TCIPG

Synchrophasor Data Quality

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Context

- Smart grid initiatives envision very reliable synchrophasor data.
- Through early 2012, power system operators report synchrophasor data had significant gaps in data quality availability.

Goals

- Gain a fundamental understanding of phasor measurement challenges.
- Characterize synchrophasor data quality (error, availability, reliability).
- Identify methods for **detecting** and **correcting** faulty synchrophasor data.
- Attribute defective synchrophasor data to synchrophasor **data generation failure** at the measurement site, **losses in the data transmission** process, or **data processing errors** at intermediate or final data storage locations.

Research Plan

Data Required / Sought

LEVEL 1 – POINT OF MEASUREMENT

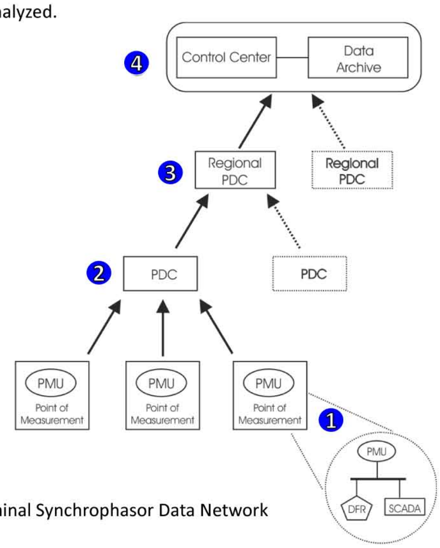
- Synchrophasor data sets with known "defective data" at Levels 1, 2, 3, & 4.
- Non-PMU data (e.g., data fault recorders, SCADA measurements) from same locations and times to be correlated with PMU data to evaluate data availability and quality.
- System information, metadata, system topology to convert "raw" data into data forms that permit analysis.

LEVELS 2 & 3 – NETWORK TRANSMISSION

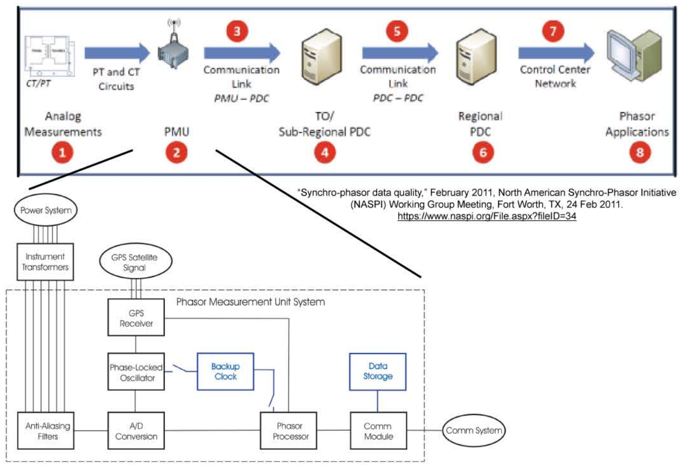
- Synchrophasor data sets at levels 2 & 3 that include known "defective data" corresponding to level 1 and 4 data sets.
- Relevant technical information about the network paths, protocols, and equipment to evaluate, assess, and attribute synchrophasor data loss causes.

LEVEL 4 – CONTROL CENTER and POINT of USE

- Synchrophasor data sets at level 4 that include known "defective data" at levels 1, 2, & 3 and corresponding state estimator solutions.
- Relevant technical information about the network paths, protocols, and equipment to evaluate, assess, and attribute synchrophasor data loss causes.
- Corresponding metadata describing the signals, storage compression, and network topologies (if necessary) needed to convert and interpret the data.
- Data sets should be accompanied by information needed to convert and correlate C37.118, concentrated, and archived data into forms that can be analyzed.



Nominal Synchrophasor Data Network



"Synchro-phasor data quality," February 2011, North American Synchro-Phasor Initiative (NASPI) Working Group Meeting, Fort Worth, TX, 24 Feb 2011. https://www.naspi.org/File.aspx?fileID=34

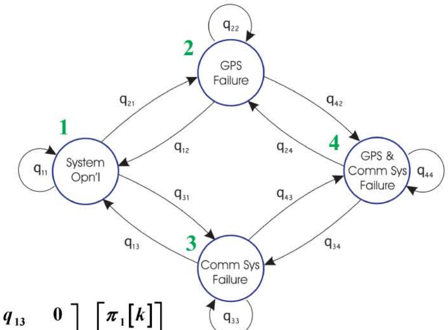
Error Sources – ID'd, not Characterized

Identified Error Sources and Proposed Error Type Classifications[1]		
Error Source	**Level(s)**	**Error Type**
Status Code Errors	1,2,3	Data Processing
Data streams disordered / shifted in processing	1,2,3	Data Processing
Loss of PDC Configuration	2,3,4	Data Processing
Improperly configured PMUs (window length/ windowing method)	1	Digital Signal Processing
Frequency calculation discrepancies (C37.118.2005)	1	Digital Signal Processing
Quality of Metering	1	Equipment Specification
Accuracy Issues (CT/PTs not properly rated for application)	1	Equipment Specification
Calculation Uncertainty – Vendor Equipment operating differences	1	Equipment Specification
Metering Locations Separated by Breakers	1	Installation
Meters not installed at recorded locations	1	Installation
PMU data streams not named according to system policies	1	Installation
Asynchronous local behaviors (e.g. DC bias injections during solar storm)	1	Measurement
Malformed Network Packets	2,3,4	Network Failure
Network Data Loss	2,3,4	Network Failure
Mislabeled Phasor Data Streams	1,2,3	PMU Configuration
Differences between PMU Manufacturer calculation approaches	1	PMU Standards

[1] ICW / Midwest Independent Transmission System Operator (MISO)

Availability Modeling

$q_{i,j}$ = State Transition Rate



$$\begin{bmatrix}\pi_1[k+1]\\ \pi_2[k+1]\\ \pi_3[k+1]\\ \pi_4[k+1]\end{bmatrix} = \begin{bmatrix} q_{11} & q_{12} & q_{13} & 0 \\ q_{21} & q_{22} & 0 & q_{24} \\ q_{31} & 0 & q_{33} & q_{34} \\ 0 & q_{42} & q_{43} & q_{44}\end{bmatrix}\begin{bmatrix}\pi_1[k]\\ \pi_2[k]\\ \pi_3[k]\\ \pi_4[k]\end{bmatrix} \Rightarrow \begin{aligned}\pi[k+1] &= e^{At}\,\pi[k]\\ \pi[k] &= A^k\,\pi[0]\end{aligned}$$

Future Efforts

- Working with multiple partners to obtain data and analyze data.
- Seeking industry partners who have fielded PMUs and can provide described data.