Synchrophasors and the Clean Energy Transition

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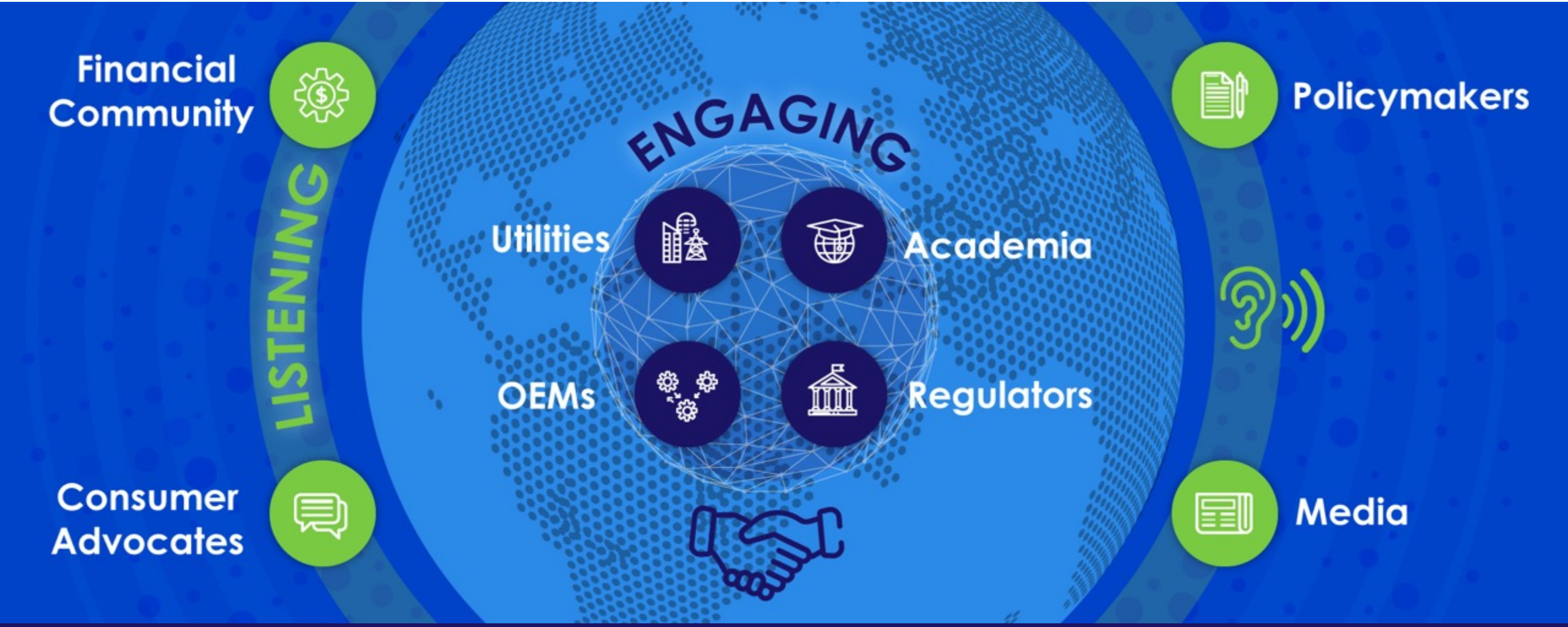
EPRI: Leading Collaborative Energy R&D Around the World



EPRI advances energy technologies and informs decision-making through ~$420M in collaborative annual research involving nearly 400 entities in ~40 countries - spanning the generation, delivery, and use of electricity.

EPRI Integrated Grid & Energy Systems R&D

Strategic Energy & Env Planning | **Long-Term System Planning** | **Real-Time Operations**

Corporate Strategy and Integrated Resource Planning

System Protection

Strategic Planning | Technology Assessment | Resource Adequacy | Trans & Dist Planning | Renewable Integration | Operations Planning | Real-Time Operations

Market Operations & Design

Energy, Environment & Climate Policy

Integrated Energy System Planning, Fuels & Markets

Transmission Planning

Transmission Operations

Bulk System DER & Renewables Integration

Distribution Operations & Planning

Distributed Energy Resource Integration

Energy Storage Systems Integration

The Vision a Decade Ago…

December 2010 T&D World

CONTROLS/Automation

Phasor Measurements Go the Last Mile

Industry collaboration and coordination bridges the gap between deployment and operation.

By **Terry Boston**, *PJM Interconnection*, **Mike Heyeck**, *American Electric Power, and* **Arshad Mansoor**, *EPRI*

Although phasor measurement units (PMUs) were developed years ago, many utilities are adding more of them to the grid today. Yet the meaningful use of this technology has not progressed much beyond the collection of massive amounts of data for display from different utilities to be synchronized and combined, providing a precise and comprehensive view of a regional interconnection. Synchrophasor data enable the determination of grid stress and can be used to trigger corrective actions to maintain reliability.

Situational Awareness

Dynamic Performance

System Model Validation

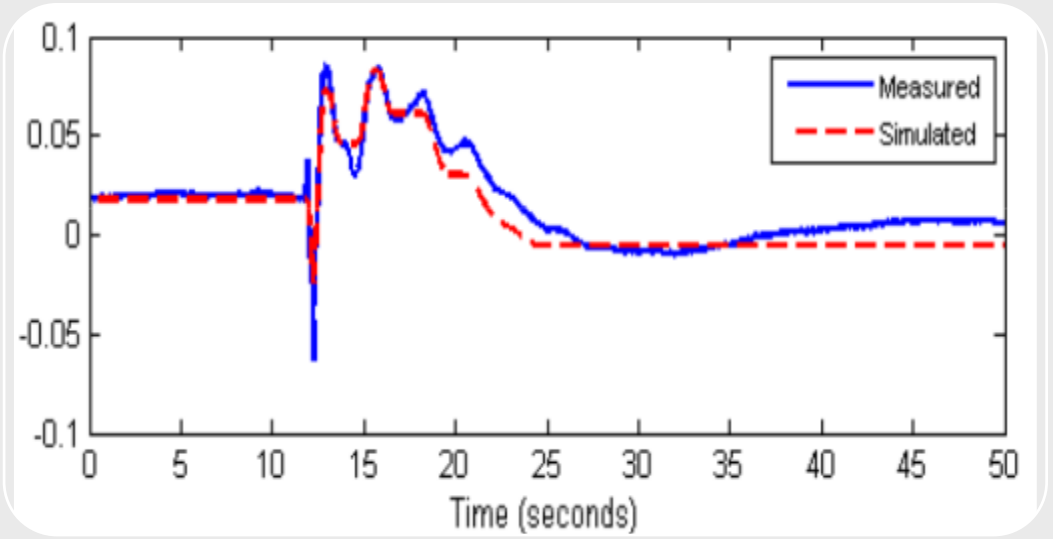
Advanced Automated Controls

State-of-the-Art Synchrophasor Applications

Operations

- Wide Area Situational Awareness
- State Estimation
- Event/Oscillation Detection
- Voltage Stability Assessment
- Islanding Monitoring & Detection

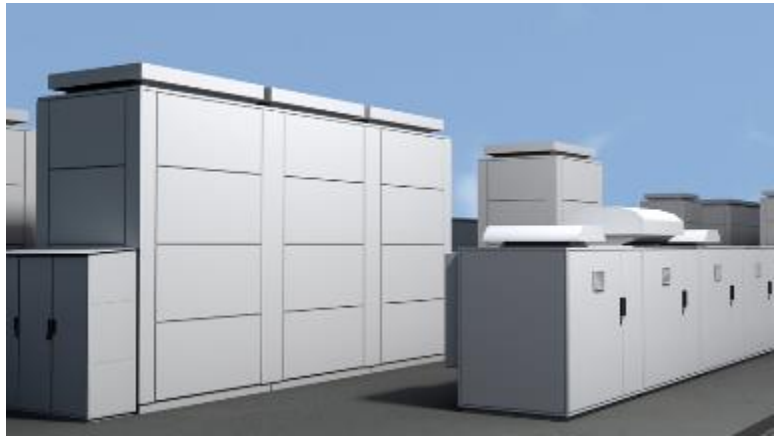
Planning



- Model Validation
  - Equipment Model
  - System Model
- Event Analysis
- Frequency Response Analysis

Grid Operations and Planning Must Evolve

Changing Generation Mix



Active Distribution Systems

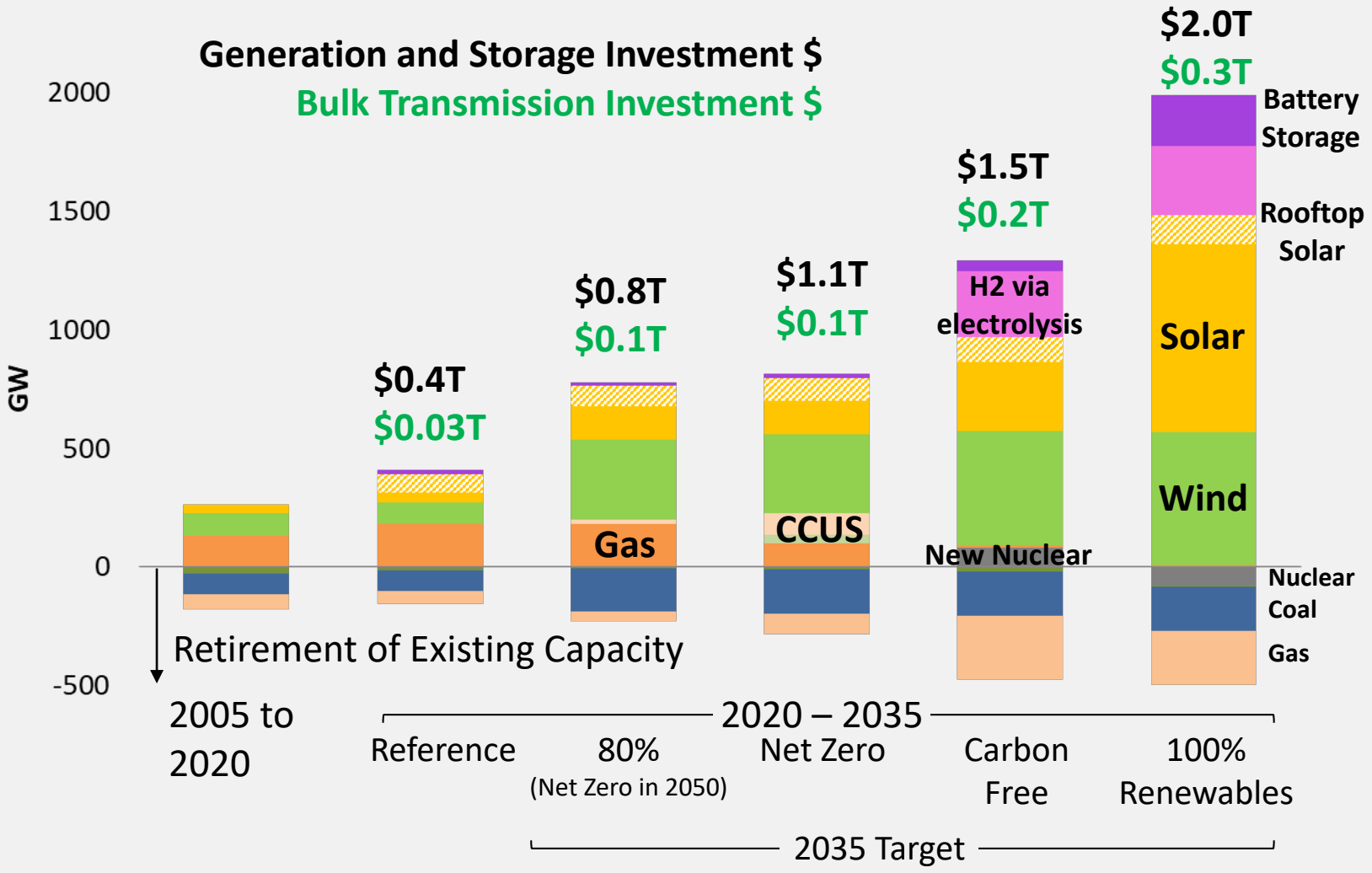
Consumer Control and Electrification

Clean Energy Transition Drives High Renewables

EPRI U.S. electric sector carbon reduction models show high renewables capacity additions for all 2035 scenarios.

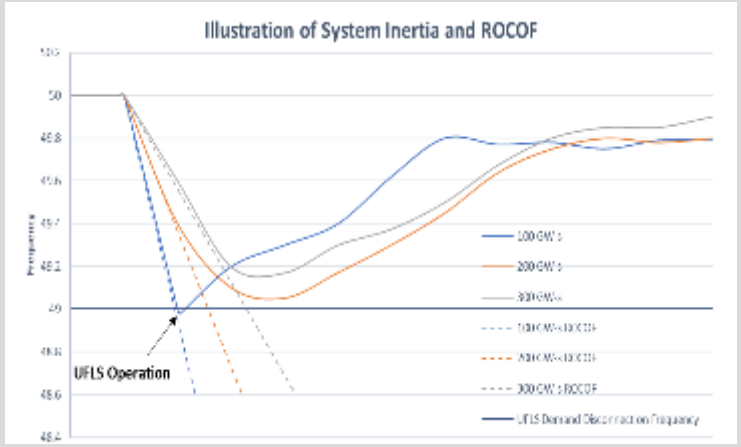
Scenario	Capacity
80% Reduction	561 GW
Net Zero	566 GW
Carbon Free	1,158 GW
100% Renewable	1,766 GW

U.S. Cumulative Capacity Additions 2020-2035

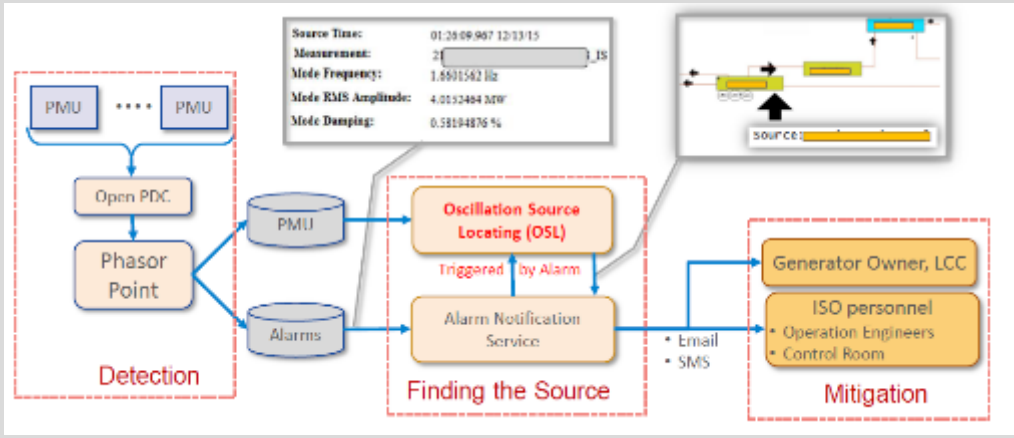


Emerging Applications Needed for Tomorrow's Grid

Inertia Monitoring

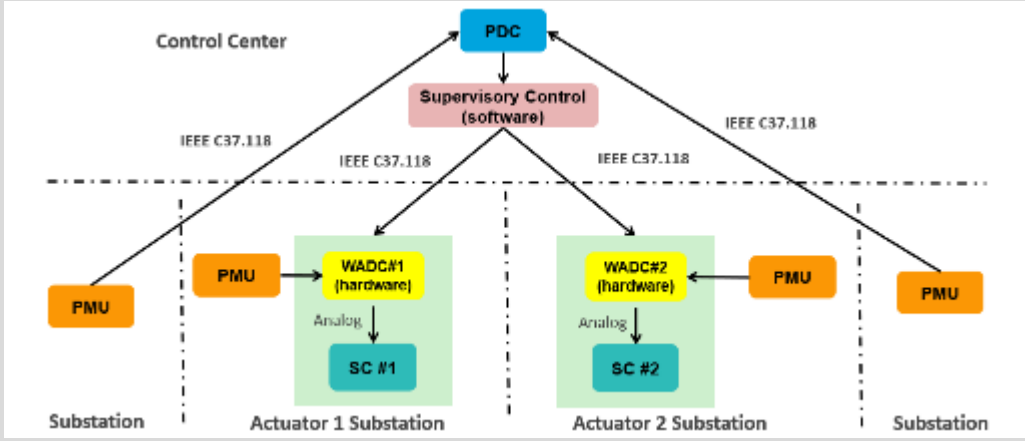


Oscillations Source Location

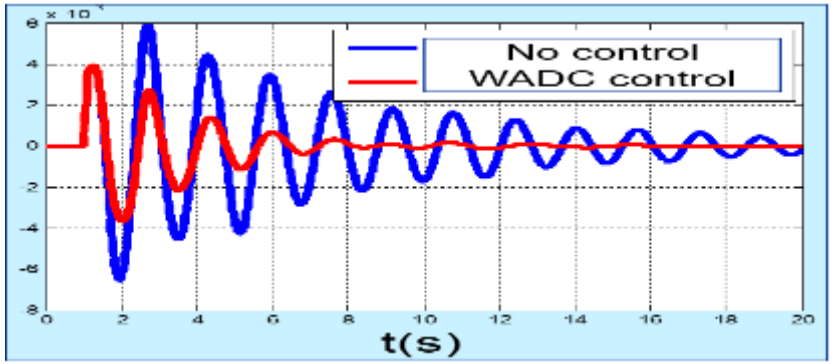


Artificial Intelligence

PMU Based Closed Loop Control

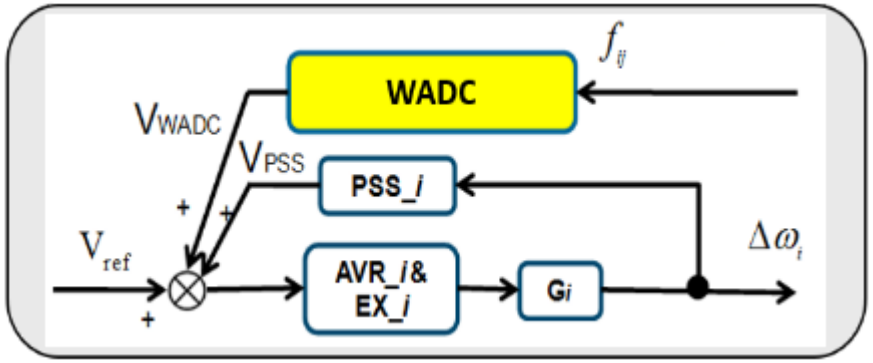


PMUs for Grid Control – Example: Oscillations Damping Control



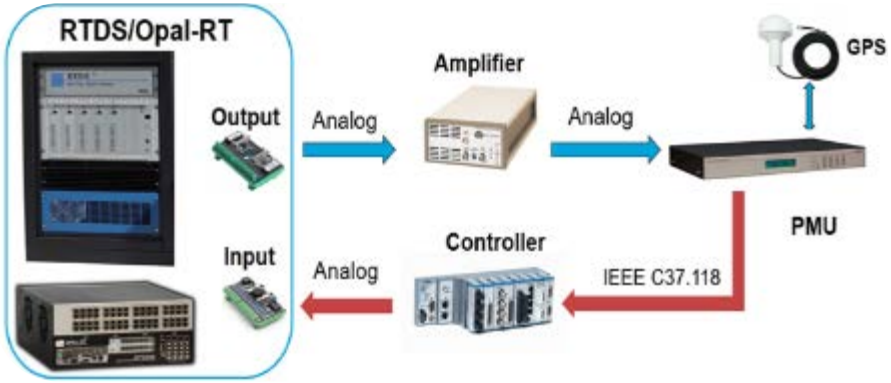
Objective

- Mitigation of Natural & Forced Oscillations through PMU-Based Closed Loop Control



Actuators

- Synchronous Machine/Synchronous Condenser
- FACTS (e.g. STATCOM, SVC), HVDC, BESS

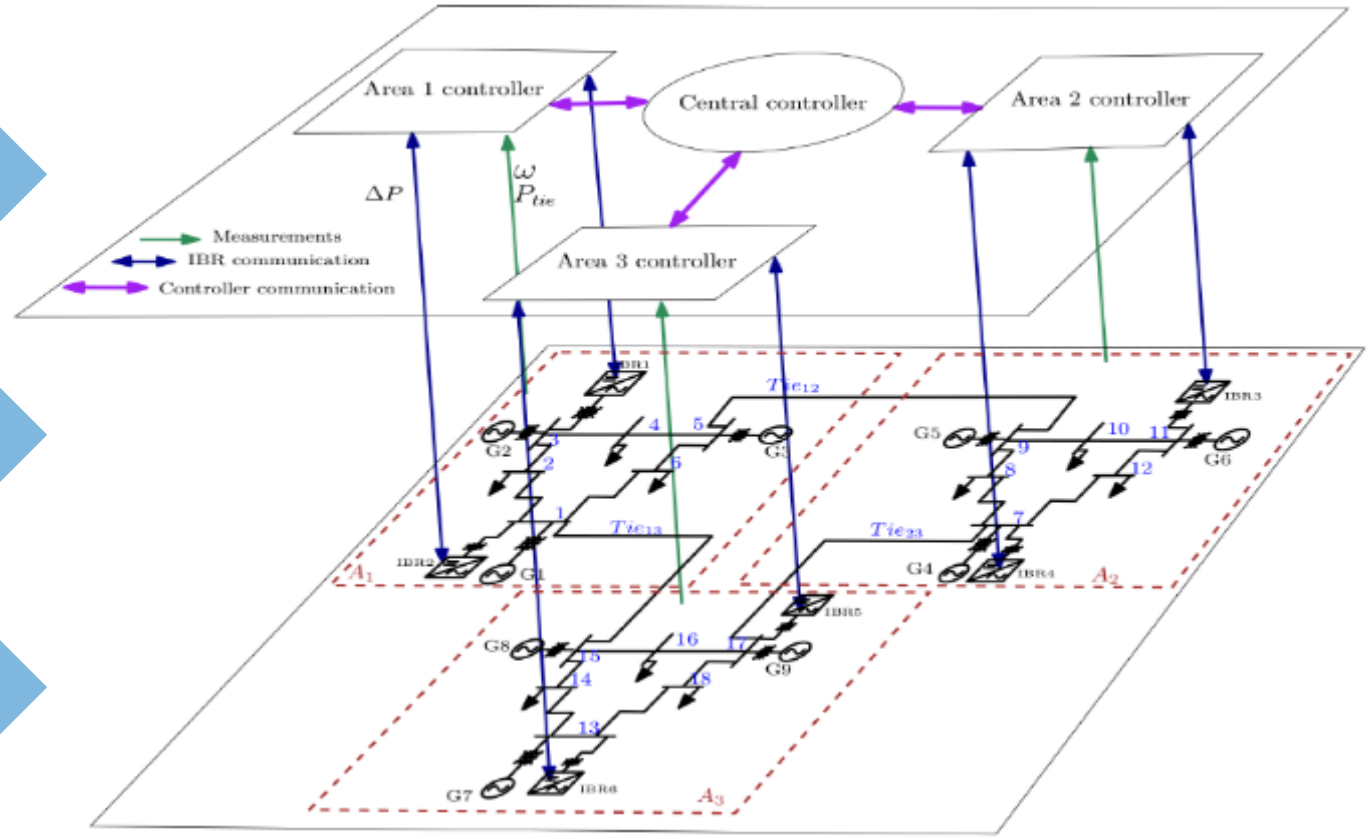


Progress

- Software and Hardware-In-the-Loop Implementation
- Case Studies: NYPA, TERNA, SEC, National HVDC Centre

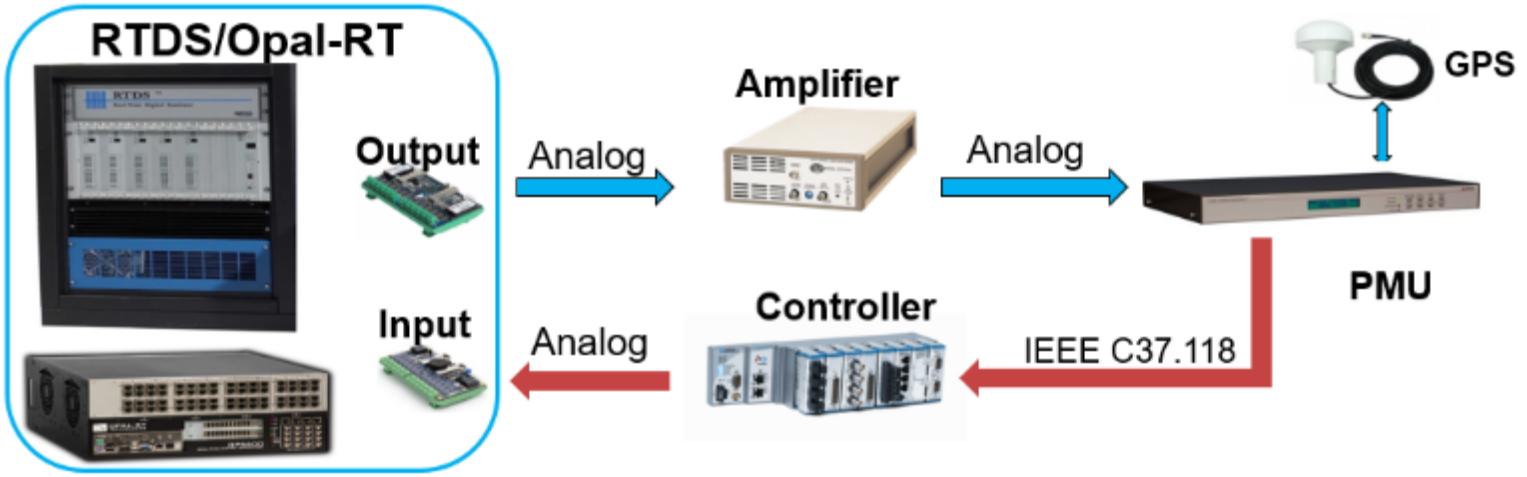
Next Generation Grid Monitoring & Control

SCADA & PMUs	Synchronized Point on Wave
Centralized Control	Hierarchical Decentralized Control
Human Control	Supervise Automated Systems



Grid Monitoring & Control with High Levels of Inverter Based Resources

PMU-Based Control - Implementation & HIL Testing



Testing and Performance Evaluation of PMU Based Control Schemes Under Emulated Realistic Operating Conditions

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