
DOMINION ENERGY'S PILOT DEPLOYMENT AND EVALUATION OF ENHANCED LINEAR STATE ESTIMATOR FOR GRID RESILIENCY

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TODAY'S AGENDA

- eLSE at Dominion Energy
 - Project goals
 - Timeline
 - Key activities
- Visualization and system operation
- Summary & Next Steps
- Q&A





LINEAR STATE ESTIMATION DEPLOYMENT

PROJECT GOALS, HIGHLIGHTS, AND ACTIVITIES



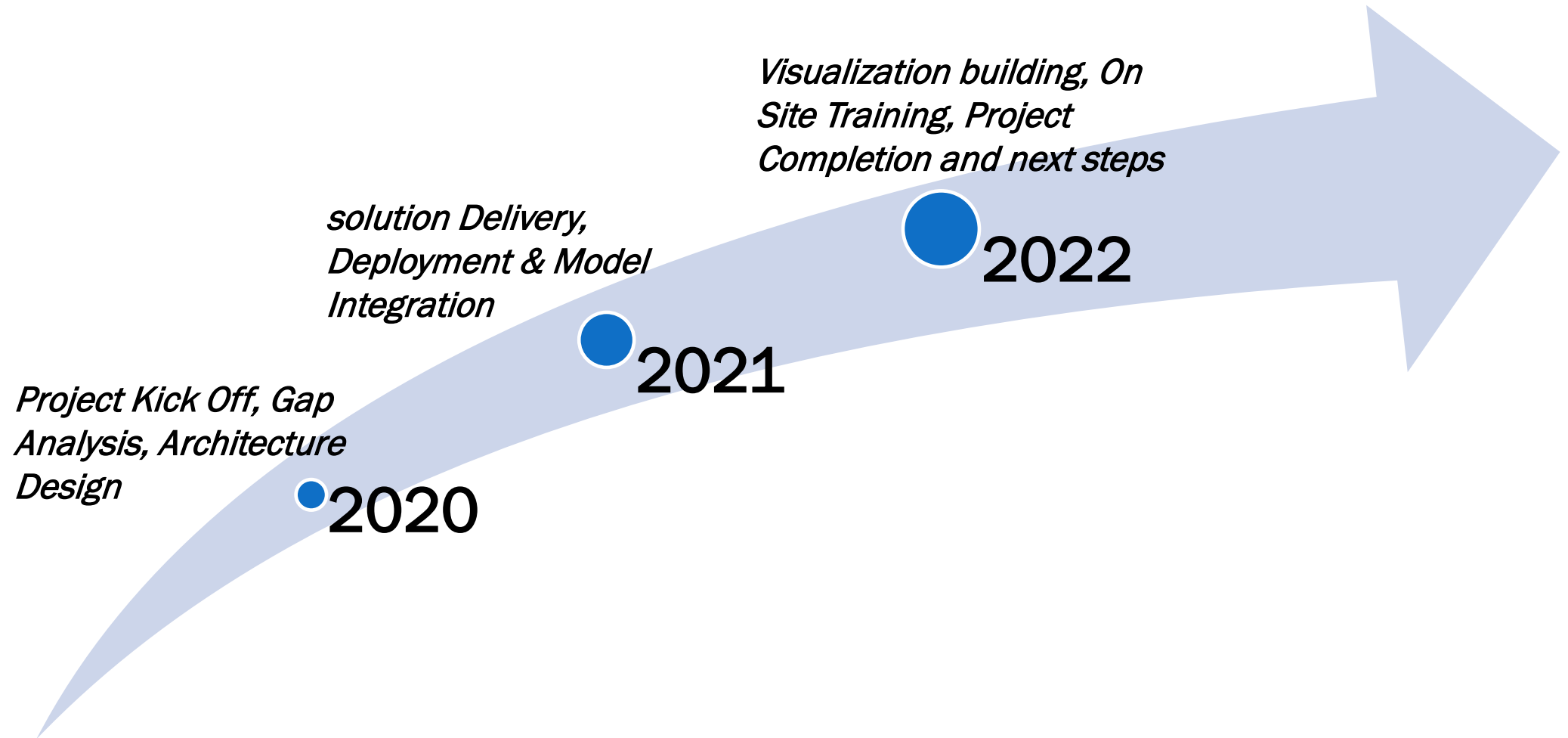
DOMINION'S SYNCHROPHASOR PILOT PROJECT GOALS

- Dominion's primary goal is to deploy LSE to address the following:
 - Detect and Identify bad [PMU data quality](#) measurements
 - [Isolate bad measurements](#) affecting real-time applications
 - Substitute poor quality and unavailable measurements with [model-based estimations](#)
 - Independent platform to serve as a [back-up platform to EMS/SE](#)
- In addition, Dominion deployed additional synchrophasor solutions to provide:
 - Real-Time Phase Angle Monitoring
 - System Frequency Response monitoring

PROJECT HIGHLIGHTS

Uses protective relays to stream PMU data	Positive Sequence Data from 128 PMUs
cover the 500kV transmission system	Data collected from 29 substations
Observability increased with LSE	Observability increased to 42 substations (out of 44)
System is fully independent from EMS/SCADA	Breakers and other digitals are directly available from PMUs
Incorporated zero-injection pseudo measurements	Dynamically evaluates candidate buses for pseudo measurements placement

PROJECT TIMELINE AND PROGRESS



DATA AND MODELS PROVIDED BY DOMINION

- Models used to commission the LSE
 - CIM Network Model
 - One Line Diagrams in Dominion's EMS format
- Data provided by Dominion for commissioning and testing
 - PMU Data from the Dominion's PDC
 - Signals included are Voltage Phasors, Current Phasors, Digitals for breaker/switch statuses, Frequency, DFDT, Status Flags
 - Mapping information to link synchrophasor measurements to CIM model

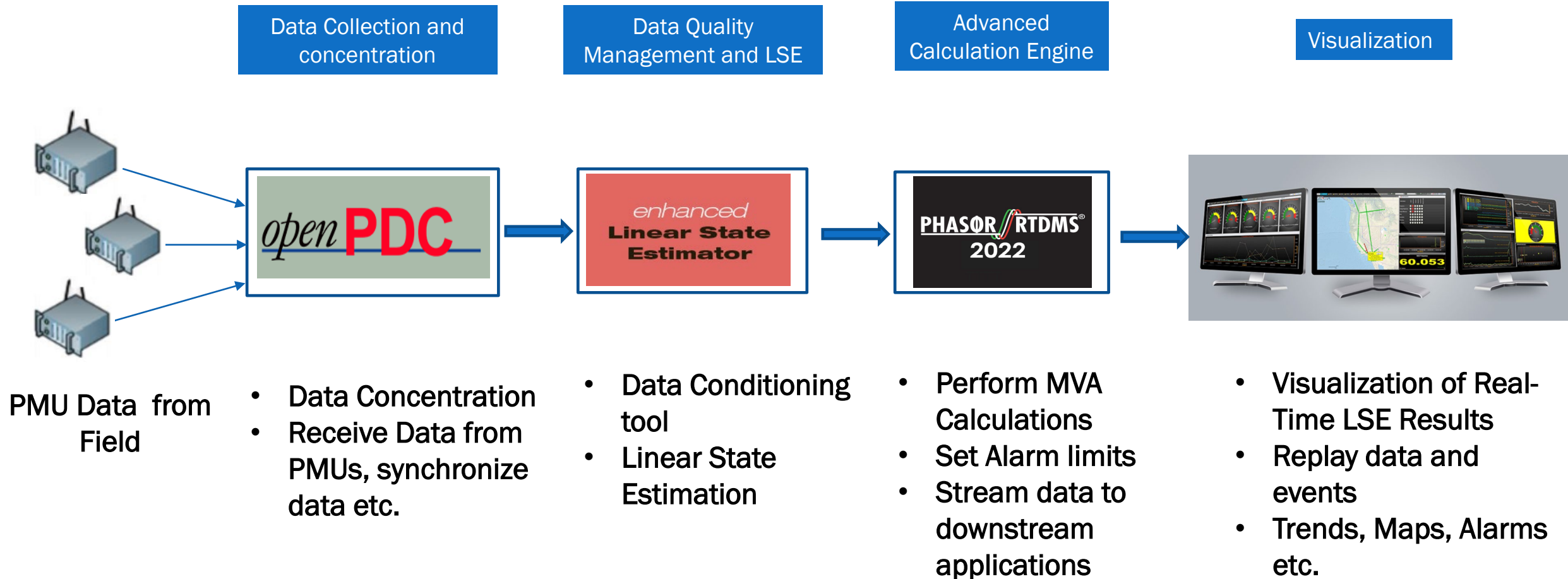
ACTIVITIES TO DATE

- CIM Model Integration
 - ✓ Integrated with Dominion's CIM Network model format to support LSE
 - ✓ Mapped PMU Measurements to CIM

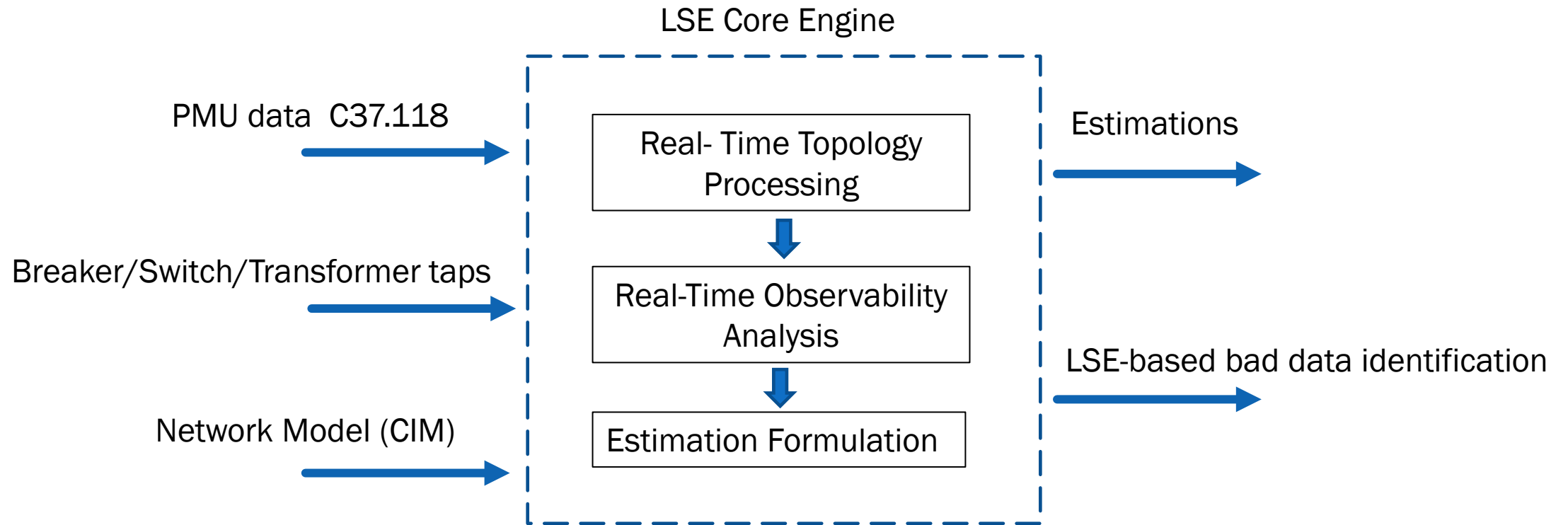
- Testing and Validation
 - ✓ Commissioned hardware for LSE Deployment at EPG's Lab
 - ✓ Deployed the eLSE using played-back measurements from Dominion's synchrophasor system

- Deployment and Commissioning
 - ✓ Commissioned LSE Platform at Dominion Energy
 - ✓ Working grade LSE now running at Dominion with live data stream
 - ✓ Developed visualization screens with focus on transmission system on geo-spatial maps
 - ✓ Identified bad data issues in Dominion's synchrophasor stream

ELSE PLATFORM AT DOMINION



LINEAR STATE ESTIMATION ARCHITECTURE



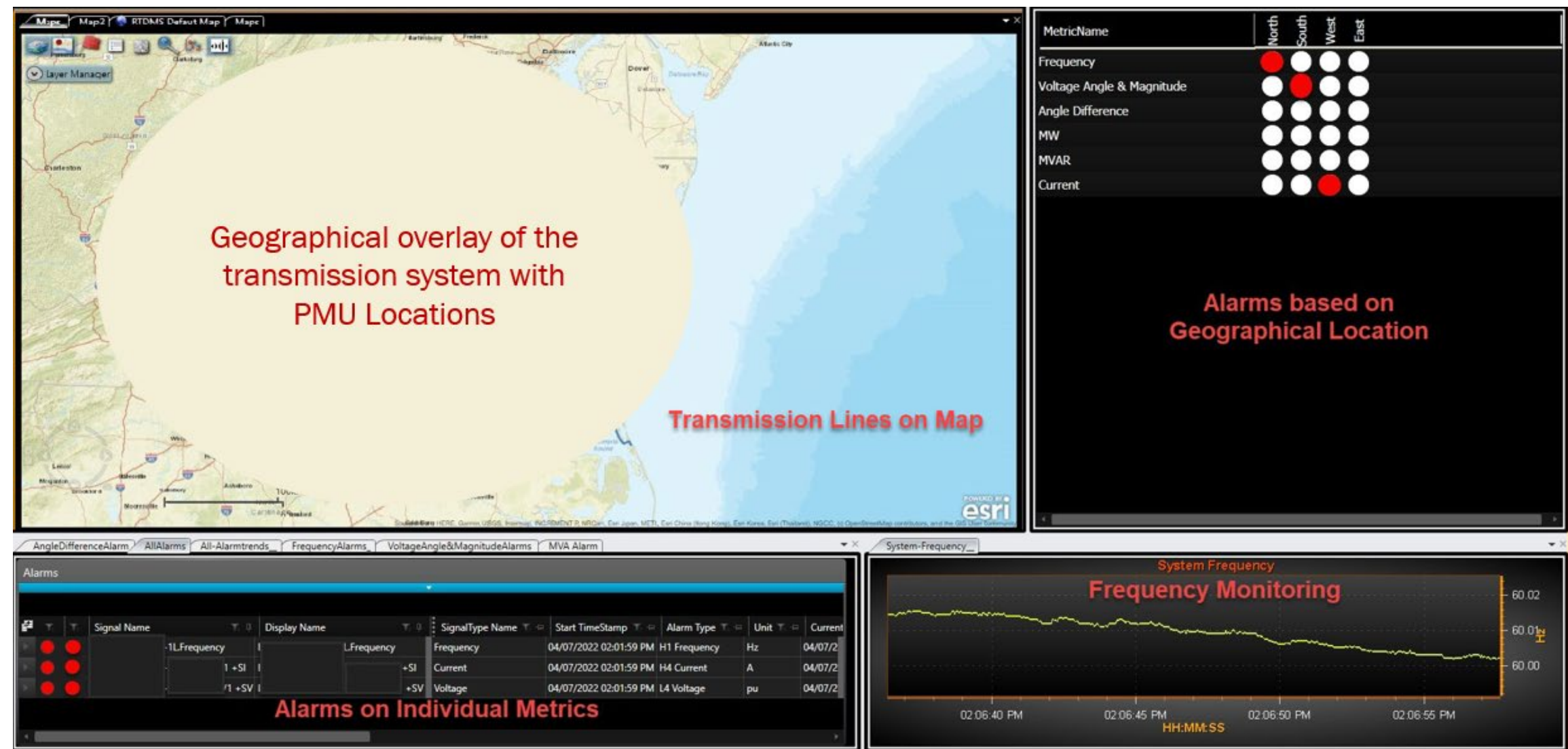
LSE Platform includes: Data quality and model management + Visualization



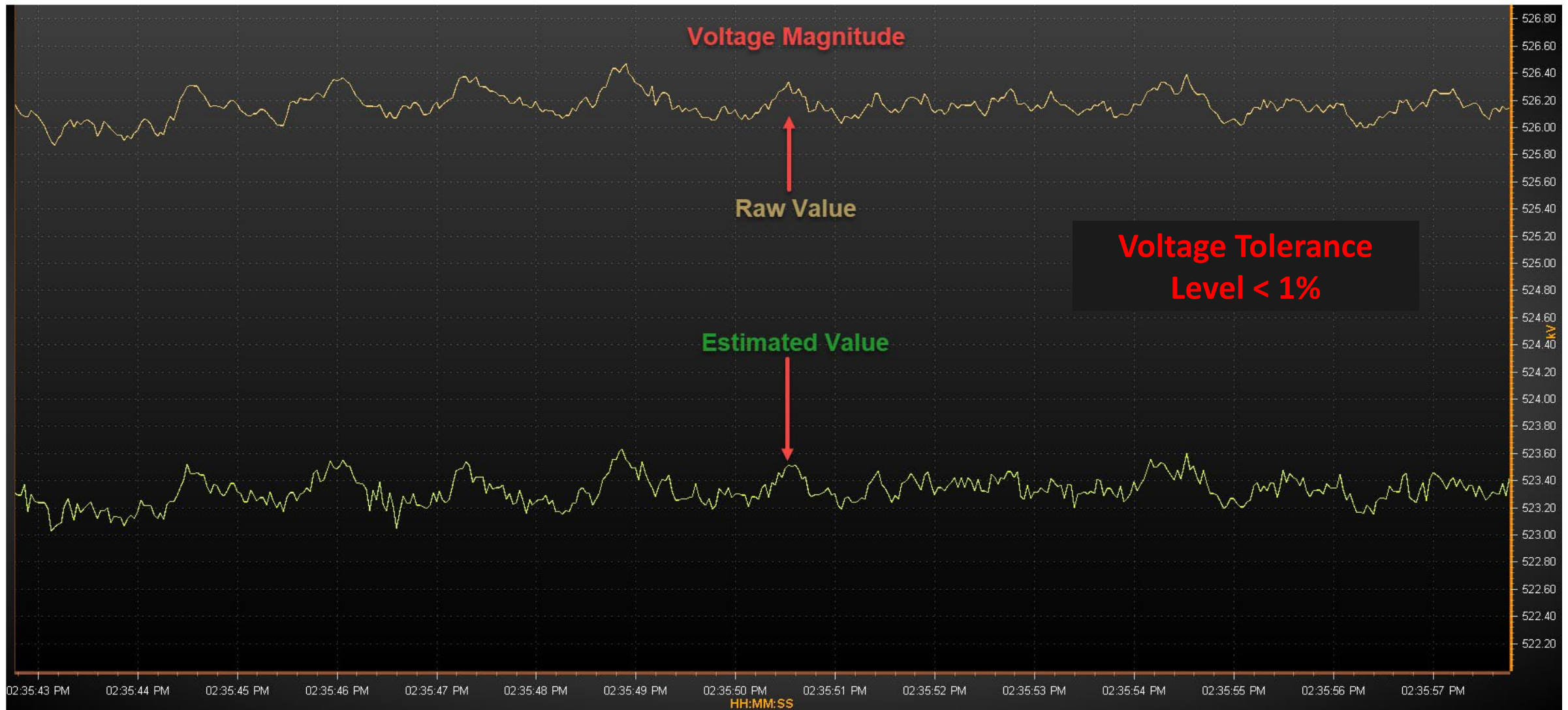
VISUALIZATION AND SYSTEM OPERATION

OPERATOR DISPLAYS

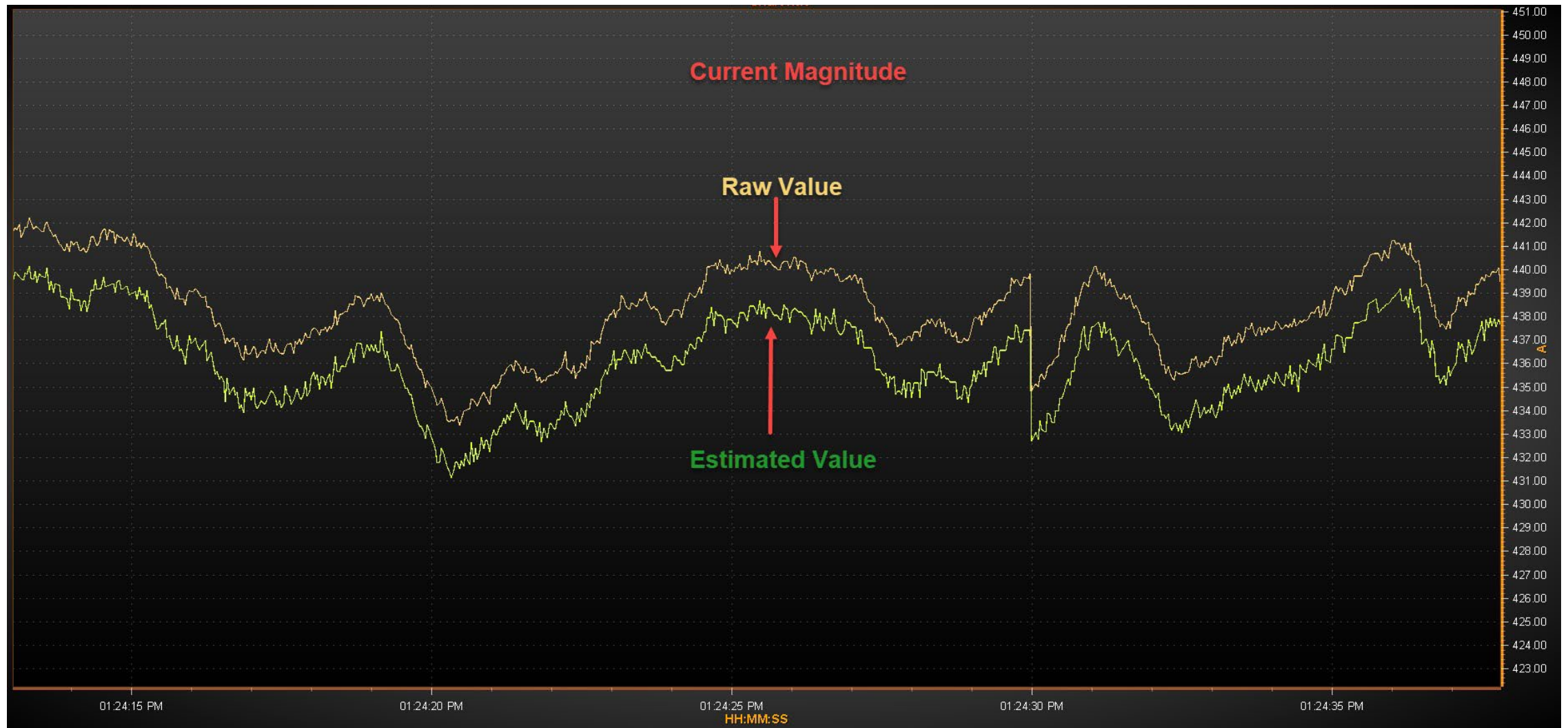
SYSTEM MONITORING WITH ALARMS AT DOMINION ENERGY



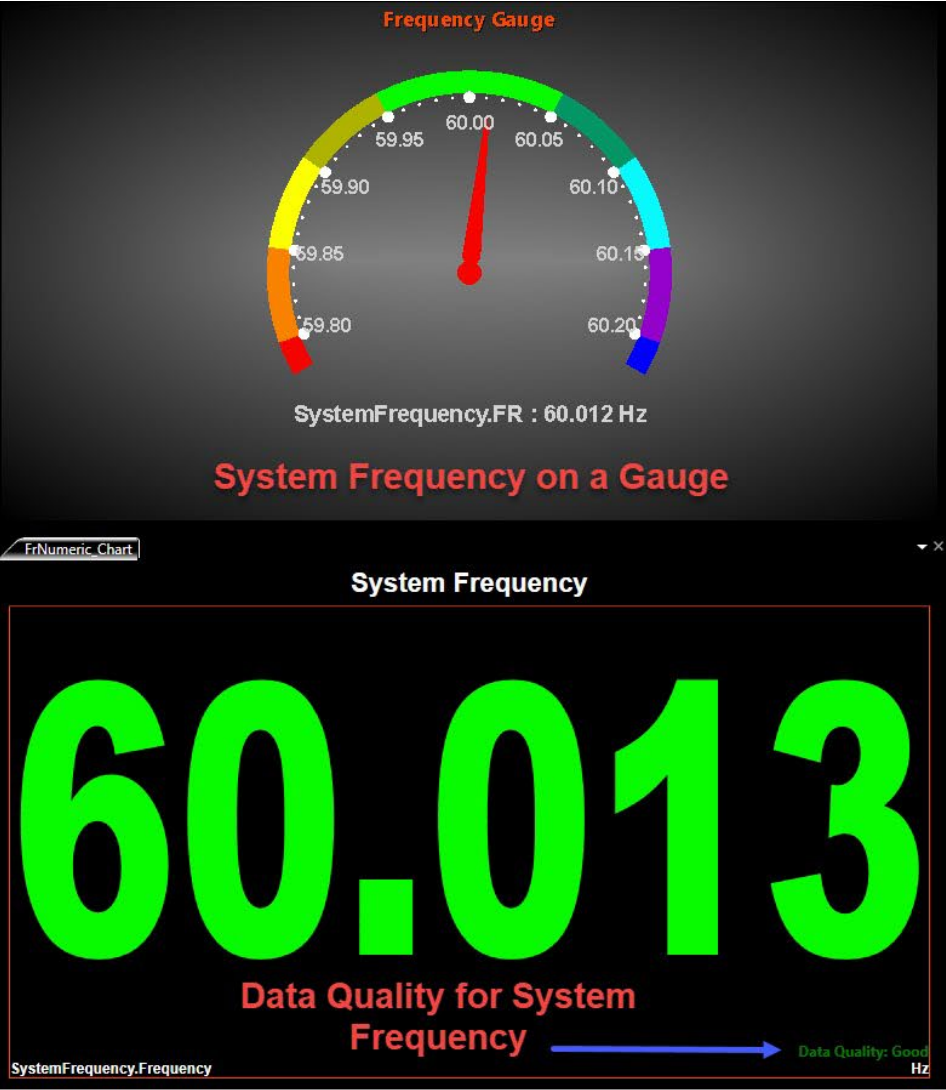
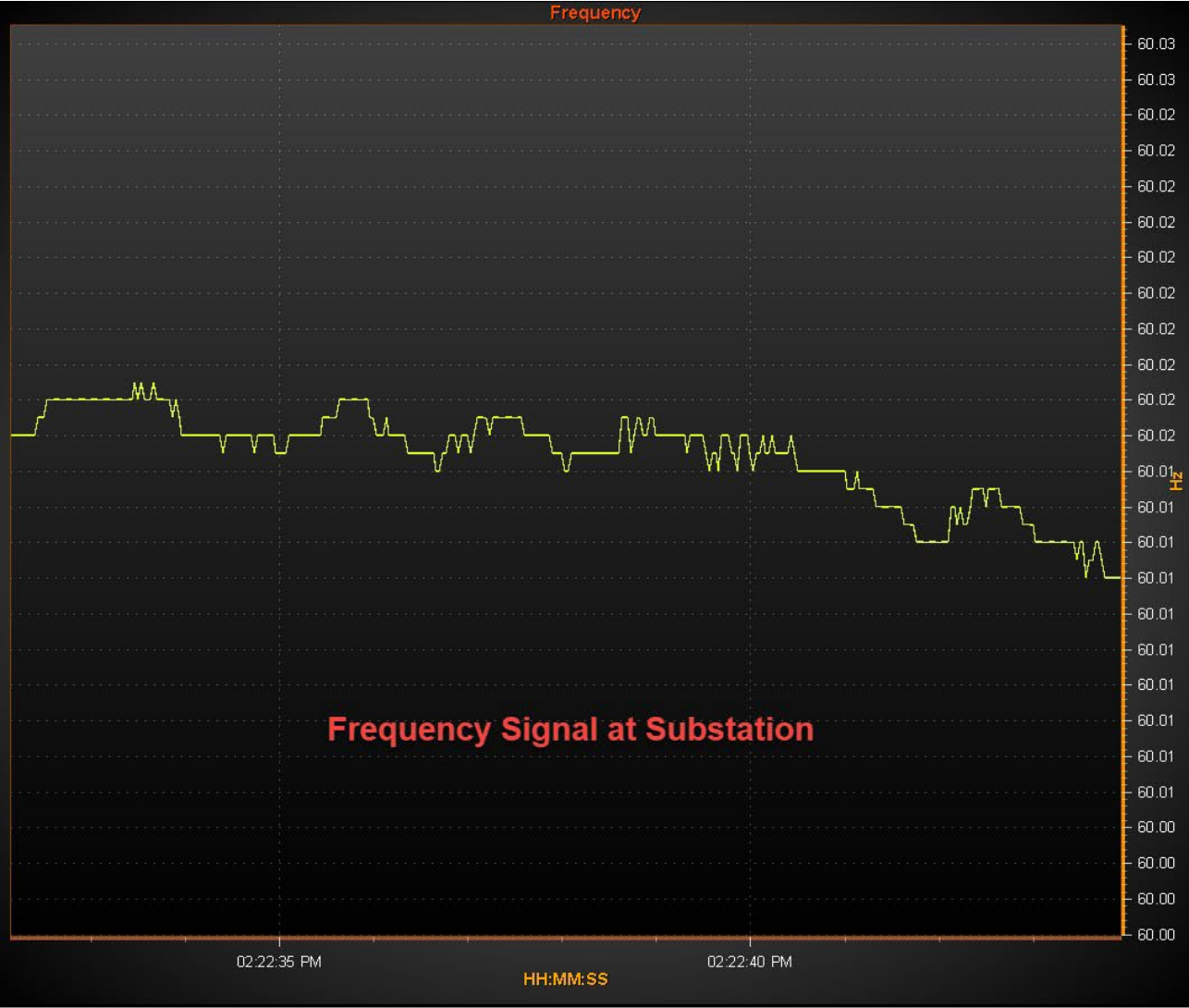
LSE ESTIMATIONS – VOLTAGE MAGNITUDE AT 500 KV SUBSTATION



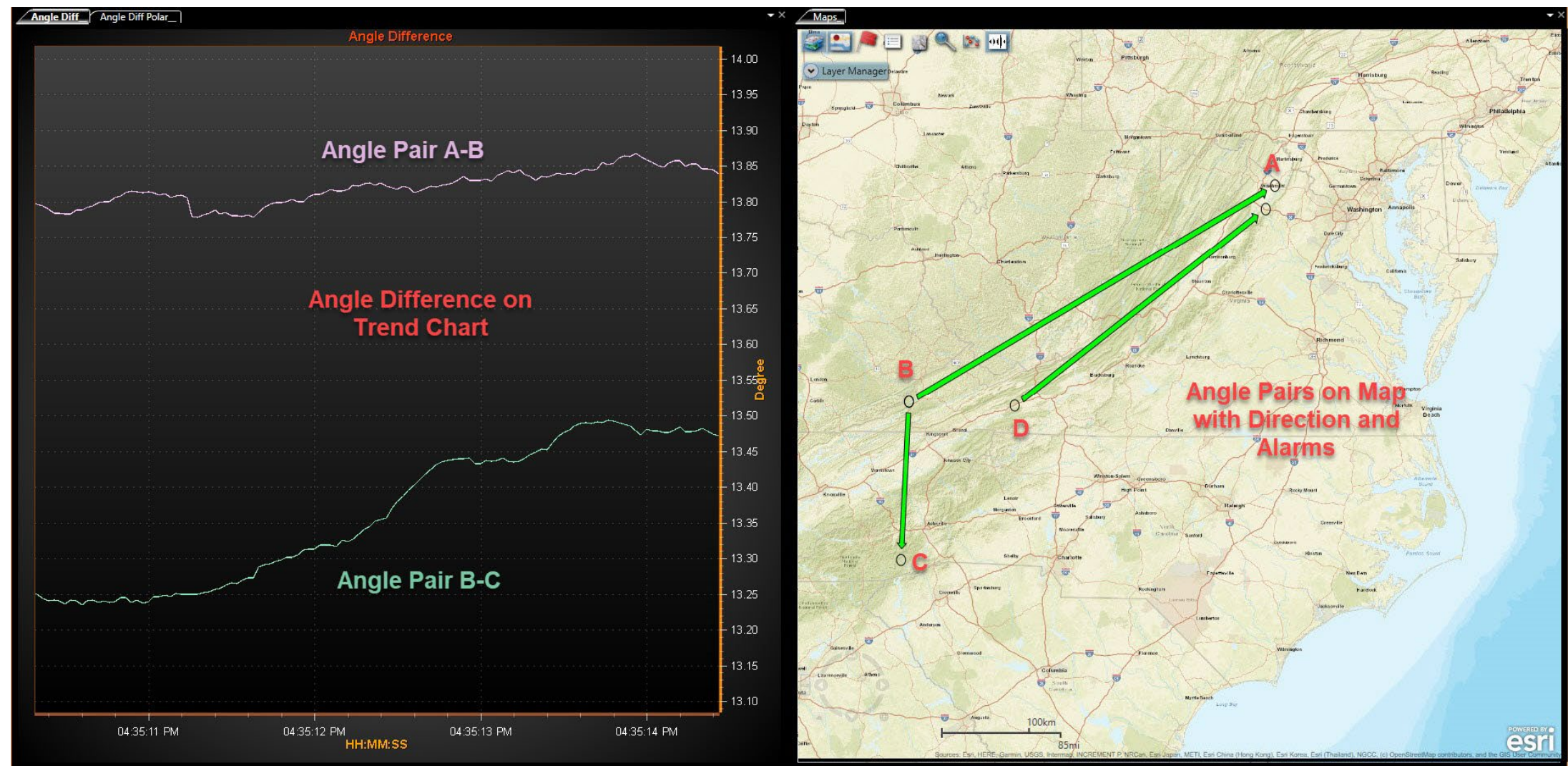
LSE ESTIMATIONS – CURRENT MAGNITUDE AT 500 KV SUBSTATION



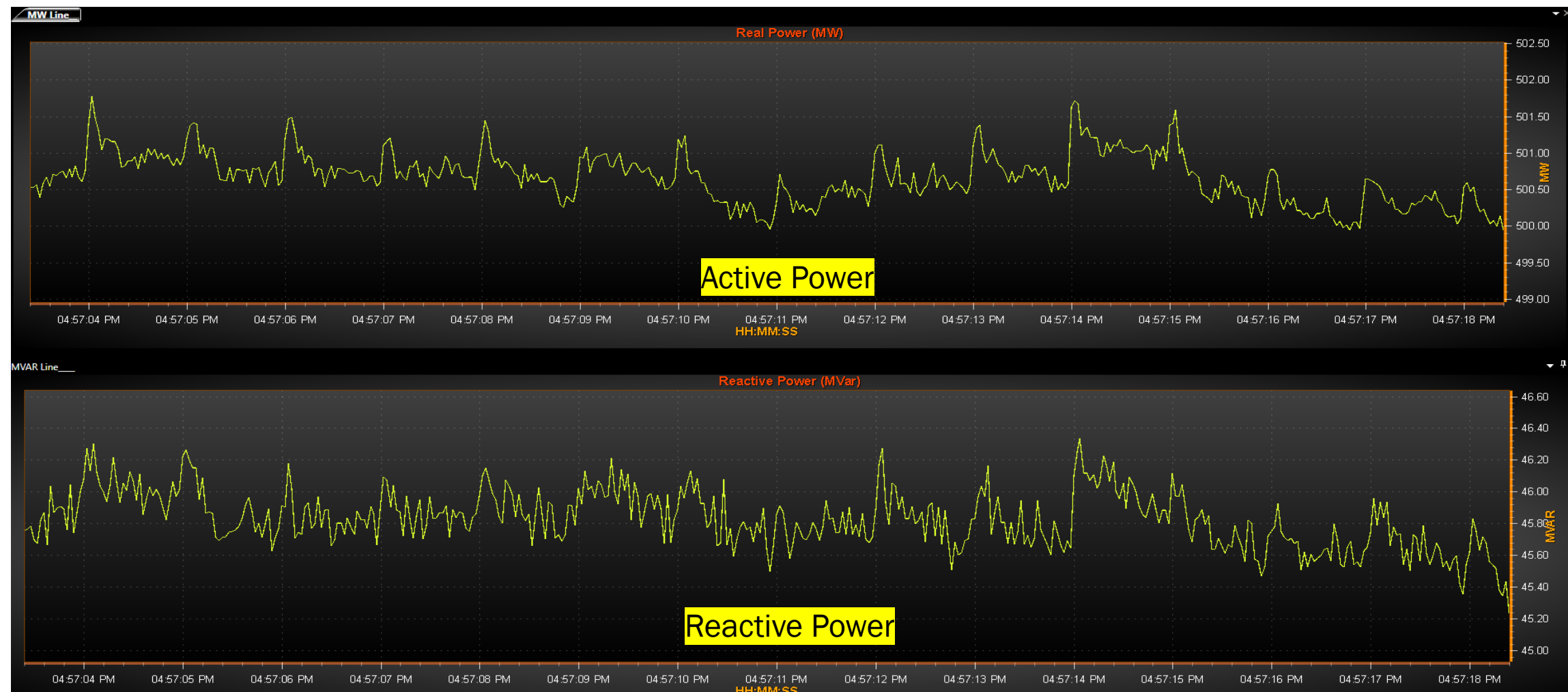
FREQUENCY MONITORING AT DOMINION ENERGY



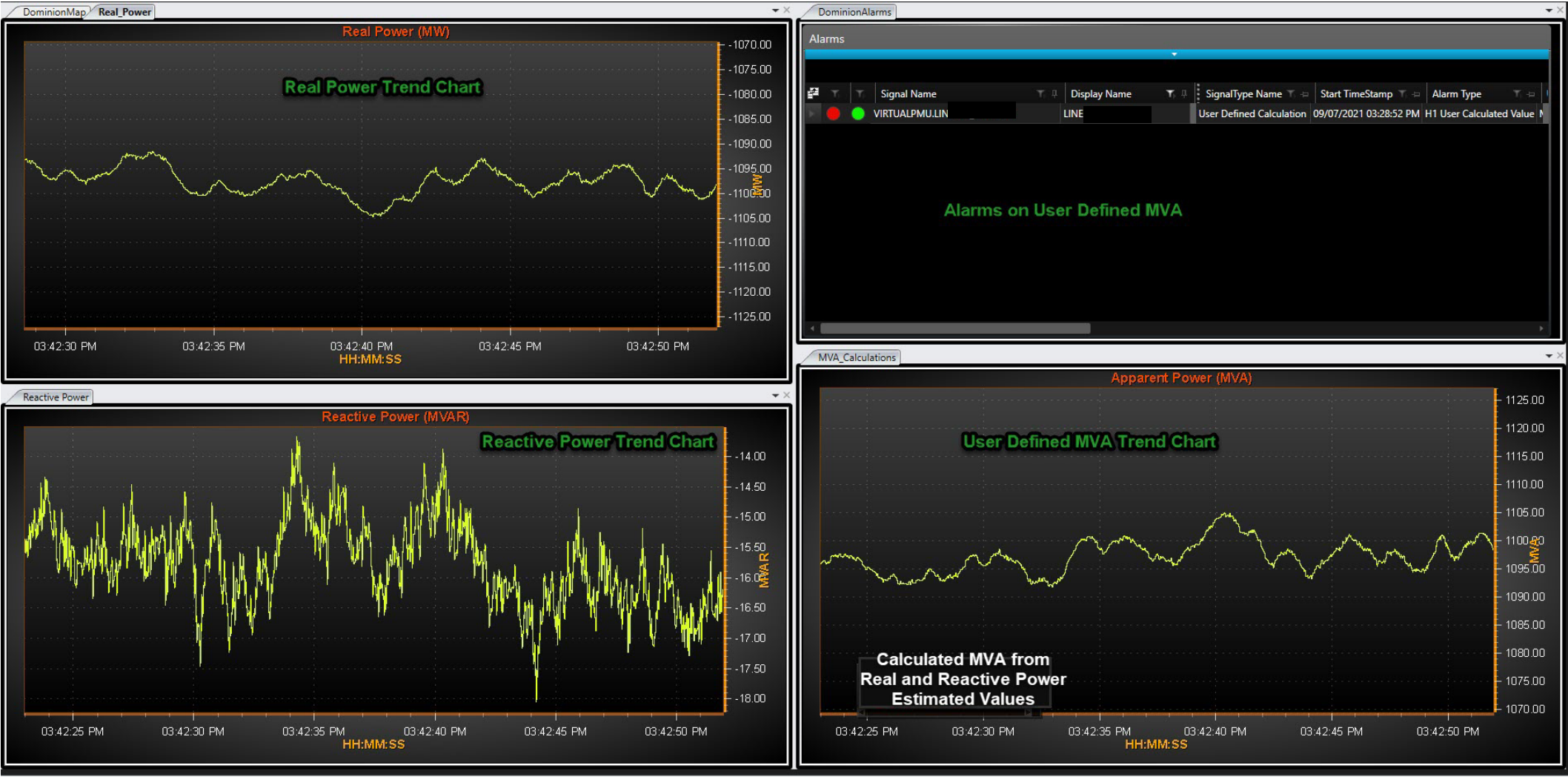
PHASE ANGLE MONITORING AT DOMINION ENERGY



LSE CALCULATIONS – POWER FLOW

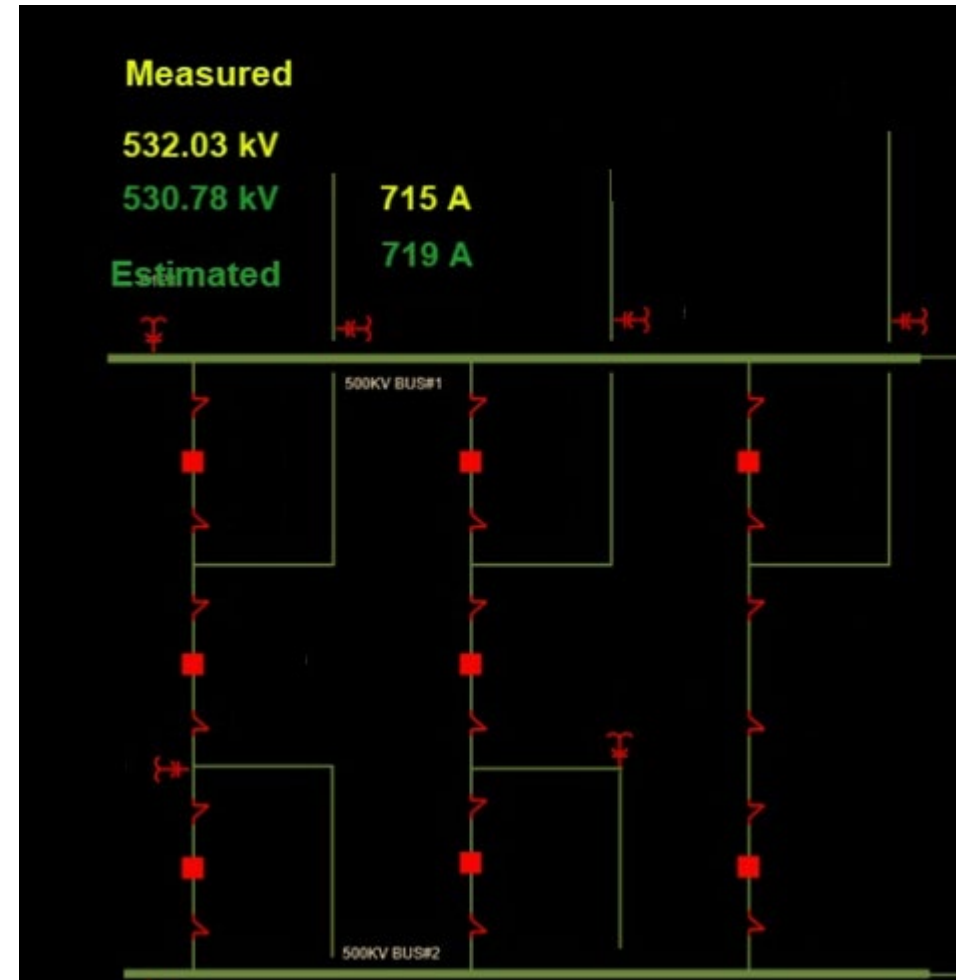


CALCULATED MVA FROM ESTIMATED REAL AND REACTIVE POWER



SUBSTATION DIAGRAMS – AUTO-CONVERSION

- Color-coded visualization of PMU data side-by-side with eLSE estimations
- Ability to display measurements from PMU.
(voltages, currents, phase angles, power, etc.)
- Ability to display digital values
(breaker status, switches, etc.)
- Ability to change element properties based on
Signal Values



LSE PERFORMANCE REPORTS

- Real Time Information about the following metrics:
 - Model Summary – Number of Observable Islands, Observable Buses, Branches, Breakers, Switches etc
 - Island Observability – Substations in each island at specific voltage level with measured or estimated observability
 - Island Signals- Signals in each island with substation name and Node/Line name
 - Breaker Status Change – Track Breaker Status changes in real-time
 - Measurement Status Change – Report any status changes in each measurements

Model Summary												
Island Observability		Island Signals		Breaker Status Changes		Measurement Status Changes						
	Observable Islands	Observable Buses	Branches	Breakers	Switches	Nodes	Line Segments	Series Compensators	Shunt Compensators	Transformers	Transmission Lines	Mapped PMU Signals
1	Island A	41	49	261	480	727	49	0	11	0	49	176
2	Island B	1	0	4	4	9	0	0	0	0	0	1



SUMMARY & NEXT STEPS



ELSE DEPLOYMENT AT DOMINION SUMMARY

- EPG's eLSE have been successfully installed and commissioned at Dominion Energy
- Application has detected and identified bad quality PMU measurements
- Observability of substations have increased from 29 to 42 substations
- MVA values for individual lines have been calculated from estimated real and reactive power values and proper alarm thresholds are established
- Frequency and Phase angle monitoring have been configured
- LSE Performance Reports have been commissioned to better assess the model summary
- Zero Bus Injections have been properly mapped in the model and commissioned
- System overview diagrams representing the 500kV have been commissioned
- Substation level One Line Diagrams are being deployed with proper mapping of measured and estimated values

PILOT NEXT STEPS

- **The following items remain open and to be completed:**
 - Integrate breaker statuses from PMU measurements
 - Generate substation one-line diagrams for visualization of all 500kV substations
 - Map measurements/estimations to one-lines
- **Gather feedback from operators on user-interfaces, and use-cases.**

ON THE HORIZON....

- EPG is working on a next-generation LSE-based platform to provide full Real-Time Assessment capability through:
 - On-demand and periodic powerflow solution capability
 - State Estimator base case generation for downstream advanced applications
 - Real-time Study Capability for “What-if” assessments
 - Full and seamless integration with Real-Time Contingency Analysis

DISCUSSION AND Q&A



Thank You



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