PMU Applications at SDG&E

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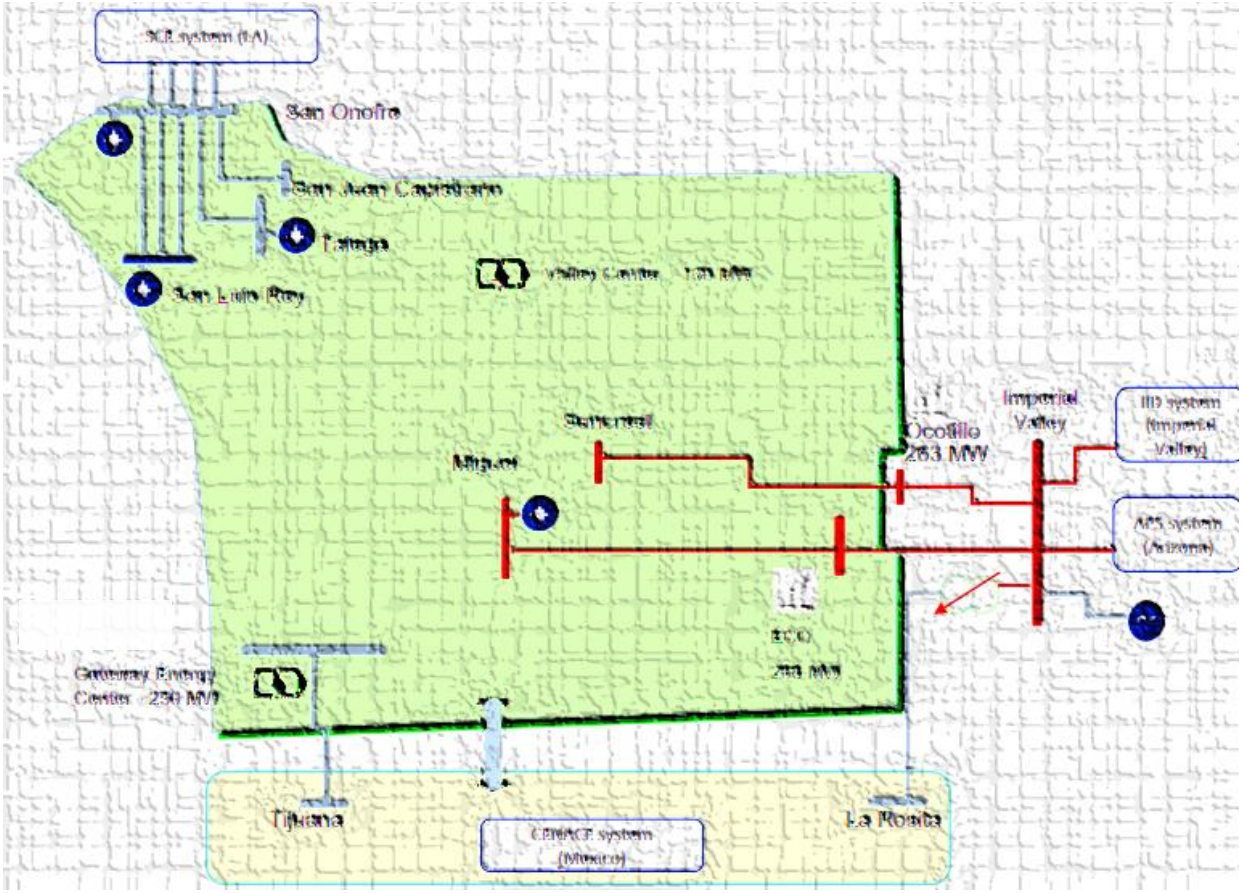
IEEE PES General Meeting 2025 | Austin, Texas | 27 – 31 July 2025

Summary

1. PMU-Based Measurements and Estimation
2. Real-Time Grid Operations and Control Room Tools
3. Stability and Dynamic System Assessment
4. Offline Analysis and Model Validation
5. Resilience and Emergency Operations
6. Protection System
7. Planning, Compliance, and Strategic Studies
8. Collaboration and Workforce Development
9. Q & A

San Diego Gas & Electric

- **SDG&E Transmission System**
- **Transmission Line Length**:
  - 69 kV: ~1,800 miles
  - 138 kV: ~300 miles
  - 230 kV: ~700 miles
  - 500 kV: ~100 miles
- **Voltage Levels**:
  - 69 kV, 138 kV, 230 kV, 500 kV
- **Total Peak Load Served**:
  - ~5 GW
- **Total Generation Capacity (Connected or Interconnecting)**:
  - ~6 GW (includes solar PV, BESS, and hybrid projects)



1. PMU-Based Measurements and Estimation

Measurement-Based Stability Assessment and Oscillation Management

- Real-time detection of oscillations using PMUs
- Detection and source location of Forced Oscillations (FO)
- Automated Mode Meter algorithms development
- WASA integration and collaboration with WSU/SEL

STATCOM Oscillation Captured by Engineering PMU Data Client System

1. PMU-Based Measurements and Estimation

Transmission Line Parameter Estimation

- Online impedance estimation using PMUs
- Methods: Pointwise, LSE, Mean-filtering
- Validation using SDG&E field data
- Improved state estimation and reduced parameter variance

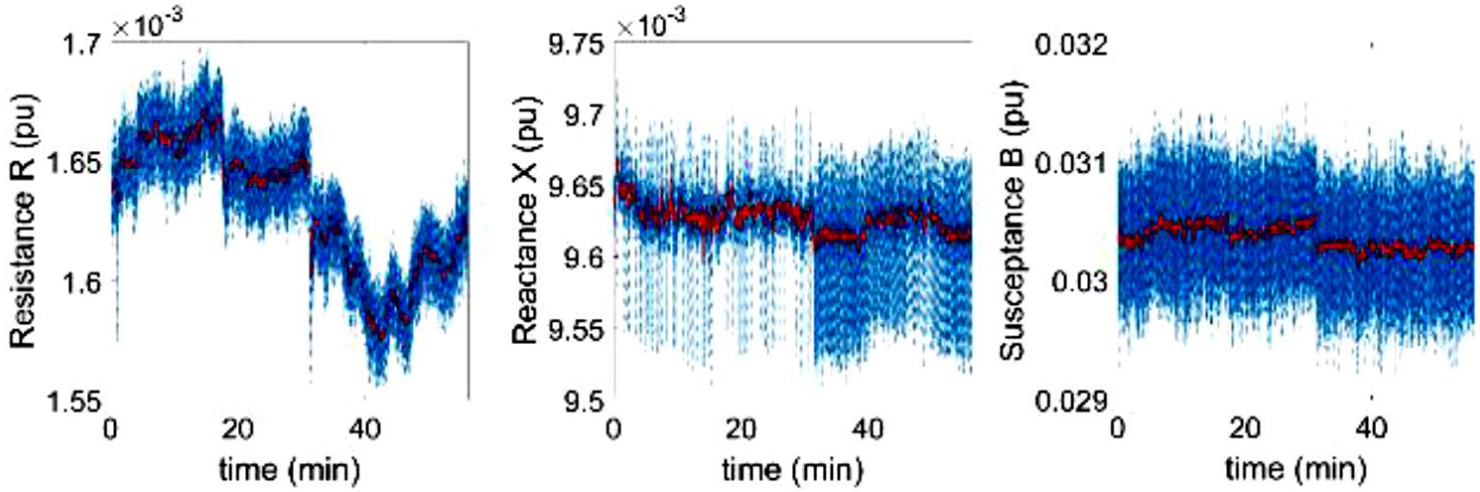
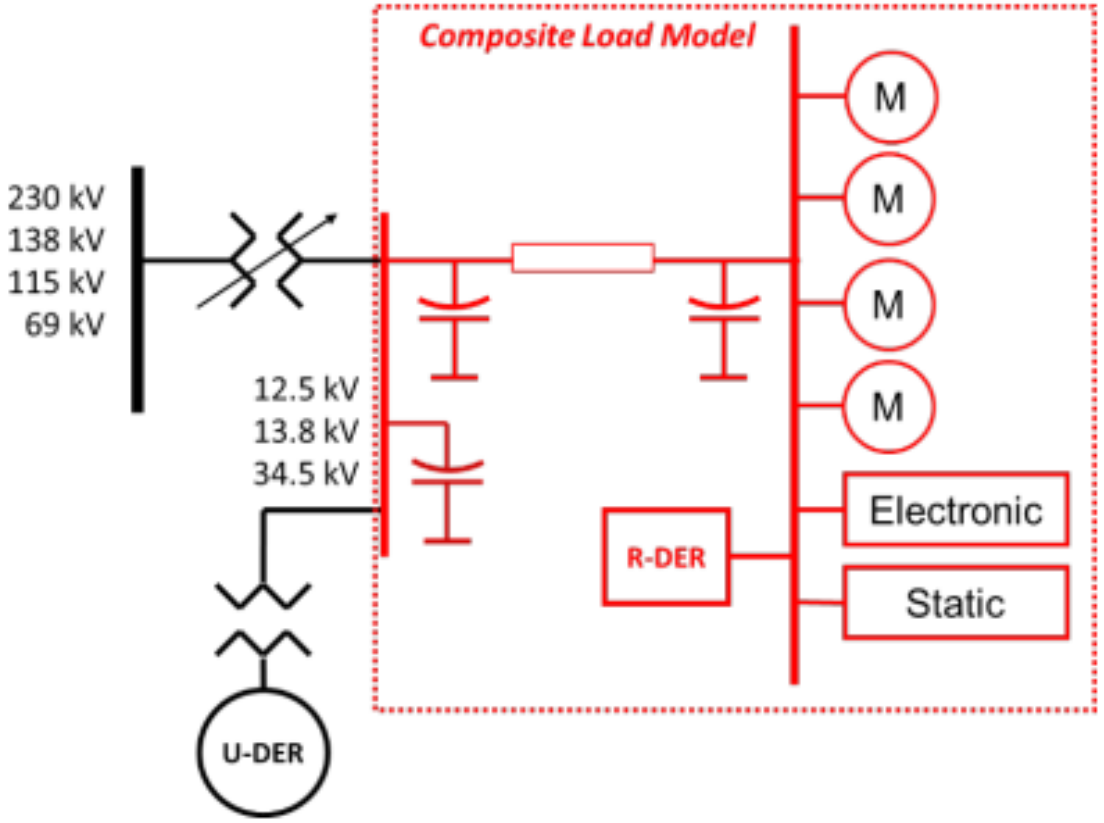


Figure 2. Two-terminal line parameter estimation results. Pointwise estimation (blue), Least Square estimation (red)

1. PMU-Based Measurements and Estimation

Power System Load Impedance Measurement (on-going)

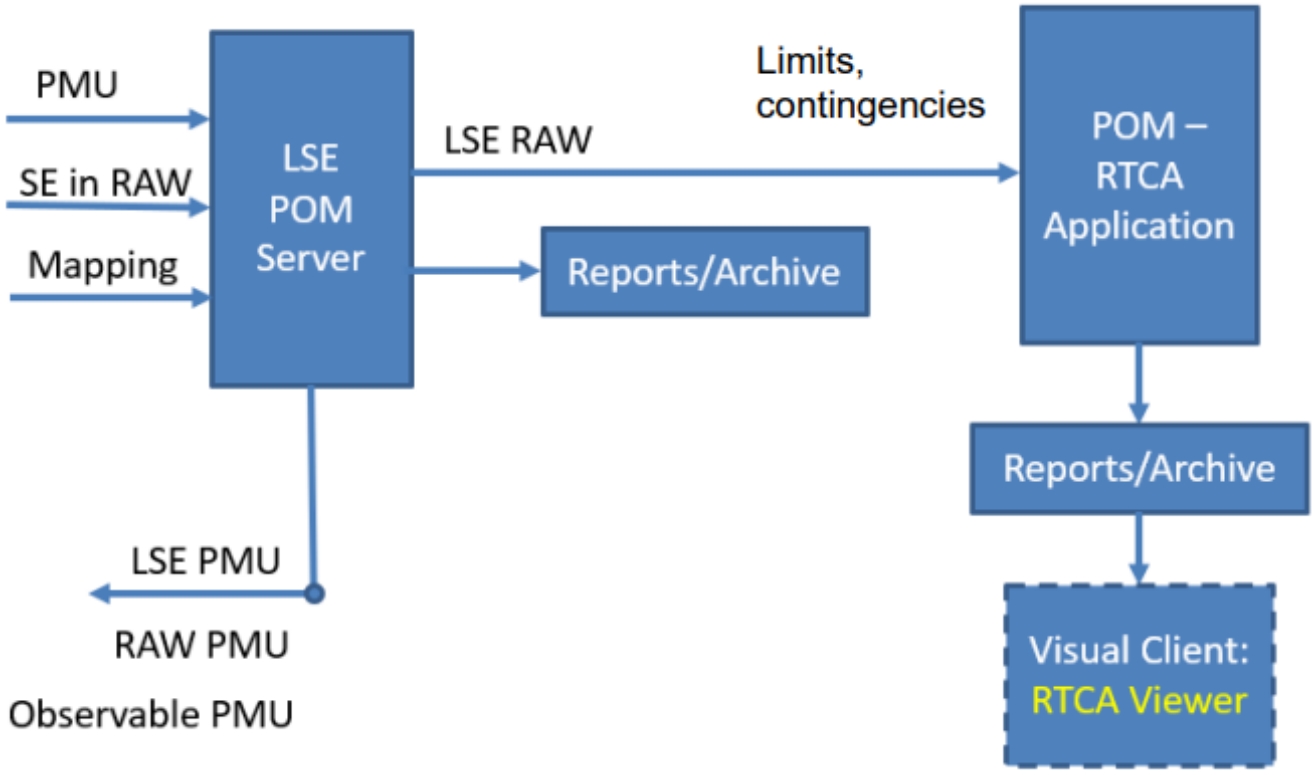
- Composite Load Model Estimation at load buses
- Non-invasive algorithms using natural load variations
- Applications in fault analysis, voltage, Transient Stability



1. PMU-Based Measurements and Estimation

Linear State Estimation & PMU placement (V&R Energy)

- Voltage and current vectors are considered as the state variable
- Improves real-time resilience as a backup to the conventional SE solution
- Checking and validation for the quality of conventional state estimator
- High speed state estimation (30 times/sec)



2. Real-Time Grid Operations and Control Room Tools

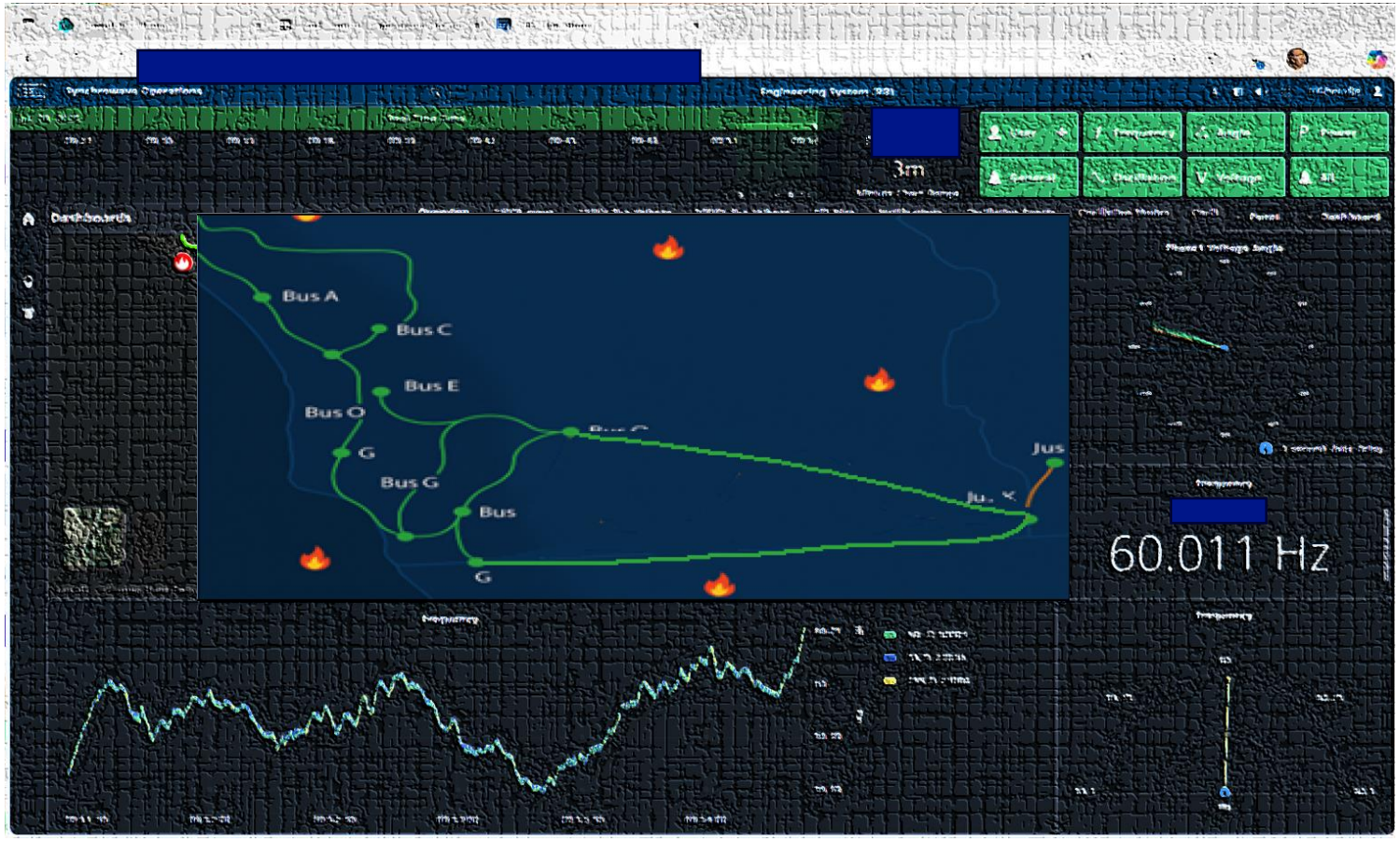
Wide-Area Situational Awareness (WASA)

- Enhanced monitoring using PMU data
- Alarming, phase angle difference, and contingency analysis
- WASA architecture supports real-time ops
- Data visualization and analytics capabilities

2. Real-Time Grid Operations and Control Room Tools

Real-Time and Offline Applications

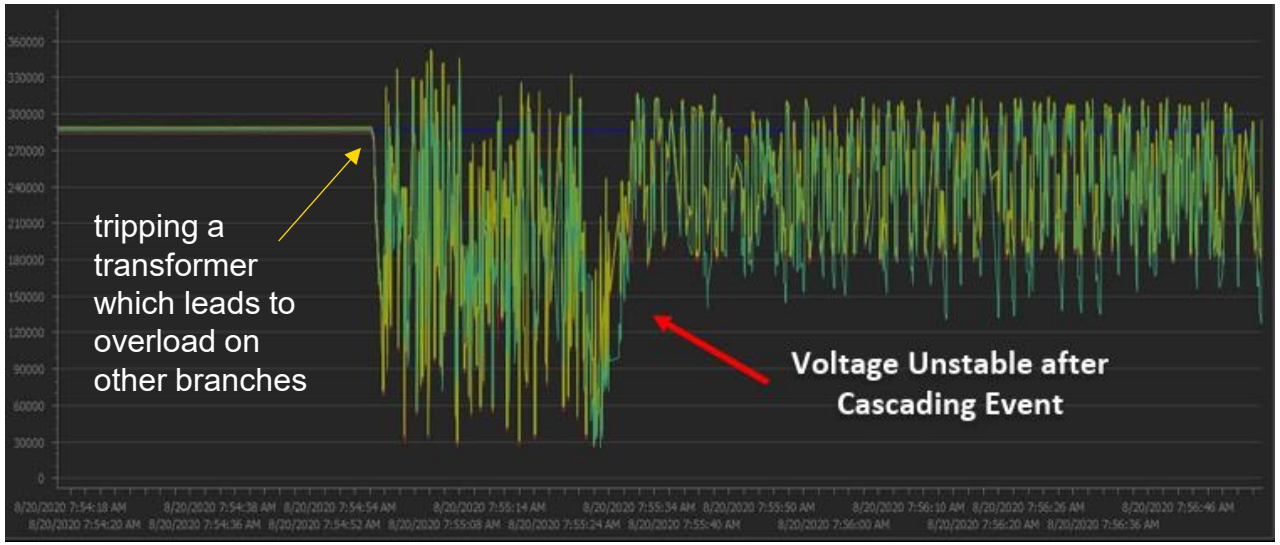
- Live oscillation alarms and stability assessment
- Post-event model calibration and trending
- Alarm management with advanced processing
- Supports operational readiness and decision-making

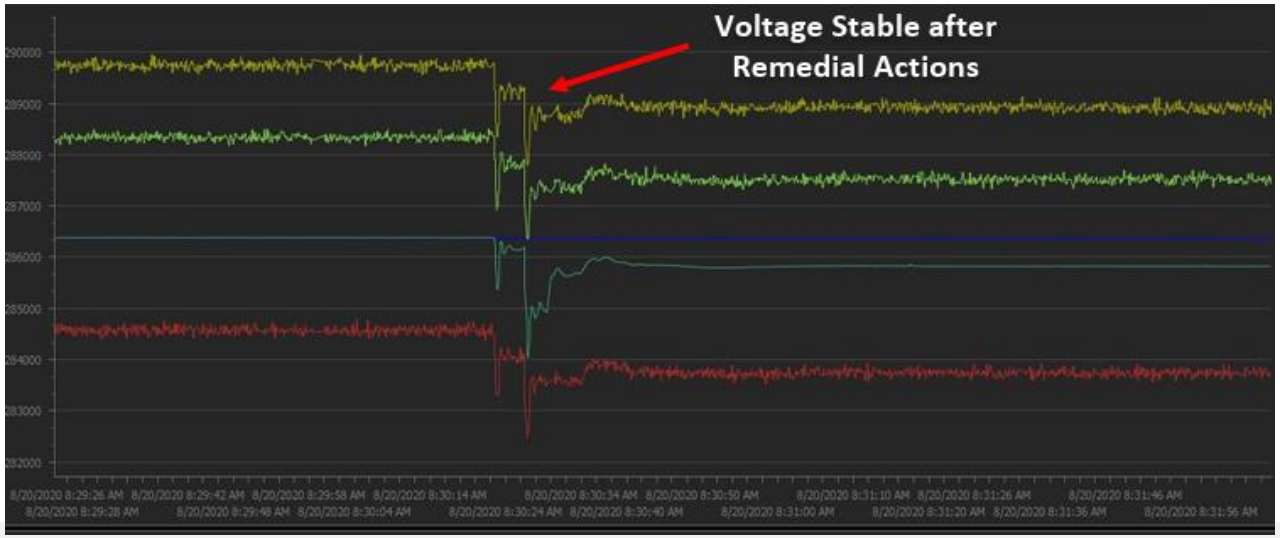


3. Stability and Dynamic System Assessment

Voltage and Frequency Stability Assessment

- Detect initiating events causing voltage or frequency stability violation
- Identify and apply corrective actions (e.g., switching, load shedding.)
- Confirm effectiveness of actions via PMU Viewer trends.
- Use same approach to mitigate Frequency Violations.

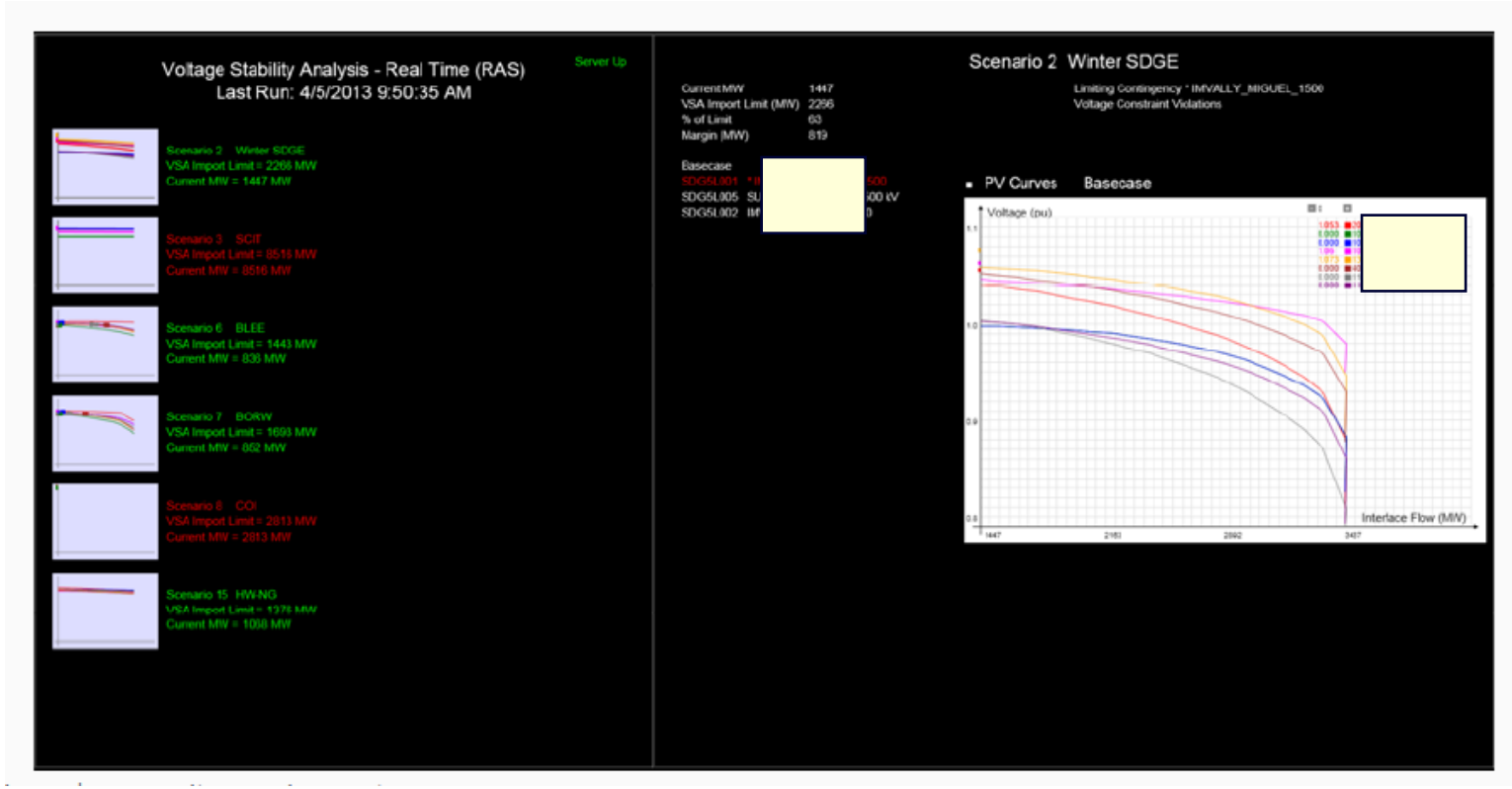




3. Stability and Dynamic System Assessment

Model Validation Tools

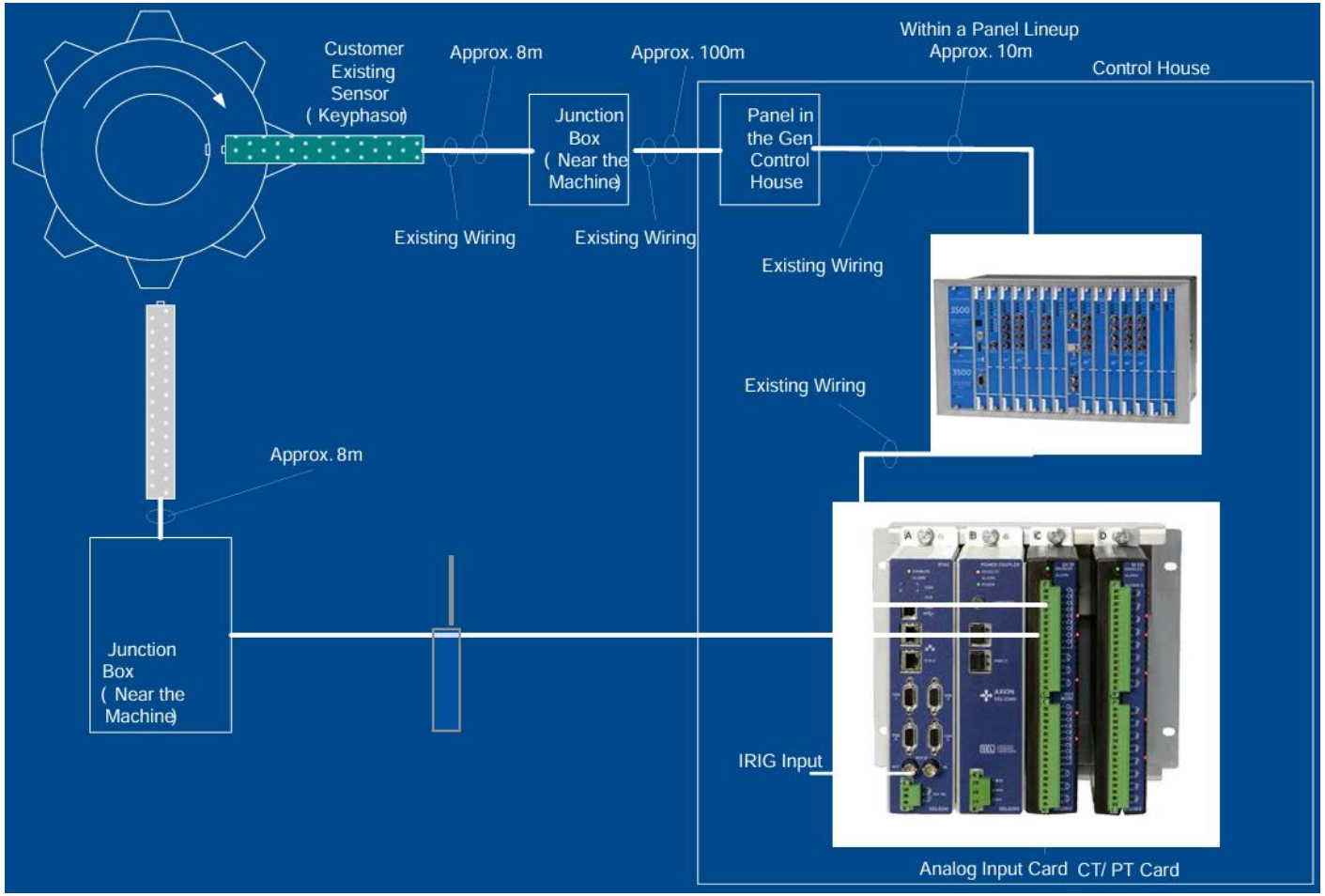
- Testing platforms like V&R's ROSE and its VSA module
- PMUs used in model validation and hybrid state estimation
- Dynamic line rating and composite load modeling
- PMU-based simulation model fine-tuning for MOD-033



4. Offline Analysis and Model Validation

Generator Monitoring, Modeling, and Validation

- Rotor angle and excitation field data captured with PMUs
- Generator parameter validation (MOD-025/027)
- Integration with V&R tools and simulation
- Integration with BPA/WSU power plant model validation tool.



5. Resilience and Emergency Operations

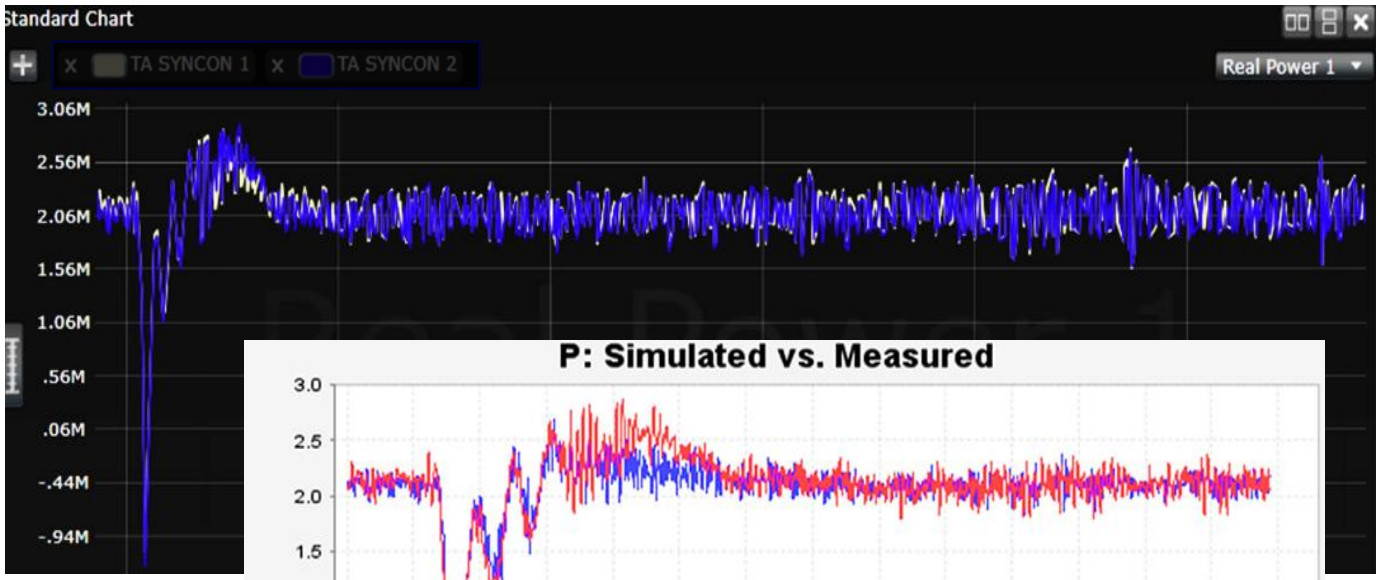
Black Start and Controlled Islanding

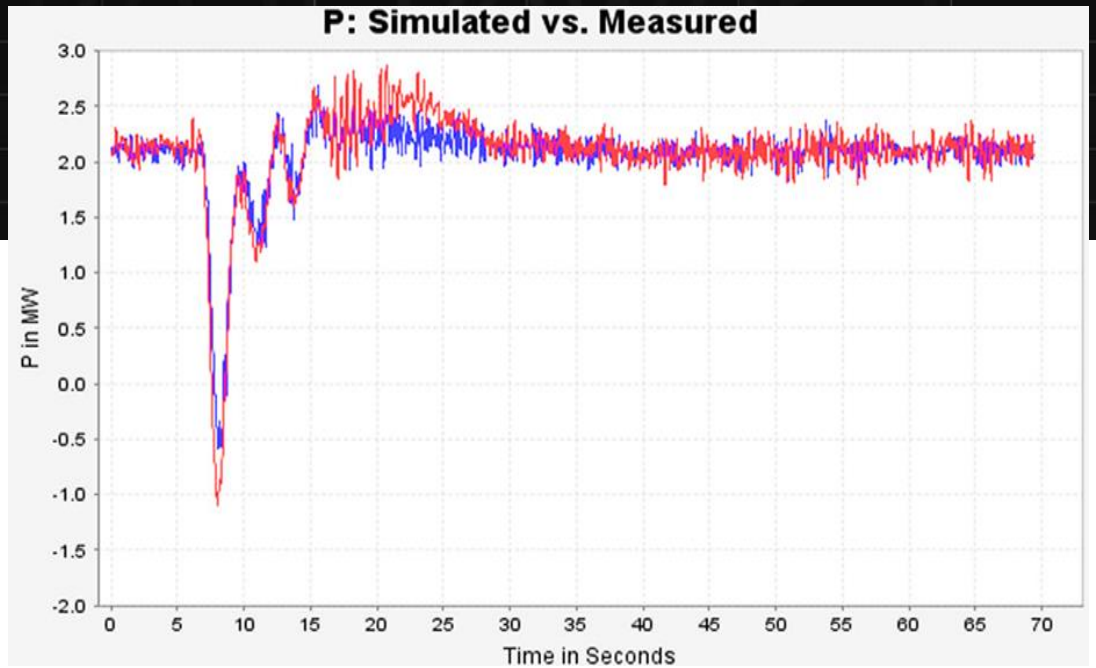
- PMUs support breaker closing during black start
- Detection of islanding conditions
- Backup for EMS/SCADA functionality
- Controlled grid separation for resilience

5. Resilience and Emergency Operations

System Inertia and SynCon Monitoring

- PMUs can be installed at the POI of power plants with dynamic units
- PMUs enable validation of both positive sequence and EMT models of power plants
- Calculate the inertial power contribution of synchronous condensers and its impact on ROCOF
- Supports appropriate settings of controllers after validating PSLF and PSCAD models





6. Protection System

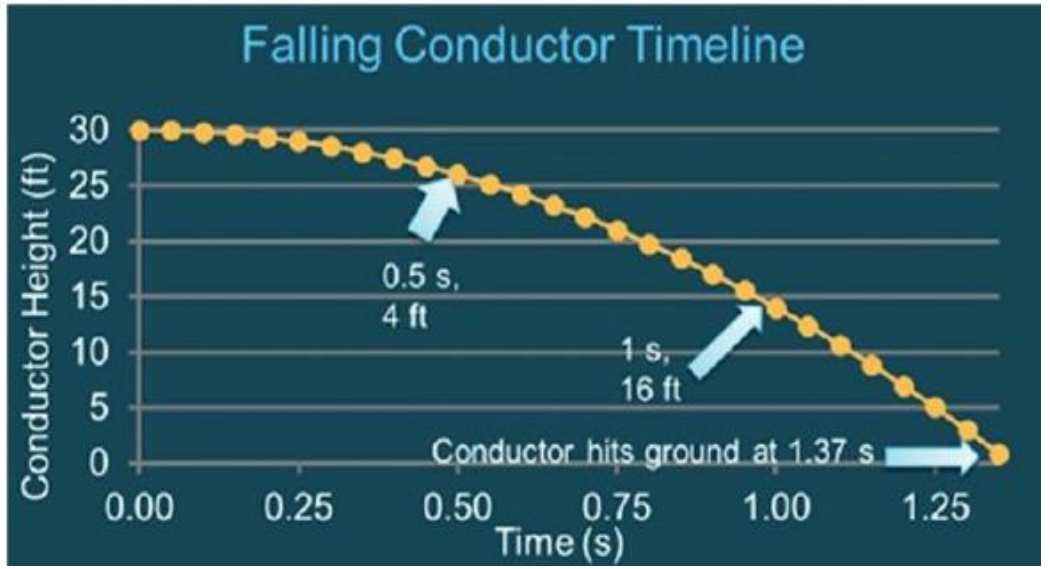
Accelerate Fault Restoration

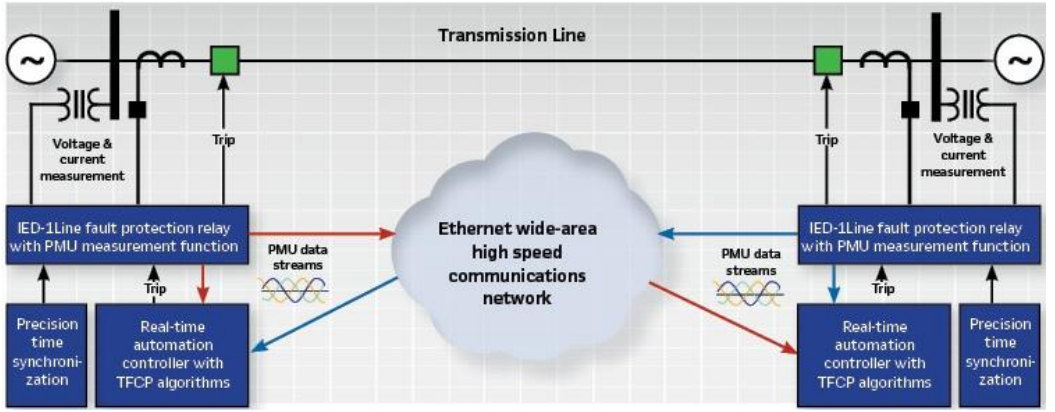
- Synchrophasor application with multi-layer geospatial displays
- Centralized intelligent event detection and alarm management
- Faster fault detection and location
- Improve fault restoration planning

6. Protection System

Transmission Line Falling Conductor Protection System

- Using existing syncrophasors from two- or three-terminal lines, algorithms, and high-speed communication
- Sensitive Ground Fault (SGF) and spike counting algorithms to detect high impedance ground fault
- Detect a breaking/broken conductor and de-energize the area before the conductor hits the ground





7. Planning, Compliance, and Strategic Studies

Regulatory and Planning Applications

- Validate planning and regulatory models using PMU data
- Support DER integration through generation profiling.
- Aid interconnection studies and ensure MOD-033 compliance.
- Supports GMD studies using data from GIC sensors.

8. Collaboration and Workforce Development

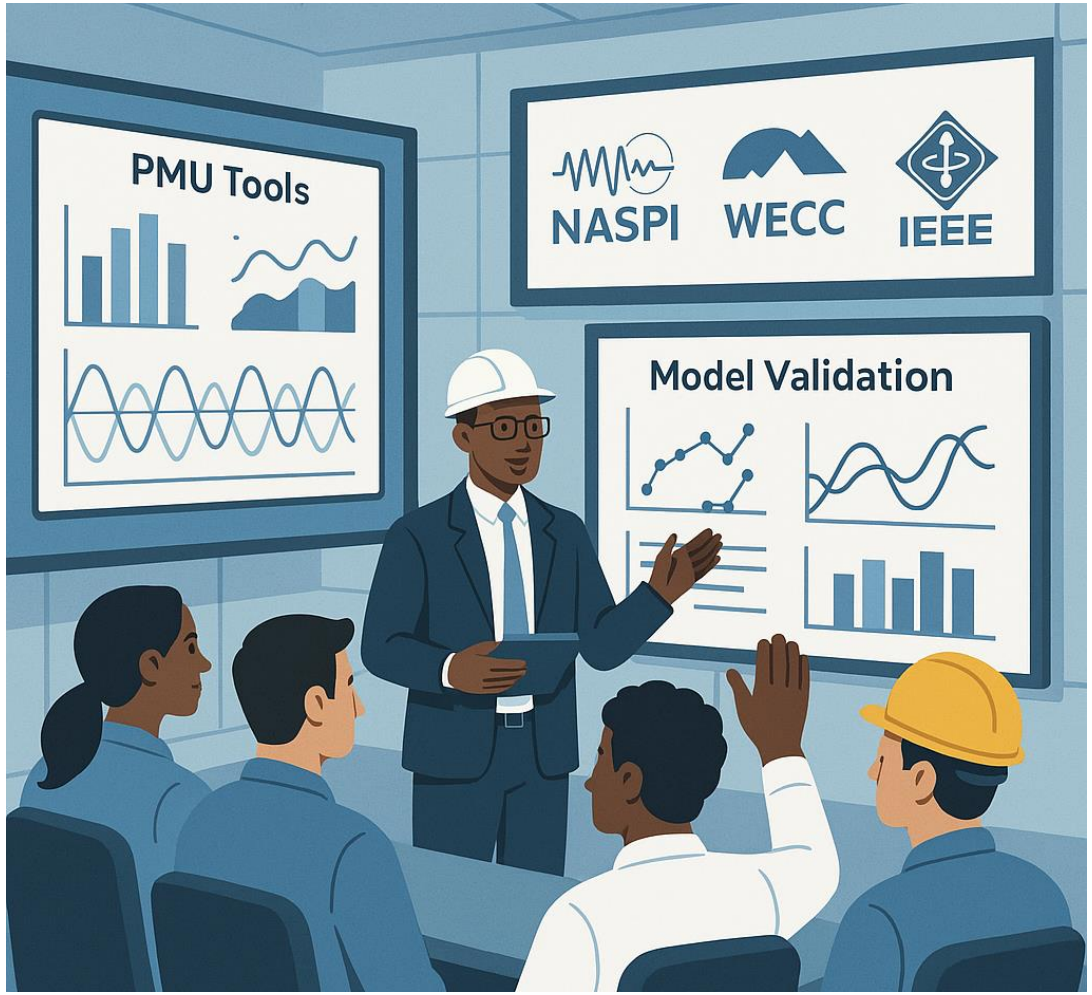
External Coordination and Standards

- Coordination with WECC, CAISO, NERC, DOE, and CPUC.
- Support of synchrophasor standards and validations.
- Participation in WECC/NERC technical committees
- Promoting PMU adoption and standardization

8. Collaboration and Workforce Development

Training, Engagement, and Communication

- Internal training on PMU tools and model validation
- Presentations at NASPI, WECC, IEEE



Q & A

What challenges do you foresee in scaling PMU applications?

How do you manage the volume and security of PMU data?

How can synchrophasor data be integrated into operator training?

What role do PMUs play in supporting future DER growth?