Overcoming Standard Limitations in Synchrophasor Systems
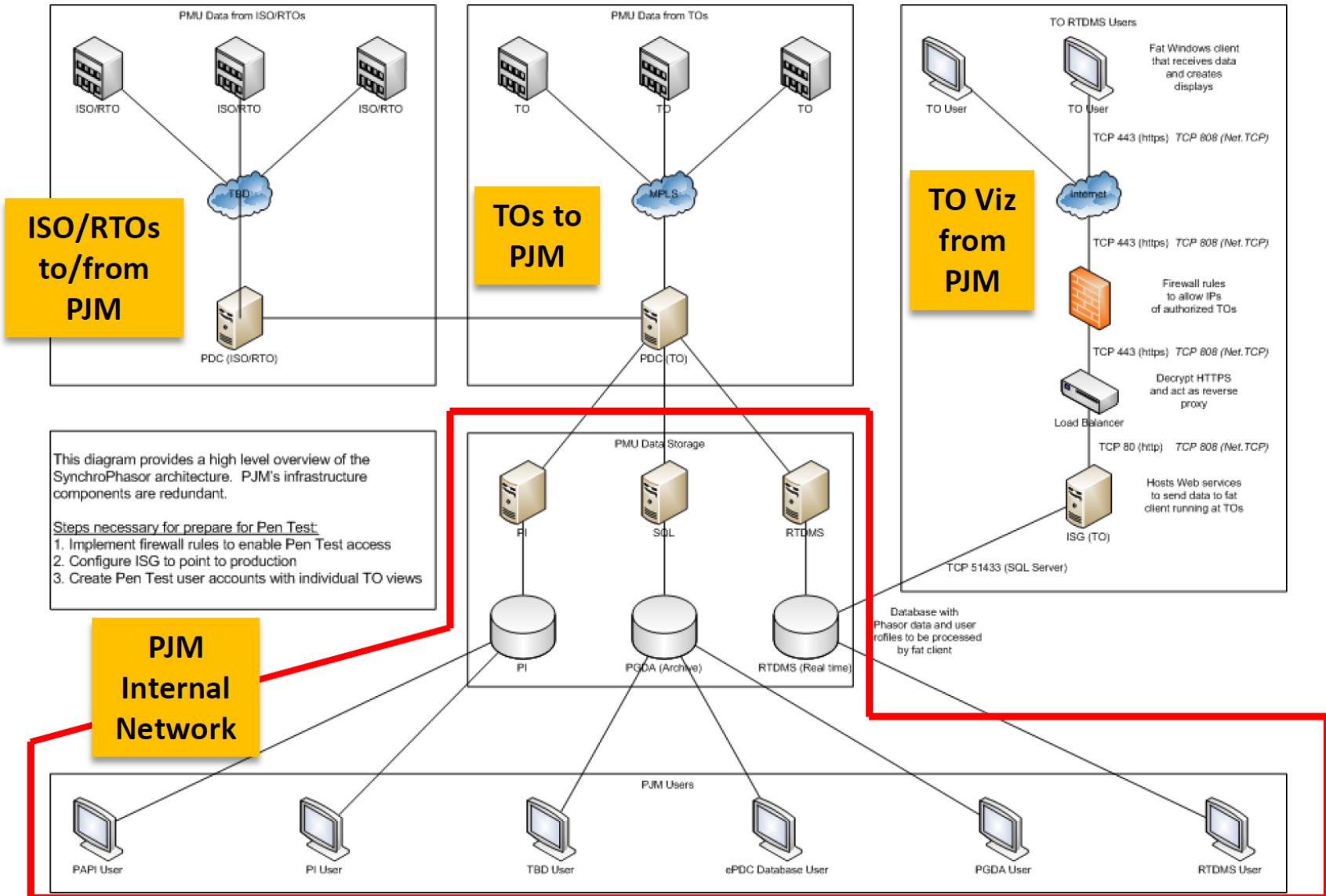
PJM PDC Testing Experience

Yi Hu, Vasudev Gharpure
Quanta Technology LLC

Bill Walker, Jing Liu
PJM Interconnection

Knoxville, TN
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- PJM Control Center PDC
- PJM PDC testing objectives
- PDC testing setup
- Tests performed
- Key findings from the testing
- Standard limitations and possible mitigation solutions
- Conclusions

ISO/RTOs to/from PJM

TOs to PJM

TO Viz from PJM

PJM Internal Network

This diagram provides a high level overview of the SynchroPhasor architecture. PJM's infrastructure components are redundant.

Steps necessary for prepare for Pen Test:
1. Implement firewall rules to enable Pen Test access
2. Configure ISG to point to production
3. Create Pen Test user accounts with individual TO views

# Functional requirements

- Total number of PMUs
  - Data from TOs
    - Installing 300+ PMUs at 100+ substations
    - Building support for 150+ substations
  - Data exchange plan – PMU data from neighboring ISOs
    - MISO: 263 PMUs
    - NYISO: 48 substations with PMUs
  - Total over 500 PMUs and at least to support twice that in near future
- Data forwarded to
  - RTDMS – must be in single stream
  - PI database – must be in single stream?

Objectives

- Determine if PDC will be able to meet PJM synchrophasor system requirements
  - Current needs
    - Getting data from all TOs
    - Adding time-tag to received data
    - Data quality
  - Future needs
    - Sufficient capacity
    - Adequate performance
- Have a clear understanding how PDC works
  - Setting status flags
  - Output behavior under various input conditions

Test setup

- Synchrophasor system simulator
  – Generate various test data streams based on the test case specification
- PMU Connection Tester
  – Capture PDC output data for analysis
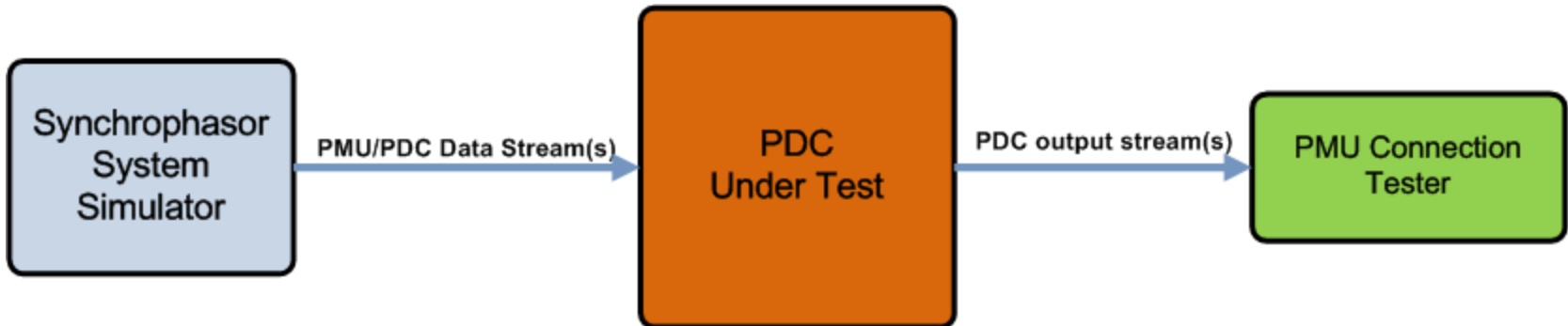
Tested scenarios

- Normal condition
- Missing data packets
- Late data arrival
- Flagged PMU data
  - Invalid/PMU error
  - Lost sync indication
  - Sort by arrival
  - Trigger flags
- PMU configuration changes
- PMU data frame CRC error
- Time of Arrival check
- Capacity test

We need PDC standard!

- Size limitation of the standard
  - Could be a major issue
- Standardized way for PDCs to respond to
  - Setting flags
    - Data quality marking
    - Processed data indication
  - Change management (e.g. Add/remove PMUs from a stream)
  - Long interruptions of all input data

Data element size in data and configuration frames
– total bytes must be < 65536 (frame size)

Data element	Data frame		CFG-1/2 frame	CFG-3 frame
	Integer	Floating		
Phasor	4	8	20	13-268
Analog	2	4	20	9-264
Digital	2	N/A	260	20-4100
Frequency	2	4	0	0
df/dt	2	4	0	0

Ultimate limit – One data element per PMU only

Data element	Max. # of PMUs in a data frame		Max. # of PMUs in a CFG-1/2 frame
	Integer	Floating	
One phasor only	10,913	6,547	1,309
One analog only	16,369	10,913	1,309
One digital only	16,369		225

A sample PMU

- One voltage phasor, two current phasors, two analog values, and zero to three digital WORD
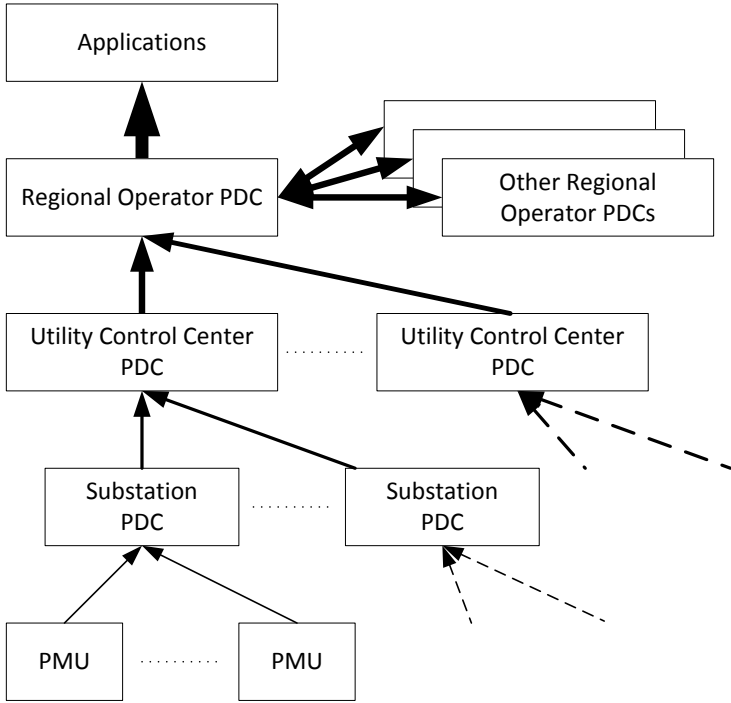
# of Digital WORD	Max. # of example PMUs		
	In a data frame		In a CFG-1/2 frame
	Integer	Floating	
0	3,637	1,925	503
1	3,273	1,723	165
2	2,980	1,559	100
3	2,728	1,423	71

Applications

Regional Operator PDC

Other Regional Operator PDCs

Utility Control Center PDC

Utility Control Center PDC

Substation PDC

Substation PDC

PMU

PMU

There are several options

- Limit data element
  - No digital, positive sequence phasors only
  - May not meet applications requirement
- Use CFG-3
  - Can get some relief
  - May not be a long term solution
- Multiple streams
  - Can be a solution
  - Complication on receiving side
- New standard or standard revision
  - Preferred but will take some time

- PDC testing is important to
  - Understand how they function
  - Whether they can meet system functional and performance requirements, and
  - Whether they are interoperable with other system components
- Using synchrophasor system simulator is an effective way to perform such tests
- For large-scale synchrophasor systems, current standard will become a major limitation in transporting synchrophasor data
  - Configuration frame CFG-1/CFG-2 is the bottleneck
- There are some mitigation options
  - Standardized approach is preferred

Questions?