GRID MODERNIZATION INITIATIVE PEER REVIEW

1.4.11 Multi-Scale Integration of Control Systems (EMS/DMS/BMS Integration)

LIANG MIN, LLNL

April 18-20

Sheraton Pentagon City – Arlington, VA

Lab team: Liang Min and Philip Top/LLNL, Mark Rice and Emily Barrett/PNNL, YC Zhang and Rui Yang/NREL, Cesar Silva-Monroy/SNL, Sidhant Misra/LANL, and Zhi Zhou/ANL

Multi-Scale Integration of Control Systems
High-Level Project Summary

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

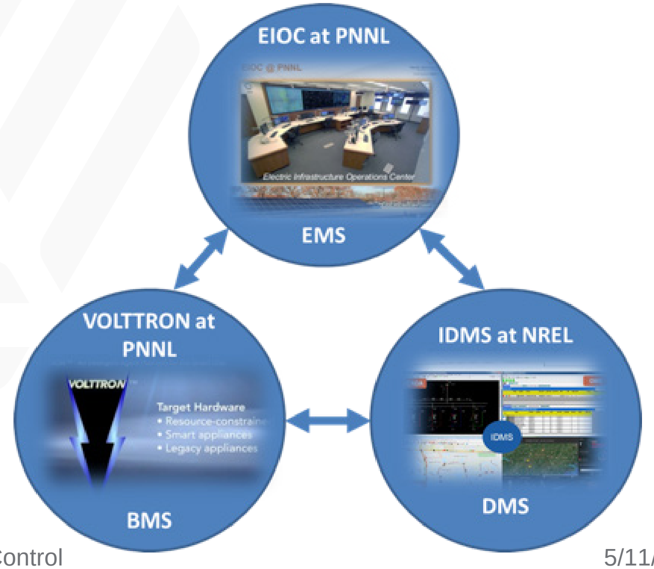
Create an integrated grid management framework for the end-to-end power delivery system – from central and distributed energy resources at bulk power systems and distribution systems, to local control systems for energy networks, including building management systems.

Value Proposition

- ✓ The current grid operating systems were developed over the last three to four decades using a piecemeal approach, within narrow functional silos.
- ✓ The rapid growth of DERs and the increased need to integrate customers with the power system are rendering the current generation of grid operating systems obsolete.

Project Objectives

- ✓ Develop an open framework to coordinate EMS, DMS and BMS operations;
- ✓ Demonstrate the new framework on a use case at GMLC national lab facilities.
- ✓ Deploy and demonstrate new operations applications on that framework.



Multi-Scale Integration of Control Systems

Project Team

Project Participants and Roles

- LLNL – PI, Task 1 lead
- PNNL – Project "+1", Task 2 lead
- NREL – Key contributor to the task 1 and 2
- SNL – Task 3 lead
- LANL – Key contributor to the task 3
- ANL – Task 4 lead
- Industry partners:
  - GE– e-terra EMS and DMS providers;
  - Duke Energy – Distribution feeder data;
  - PJM Interconnection LLC – Transmission Data.

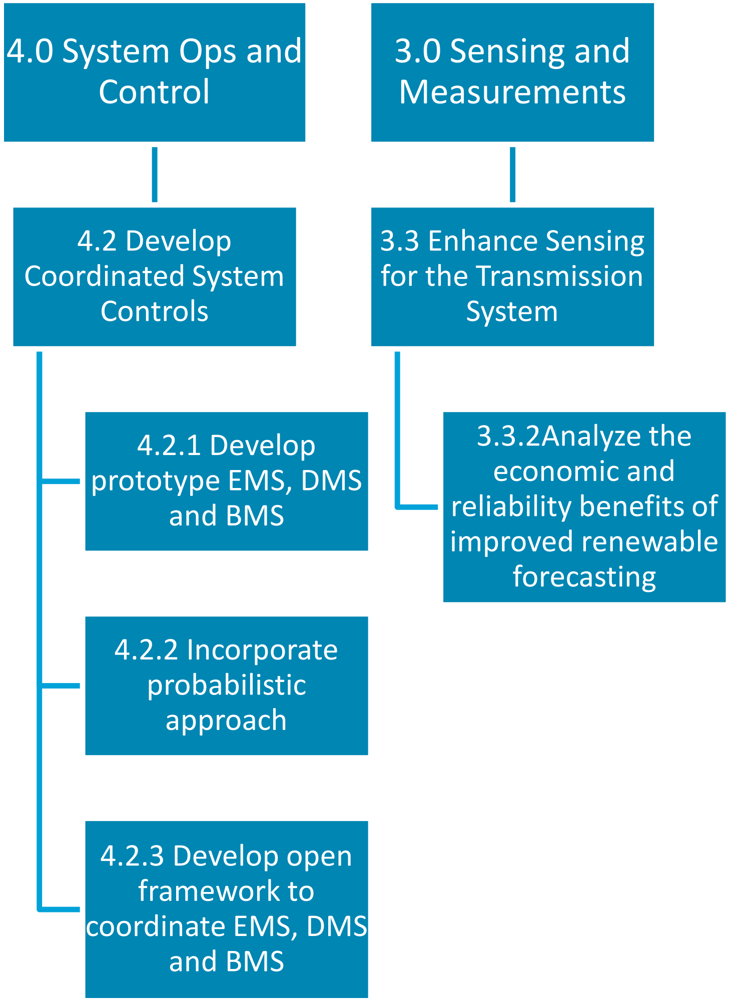
PROJECT FUNDING

Lab	FY16 $	FY17$	FY18 $
LLNL	300	266	290
SNL	100	187	170
LANL	70	82	75
PNNL	380	276	270
ANL	150	142	150
NREL	200	197	195
Total	1200	1150	1150

Multi-Scale Integration of Control Systems
Relationship to Grid Modernization MYPP

This project will support DOE's GMI to accomplish the following three Major Technical Achievements that will yield significant economic benefits of a modernized grid

- **Reduce the economic costs of power outages.** It will help grid operators leverage distributed energy resources and avoid conditions that could lead to load shedding or cause outages.
- **Decrease the cost of reserve margins while maintaining reliability.** It will substantially reduce the amount of system reserve capacity needed to cope with generation and load fluctuations, while maintaining and even increasing system reliability.
- **Decrease the net integration costs of distributed energy resources.** EMS/DMS/BMS coordination with controllability to engage response loads will help balance the variability of DERs.



Multi-Scale Integration of Control Systems
Approach

- Technical tasks
  - Task 1: Use case development
  - Task 2: Open framework development for EMS/DMS/BMS integration
  - Task 3: Integration of new DMS/BMS applications into EMS operations models
  - Task 4: New application: EMS/DMS/BMS uncertainty modeling and forecasting method

- Key innovations and project uniqueness
  - An framework to coordinate EMS, DMS, and BMS operations, and being the FIRST in the industry to demonstrate the new framework on an industry test system.
  - New transformative operations applications (probabilistic risk-based operations and forecasting data integration and decision support) that transform or extend existing EMS and DMS applications.

Multi-Scale Integration of Control Systems

Key Project Milestones

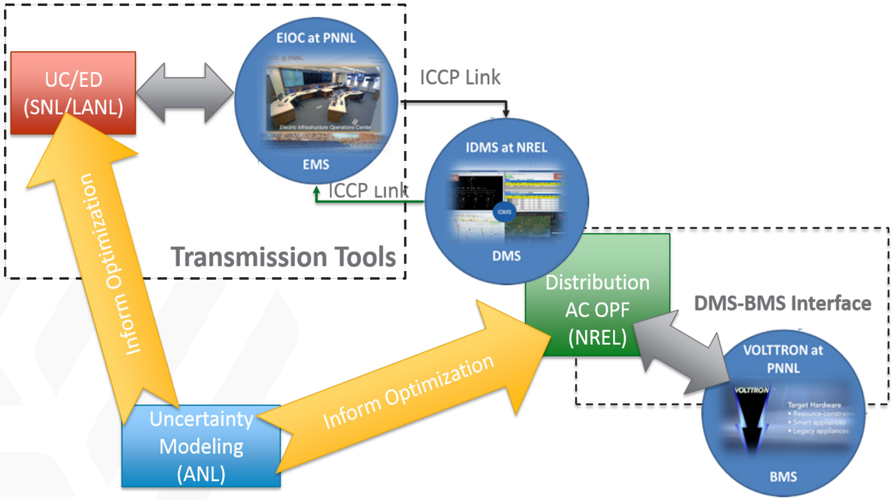
Milestone (FY16-FY18)	Status	Due Date
FY16 Mid-year Milestones: Completed the use case report and data exchange requirements/protocols report.	Done	12/1/2016
FY16 Annual Milestones: Complete integration of LANL ED with SNL UC engine; Complete integration of renewable forecasting into UC and ED.	Done	3/30/2017
FY17 Annual Milestones: Demonstrate integration of DMS and BMS information on the use case proposed under task 1; Complete the formulation of new DMS/BMS applications for EMS operations and implementation into UC/ED;	10%	3/30/2018
FY18 Annual Milestones: Successfully demonstrate integrated EMS/DMS/BMS platform; Demonstrate new DMS/BMS applications in UC/ED EMS; Demonstrate the uncertainty modeling and forecasting method in the integrated EMS/DMS/BMS system.	Not started	3/30/2019

Multi-Scale Integration of Control Systems

Accomplishments to Date

- Completed Version 1 of use case document and communication/control requirements document (Go/No-Go Milestone).
  - the connection between EIOC at PNNL and IDMS at NREL through the ICCP link (engaged the vendor, coordinating with another two GMLC projects.)
  - the connection between VOLTTRON™ at PNNL and IDMS at NREL through VOLTTRON™ Internet Protocol (Standardization is important)
- Collected Duke distribution data and Identified PJM transmission data for the Y2&3 demo.
- Presented the project goals and accomplishments at ADMS industry workshop and IEEE conferences.

Interface Definition

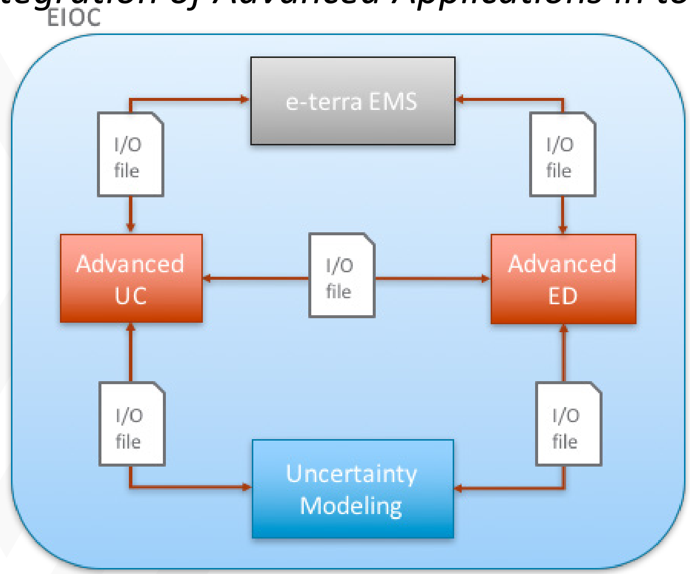


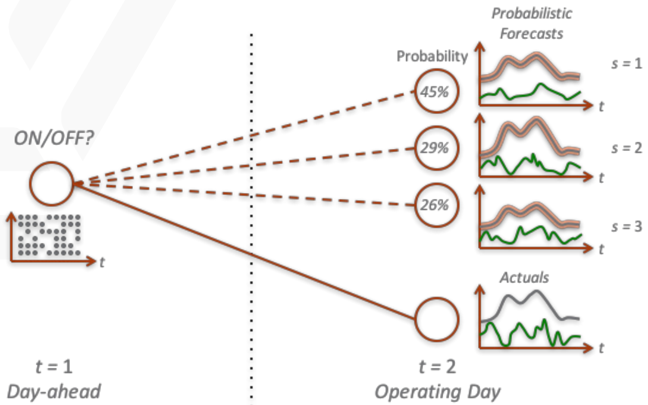
Multi-Scale Integration of Control Systems

Accomplishments to Date

- Completed the benchmarking of stochastic unit commitment and economic dispatch;
- Completed the report of a summary on major uncertainty sources for grid operations;
- Completed integration of LANL ED with SNL UC engine; Complete integration of renewable forecasting into UC and ED;
- Completed interface definition of integrating stochastic wind forecasting, stochastic UC and ED into EIOC.

Integration of Advanced Applications in to EIOC





Recommendation	Response
Please make sure there is "congruence" between the use cases/test cases in the TDC design and planning tools project with this Control Theory project.	This project's use case focus on operations. The team has provided the use case to 1.4.15 Integrated Transmission, Distribution and Communication co-simulation project for coordination.

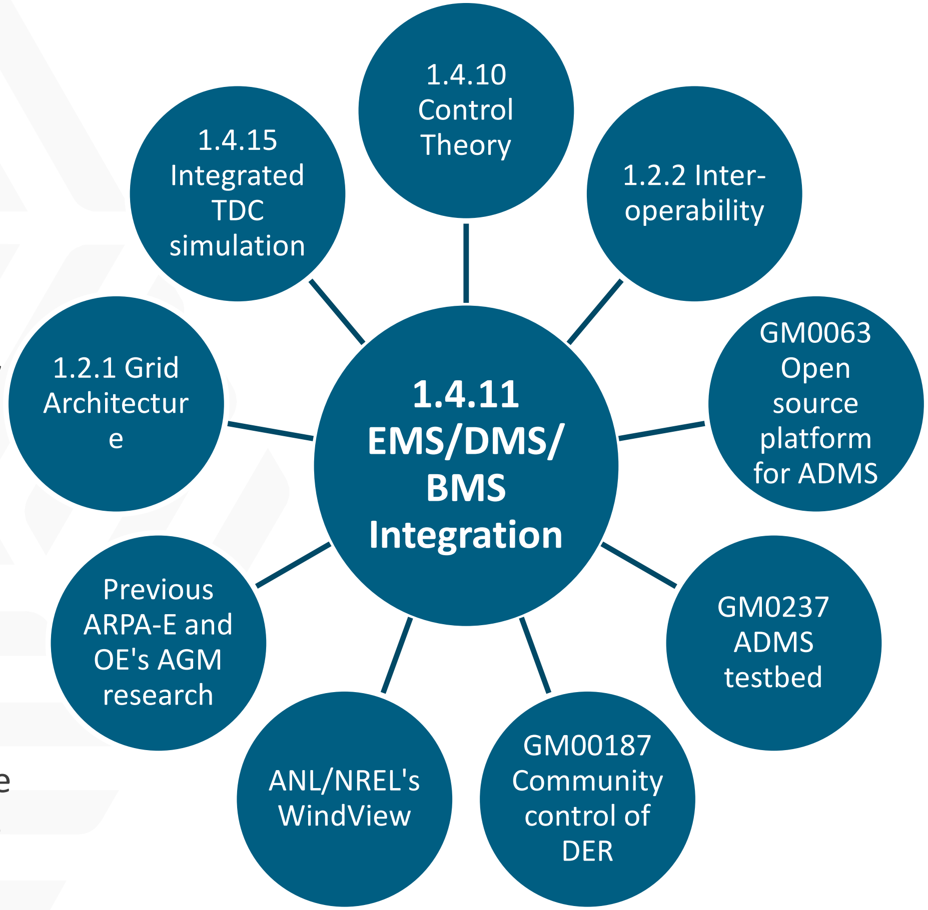
Multi-Scale Integration of Control Systems

Project Integration and Collaboration

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

- This project coordinates with another foundational projects -1.4.10 (control theory) and 1.4.15 (integrated TDC).
- This project coordinates with core areas 1.2.1 (grid architecture) and 1.2.2 (interoperability) to use appropriate future system architecture and interoperability standards to ensure project success.
- This project is a part of the DOE ADMS program and coordinates closely with other efforts under the program; this project coordinates with Cat 2 WindView project to visualize wind forecasting.
- This project leverages previous ARPA-E and OE's AGM research results on stochastic optimization area.

- Participated and presented at the Advanced Distribution Management System (ADMS) Industry Steering Committee kick-off workshop, April 2016
- Participated and presented at the 2016 IEEE Innovative Smart Grid Technologies ADMS panel, September 2016
- Will present at the 2017 IEEE Innovative Smart Grid Technologies ADMS panel, April 2017.



GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Key activities planned for FY17 include:

- Demonstrate the integration of DMS and BMS using Duke Energy's data by the end Q4 of FY17.
- Complete the implementation and testing of UC and ED into EIOC computational environment using PJM data by the end Q3 of FY17.
- Identify models/emulators for testing (FY17) with full-scale demonstration deployed in FY18 by the end Q4 of FY17

Multi-Scale Integration of Control Systems
Technical Details

Use Case Description

- Multi-scale integration of controls systems (EMS/DMS/BMS integrations) help coordinate and operate new distributed control schemes which utilize PV inverters and demand response programs to mitigate voltage instability issues.
- EMS - Out of the 10 PJM IROLs, 8 of them are reactive power interfaces. PJM dispatch utilizes the PJM Security Constrained Economic Dispatch (SCED) system to assist operators in making cost-effective decisions to control projected constraints and Reactive Interfaces.
- DMS - When voltage instability occurs, each PV inverter supplies the maximum available reactive power output and supports transmission Var emergency demand.
- BMS - Demand response programs can also be called to reduce air-conditioner compressor induction motor load. This helps recover system voltage to acceptable level instantly and prevent system voltage collapse.

Multi-scale Integration of Control Systems
(EMS/DMS/BMS Integration)

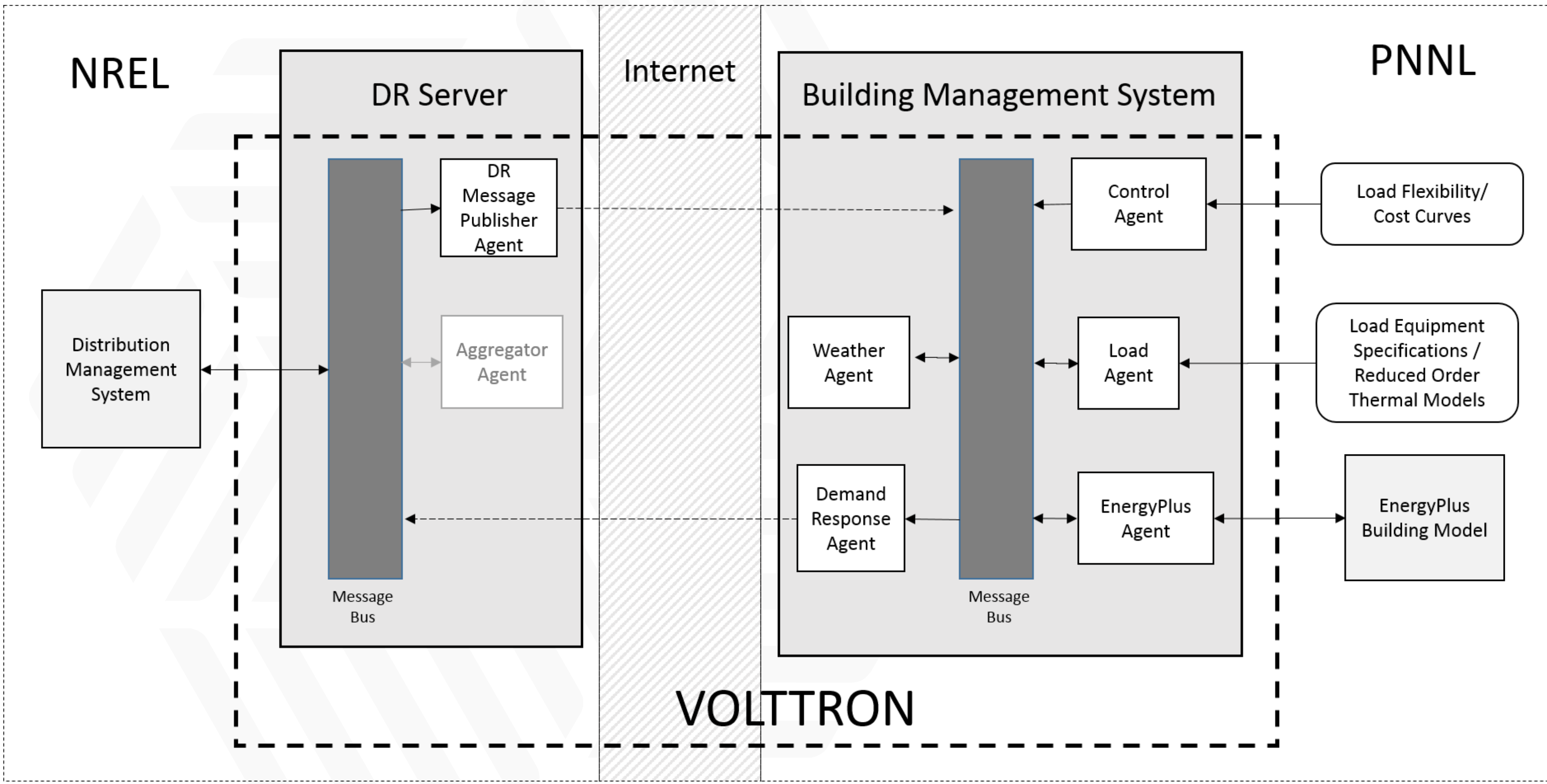
1 Descriptions of Simulation Case

1.1 Background

Our of the 10 PJM IROL facilities, 8 of them area reactive power interfaces. PJM dispatch utilizes the PJM Security Constrained Economic Dispatch (SCED) system to assist operators in making cost-effective decisions to control projected constraints and Reactive Interfaces. PJM Real-Time Market uses the same SCED reactive interface constraints in calculating the real-time LMP. In case of voltage instability, the online VSA tool installed will provide control suggestions, for example, switching on/off capacitors and reactors, adjusting generator var output, re-dispatching generator MW output or load shedding. Besides these types of transmission level control schemes, we may also utilize distributed energy resource (such as smart inverters and demand response)-based distributed control scheme to prevent system instabilities.

Reactive Transfer Limit / Thermal Rating	Reportable IROL Violation
Eastern Reactive Transfer Interface	Flow exceeds Last Convergent Case Limit for 30 minutes (T[illegible])
Central Reactive Transfer Interface	Flow exceeds Last Convergent Case Limit for 30 minutes (T[illegible])
5004/5005 Reactive Transfer Interface	Flow exceeds Last Convergent Case Limit for 30 minutes (T[illegible])
Western Reactive Transfer Interface	Flow exceeds Last Convergent Case Limit for 30 minutes (T[illegible])
AP South Reactive Transfer Interface	Flow exceeds Last Convergent Case Limit for 30 minutes (T[illegible])
Bedington – Black Oak Reactive Transfer Interface	Flow exceeds Last Convergent Case Limit for 30 minutes (T[illegible])
AEP-DOM Reactive Transfer Interface	Flow exceeds Last Convergent Case Limit for 30 Minutes (T[illegible])
Cleveland Reactive Transfer Interface	Flow exceeds Last Convergent Case Limit for 30 Minutes (T[illegible])
Kammer 765/500kV Transformer Thermal Rating	Post-contingency Simulated Flows exceed the Load Dump Limit for 30 Minutes (T[illegible])
Belmont #5 765/500 kV Transformer Thermal Rating	Post-contingency Simulated Flows exceed the Load Dump Limit for 30 Minutes (T[illegible])

1 9/27/2016



NREL
DR Server
Internet
Building Management System
PNNL
DR Message Publisher Agent
Aggregator Agent
Message Bus
Distribution Management System
Control Agent
Weather Agent
Load Agent
Demand Response Agent
EnergyPlus Agent
Message Bus
Load Flexibility/ Cost Curves
Load Equipment Specifications / Reduced Order Thermal Models
EnergyPlus Building Model
VOLTTRON

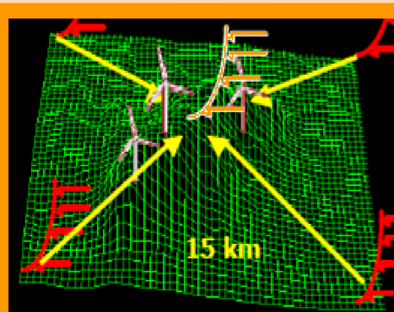
Multi-Scale Integration of Control Systems
Technical Details

NWP Output Data

Weather Data

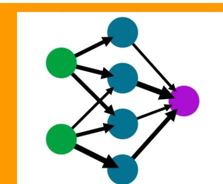
Off-site Met Data

Site Power Gen & Met Data



Physical Models

$$X_t = c + \sum_{i=1}^{p} \varphi_i X_{t-i} + \varepsilon_t.$$



Statistical Models

Wind Forecasts are the Result of Combination of a Diverse set of Models and Input Data

Forecast Results