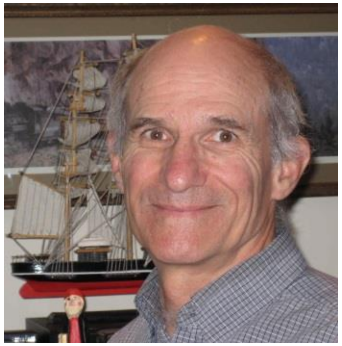
Synchrophasor Data Diagnostics: Detection & Resolution of Data Problems for Operations and Analysis

Webinar

Jan 28, 2014



Presented by
Ken Martin

Electric Power Group

Why Is There Concern About Synchrophasor Data Quality?

- High resolution means lots of data: More errors & missing data
- Applications: Bad data should be detected and eliminated from display and analysis
- Understanding data: Noise, spikes, swings – real or bad data?
- New metrics e.g., phase angles & sensitivities: Are they valid and meaningful?
- Experience with synchrophasor systems: Limited, longer time to detect problems and repair, less knowledge and experience in finding root causes

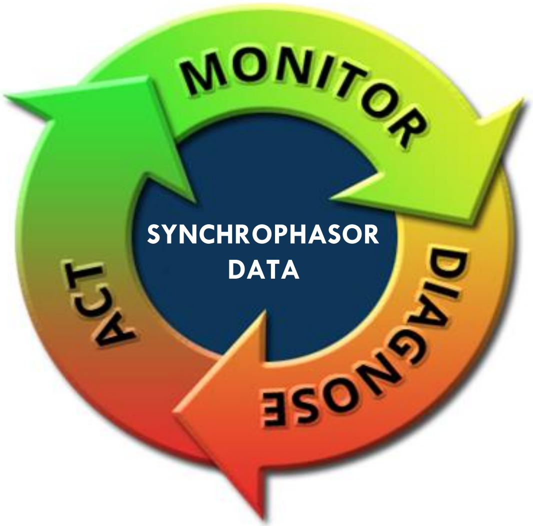
Frequently Asked Questions?

- What performance can I expect from phasor data?
- How do I make sure that data is good and usable?
- How do I detect and diagnose data problems?
- How do I get problems fixed?

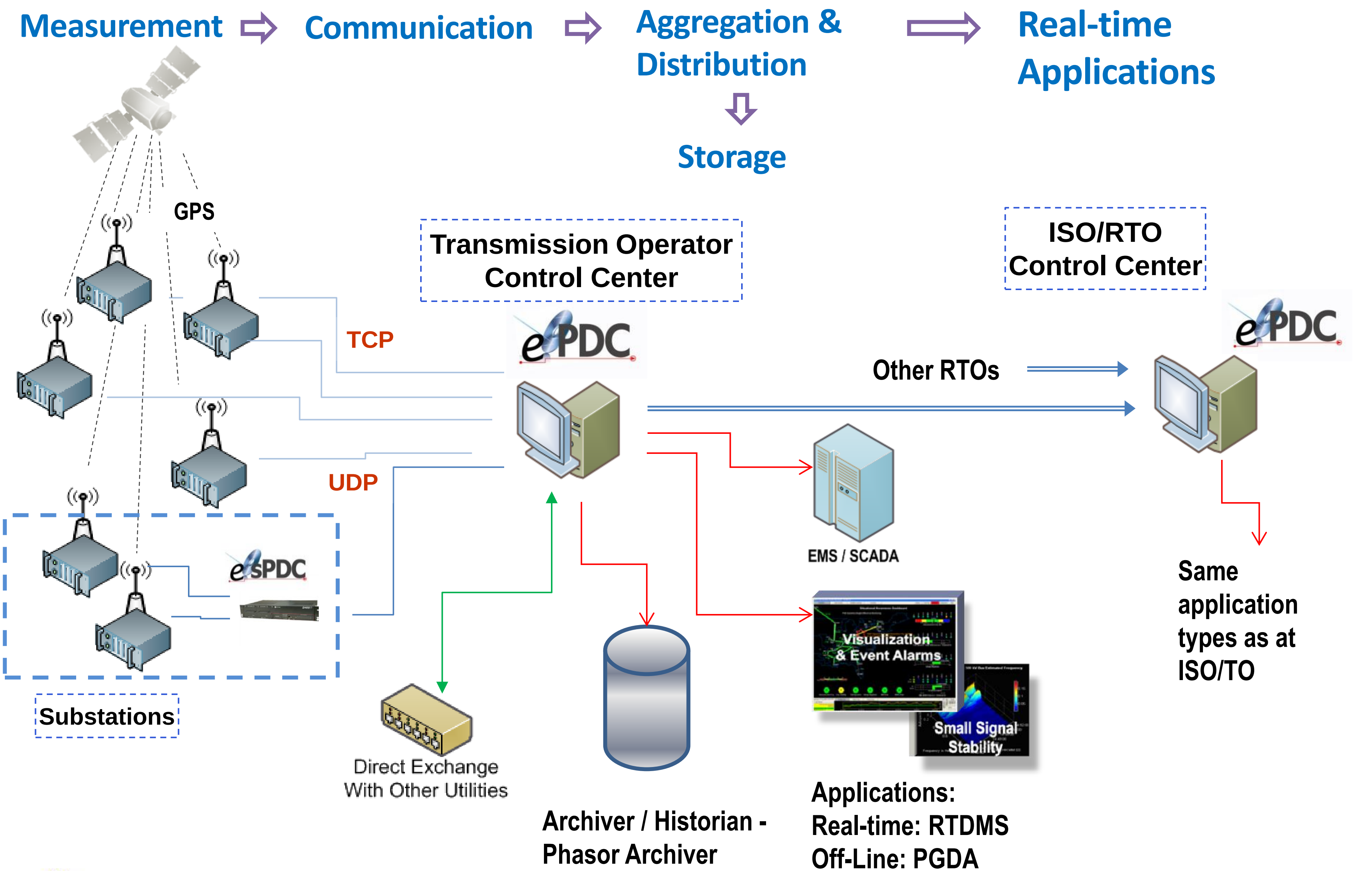
When Can I trust the data for Operations and Analysis?

Presentation Outline

- Synchrophasor systems
- Comparison with SCADA
- Typical data problem examples
- Building blocks of a synchrophasor system for high data quality
- Summary
- Q & A



Typical Synchrophasor System



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Phasor vs. SCADA Measurements

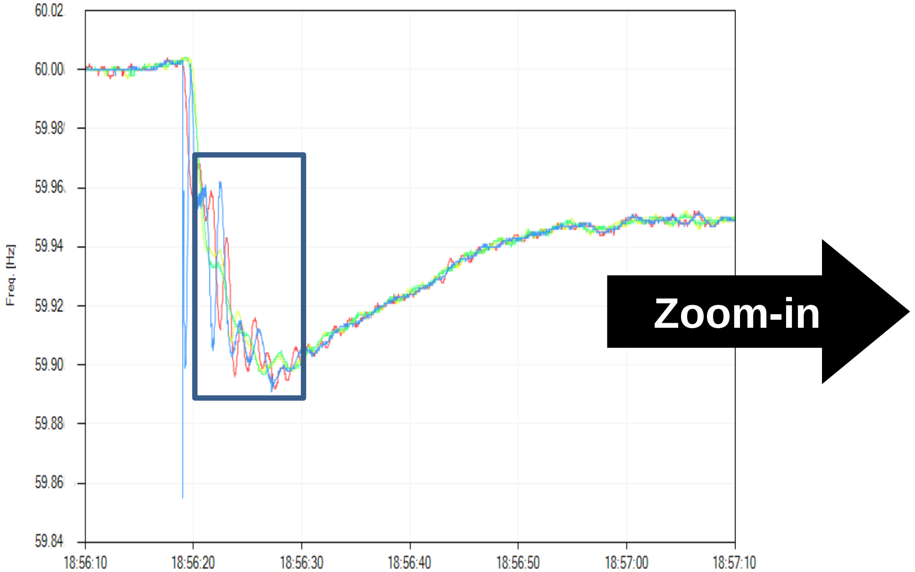
Why are we implementing Synchrophasors in addition to existing SCADA systems?

ATTRIBUTE	SCADA	PMU
Resolution	1 sample every 2-4 seconds *(Steady State Observability)*	10-60 samples per second *(Dynamic/Transient Observability)*
Measured Quantities	Magnitude Only	Magnitude & Phase Angle
Time Synchronization	No, correlation at master only *(1-4 sec data skew)*	Yes, at measurement *(no data skew)*
Data reporting	Polled by master, delay on poll & re-poll *(1+ sec)*	Pushed by PMU, minimal delay *(<100 ms)*
Data easier to use	MW/MVAR need estimation to give bus angles	Direct application to model, Linear State Estimation
Focus	Local utility monitoring; load flow & steady-state limit control	Wide-area monitoring; steady-state & dynamic performance control

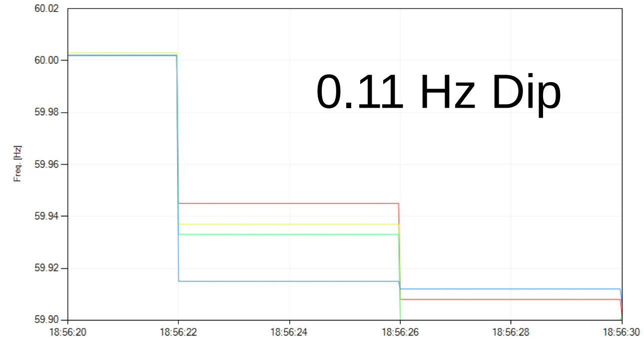
SCADA and PMU Observability - Example

Dynamic system interactions as seen in the Frequency measurement

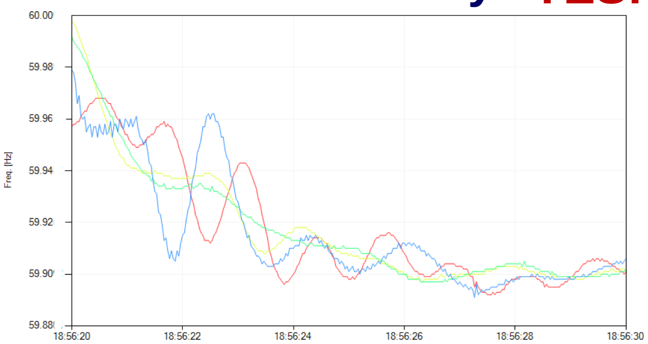
Observability



SCADA Observability **NO!**



PMU Observability **YES!**



SCADA - Frequency appears to be similar at all locations – no oscillations

PMUs - Frequency measurements show dynamic interaction
– allows investigation of inter-area dynamics

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Synchrophasor and SCADA Systems

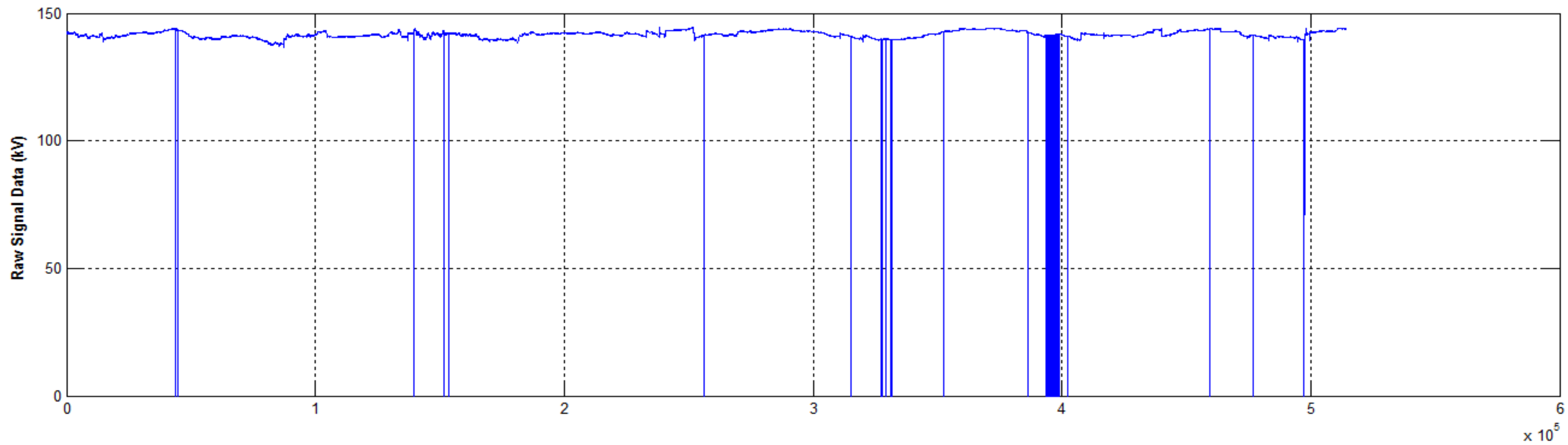
- **Similarities – Both Systems**:
  - Report power system measurements & other parameters
  - Gather data from substations & power stations
  - Report system data
- **Synchrophasor Data – Attributes**:
  - Gather data at a much higher data rate
  - Push data, no polling from a master
  - Measure voltage & current phase angles
  - Utilize high accuracy timing
  - Use a complex algorithm to compute values
  - Precisely timetag all data
  - Covers entire grid – Not Limited to Control Area Footprint

Synchrophasor System Data Issues

- More system elements required – more things can fail
- Data gathered at a higher data rate
  - Momentary interruptions & network congestion – data loss
  - With high resolution applications, data loss very visible
- Data pushed from PMU/PDC
  - No retransmission
- High accuracy timing required
  - High-accuracy, continuous timing has many failure modes
  - Newer technology, many unexpected errors
- Complex algorithm required to compute values
  - New technology, many unanticipated difficulties

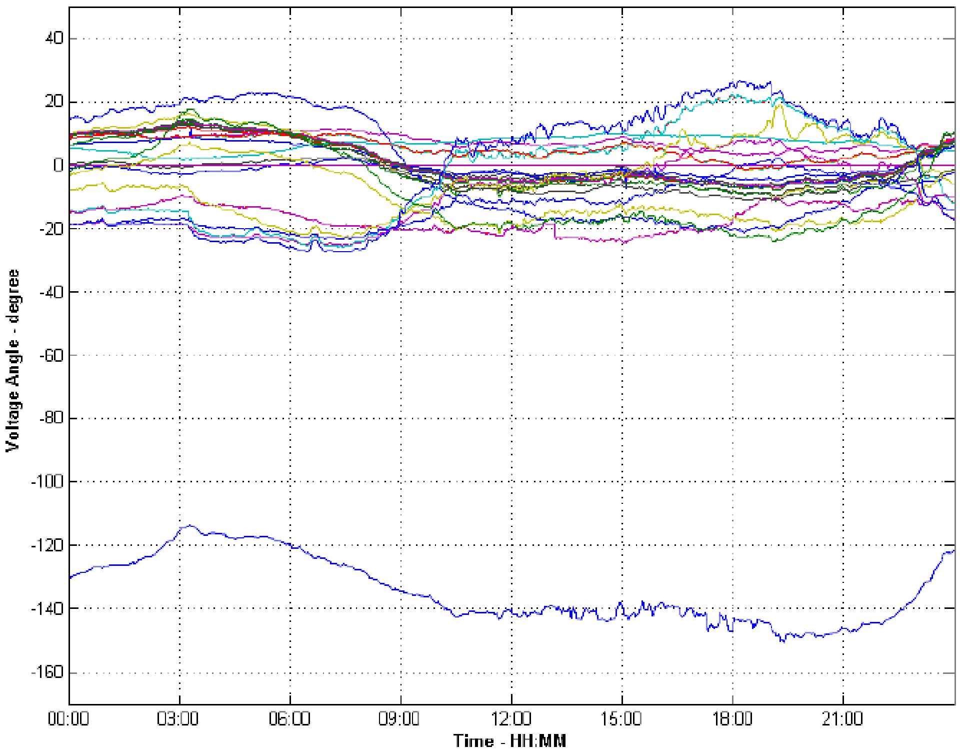
Data Problem - Dropouts

- **Data dropouts – communication issues**
  - The most common problem
  - Often visible – data not flagged or flags ignored
- **Resolution:**
  - Investigate & correct communication problem
  - Flag data to prevent use of "filler" data



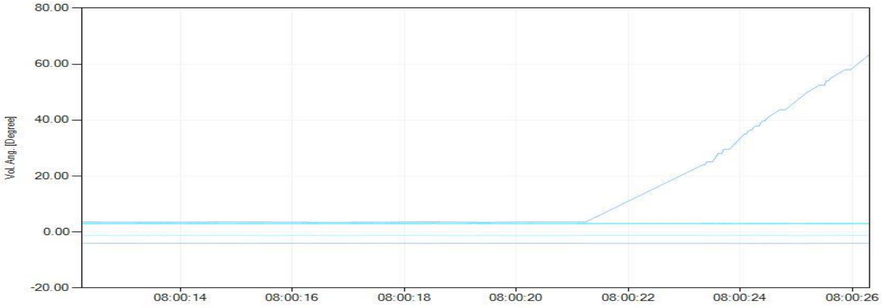
Data Problem – Phase Angle Offset

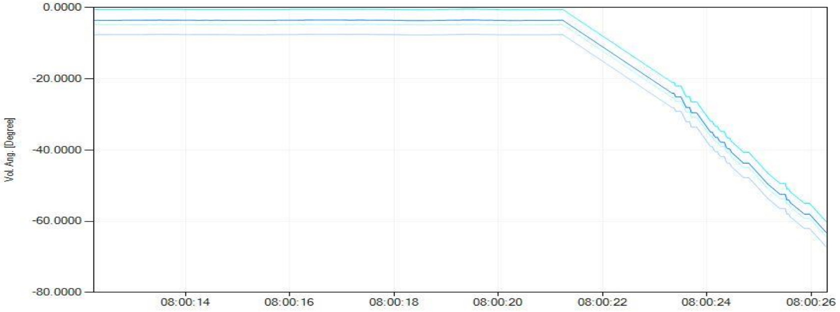
- **Phase angle offset, mismatch from expected**
  - Here one phase angle 120° offset from others
  - Could be Y- Δ confusion, timing, or other issue
- **Resolution**
  - Determine error
  - Correct phase reference
  - Use data system to adjust angle



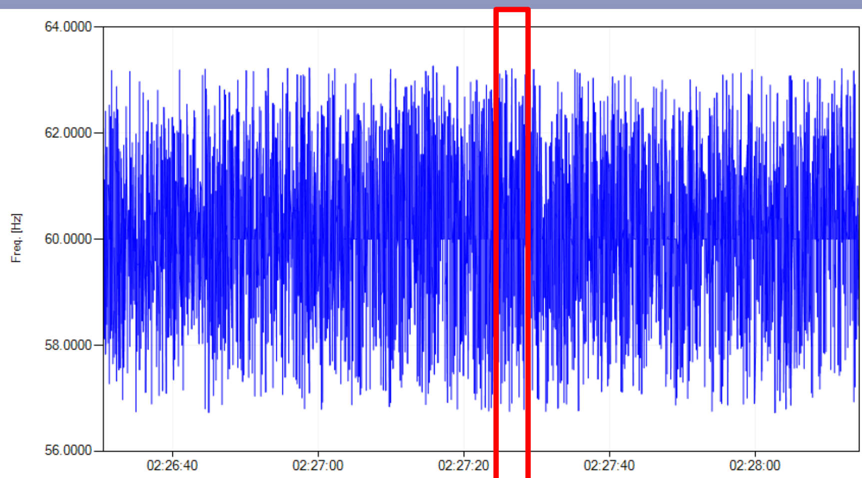
Data Problem – PMU Sync

- One angle drifts away from group—PMU sync is lost
- All angles drift away—sync for reference PMU is lost
- Resolution:
  - Repair timing input to PMU
  - Data system flags block use of errored angles

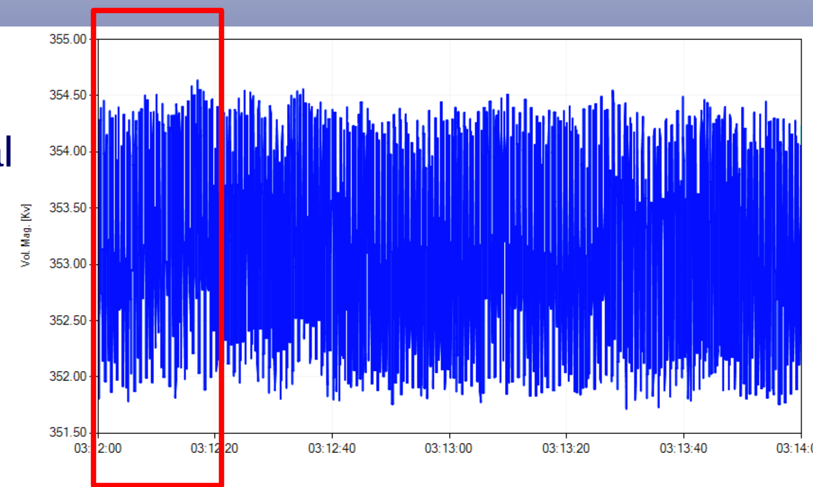




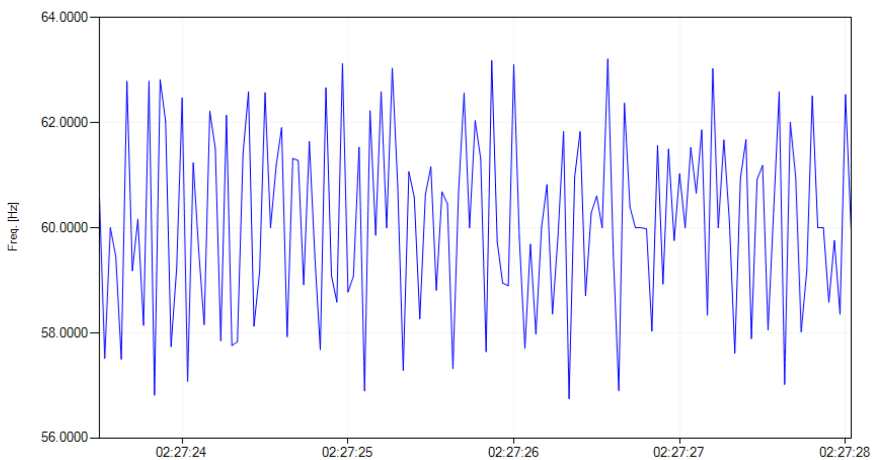
Data Problem – High Noise on Signal



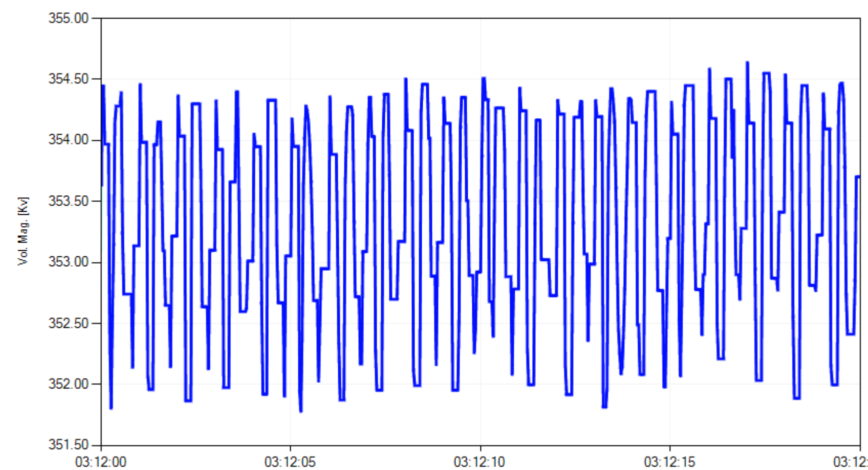
Noise or Real Signal



Expanded View



Oscillations due to PMU Error



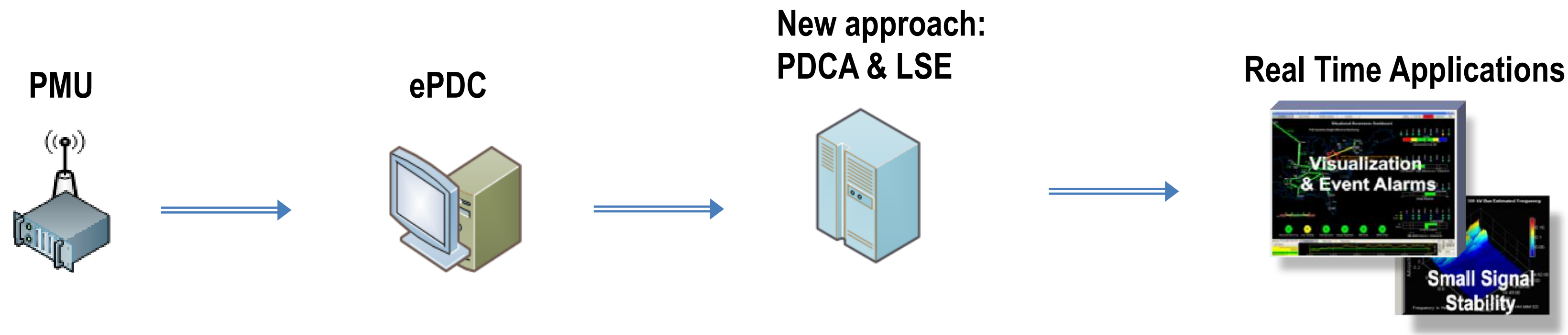
Power System Event Oscillations

System Implementation for High Quality Data

- **Qualify System Elements (equipment)**
  - PMUs meet measurement standards & utility requirements
  - GPS and IEEE 1588 standard clocks report time quality accurately
  - Communications meets bandwidth, latency, & reliability
  - Applications interpret flags
- **Validate Installations**
  - Assure naming, wiring, polarity, signal identifications correct
  - Calibrate measurements
- **Use Flags for Error Detection and Timely Repairs**
  - Detect, flag, and identify problems
  - Repair data where possible

High Data Quality Synchrophasor System

Detect & Flag Problems at Each Stage



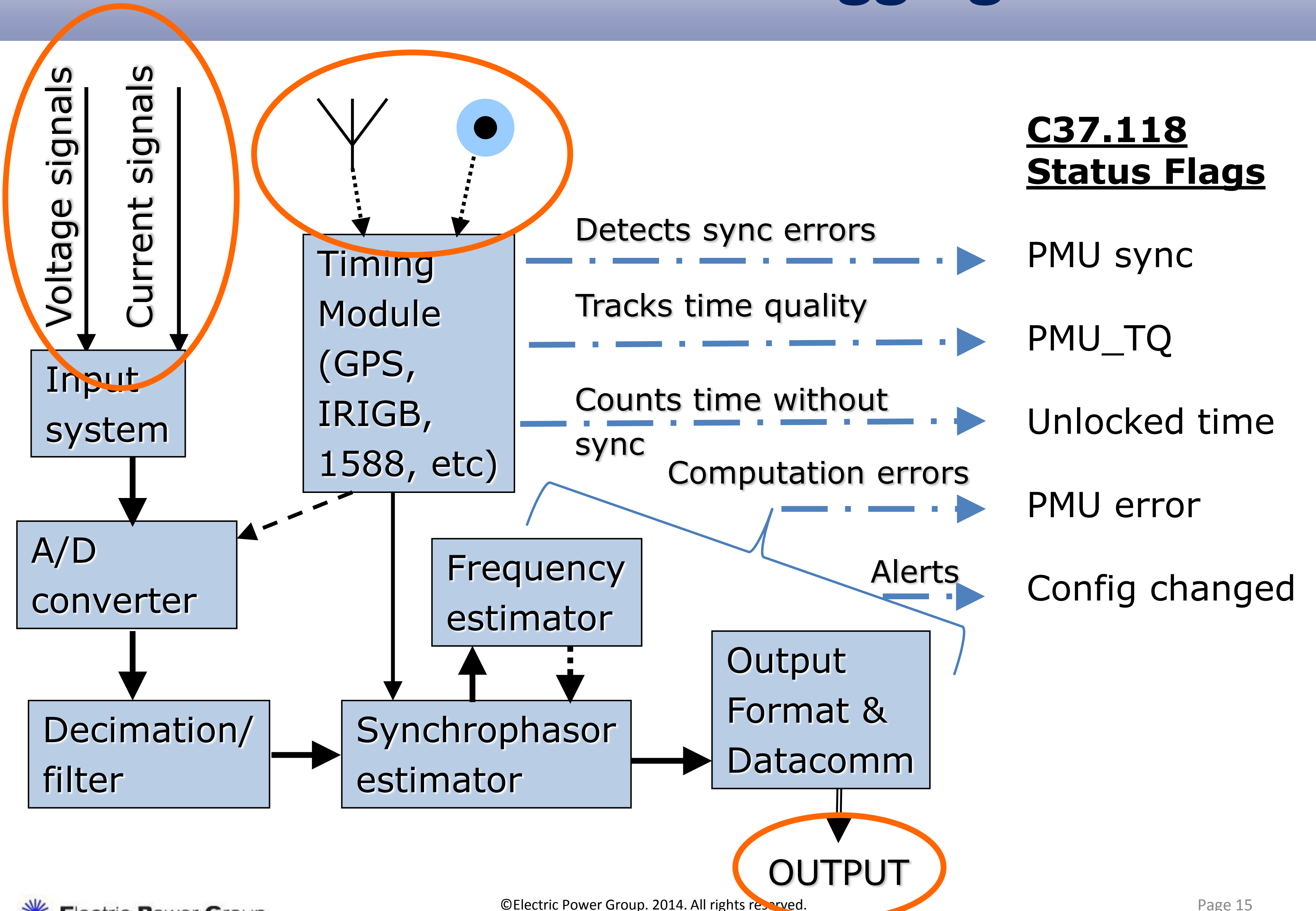
- Hardware/ firmware check
- Algorithm solution validation
- GPS sync check
- Trigger detection

- Communication
- Dropouts
- Latency check
- Status check
- Time quality check

- Time quality check
- Range check
- Stale check
- Noise check
- Topology check
- Scaling factor check

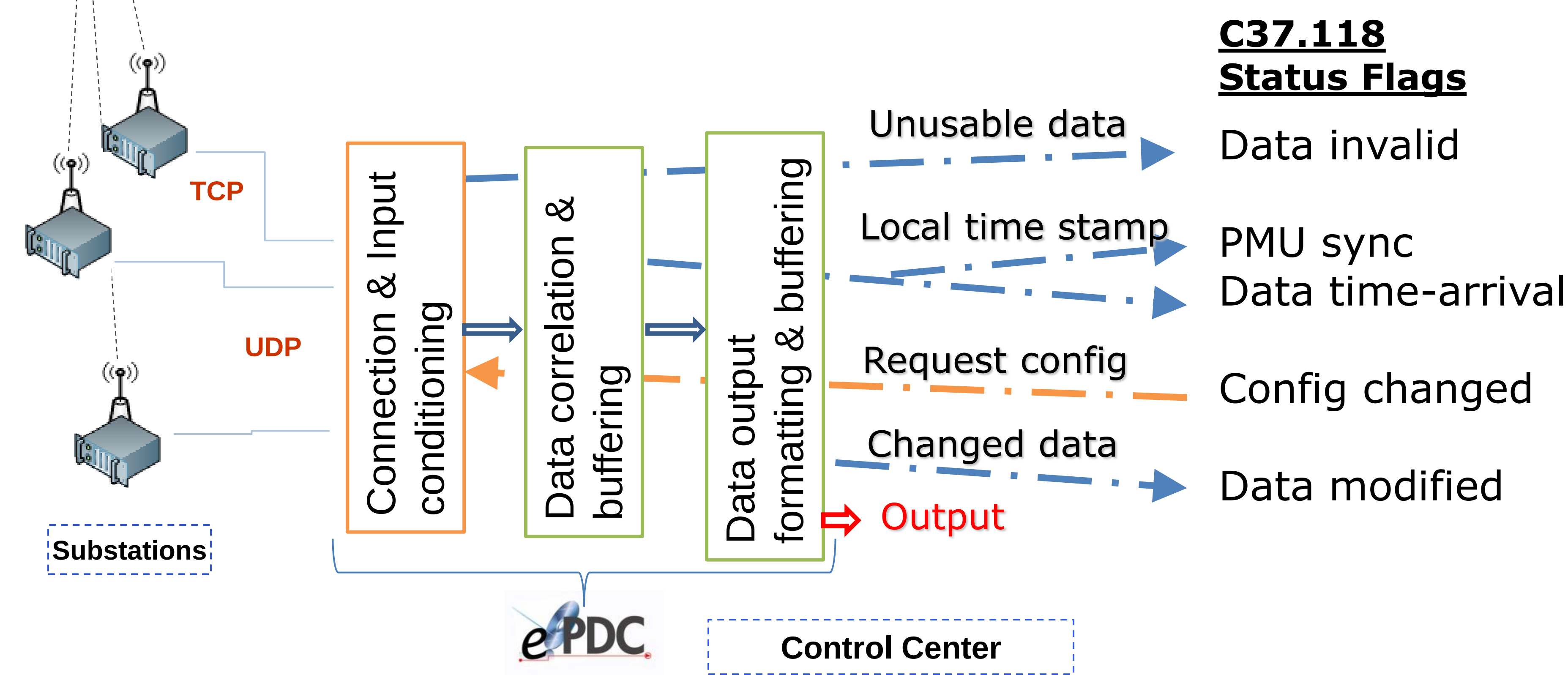
- Display adjustment for status flag
- Range adjustment
- Time quality check

Problem Detection & Flagging – PMU



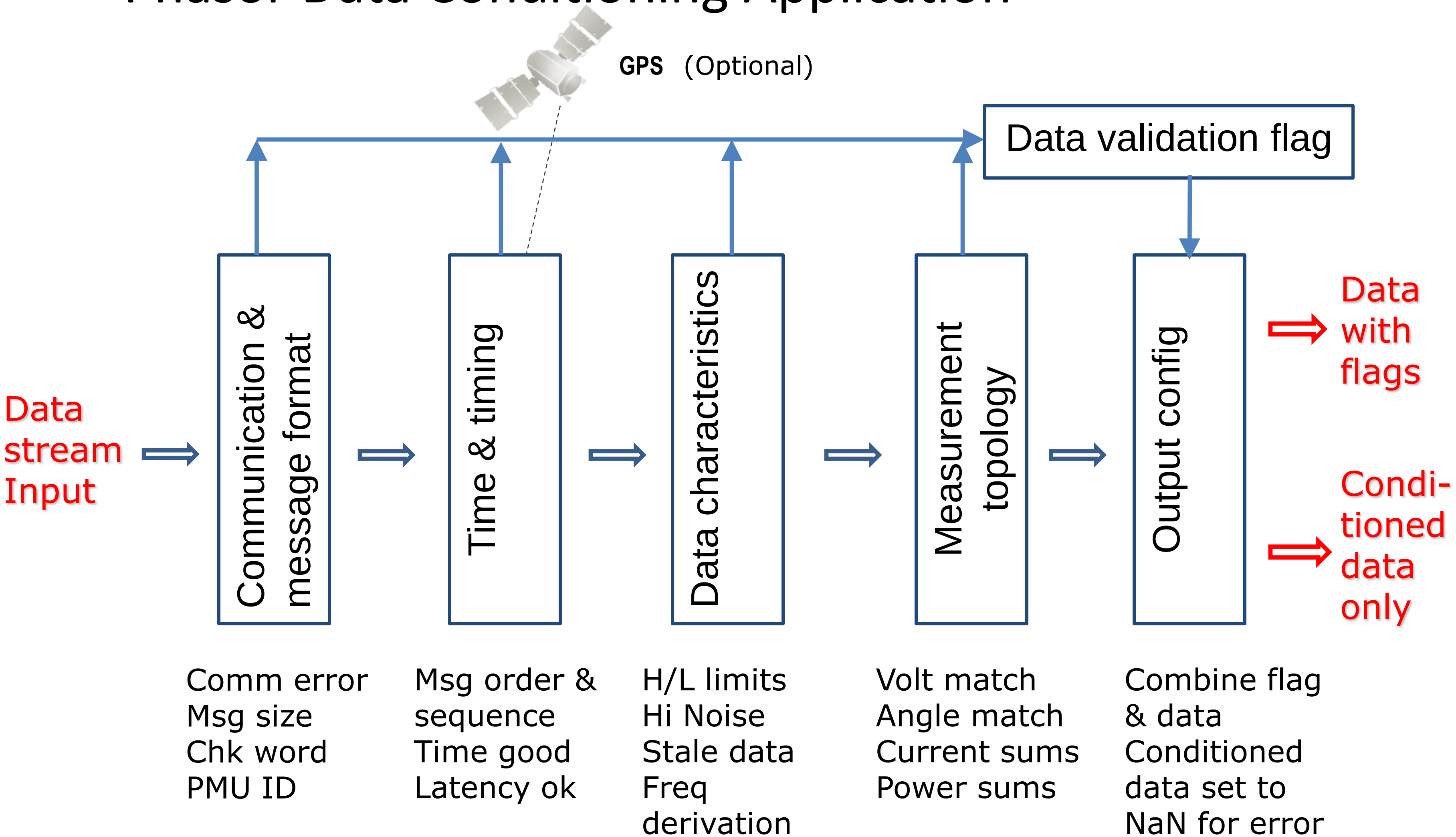
Using Flags for Problem Detection – PDC

- Detects/flags transmission errors & lost data
- Flags synchronization errors
- Detects configuration changes, request update
- Flags any data modification (fill-in, repeat, etc.)

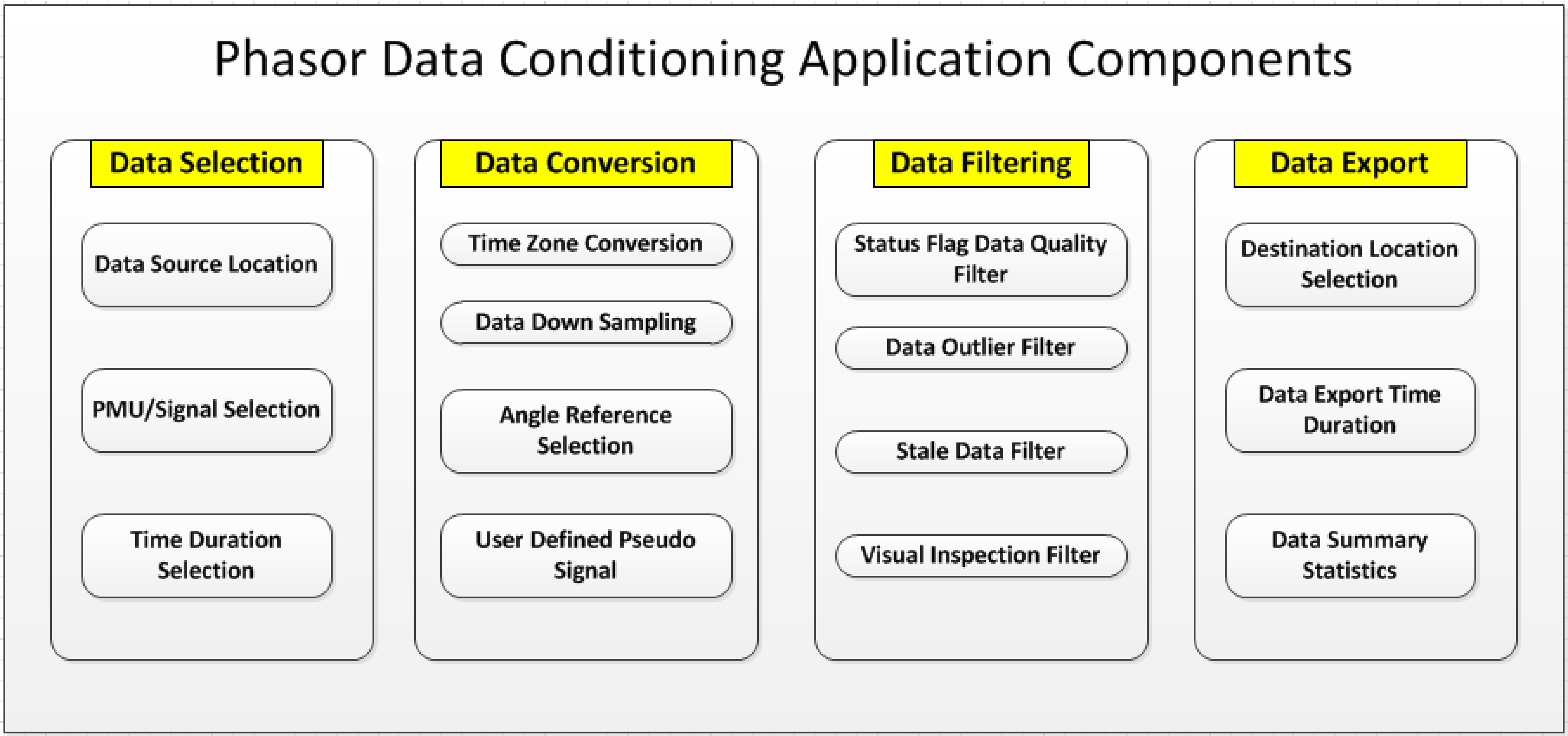


Algorithmic Problem Detection and Data Conditioning – PDCA

- Phasor Data Conditioning Application



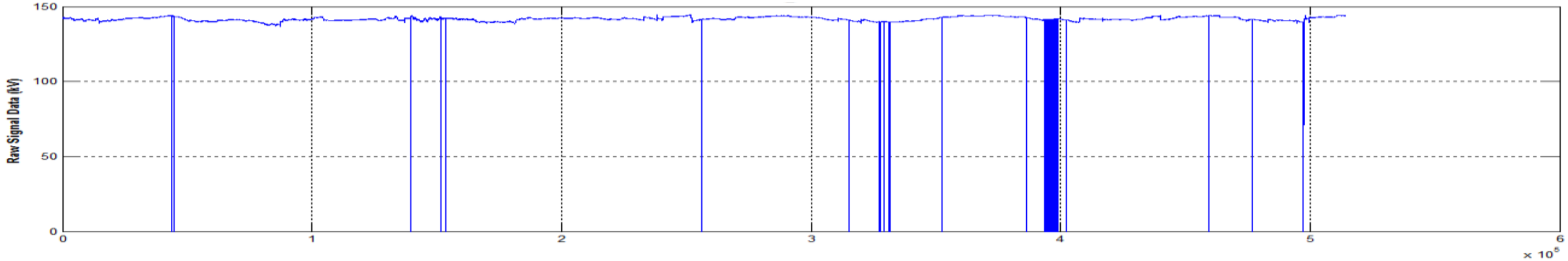
Use of PDCA for Historical Data Validation and Conditioning



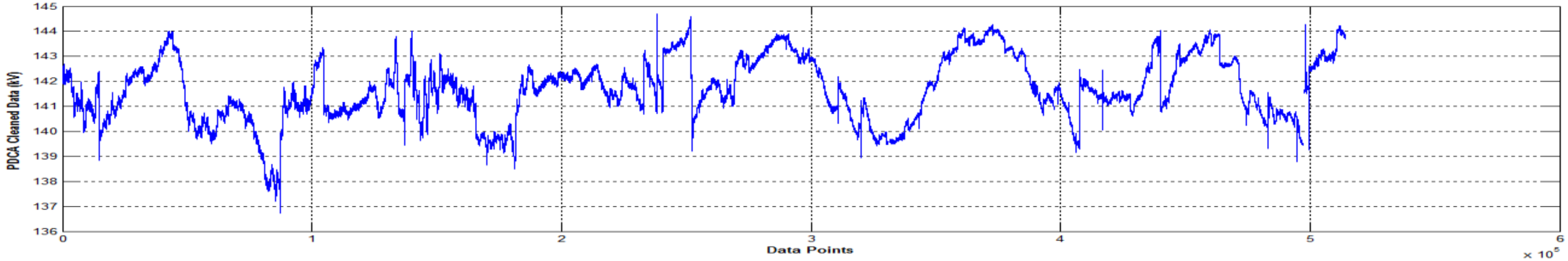
Used for cleaning 6-months worth of ERCOT data

Example – Dropout Data Repair

- Data dropouts – flagged by PDC
- Repair by PDCA:
  - Data approximated by linear or quadratic interpolation
  - Close approximation to original (limited by reporting bandwidth)

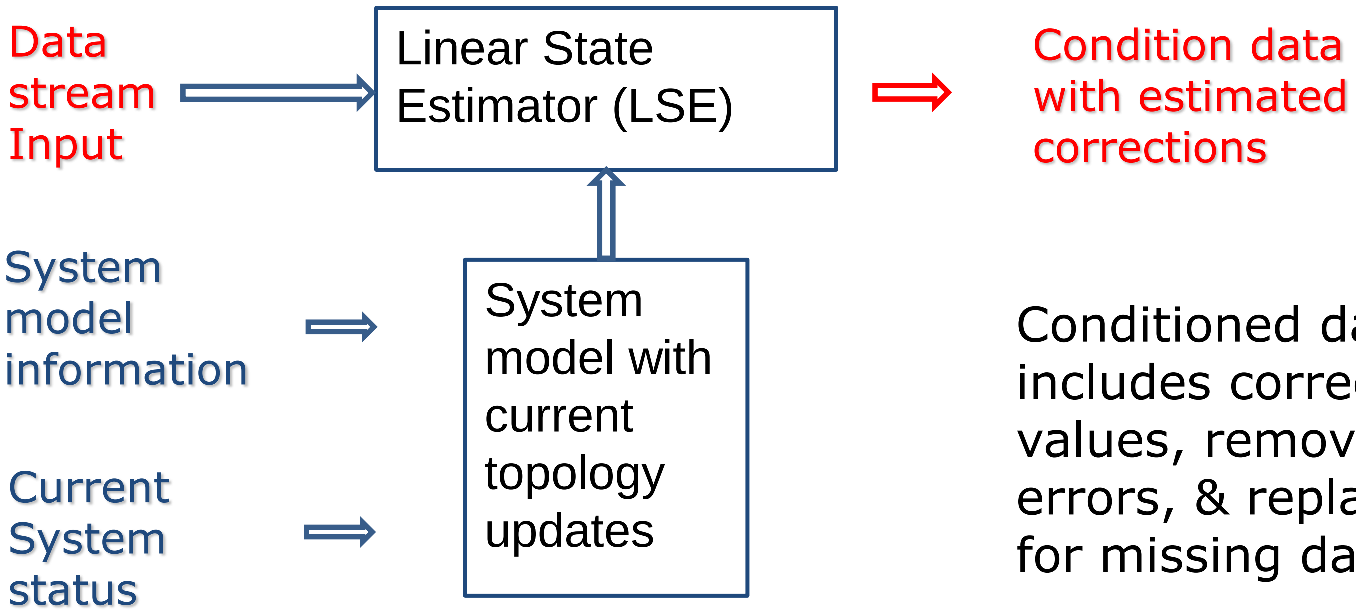


Repaired by PDCA



Linear State Estimation – Model Based Error Detection & Repair

- Improve accuracy
- Detect errors
- Supply missing values



Conditioned data includes corrected values, removal of errors, & replacements for missing data

Synchrophasor System Data Management

- Implement business process to manage the system
- Assure that applications identify & handle data errors
  - Utilize alerts for needed repairs
- Create catalog of data problem signatures
  - Allows quick identification of typical problems
- Maintain logs of problems and their resolutions
  - Helps new personnel to 'come up to speed'
  - Identify persistent problem areas for redesign or equipment replacement
- Establish training programs for synchrophasor system personnel

Summary

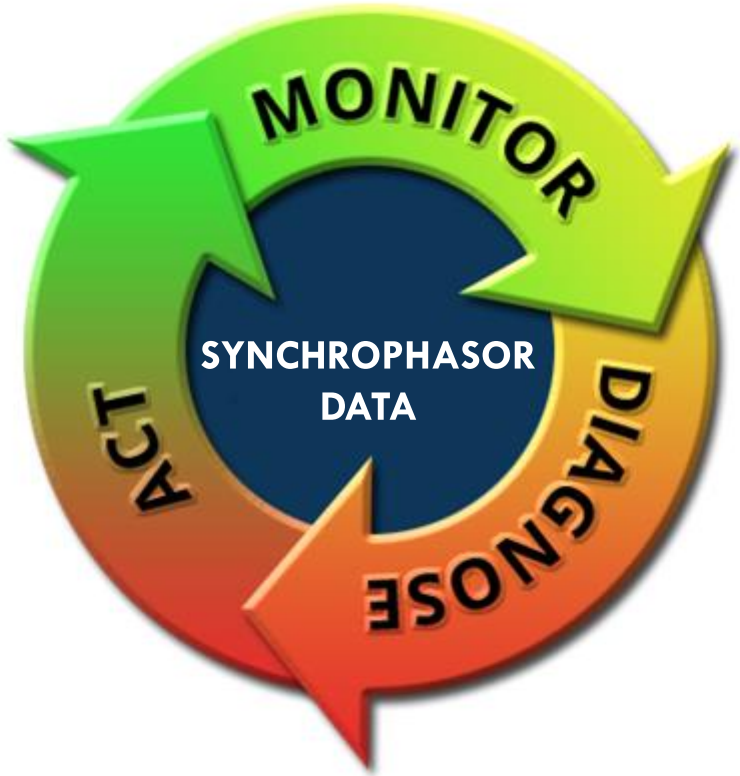
- Data quality starts with good design & implementation
- Detect and resolve ongoing problems with a high quality phasor system
- Achieve continued high performance with good system management

WITH THIS APPROACH, PHASOR DATA CAN BE USED WITH CONFIDENCE

Using Synchrophasor Data for Operations & Analysis

Good Synchrophasor System Design and Implementation

Smart Applications and User Training



Effective Data Validation and Conditioning

EPG Webinar Series

URL: http://www.electricpowergroup.com/solutions/index.html

Webinars are planned monthly, on a Tuesday from 11 a.m. to 12 Noon Pacific. The webinar topic list includes:

- System Events - Deciphering the Heartbeat of the Power Grid (Jul 16, 2013)
- Using Synchrophasor Technology For Real-Time Operation and Reliability Management (Aug 20, 2013)
- Phase Angle Differences – What They Mean and How to Use Them For Operations (Sep 17, 2013)
- Establishing Alarm Limits For Use in Operations (Oct 8, 2013)
- Phasor Simulations – How Can They Be Used in Operations? (Nov 19, 2013)
- **Synchrophasor Data Diagnostics: Detection & Resolution of Data Problems for Operations and Analysis (Jan 28, 2014)**
- **Model Validation (Feb 18, 2014)**
- **Voltage and Angle Sensitivities – What Do They Mean and How Can They Be Used (Mar 18, 2014)**

Feedback

Your feedback and suggestions are important!
PLEASE do let us know…

Q&A

Thank You!

For questions, please contact **Frank Carrera**:
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Or if you prefer, call and tell us directly:
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