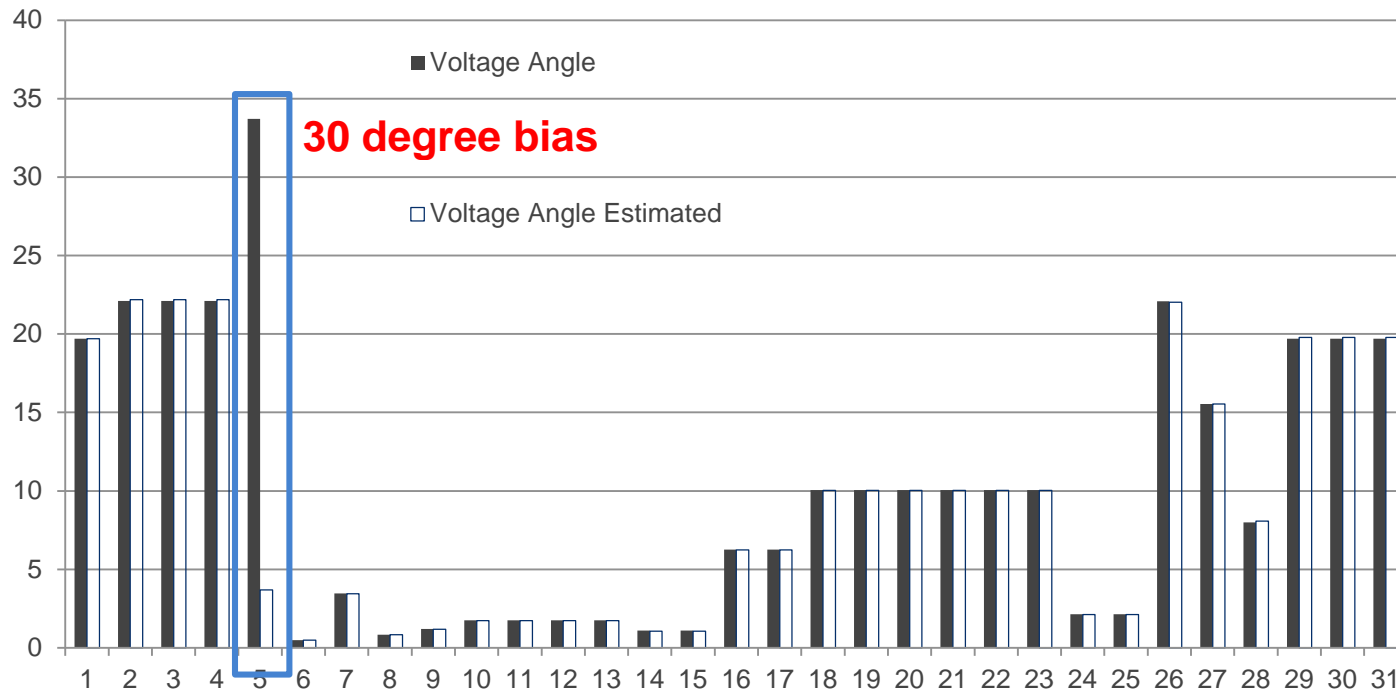


# Addressing Data Accuracy



# Linear State Estimation

- Validate **data accuracy** (bad data detection and correction).
- Capable of running at **sub-second rate**.
- Catch **CT/PT** errors OR **Angle Offset** errors.

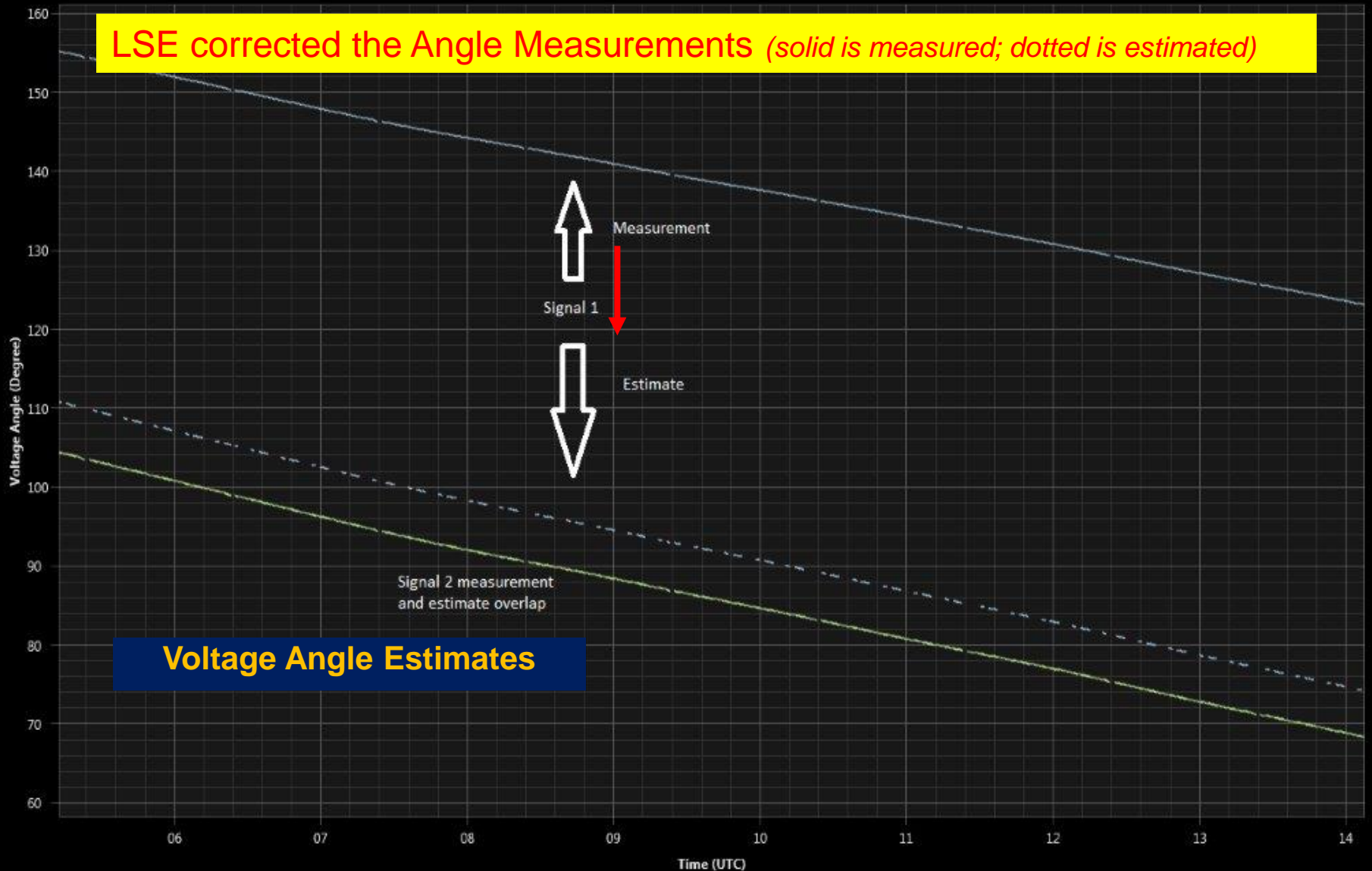


**OPERATE IN REAL TIME AND STUDY MODES**



# Example: Phase Angle Offset Detection & Correction.

LSE corrected the Angle Measurements (solid is measured; dotted is estimated)



Voltage Angle Estimates

THANK YOU

