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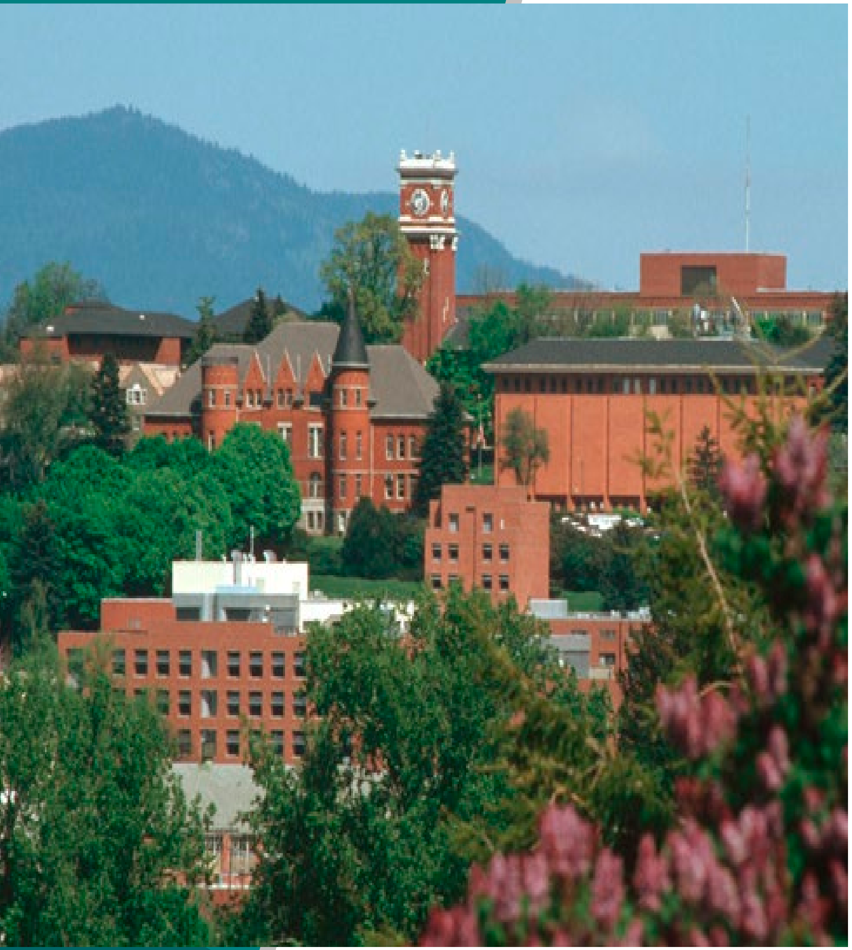

The Increasing Data Streams in Power Grid Operation

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IEEE BDA Tutorial Series: Big Data & Analytics for Power Systems

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Thoughts I want to leave you with

The data landscape for the power grid

- Static data, real-time data, historical data

The system operation data

- Markets: Energy, Capacity
- Transmission: EMS-SCADA, PMU
- Distribution: DMS-SCADA, OMS, AMI

The operation challenges for transforming grid

- Monitoring, operating distributed generation
- Resiliency (including recovery)

Data communication, management, application

Power Systems Data

Fixed Data (Assets)

- 7,500 generation plants
- 75,000 transmission substations
- 300,000 miles transmission (100,000 lines and transformers)
- 2.2 million miles distribution (1 million distribution feeders)
- 300 million customers

Power Flow data for transmission system ~ 2GB

Data for all equipment in PB

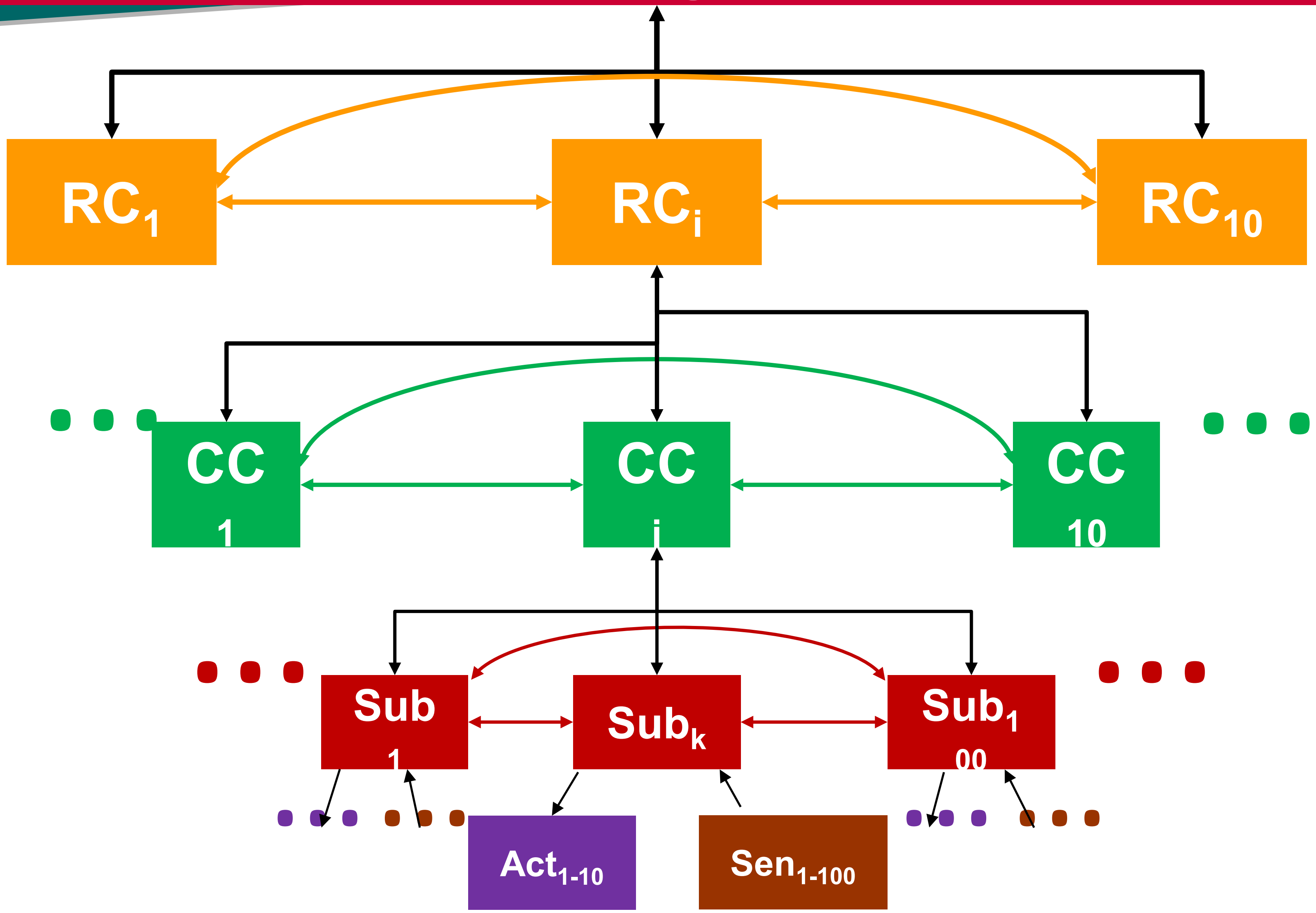
Applications for System Data

- System data for assets is fixed (changes slowly)
- Each engineering application requires a (small) subset of systems data
- Are there applications that require all data?
  - Asset Management
  - Inventory Control
  - Maintenance Records
  - Automated Mapping/Facilities Management
  - Etc.

Measurement Data (Variables)

- Power, Var, Voltage, Current, Frequency, etc.
- SCADA (EMS, DMS)
- PMU data (transmission)
- AMI data (customers)
- Substation, Generation, Microgrid (stored local)
- Measured at various frequencies
  - EMS SCADA at 2-10 seconds
  - DMS SCADA at 10-60 seconds
  - PMU 30-120 times per second
  - AMI 5-15 minutes
  - Substation/Plant data stored at various rates

Eastern Interconnection Control Monitoring Center



Average EMS Data Flows Today

- Average Reliability Coordinator has 10 Balancing Authorities (control centers)
- Average Control Center has 100 high voltage substations
- Average substation has 100 measurement points
- Average polling rate for real time data is 5 seconds

So

- Average data rate from each substation is 20/sec
- Average data rate to a control center is 2K/sec
- Average data rate to a RC is 20K/sec

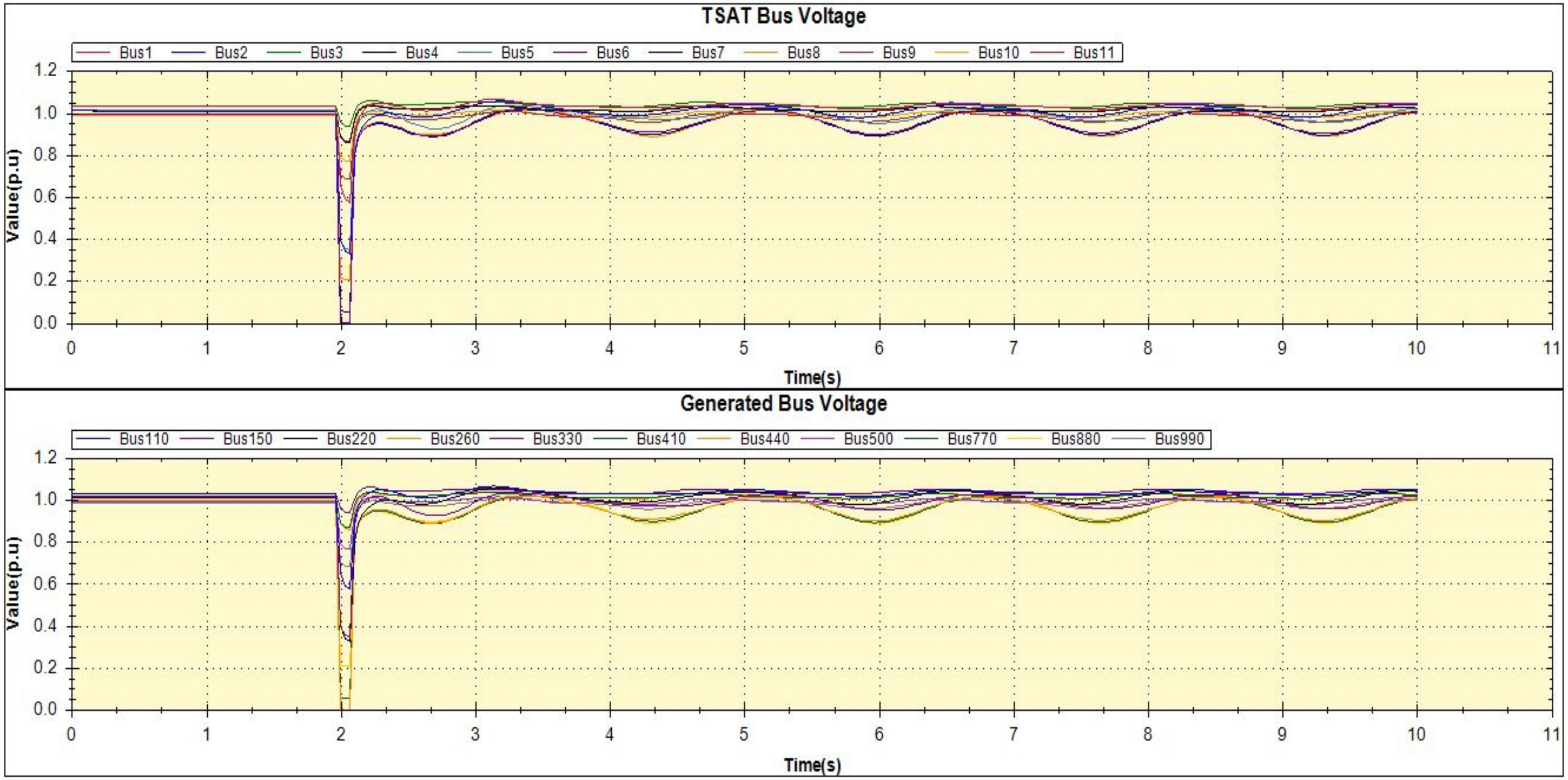
Data Collection by PMUs

- PMU sampling rates: 30-120 per second
- Assume 100 values per second

If we assume all 100 points in a sub are PMUs

- Average data rate per sub is 10K/sec
- Average data rate for the total of 100 subs in a BA is 1M/sec
- Average data rate for the RC is then 10M/sec

Simulated Bus Voltages by Powertech TSAT Generated PMU Measurements 33 msecs time steps

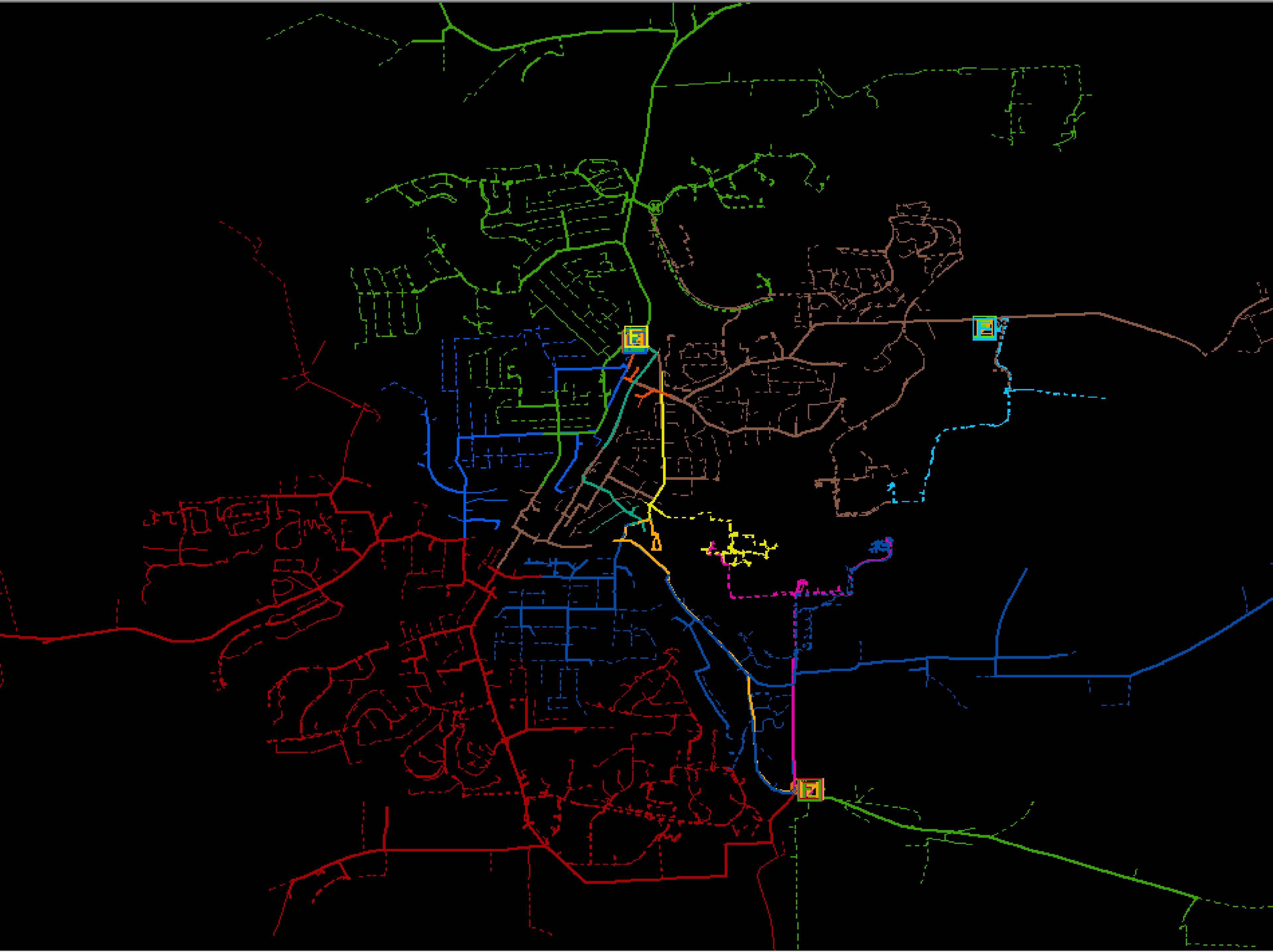


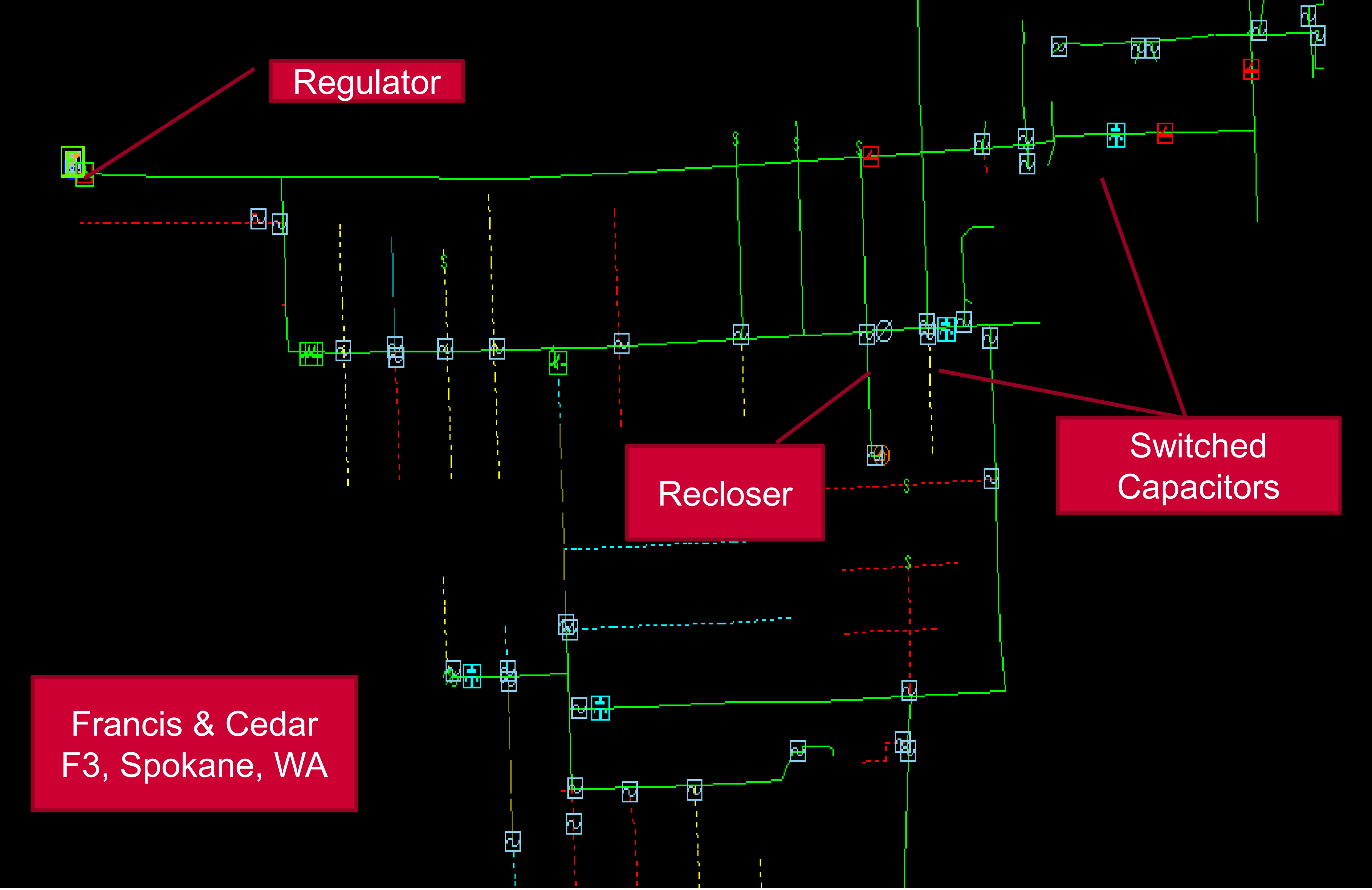
ADMS Data

- DMS SCADA data
  - P, Q, regulator at substation
  - P, Q, status at intelligent breakers (few)
- Outage Management System (OMS)
  - Customer status
  - Estimated status of breakers/sectionalizers
- AMI (customer) data
  - P, Q
  - Usually not available in real time
- No data from primary, secondary transformers

Distributed Generation & Microgrids

- Generation connected to distribution feeders
- Storage connected to distribution feeders
- Generation on secondary transformers (customer side like rooftop solar)
- Storage on secondary transformers (customer side like EV or HVAC)
- Microgrids: grid side or customer side



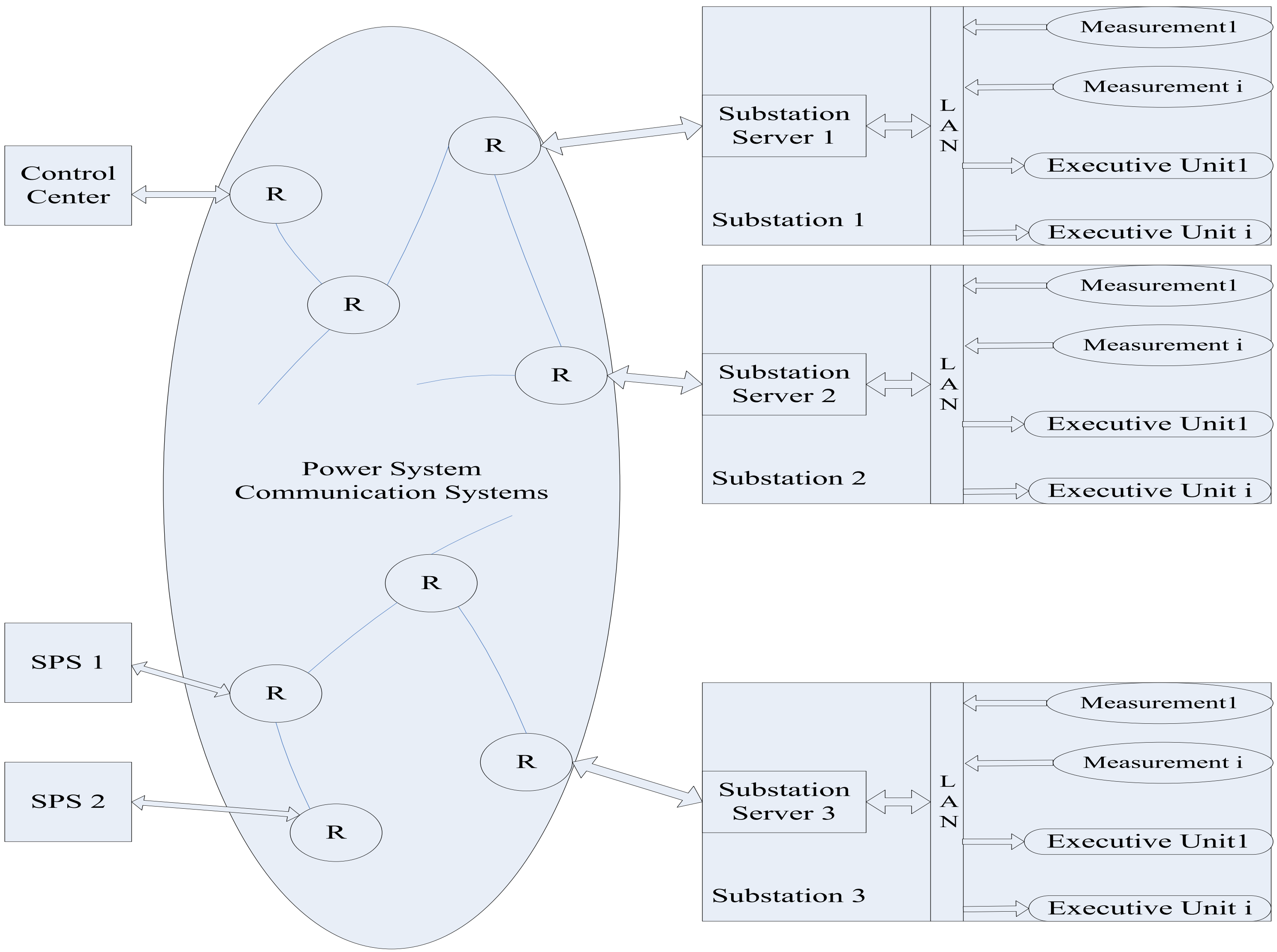

Regulator
Recloser
Switched Capacitors
Francis & Cedar F3, Spokane, WA

Data Exchange Issues

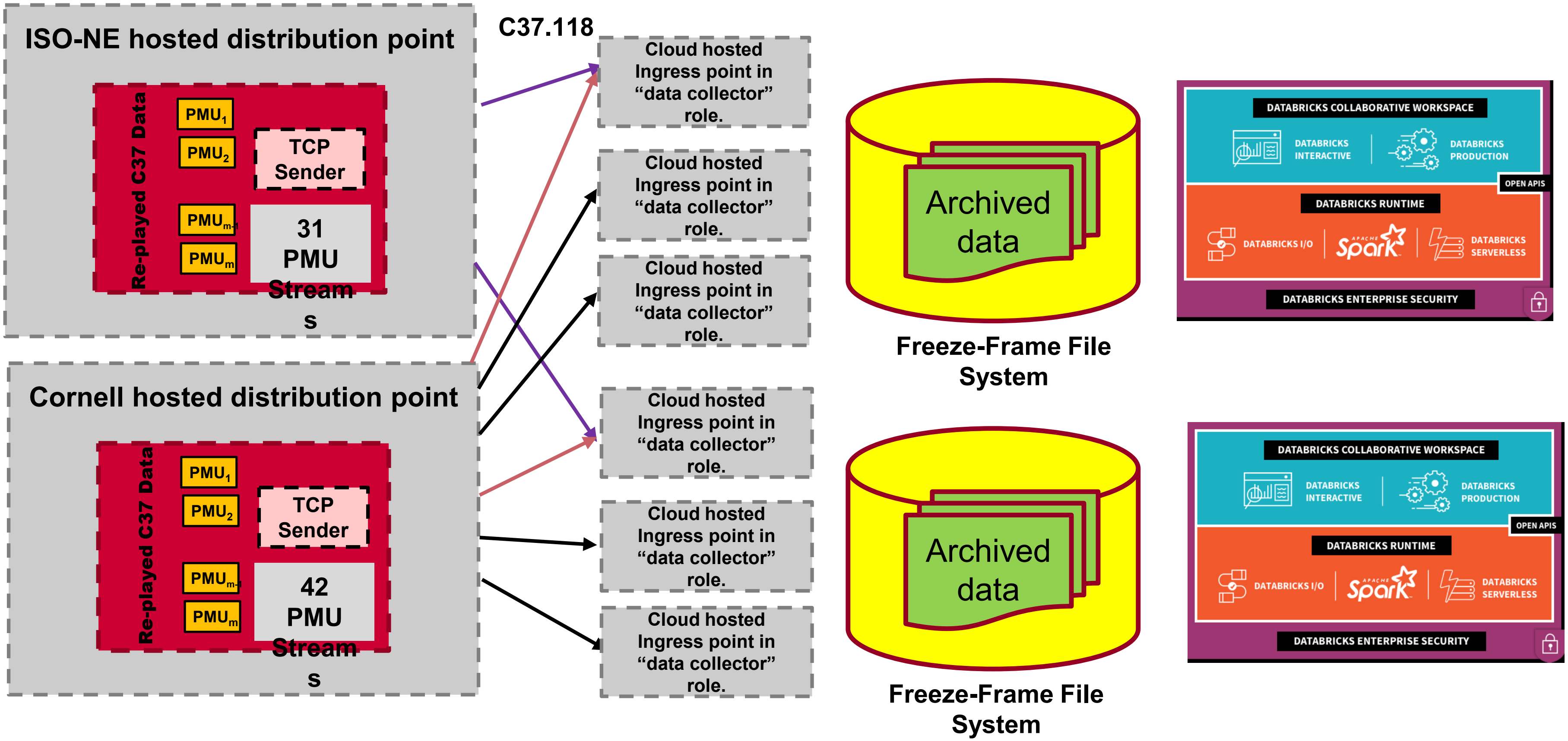
- Within one organization
  - Data movement between EMS, BMS, DMS, OMS, AMI, etc. is non-trivial
- Within one hierarchy
  - Several TOs to ISO
  - Several BAs to RC
- Laterally between neighbors
  - Bilateral agreements too many to be manageable
- Bandwidth, volume, latency

Standardization is the key

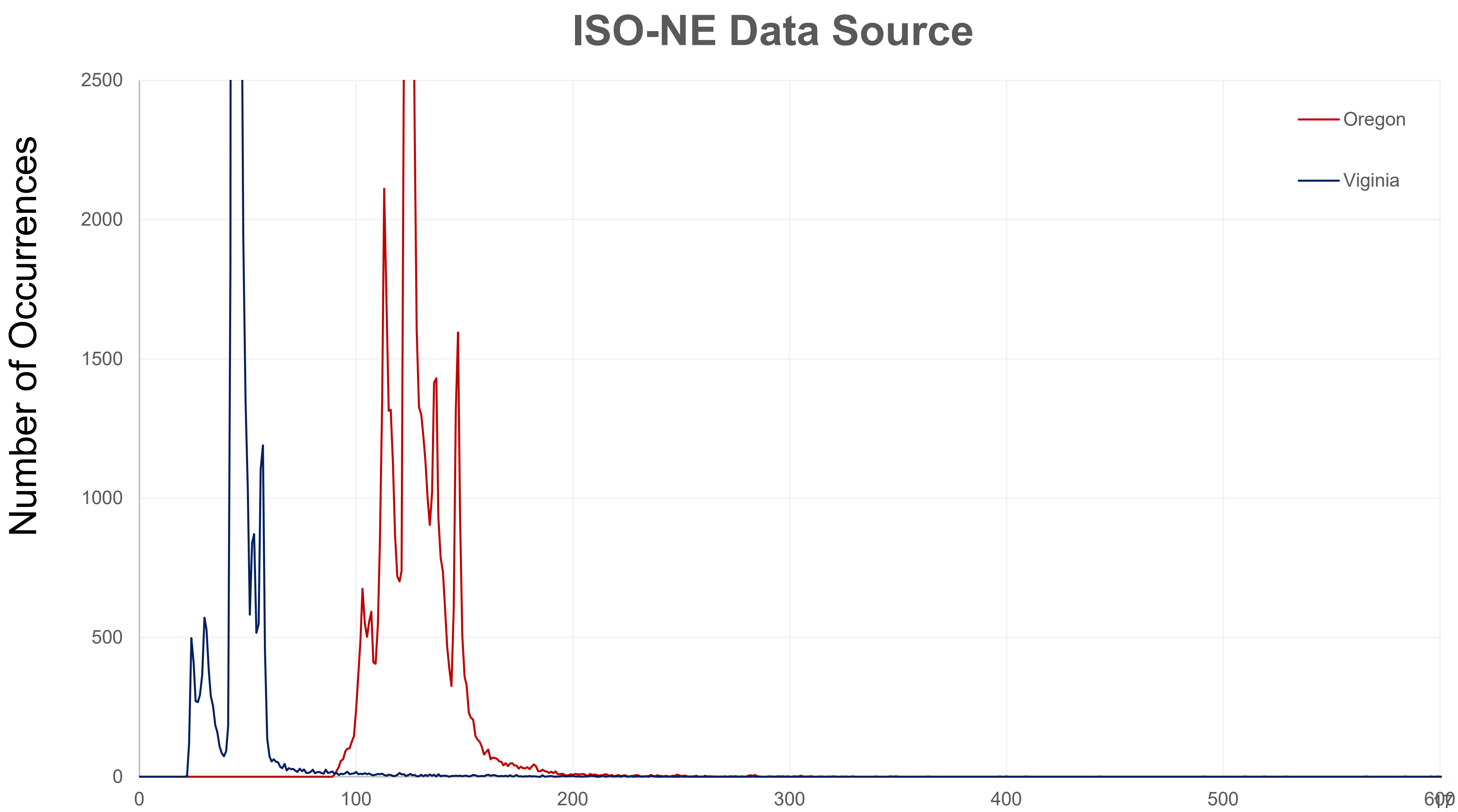
Networked Communications



Cloud WAMS Deployment: Data Archive + Analytics



Histogram: L3 Raw Data Round Trip Latencies



TSO-DSO Data Exchange

Today there is no EMS-DMS data exchange

- EMS and DMS get the same SCADA data from the substation step-down transformer
- There is voice communication between TSO-DSO

When large fraction of generation is on distribution

- More DMS data will be needed in the EMS
- Generation, storage, active loads, microgrids

Data exchange depends on generation mix

Data Base Issues

- **Real time data base must be distributed**
  - **Large amounts of calculated data must be part of this data base**
- **Static data base must be distributed**
- **Historical data base will require still another design**
- **Substation data bases and system level data bases have to be coordinated**
- **All data bases in the same interconnection will have to be coordinated**
- **Standards will be key (CIM – IEC61970)**

Applications

There are dozens of applications needed in the control centers for system operations

- New technologies promise new applications
- Some apps may be distributed (not centralized)
- Data must be stored/moved to support apps

Let us choose three apps to illustrate

- Volt-VAr control
- Power balance/frequency control
- Resiliency/restoration

Volt-VAr Control

- Voltage control requires controlling VAr resources
- VAr resources should be nearby

For Transmission Lines

- VAr sources at same sub (gens, shunts, trans)

For Distribution Feeders

- Main control at source sub
- Boost control with switch caps

If Distribution has gen, microgrid, active load

- More controllability but need coordination
- Transmission & Distribution can interchange VArs

Power Balance (AGC)

- Balancing Authority (BA) calculates ACE for Area
- BA EMS apportions ACE to trans owners (TO)
- Each TO EMS apportions their ACE to their gens

As higher fraction of generation becomes distributed to lower distribution voltages

- Those gen measures come to DMS
- The AGC signals have to be apportioned by DMS
- The DMS-EMS data exchange becomes crucial

Restoration

Restoration of customer service falls mainly on Distribution Operators

- Assessment of damage
- Availability of replacement inventory
- Crew dispatch

Resiliency will depend more on distributed generators/customers/microgrids

- Data availability and communications
- Imitate black start protocols

Control Centers

- The next generation of control centers will have a more flexible (decentralized) architecture
- The boundaries between various XMS functions (including protection and local controls) will fade
- The automatic coordination between entities that are interconnected will increase
- This will require large movement of data both hierarchically and laterally
- This cannot be done without wide adoption of standards across the interconnection

Large Data Applications

Historical Data (Measurement Data Only)

- **Data Science has many usable tools**
- **Identify measurement anomalies (model-free)**
- **Identify trends (loads, renewable generation, outages – equipment failures, control operations)**
- **Identify patterns (correlations between loads, solar, wind, maintenance, external events)**

Large Data Applications

Historical Data (Measurement + Model)

- Event analysis
- Identify measurement anomaly (SE bad data)
- Simulation management
- Planning scenario development
- Training scenario development
- Cross infrastructure analysis
- Controller design

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Model Validation using CIM Tool

Fig. Dashboard for the CIM-based Framework

- **Simulation**: The tool populates all the customers (~500) in the GridLAB-D model with appropriate AMI data from PI server.
- **Comparison**: Simulation results are compared with actual SCADA measurements for the corresponding day.
- **Deviation:** Mainly due to inconsistent AMI data
- **Functionality** : Facilitates emulating real-network scenarios

November 2020

December 2020

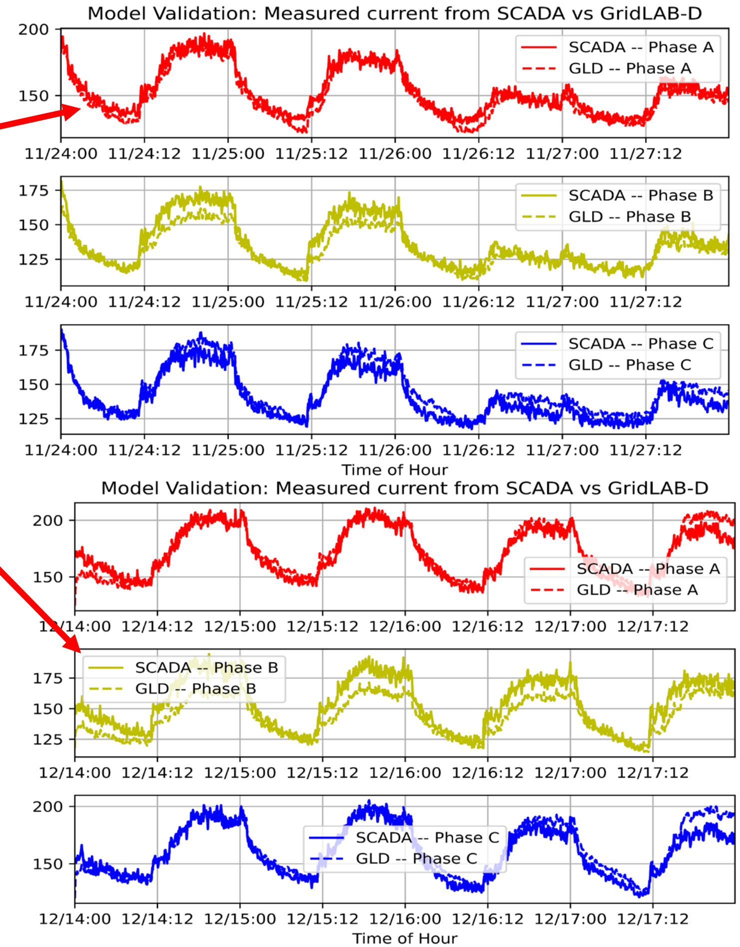

Fig. Model Validation: AMI populated GridLAB-D vs SCADA

Concluding Remarks

- Data science is the use of big data in NEW ways (NOT the use of existing power applications with bigger data)
- Are there uses of data that does not require physical models?
- Are there new applications that take advantage of both big data and physical models?
- Are there on-line applications that can use big data to help operators make decisions?