Phasor Data Validation and Error Correction Across Power Grid

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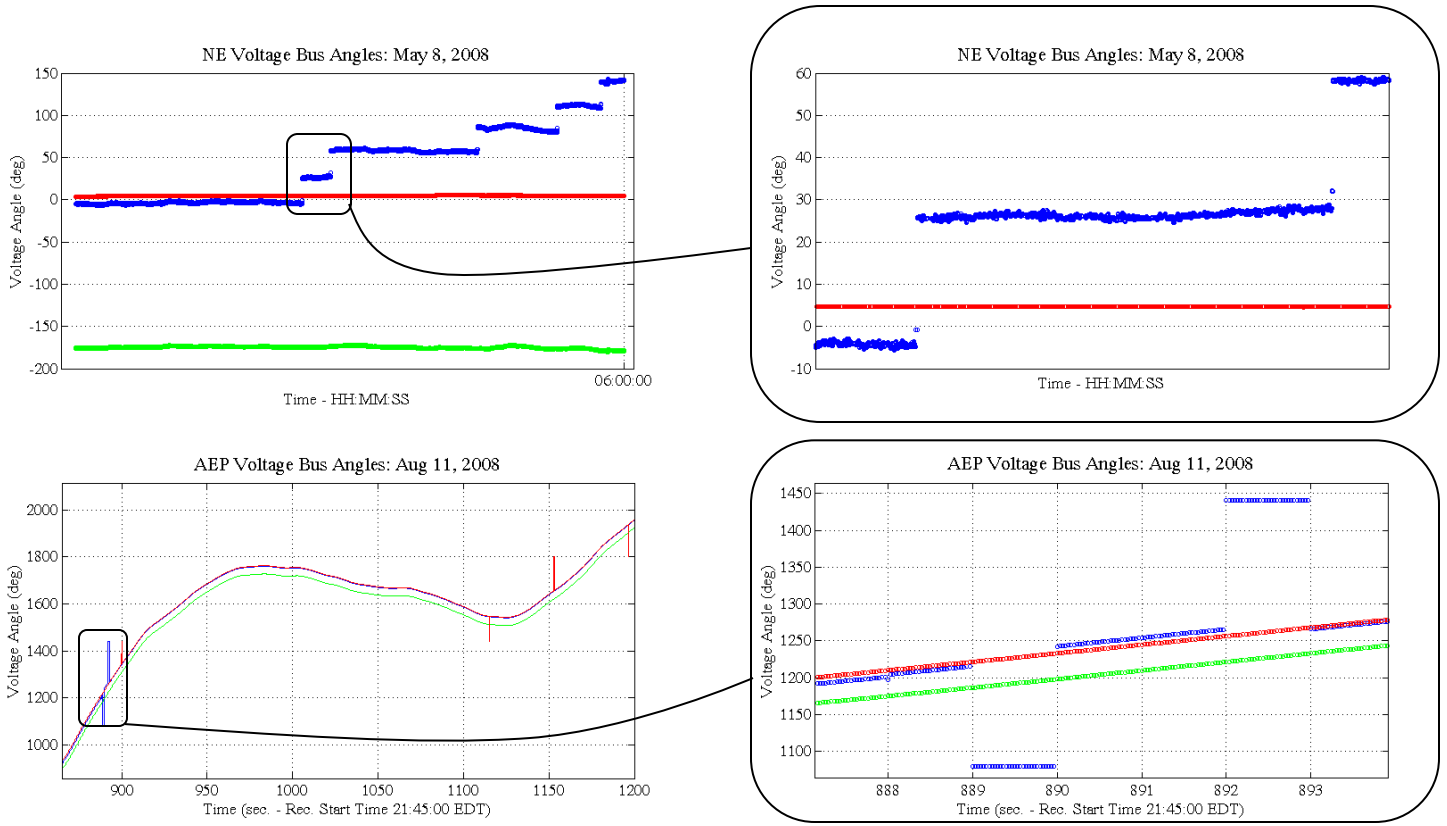
Phase Angle Errors in PMU Data

- We have worked with phasor data from over 30 PMUs and have the following observations.
- Voltage and current magnitude data are quite accurate (~1% error).
- Voltage and current phase angle errors occur in some PMUs
  - "Random" jumps of 7.5 degrees or integer multiples of it, followed by resets at a later time
  - Slew/ramp with periodic resets (not the 180 deg wrap-around situation)
- The errors are attributed to
  - Wrong phase connection to a PMU: a constant bias, trivial to correct
  - Signal processing algorithms used in the PMU: off-nominal frequency values and phase-lock loop implementation
  - Error with time synchronization: GPS clock signal overload and loss of GPS signal
  - Delays due to instrumentation cables and filter time constants

Phase Errors Observed in PMU Data

Persistent, random, and drift errors in PMU phase data

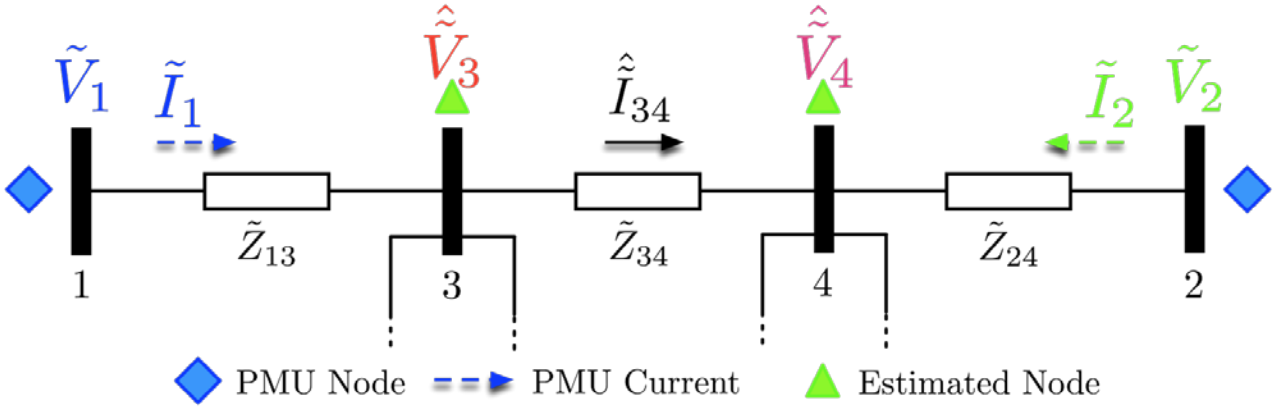


Phase Angle Error Detection and Correction

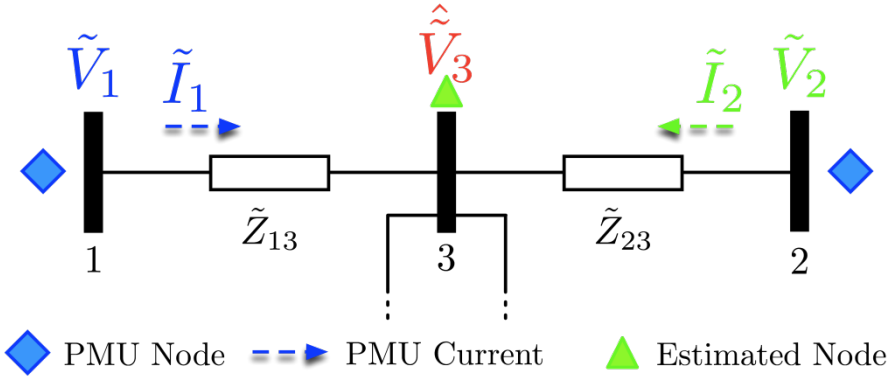
- Need a sufficient number of synchronized PMU voltage and current phasor measurements
  - *Observability*: all non-PMU bus voltage and line current phasors in a power network can be calculated from the PMU data
  - *Redundancy*: all non-PMU bus voltage phasors can be computed from two independent sets of PMU measurements.
- Observation
  - If an angle error exists in one phasor quantity from a PMU, then the same error occurs in all the other phasor quantities from the same PMU.
- Approach
  - The common phase error makes it possible to assign a bias variable for each PMU and correct for it as an optimization problem.
  - It is important that the optimization problem is formulated in the polar coordinates, because the magnitude and phase are assumed to be largely decoupled variables.
  - A phasor-only state estimator has been developed.

Observability and Redundancy

- Buses 3 and 4 are observable: their voltage phasors can be computed from the PMU data at Buses 1 and 2. Also the line current between Buses 3 and 4 can be computed.

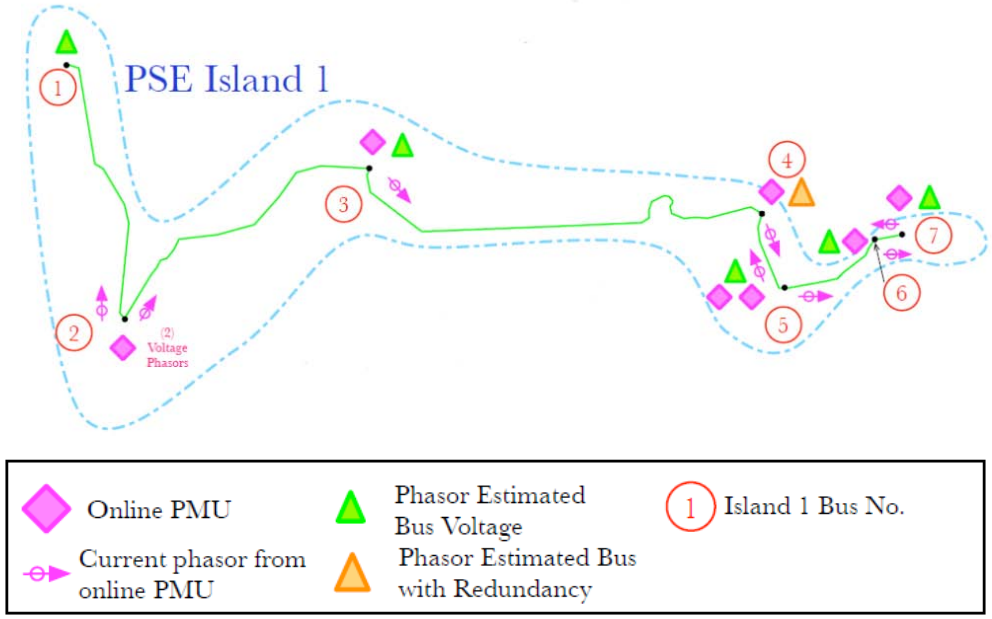


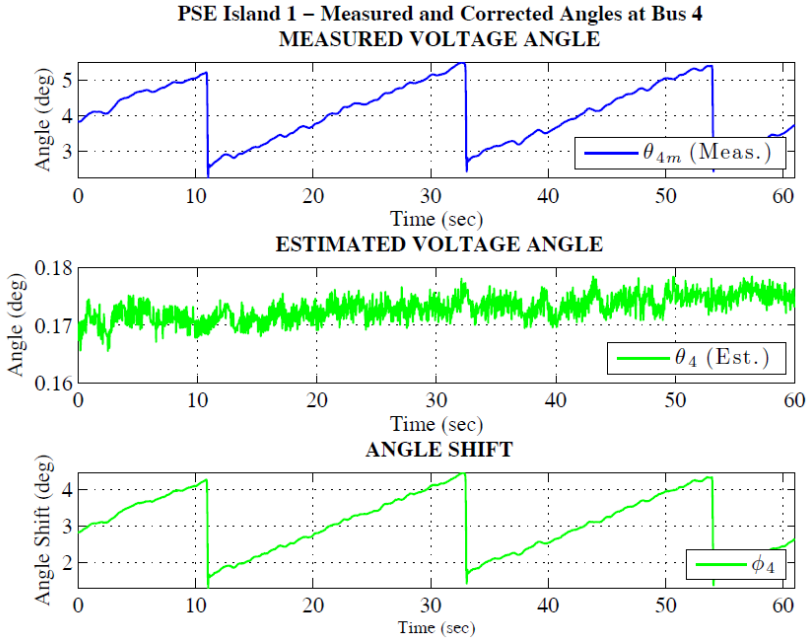
- Bus 3 is redundant: its voltage phasor can be computed independently from the PMU data at Buses 1 and 2.



Example: Phase Error Correction

Phasor-only state estimator (PSE) capable of error correction given measurement redundancy





- Advanced development – network topology inference, loss of PMUs, …
- To establish clear visibility of all HV bus voltage phasors and line current phasors across multiple control regions, in EI and WECC