System Operations, Power Flow, and Control

Jeff Dagle, PE

Pacific Northwest National Laboratory

Grid Modernization Initiative Peer Review

PNNL-SA-125328

System Operations and Control

Advanced control technologies to enhance reliability and resilience, increase asset utilization, and enable greater flexibility of transmission and distribution systems

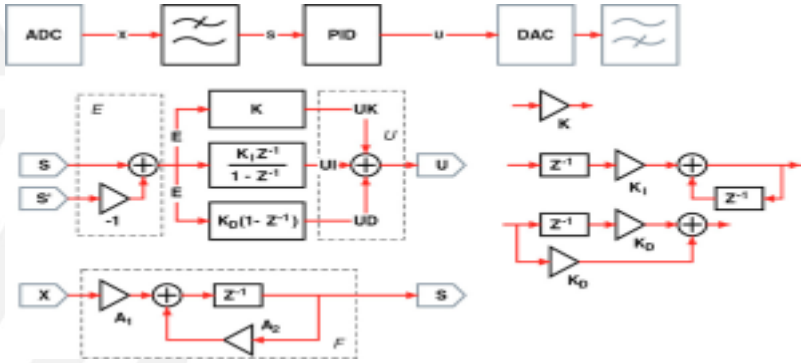
Expected Outcomes

- By 2020 deliver an architecture, framework, and algorithms for controlling a clean, resilient and secure power grid
  - Leveraging advanced concepts, high performance computing, and more real-time data than existing control paradigms
  - Involving distributed energy resources as additional control elements
- Develop software platforms for decision support, predictive operations & real-time adaptive control
- Deploy, through demonstration projects, new classes of power flow control device hardware and concepts
- Advance fundamental knowledge for new control paradigms (e.g., robustness uncompromised by uncertainty)

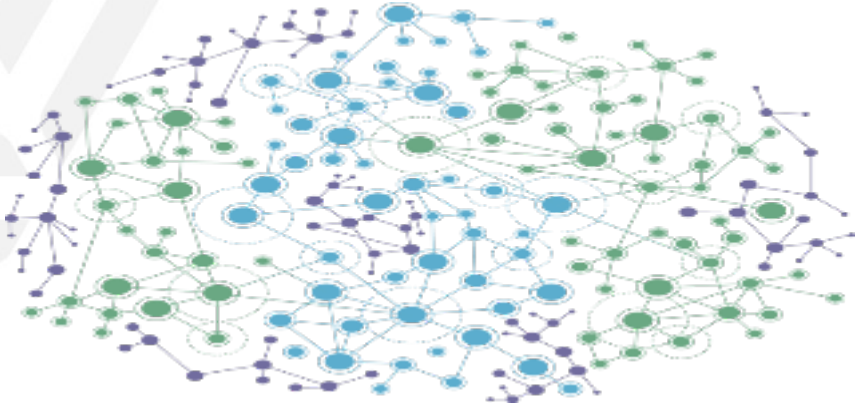
Federal Role

- Convening authority to shape vision of advanced grid architecture, including new control paradigms for emerging grid to support industry transformation
- Deliver system engineering and other supporting capabilities from the National Laboratory System to research & develop integrated faster-than-real-time software platforms and power electronics controls

Conventional Controls



Distributed Controls



Multi-Year Program Plan (MYPP) Activities

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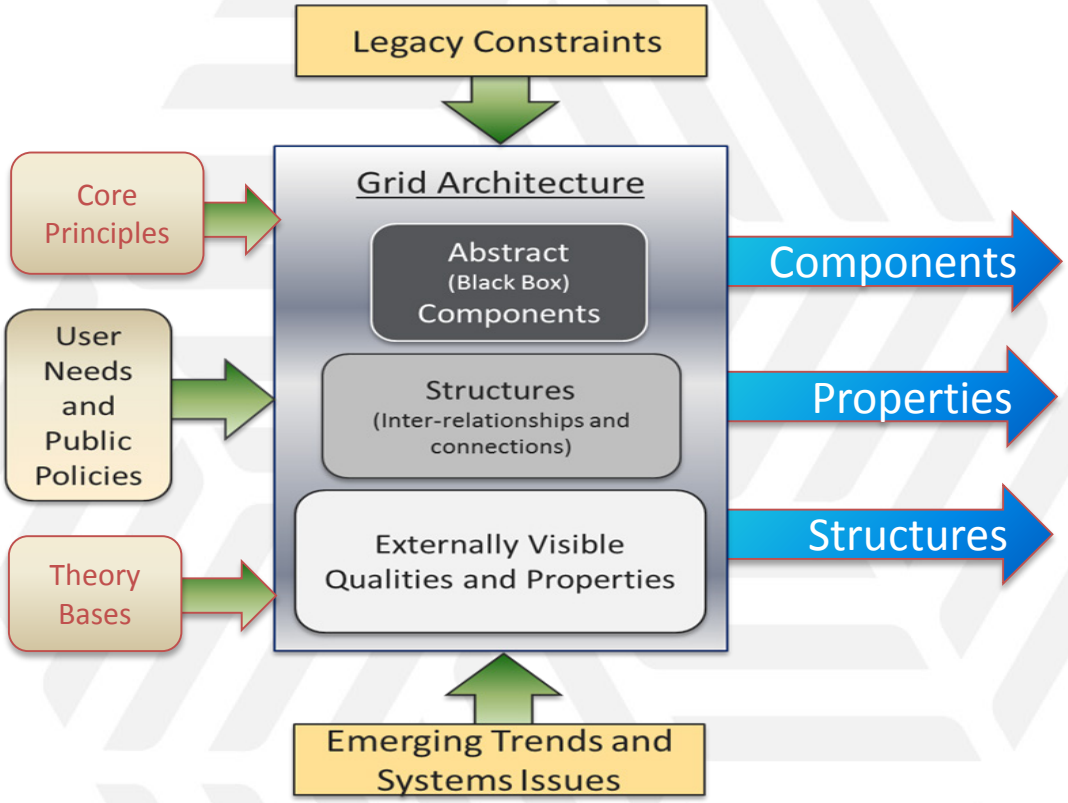
Activity	Technical Achievements by 2020
1. Develop Architecture and Control Theory	• Comprehensive architectural model, associated control theory, and control algorithms to support a variety of applications to improve grid flexibility, future adaptability, and resilience while not compromising operational reliability or security. • Wide-area control strategies to improve reliability, resilience, and asset utilization.
2. Develop Coordinated System Controls	• New control grid operating system designs reflecting emerging system control methodologies. • Framework(s) for integrating the next generation energy management system (EMS), distribution management system (DMS), and building management system (BMS) platforms.
3. Improve Analytics and Computation for Grid Operations and Control	• Future and real-time operating conditions with short decision time frames and a high degree of uncertainty in system inputs can be evaluated. • Automation with predictive capabilities, advanced computational solvers, and parallel computing. This includes non-linear optimization of highly stochastic processes. • Decision support to operators in control rooms through pinpoint visualization and cognitive technologies.
4. Develop Enhanced Power Flow Control Device Hardware	• Low-cost, efficient and reliable power flow control devices that enable improved controllability and flexibility of the grid.

1.2.1: Grid Architecture



PoP: FY16/17/18

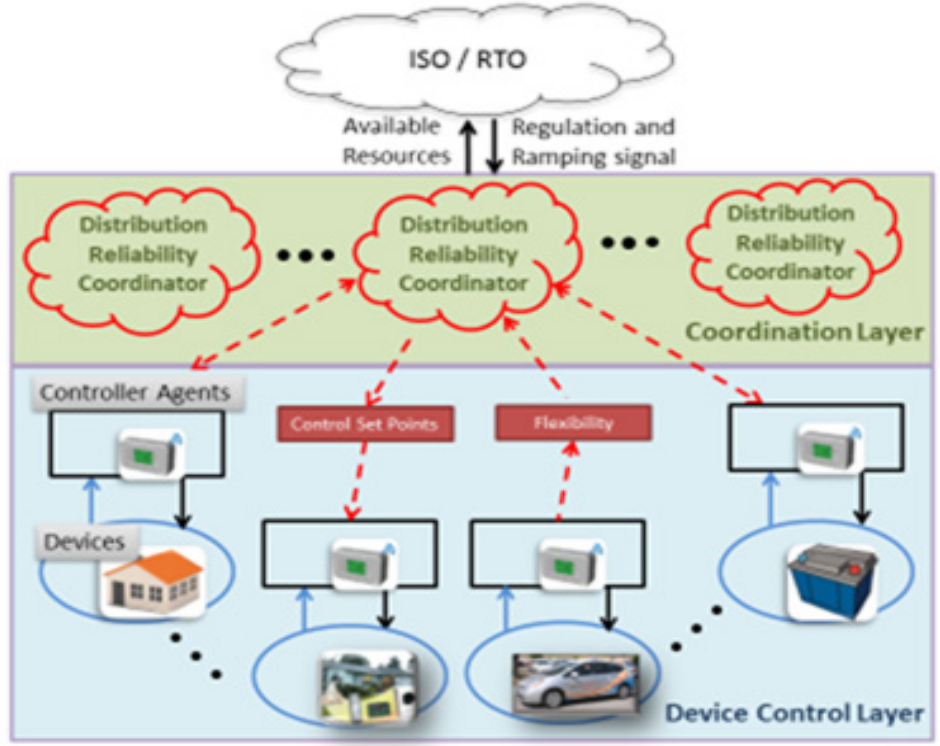
Budget: $3M

Labs: PNNL, ANL, NREL, ORNL, LANL, LBNL, LLNL, SNL

Partners: GE, EPRI, GWU, UTC, SGIP, Omnetric Group, CA ISO

Build a new stakeholder-driven architecture for grid modernization, provide it to the industry along with the tools they need to adapt it to their needs, and use it to inform the playbook for the GMLC program managers. The result will be superior stakeholder decision-making about grid modernization activities of all kinds.

1.4.10: Control Theory



Candidate hierarchical distributed control architecture based on future distribution reliability coordinator model

PoP: FY16/17/18

Budget: $6.5M

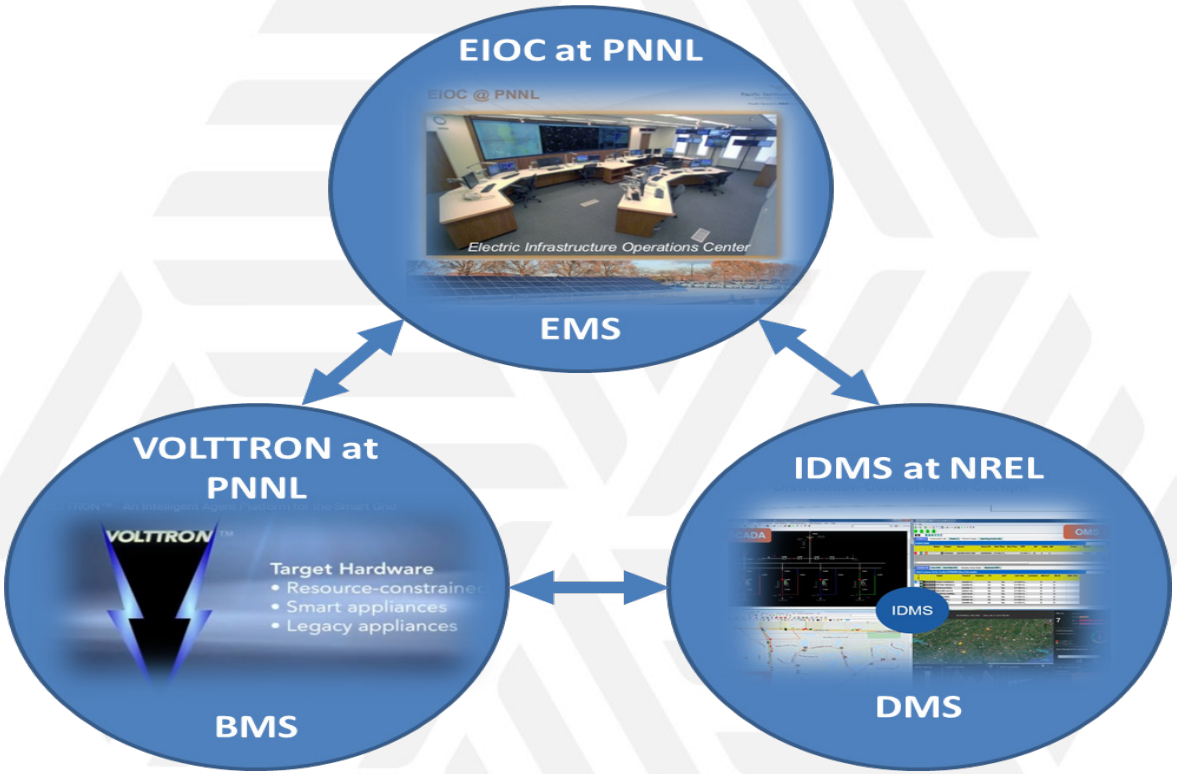
Labs: LANL, PNNL, ANL, INL, NREL, SNL, LLNL, ORNL

Partners: Oncor Electric Delivery, PJM Interconnection LLC, United Technologies Research Center

Develop new control solutions including topologies, algorithms and deployment strategies for transitioning the power grid to a state where a huge number of distributed energy resources are participating in grid control to enable the grid to operate with lean reserve margins. The theoretical aspect of this project will recognize the need to engage legacy control concepts and systems as we transition to more distributed control.

1.4.11: Control Integration

Energy Management System (EMS)



Building Management System (BMS) **Distribution Management System (DMS)**

PoP: FY16/17/18

Budget: $3.5M

Labs: ANL, BNL, LANL, LLNL, NREL, PNNL, SNL

Partners: GE, Duke Energy, PJM Interconnection LLC

Create an integrated grid management framework for the end-to-end power delivery system – from central and distributed energy resources at bulk power systems and distribution systems, to local control systems for energy networks, including building management systems.

Regional Demonstration Projects

- 1.3.01 Southeast Regional Consortium: Improving Distribution Resiliency through Reconfiguration in the Presence of Renewable Energy and High Impact Low Frequency Events
  - Lead organization: Savannah River National Laboratory
  - Other organizations involved: ORNL, EPB, UNCC, Santee Cooper, Duke, Clemson, Southern Company, TVA
- 1.3.09 Smart Reconfiguration of Idaho Falls Power Distribution Network for Enhanced Quality of Service
  - Lead organization: Idaho National Laboratory
  - Other organizations involved: PNNL, SEL, WSU, Idaho Falls Power
- 1.3.10 Vermont Regional Partnership Enabling the use of DER
  - Lead organization: Sandia National Laboratories
  - Other organizations involved: NREL, Green Mountain Power, Vermont Electric Coop, Vermont Electric Company, University of Vermont, Vermont Department of Public Service, Vermont Energy Investment Corporation, Spirae
- 1.3.99 Transactive Campus Demonstration
  - Lead organization: Pacific Northwest National Laboratory
  - Other organizations involved: State of Washington, UW, WSU

Program Specific Projects

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- GM0061 Virtual battery-based characterization and control of flexible building loads using VOLTTRON
- GM0062 Vehicle to Building Integration Pathway
- GM0063 Development of an Open-Source Platform for Advanced Distribution Management Systems
- GM0076 Emergency monitoring and controls through new technologies and analytics
- GM0085 Systems Research Supporting Standards and Interoperability
- GM0086 Modeling and Control Software Tools to Support V2G Integration
- GM0091 Unified Control of Connected Loads to Provide Grid Services Novel Energy Management and Improved Energy Efficiency
- GM0140 VOLTTRON Controller for Integrated Energy Systems to Enable Economic Dispatch Improve Energy Efficiency and Grid Reliability
- GM0172 VOLTTRON Message Bus Protocol Adapter
- GM0187 Community Control of Distributed Resources for Wide Area Reserve Provision
- GM0252 Optimal Stationary Fuel Cell Integration and Control (DG-BEAT)
- GM0253 Operational and Strategic Implementation of Dynamic Line Rating for Optimized Wind Energy Generation Integration
- SI-1673 Dynamic Building Load Control to Facilitate High Penetration of Solar PV Generation
- SI-1714 Enabling High Penetration of Distributed Photovoltaics through the Optimization of Sub-Transmission Voltage Regulation
- SI-1748 A ToolSuite for Increasing Performance and Reliability of Combined Transmission-Distribution under High Solar Penetration
- WGRID-04 Providing Ramping Service with Wind to Enhance Power System Operational Flexibility

Accomplishments and Emerging Opportunities

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Accomplishments

- 1.2.1: Stakeholder engagement initiated and inter-project collaboration underway for the development of architectural views and mappings that represent, requirements, use cases, emerging trends, and business models.
- 1.4.10: Documented architectural reference models for control that includes three key scenarios: legacy systems, communications-heavy systems, and communications lite systems.
- 1.4.11: Version 1 of use case document complete, communication and control requirements documentation in progress. Computational testing underway for unit commitment and economic dispatch controls.

Path Forward

- 1.2.1: Architecture development complete (FY17) and validated (FY18)
- 1.4.10: Hierarchical control theory with closed loop control and optimization (FY17) with analytical solutions developed and documented (FY18)
- 1.4.11: Demonstrate the integration of distribution management and building control systems; identify models and emulators for testing (FY17); full-scale demonstration deployed (FY18)

Summary

- System Operations, Power Flow, and Control technical area overview
- Elements of the Multi-Year Program Plan
- Foundational Projects
  - Architecture
  - Theory
  - Integration
- Regional Demonstrations
- Program Specific Projects
- Accomplishments and Emerging Opportunities