Advanced Analytics and Data for PMU Applications

Bill Blevins-ERCOT

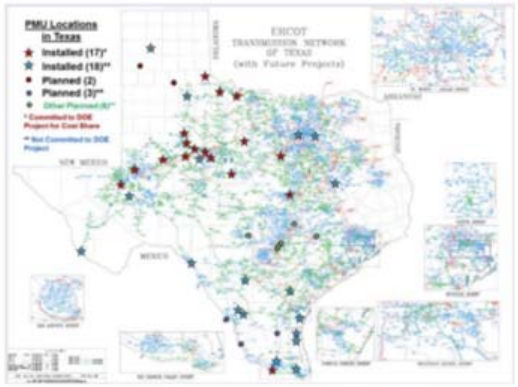
Prashant Palayam-Electric Power Group

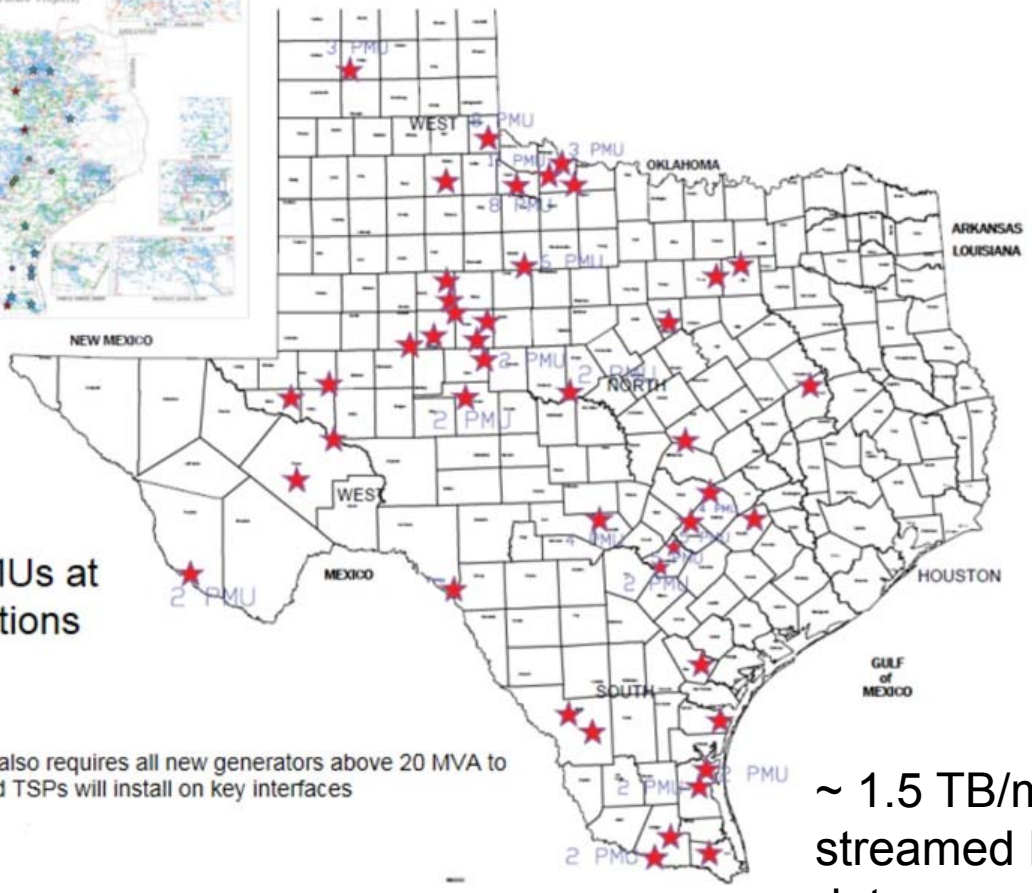
Initial PMU history

- Center for the Commercialization of Electric Technologies (CCET) initial PMU demonstration 3 PMUs in 2005
- 2010, CCET grant Department of Energy (DOE) under Award Number DE-OE-0000194 goal was to install PMUs at 13 additional locations.
- DOE project resulted in adding 76 PMUs at 35 locations.

Growth of PMU data within ERCOT

76 PMUs at
35 locations
2014





100 PMUs at
44 locations
2017

Jan 2017 Operating guides also requires all new generators above 20 MVA to install PMUs and as directed TSPs will install on key interfaces

~ 1.5 TB/month streamed PMU data

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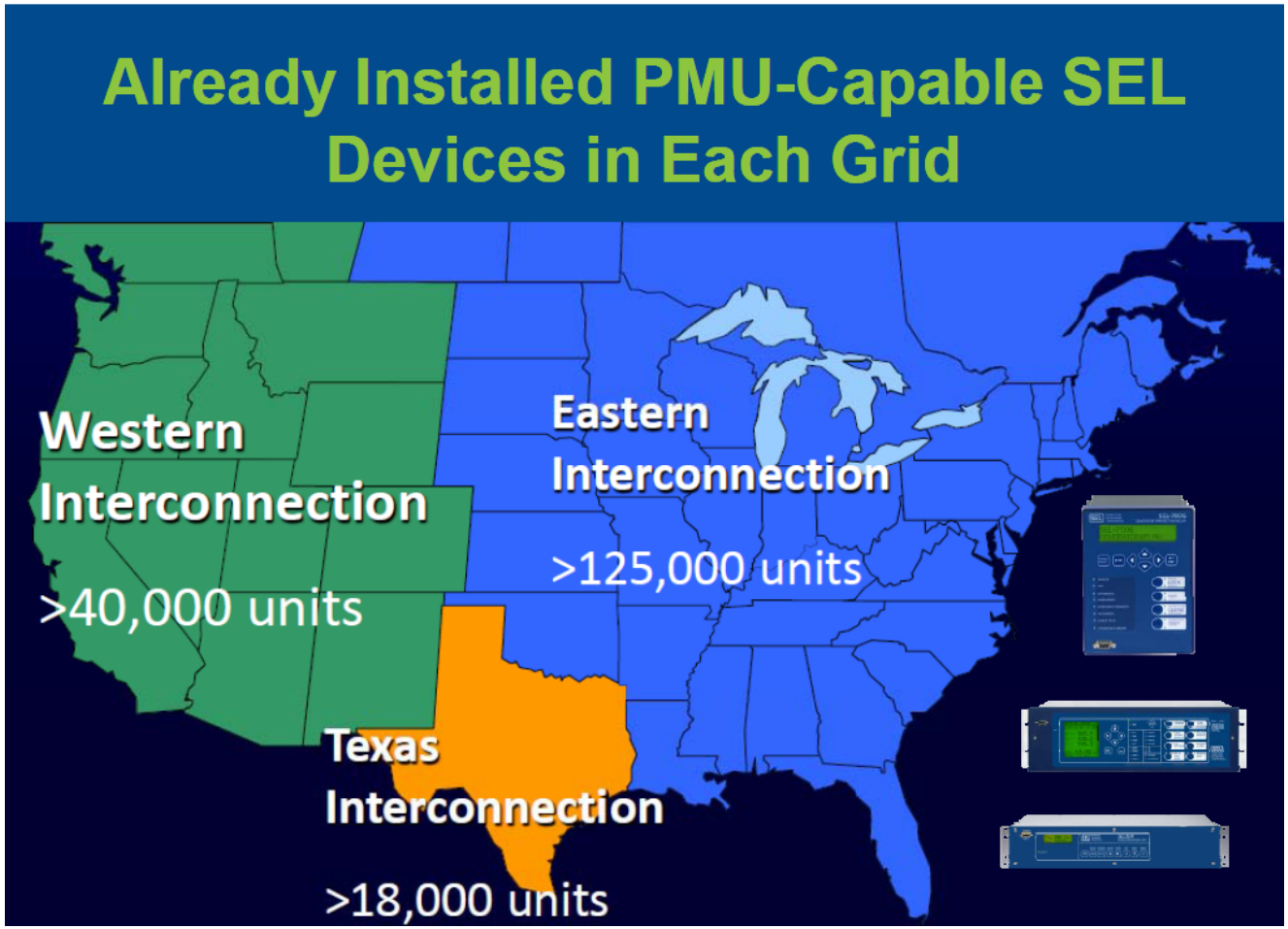
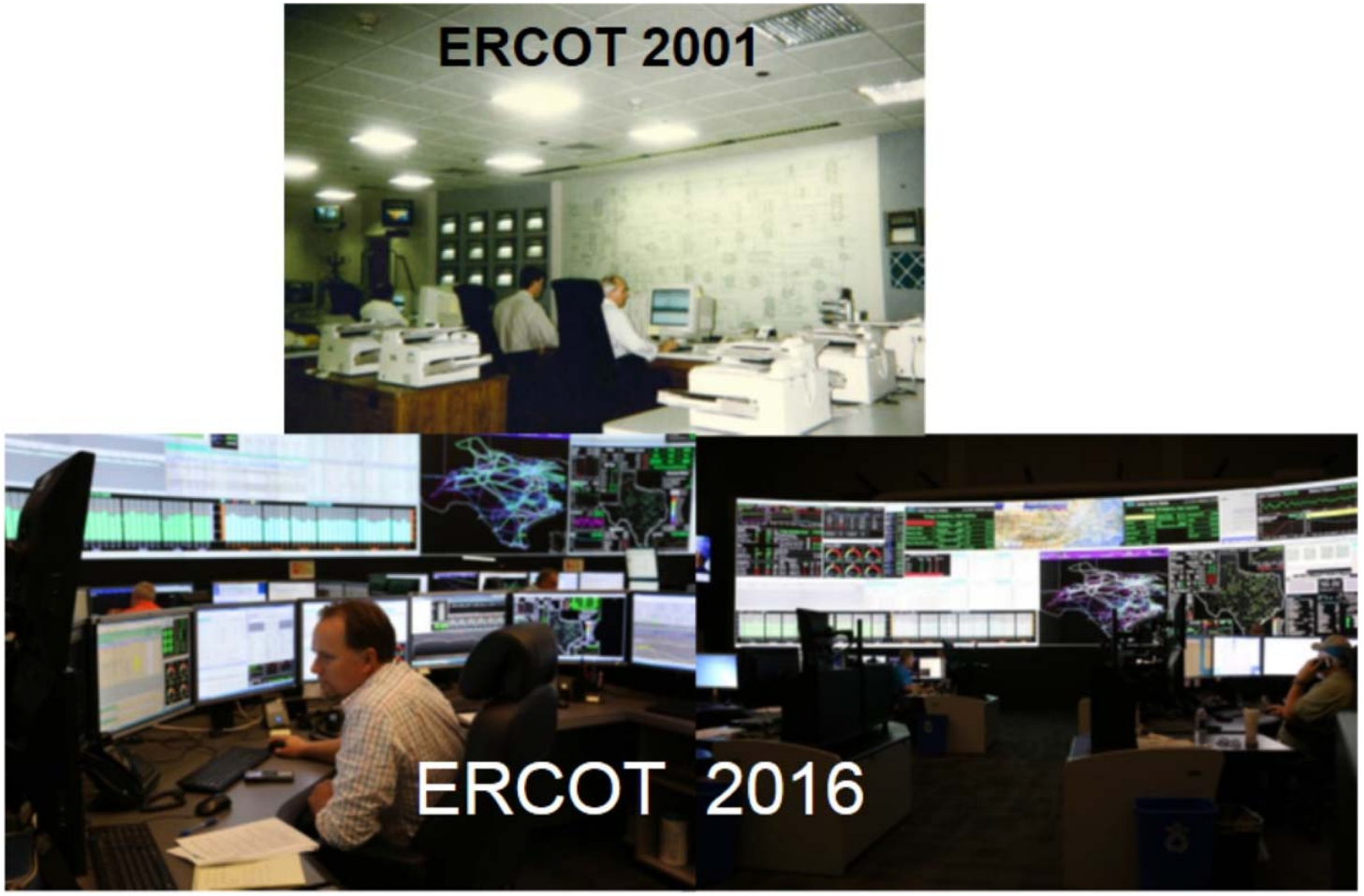
Potential PMU devices



Source: Synchrophasor Applications ERCOT STF Meeting Feb 5, 2014

Potential 7.5 Petabytes/Month in North America
Source: Big Data Best Practice Sean Patrick Murphy JSIS Salt Lake City May 23 2017.

ERCOT control room technology impacts



DOE Project lessons-PMU policies

- Phasor data repository design and implementation requirements and data archiving policies
- Data sharing policies (inside and outside ERCOT)
- Phasor data management policies (e.g. PMU naming convention, change management)
- PMU location selection principles and criteria
- PMU use cases
- Develop PMU rules for use cases

DOE Project lessons-PMU Best practices

- Validate data 2012-2014
  - Validated that all data received by ERCOT is faithfully archived in the appropriate phasor data base.
  - Developed phasor data performance standards .
  - Baselining study compared PMU data and SE data.
  - Cluster Analysis between PMUs which are electrically near and respond similarly.
  - Observe system changes during large CREZ buildout.

DOE Project-PMU Analytics

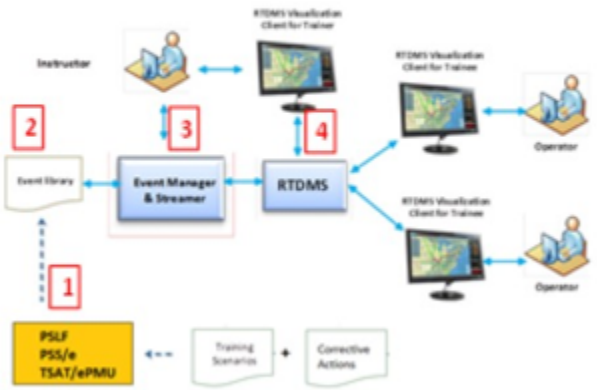
- Performed post-event analysis and forensics on grid events and disturbances
- Assessed low voltage ride through performance of wind generation
- Assessed the impact of wind generation on system inertial and governor frequency response
- Detected, monitored and analyzed power system oscillations and the interaction of wind generation
- Implemented a means of validating model-based predictions of generator response to disturbances

Operational Lessons learned

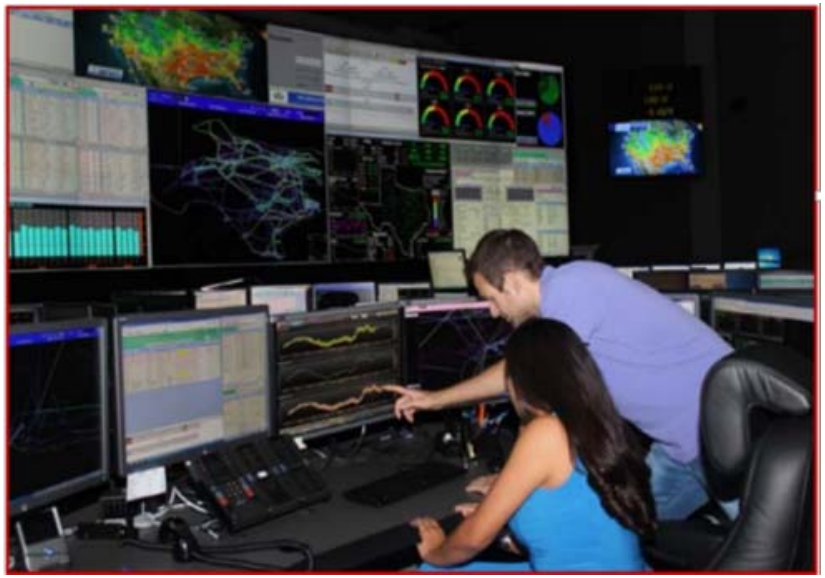
- Develop Real-time PMU systems that process PMU data.
- Systems should handle analytics for operators.
- Alarms and visualizations need to reduce the data into actionable information.

Phasor Simulator for Operator Training (PSOT)

Event Library Approach



1. Using Off-line Simulations Tools
2. Event Library = Simulated + Recorded events
3. Event Streamer & Manager to replay events in library to RTDMS
4. Visualization Tool – RTDMS



PSOT Simulator

Staff need training tools to become familiar and adopt PMU tools.
These tools need to be trained on along side the other operational tools.

PHASOR RTDMS®

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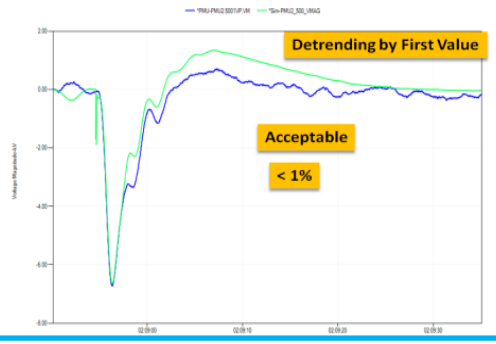
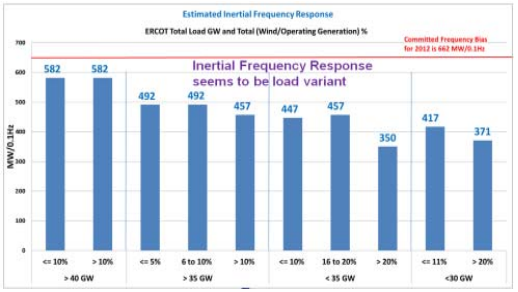
Offline data Analytics

Oscillation Analysis – Mode, Damping and Energy

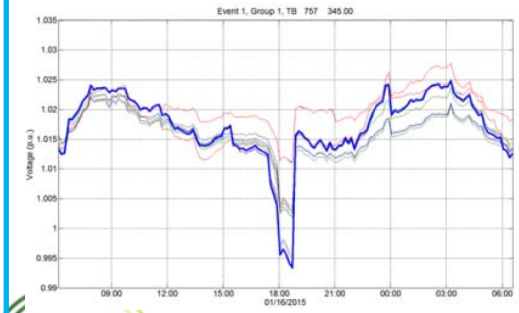
System Level Model Validation – NERC MOD-033-1



Impact of Renewables on Frequency Response – MW/0.1Hz Unit Trip Events

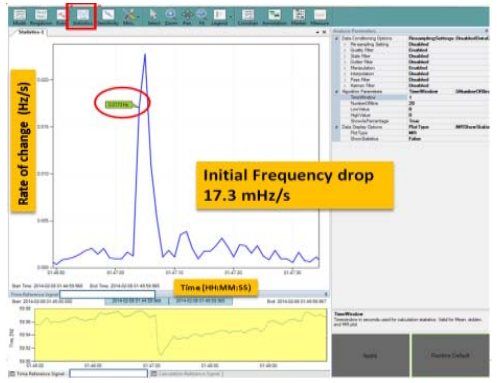


Cluster Analysis of Reactive Zones



Phasor Grid Dynamics Analyzer™

Identify Alarm Parameters



Future Analytics – Event Mining

Oscillation Events by Location, Severity, Mode & Duration

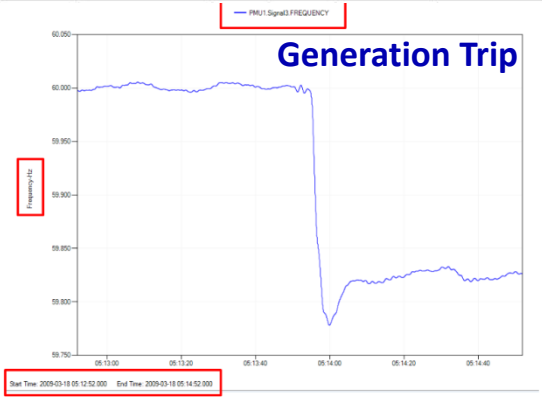
6	50	2	5	4 Days, 5 Hrs, 40 Min		15 (~0.1Hz)	Count of Events = 10
Signal Type	Location	Event Year	Event Month	Event Start Date, HH:MM, TZ	Event End Date, HH:MM, TZ	Average Oscillatory Frequency (Hz)	Maximum Peak-to-Peak Magnitude
MW	Signal Name 1	2009	12	18, 16:32, UTC-7:00	18, 17:32, UTC-7:00	3.33	15 MW
MW	Signal Name 1	2010	1	05, 02:32, UTC-7:00	05, 02:50, UTC-7:00	3.33	10 MW
MW	Signal Name 2	2009	6	05, 02:32, UTC-7:00	05, 02:50, UTC-7:00	0.74	6 MW
VM	Signal Name 5	2009	8	05, 02:32, UTC-7:00	05, 02:50, UTC-7:00	1.58	3 kV

Poor and Negatively Damped Contingencies

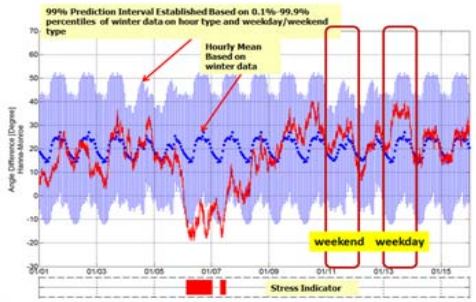
File Name	Signal Name	Signal Type	Oscillatory Frequency (Hz)	Damping Ratio (%)
345kV C1	POWR2[unit20.6900]W1	MW	1.46	2
345kV C1	POWR1[unit1 18.000]N1	MW	1.04	0
345kV C2	POWR1[unit1 18.000]N1	MW	0.73	11
345kV C3	POWR1[unit1 18.000]N1	MW	0.08	11
345kV C1	VOLT [unit1 18.000]N1	VM	3.06	3
345kV C1	FREQ [unit1 18.000]N1	FREQ	2.00	-2

Frequency Events by Location, Severity, Timing & Count

Event #	Location	Event Year	Event Month	Event Date, HH:MM, UTC-7:00	**Frequency declined to (Hz)
Event 1	Signal Name 1	2009	3	18, 16:32	59.78
Event 2	Signal Name 5	2009	5	1, 5:10	59.85
+ Event 3	Signal Name 6	2009	8	5, 8:14	59.6
+ Event 4	Signal Name 10	2009	10	25, 22:10	59.75

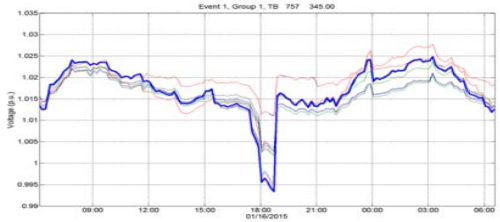


Wide Area Angle Events by Location, Timing, Count, Severity



Automatic
Event
Miner

Voltage Events by TOP, Severity, Duration, Count



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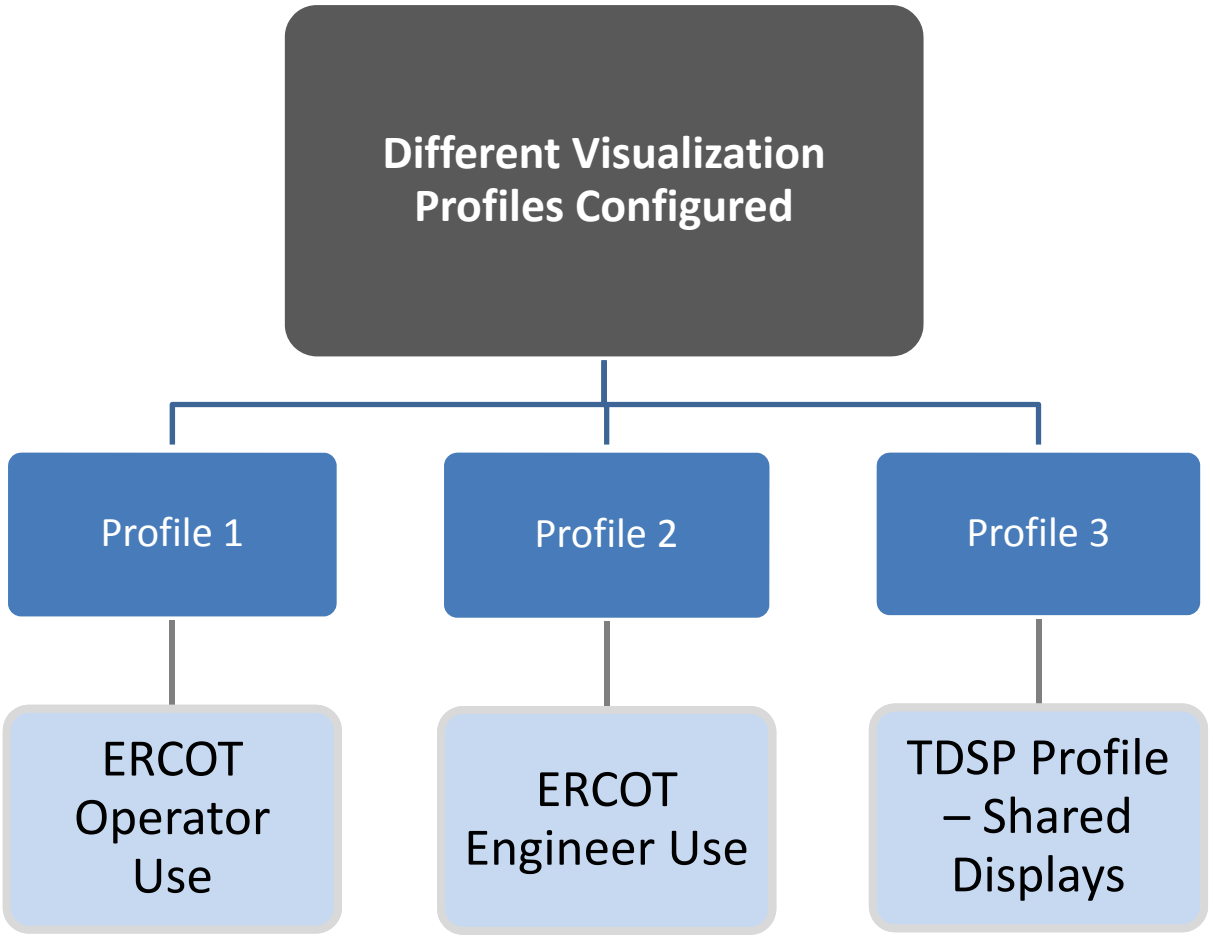
Sharing Profile/Display with TDSP



Cloud Solution for Data Sharing

- Sharing Profile/Display with TDSP
- Generator and TDSP Operator Training