Distributed Real Time Simulations Using RTDS®

A Joint Collaboration Between Idaho National Laboratory & National Renewable Energy Laboratory

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Energy Systems Integration Group

• ‘Real Time Power and Energy Systems Innovation Lab’ located at Idaho National Laboratory

• Real time research related to:
  – Power systems modeling and simulation
  – Controller-Hardware-In-the-Loop (CHIL)
  – Power-Hardware-In-the-Loop (PHIL)
  – Wind power and storage
  – Hydro electric modeling
  – Microgrid and controller rapid prototyping
  – Electrolyzers and demand response
  – Vehicle charging and battery storage
Grid Activities at INL

175+ million dollars
Amount of grid-related funding INL has received since 2008

13+ Number of grid-related test ranges, user facilities and laboratories at INL

10+ Grid-related software programs created at INL

> 85 Number of staff working on grid-related projects

20+ Grid related software intellectual property
Grid-Related Physical Infrastructure

Wireless Communications Test Bed

Electric Grid Reliability Test Bed – 138kV

Center for Advanced Energy Studies

Battery and Vehicle Infrastructure Testing Center

Dynamic Energy Storage HYTEST Lab

Biofuels Process Demonstration Unit

Control Systems Testing and Cyber Security

In-town facilities along “Research Row”

Energy Systems Laboratory
Motivation

• Leverage the distributed physical assets at multiple Department of Energy (DOE) labs

• Idaho National Laboratory (INL)
  – Energy Systems Lab, INL Wireless Test Bed, CITRIX

• National Renewable Energy Laboratory (NREL)
  – ESIF, NWTC, and so on

• Integrate these unique facilities based on standard communication protocols

• Expand Real Time Simulation (RTS) capacity to address greater network challenges

• Stimulate and sustain inter-organizational research collaborations
Super Lab Concept

INL
- Power System Grid Test Bed
- Wireless Test Bed
- SCADA / Cyber Security Test Bed
- Energy Systems Laboratory

PNNL
- NorthWest GridWise Testbed
- Grid Monitoring of the WECC

Washington State Univ.
- Real time modeling

LBL
- Microgrid Test Bed
- Integration

CAES - UI, ISU, BSU

SNL
- Energy Storage Test Program
- SCADA Test Bed

NREL
- Energy Systems Integration Facility
- National Wind Technology Center

ANL
- Pump Hydro Energy Storage Systems

ORNL
- Reactor Modeling

MIT
- Energy Systems Modeling

Florida State Univ.
- 5 MW Grid simulator

Univ. of Texas at Austin.
- Physics Based Modeling

Colorado State Univ.
- Power System Dynamic Modeling

Univ. of New Mexico
- Wind Dynamic Modeling

RTDS Link

INL

NREL

SIEMENS

IDaho Power

PacifiCorp

PARC

aeso

SONONIQUE
Introduction

• RTS using geographically distributed RTDS® such that data links are equivalent to transmission line connecting the subsystems
  – Events take approximately the same time as data transfer
  – Transients and other fast events are localized
• Research personnel experienced in RTDS® over decade
• Florida State University and Sandia National Laboratory experience of remote hardware testing (2004)
  – CAPS-SNL worked on RTDS® to SCADA testing
  – RTDS® simulated power systems and SCADA hardware collected measurements and control commands
• Mississippi State University and Texas A&M University remote simulations using RTDS® (2009)
  – Testing different protocols between two power system simulations
  – NI DAS used as protocol interpreter at both ends
• TCP and UDP based RTS at Aachen University, Germany
Current Architecture

INL Assets

- Power and control systems modeling
- PHIL – vehicles, batteries, wind, super-capacitors, microgrid, etc.
- CHIL – front end controllers

NREL Assets

- Power systems modeling
- Wind turbines and CGI at NWTC
- ESIF assets – electric vehicles, electrolyzer, etc.
Ping Test Results

- Maximum = 3433 milliseconds
- Minimum = 26 milliseconds
- Average = 34.7855 milliseconds
- Data drops = 43

- Maximum = 810 milliseconds
- Minimum = 26 milliseconds
- Average = 27.2044 milliseconds
- Data drops = 327
Distributed RTS

- 2 RTDS® models developed:
  - 4 bus 2 area test system (Developed by Dr. Kundur)
  - IEEE 13 node feeder test system
- Transmission network (source) at INL and the distribution network (sink) at NREL
- Transmission network comprises of a current source that approximates the load
- Distribution network comprises of a voltage source that approximates the source
- PEM FC model connected at the distribution network and operated as an electrolyzer
- Socket (SKT) firmware used to exchange TCP/IP data
Data Stream Exchanges
Results - I
Results - II

[Graphs showing waveforms and data plots related to subsystems and variables]
Results - III
Results - IV
Results - V
Microgrid R&D

MGC – Hardware-In-the-Loop Environment

Real Time Digital Simulation Environment

MGC – Communication Interface

GTNET – Communication Interface

I/O Interface

CERTS Microgrid
Vehicle Charging Station and RTDS®

Vehicle Test station:
1) Electric Vehicle with the battery
2) Associated charging station
220V/480V, variable current

Power Amplifier
Analog signal: 5-10 V, 10mA

Power Converter
House Supply

House Supply

Grid Model (V2G)

ESL RTDS LAB

Real Time Digital Simulator (RTDS) and its graphical interface RSCAD

Grid Model G2V
Key Research Questions

• How are ancillary service provided by variable generation
  – How can they contribute into grid reliability improvement and cost of energy reduction
• How smart grid technologies can be implemented and expanded in “Large Grid” applications
• How much renewable penetration can be supported by the existing infrastructure
  – What future upgrades and expansions are needed
• What modifications and improvements to grid regulations are needed to accommodate more renewables
• What testing along with changes, modifications, and improvements are needed for various standards of inverter based generation to meet grid interconnection requirements
• Due to fossil fuel plants reductions causing rotational and thermal inertia loses, what value will Hybrid Storage could contribute to the power quality
Concluding Remarks and Future Work

- RTS conducted on geographically distributed RTDS® at INL and NREL
- Demonstrate the applicability to RT PHIL and assess relevant simulations
- Immense potential observed in the formalized integration of RTDS® racks at different locations to leverage assets
- Enhance research collaboration with DOE labs, industry, utility, and academic organizations using RTDS®
- Perform a large scale RTS based on the experiences from INL-NREL connectivity
- Future work:
  - Formalize the distributed RTS along with PHIL approach
  - Accuracy analysis using time-stamped data
Future Work

Potential technical capabilities for INL:
- Dynamic simulations for large power networks & future grid
- Integrated analysis with INL’s existing capabilities of PSH simulations
- Remote PHIL testing

Utility partners?
Idaho National Laboratory