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Synchrophasor System Data Quality – Can We Do Better?

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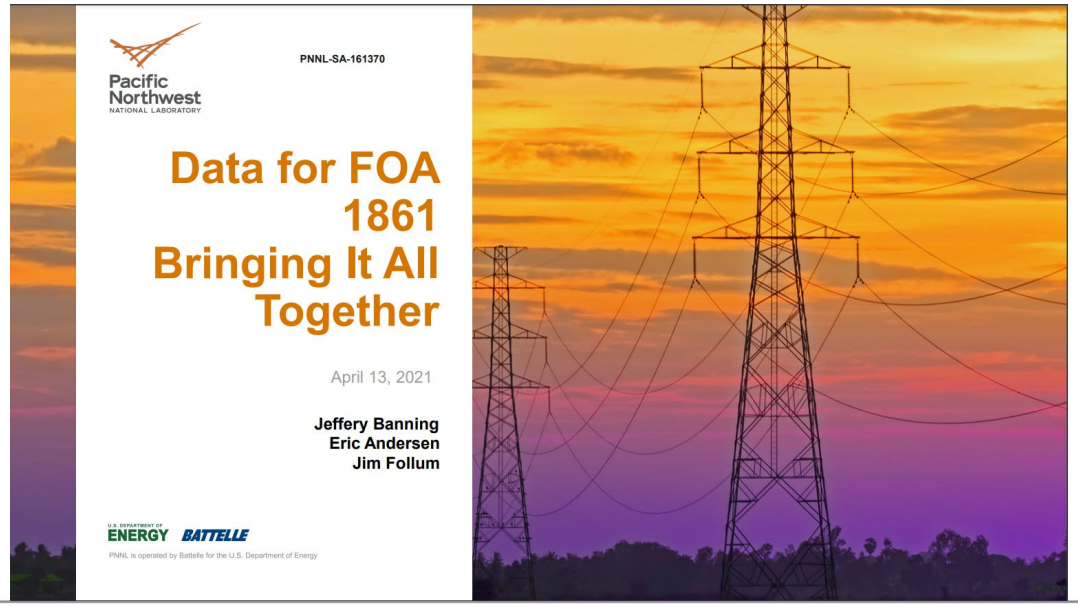
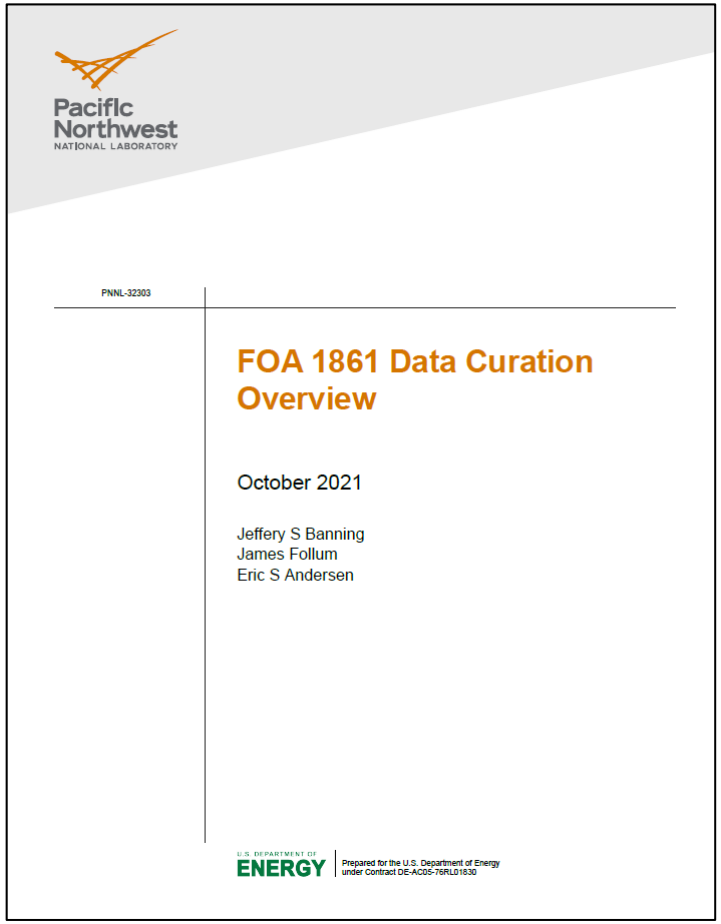
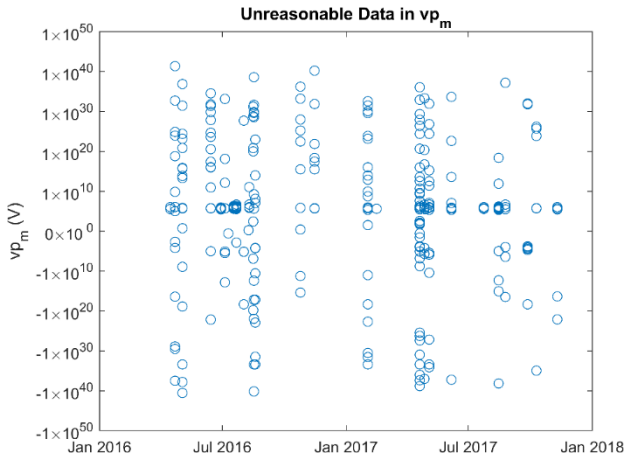
DOE 1861 Program Provided Synchrophasor Datasets

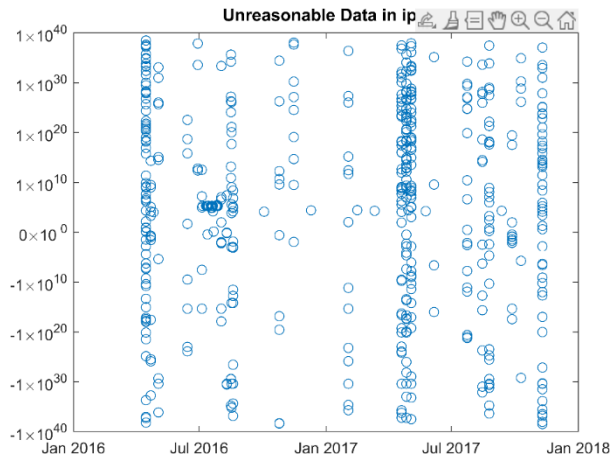
- Two years of archived PMU data with event logs from three interconnections – curated and sanitized
- Split into training dataset (20.4 TB) and test dataset (7.1 TB)
- Included STAT word in addition to data

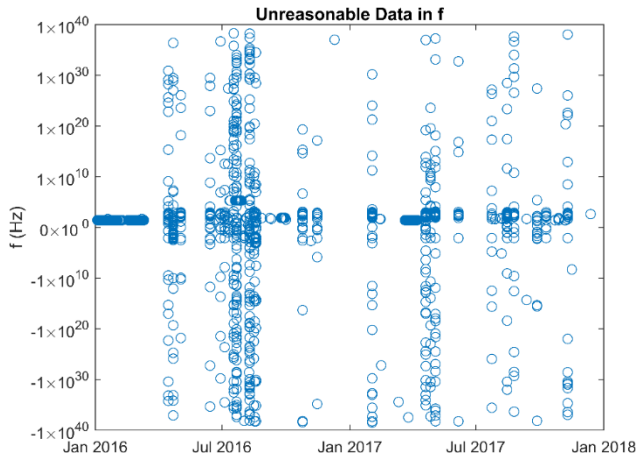




Key Observations from Datasets Provided by DOE in 1861 Program

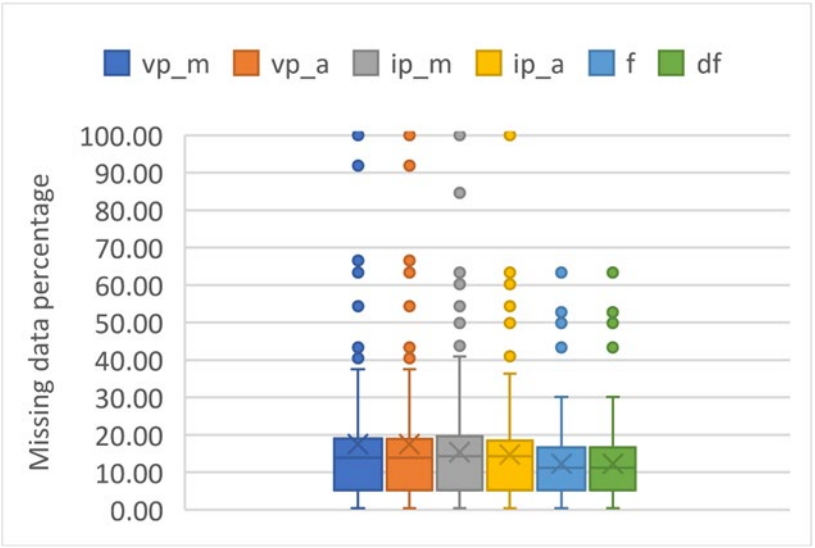






Common issues seeing among 188 PMUs

- Missing data – most missing 5%-20% and some even more
- Unreasonable values – out of normal range

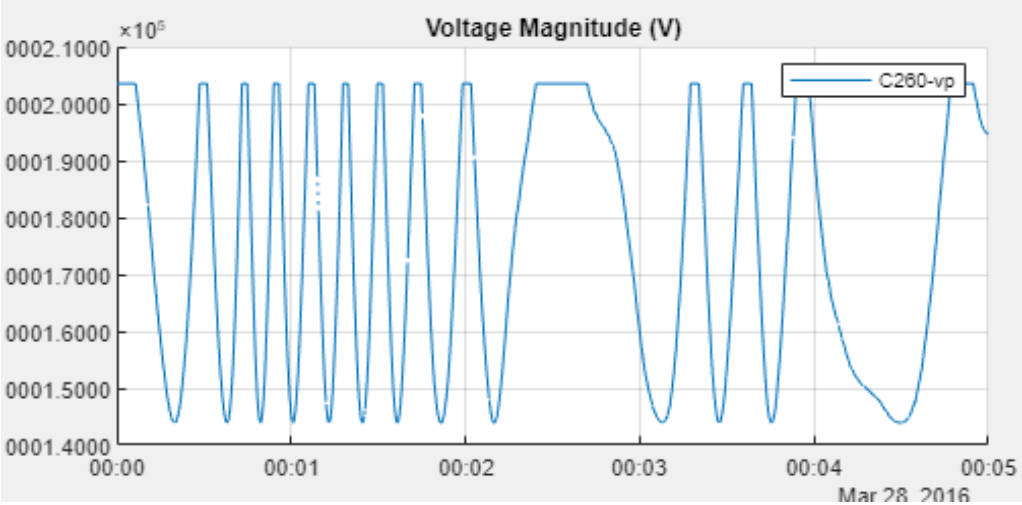


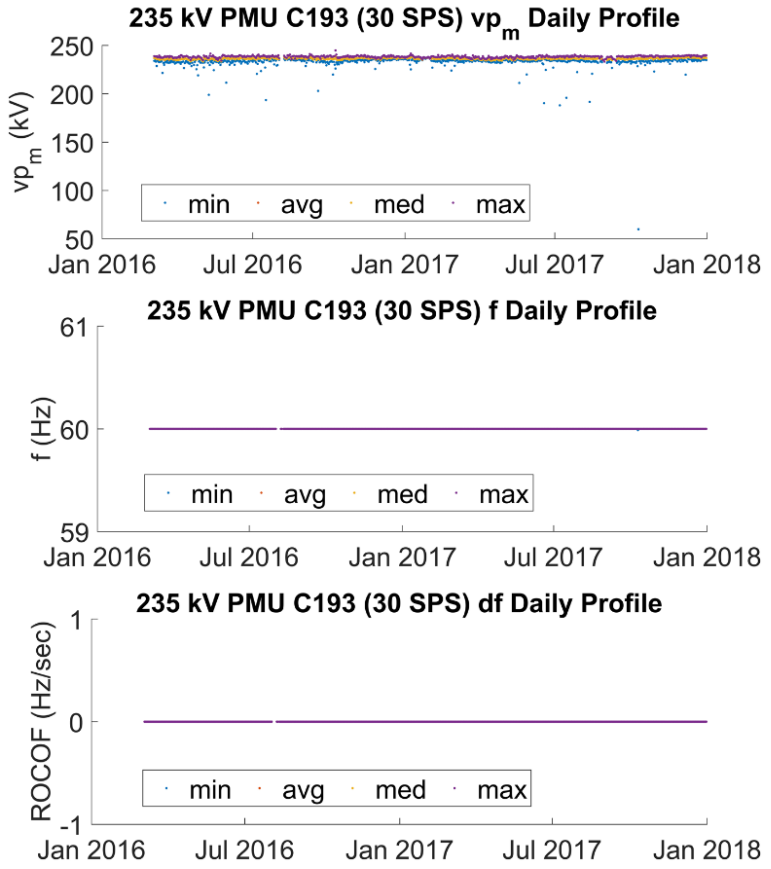
Z. Cheng, Yi Hu, Z. Obradovic, and M. Kezunovic, "Using Synchrophasor Status Word as Data Quality Indicator: What to Expect in the Field?" IEEE PES SGSMA 2022, May 2022

Key Observations from Datasets Provided by DOE in 1861 Program

Unique issues

- One PMU has a fluctuating voltage magnitude between 145kV and 205kV
- 18 PMUs show constant 60 Hz frequency value





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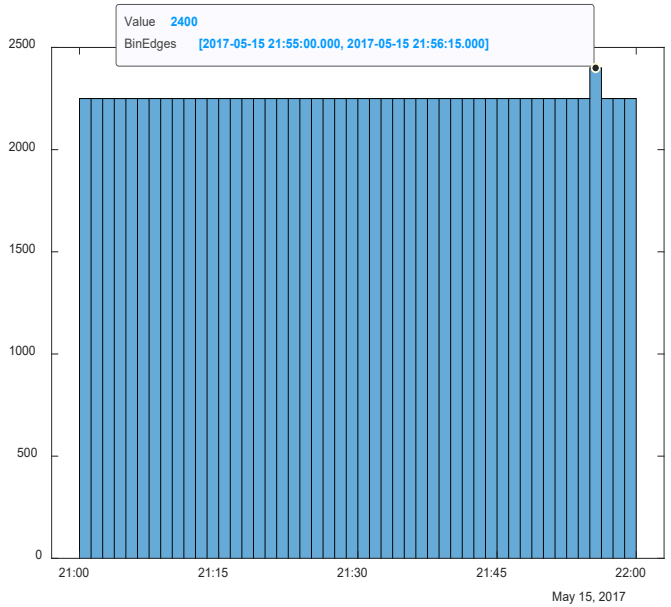
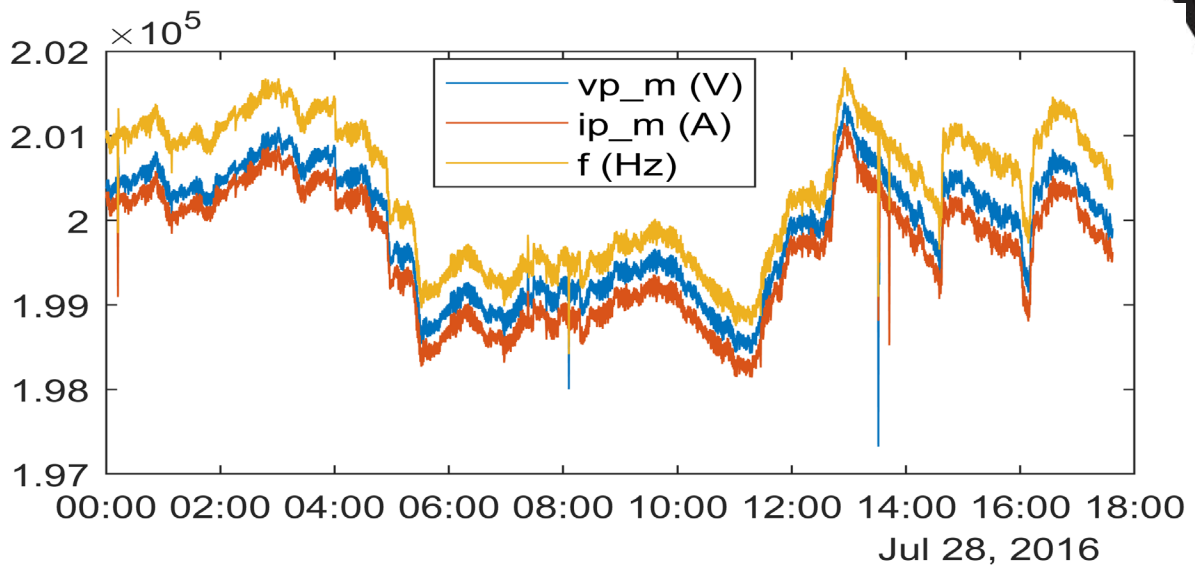




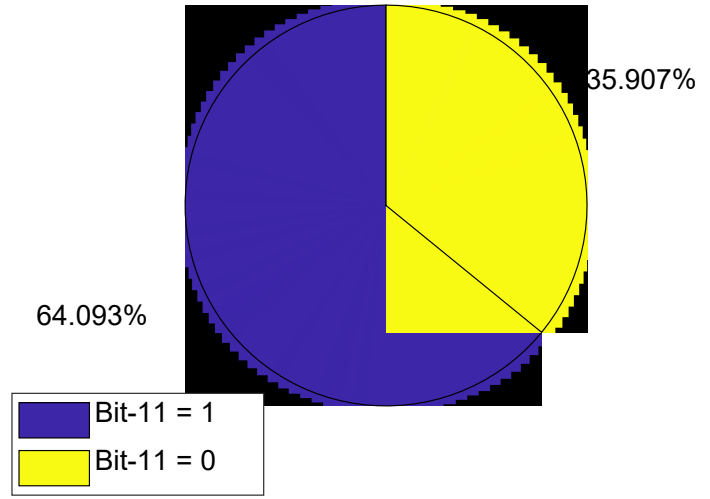
Other issues

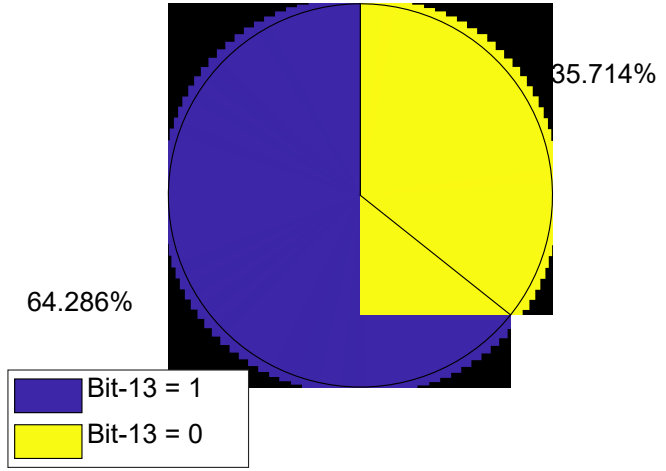
- Duplicated data
- Misplaced data
- Time tag format variations

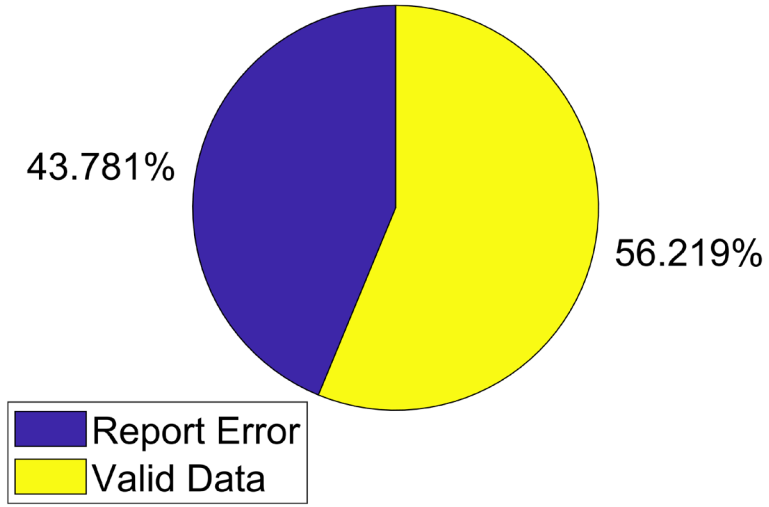
Type-I	Type-II	Type-III
'00:00:00.000000000'	'00:00:00.000000000'	'00:00:00.000000000'
'00:00:00.033340000'	'00:00:00.033000000'	'00:00:00.033000000'
'00:00:00.066680000'	'00:00:00.067000000'	'00:00:00.066000000'
'00:00:00.100000000'	'00:00:00.100000000'	'00:00:00.100000000'
'00:00:00.133340000'	'00:00:00.133000000'	'00:00:00.132000000'
'00:00:00.166670000'	'00:00:00.167000000'	'00:00:00.165000000'
'00:00:00.200010000'	'00:00:00.200000000'	'00:00:00.200000000'
10 PMUs	80 PMUs	98 PMUs

Unable to Use/Trust The STAT Bits Information

- No standard version number (2005 or 2011) in the dataset
- Inconsistent bit setting
  - Trigger bit 11 vs. Trigger Condition bits 03-00
  - Sync bit 13 vs. Unlocked Time bits 05-04 and Time Quality bits 08-06 (2011)
  - Data Quality bits 15-14 vs. Sync bit 13
- Poor correlation of the data quality between observed and Data Quality bits 15-14 indicated







What Could We Do to Improve Synchrophasor System Data Quality?

- Standards
  - Specify clear STAT bits definitions and the associated conditions to set and reset– nothing should be subject to implementer's interpretation
  - Add missing information – e.g., ensure version number is available both in real-time data and in archived data
  - There are many more areas well-done standardization could help
- Certification testing
  - An effective way to ensure all products will function and perform the same according to the same standard
- Adopt system designs that enable higher data availability
  - Enable fast data missing issue identification and location
  - Avoid system designs that may cause data quality issues
    - Prone to single-point of failure
    - Data may be dropped by certain intermediate system component
    - Impacted by communication protocol choices

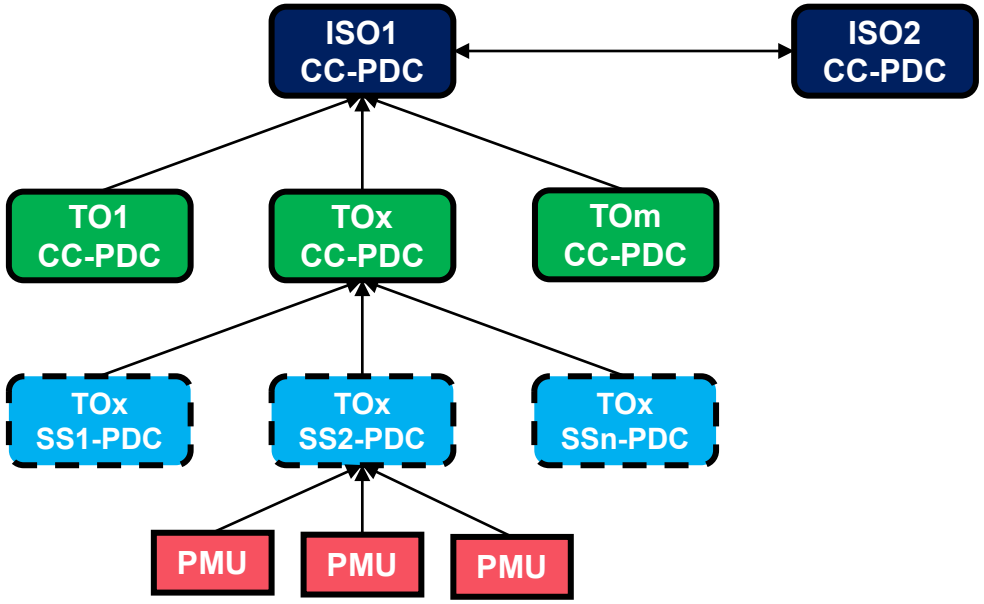
Enable Fast Data Loss Detection and Remediation

- Current best practices
  - Monitor the data availability at the data receiving or consumption point continuously
  - Generate alarms or notifications when excessive data loss is detected (i.e., triggered by targeted availability threshold)
  - Trace the data flow path until the source of the data loss is determined
  - Remedy the situation to prevent future data losses
- The issues
  - Data losses below the threshold may not get much attention, let alone to fix them – some of such losses could evolve to cause major losses
  - Tracing the data flow path to find the data loss source is a time consuming task when involve multiple entities
  - Difficult to trace non-repeatable data loss incidents
- A synchrophasor system could be its own automated data loss monitoring system
  - Each intermediate data transferring component (IDTC such as PDCs, Gateways, etc. that receive and resend the data) knows its own data loss situation in detail
  - Save such info at each IDTC will enable source of the data losses to be determined much faster
  - Send such info to downstream IDTCs or enduse point would enable automated data loss source determination
- The result
  - Faster detection and remediation ➔ Short data loss duration ➔ Higher data availability
- What can be done?
  - A NASPI guideline?
  - An IEEE standard?

Design Synchrophasor System for High Data Availability

- CC-PDC – Control Center PDC
- SSn-PDC – Substation n PDC

Typical System Design



- Include built-in redundancy
  - System level – make everything redundant, or
  - Only the ones that have more impact on the data losses
- Aware intermediate PDC could drop data that are arrived too late
  - Wait or not wait?
- Choose data transfer protocol appropriately
  - TCP or UDP?
  - Unicast or multicast?

Conclusions

- There are still rooms for further improvement in synchrophasor systems data quality
- It will take a concerted effort by all stakeholders to properly address all known and emerging issues that impact the data quality
- While great progresses have been made, the data availability of synchrophasor systems could be further improved
- System design choices could have a direct impact on a synchrophasor system's data availability

Thank You!

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