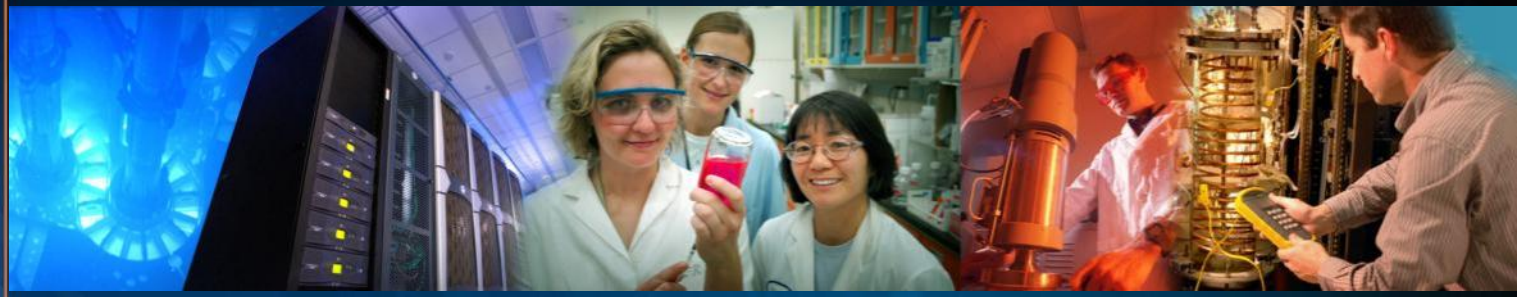


DRTS-DRTS Link for Distributed Real Time Simulation

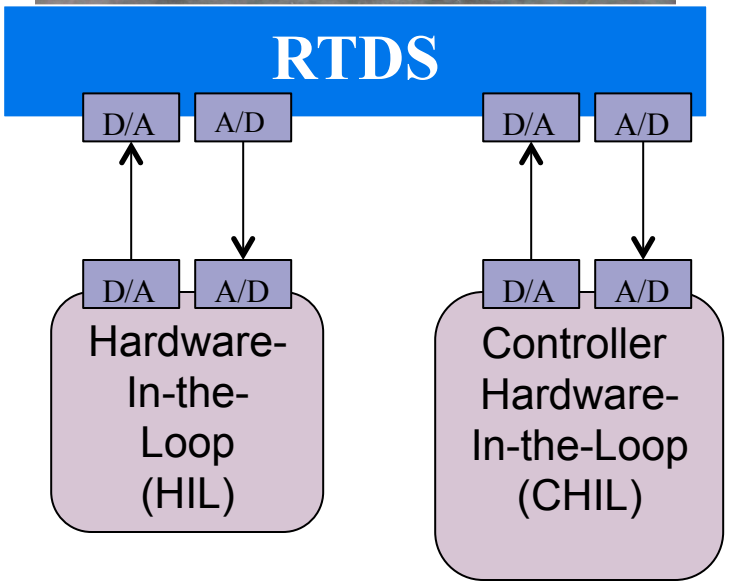
Dr. Rob Hovsapian

www.inl.gov

Idaho National Laboratory

Digital Real Time Simulator

- High-fidelity transient power system simulation
  - Time-domain solutions of dynamic system behaviors
- System level study at 50/2 μs time steps
- Digital and analog I/O enable “real-world” feedback
- Specialized / dedicated computer hardware and software system for energy system simulations and hardware emulations
  - Utility quality system analysis tool



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**

Introduction

- **RTS using geographically distributed RTDS® such that data links are equivalent to transmission line connecting 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**

Super Lab Concept - Leveraging Other National Labs and Academic Institutes

Idaho National Laboratory

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

NREL
- Energy Systems Integration Facility
- National Wind Technology Center

ANL
- Pump Hydro Energy Storage Systems

SNL
- Energy Storage Test Program
- SCADA Test Bed

PNNL
- NorthWest GridWise Testbed
- Grid Monitoring of the WECC

Florida State Univ.
- 5 MW Grid simulator

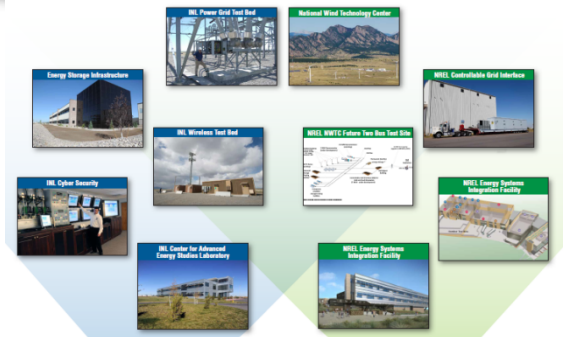
Washington State Univ. - Real time modeling

Univ. of Texas at Austin.
- Physics Based Modeling

CAES – UI, ISU, BSU

Colorado State Univ.
- Power System Dynamic Modeling

Univ. of New Mexico
- Wind Dynamic Modeling



RTDS Link

INL — NREL

TESLA

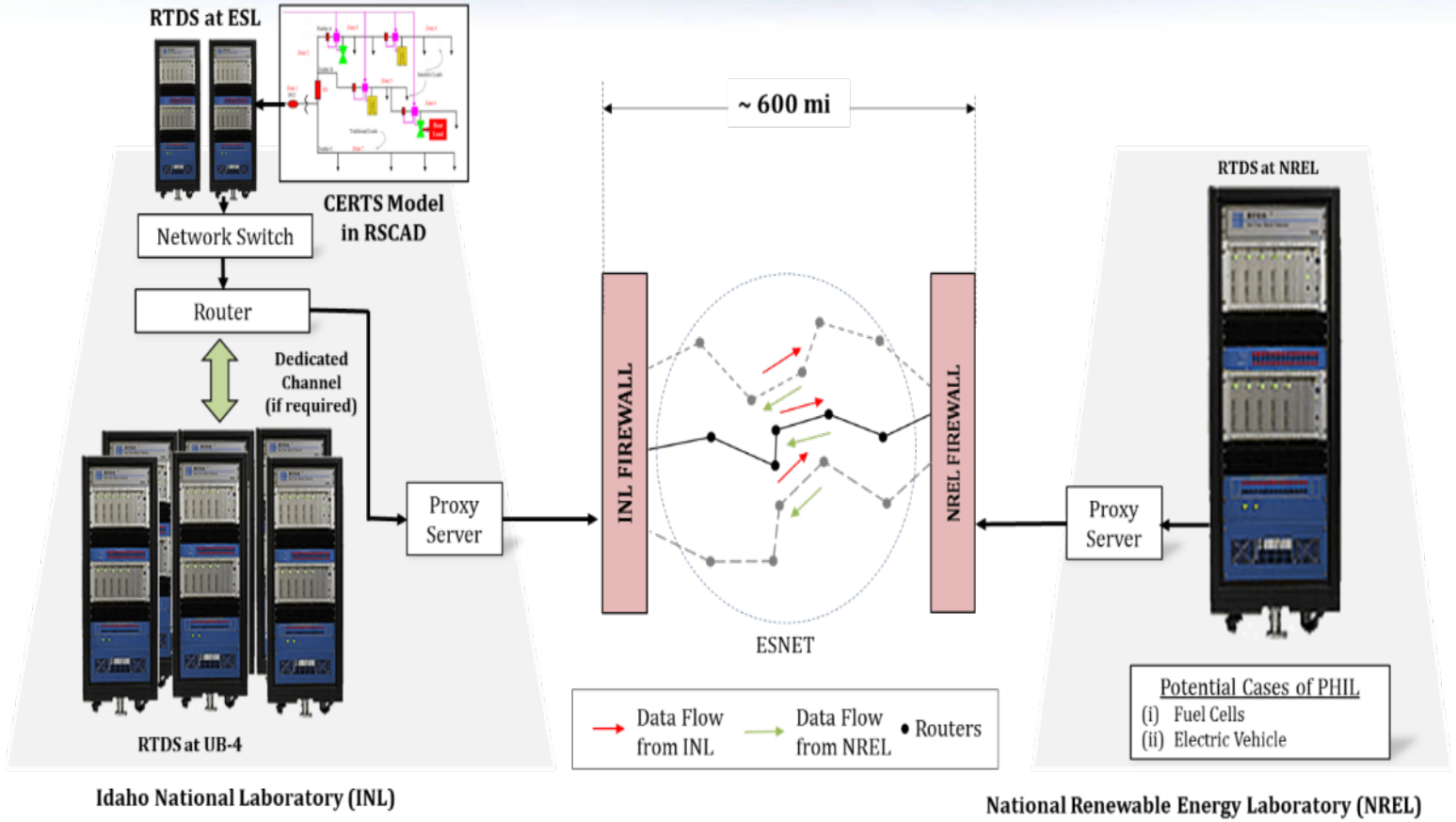
SIEMENS

California ISO
Shaping a Renewed Future

SDGE
A Sempra Energy utility

PG&E

Current Architecture



INL Assets

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

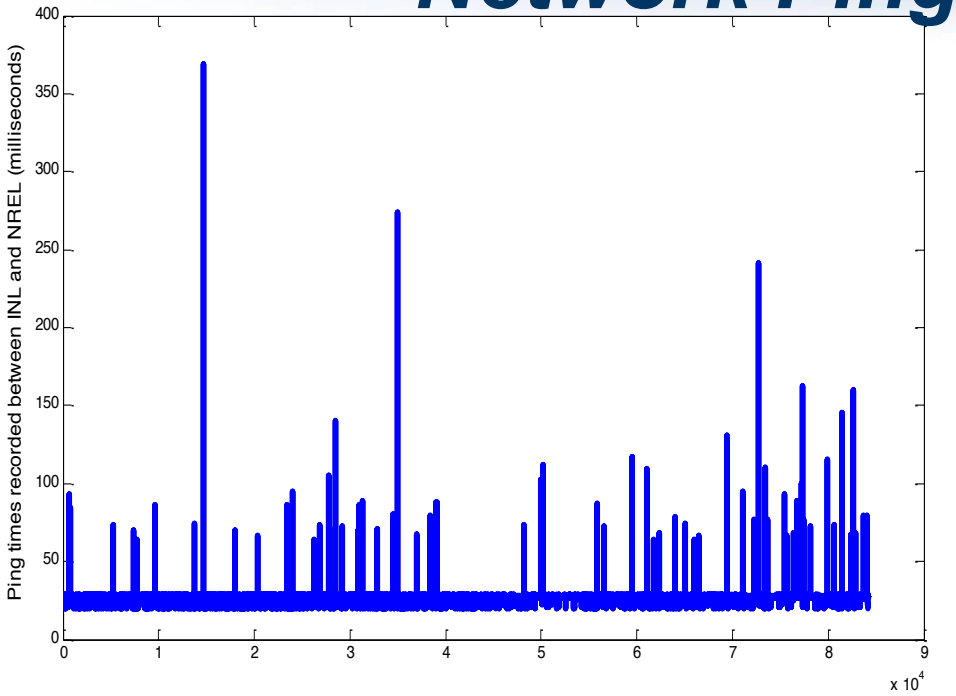
NREL Assets

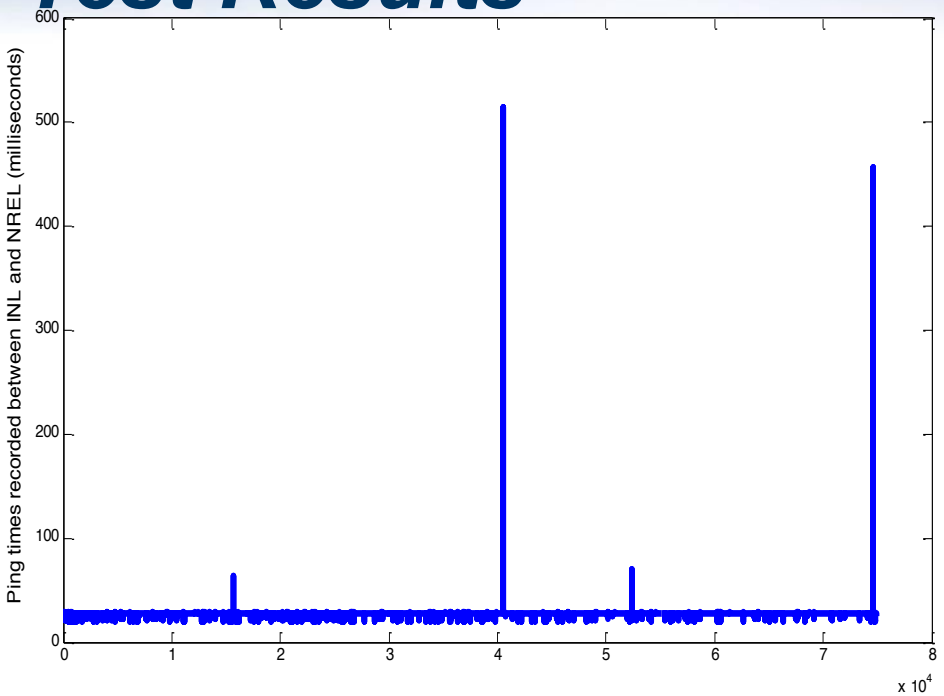
- Power systems modeling
- Wind turbines and CGI at NWTC
- ESIF assets – electric vehicles, electrolyzer, etc.

Current Distributed RTS Test Environment

- **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**

Network Ping Test Results





- Maximum = 369 milliseconds
- Minimum =20 milliseconds
- Average = 27.1557 milliseconds
- Data drops =24

- Maximum = 515 milliseconds
- Minimum =20 milliseconds
- Average = 27.0409 milliseconds
- Data drops =17

Real Time Modeling and Simulation

- **'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

Objectives RTDS-RTDS Distributed Simulation

- *Technical Objectives*

Develop Real Time Digital Simulation capabilities; capable of interfacing with other geographically distributed real time simulation assets at other national labs, universities, and utilities; to conduct dynamic and transient analysis of larger power and energy systems. This will utilize existing lab assets and leverage other computational and simulation assets by expanding INL's capabilities to study and analyze large regional and possible national scale power & energy systems.

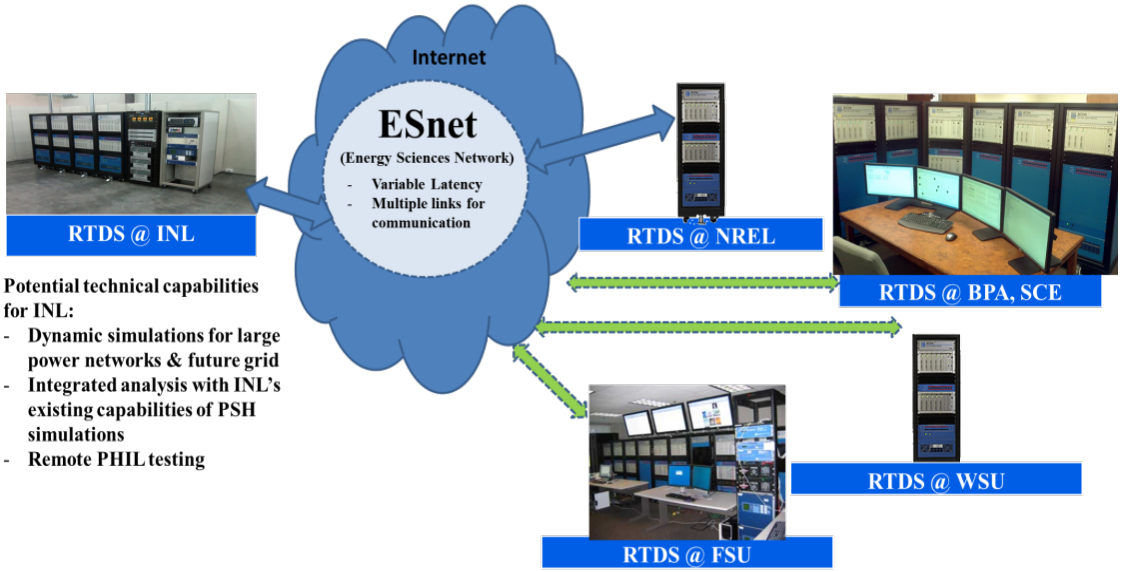
- *Mission/Business Objectives*

In recent DOE – Grid Tech (Grid Modernization) efforts it was identified by DOE OE and EERE that there are existing gaps in the design and operational tools for conducting dynamic analysis to better understand power quality challenges facing the power and energy industry. Inability to model / simulate the dynamics of newer devices (Power convertors & Power Electronics) operating in seconds to minutes time scale, and the challenges in predicting transients (microseconds to seconds). Those challenges are increasing due to an increase in integration of distributed generation, renewable generation, and hybrid energy systems. With these added capabilities and expertise, INL will be at forefront of the science, and better able to address those regional and national power and energy challenges.

Objectives (Cont.)

- *Significance & Impact*

The proposed development of these capabilities will foster stronger ties and collaboration with researchers and scientist from other National labs, academic researchers, and utilities for future dynamics and transient simulation research for large power and energy systems. Once successful, this research will have regional and national impact.



Innovation

Current State of the Art

Currently the real time simulation community is limited to size of each individual system. A limited connectivity was done between academic systems and another National Lab (Sandia) in 2006, with the latest advancement of the computational systems, which will allow the connectivity of even larger real time simulation systems.

Innovation

- Develop a unique and innovative integrated real time co-simulation platform, capable of co-simulating with other real-time simulator(s) (local or geographically distributed) using Power-Hardware-In-the-Loop, Controller-Hardware-In-the-Loop (CHIL). Capabilities include the co-simulation of electrical/thermal/mechanical subsystems at different computational time steps.
- Investigate and establish ways to address data latencies and develop power grid network equivalence techniques on geographically distributed test systems.

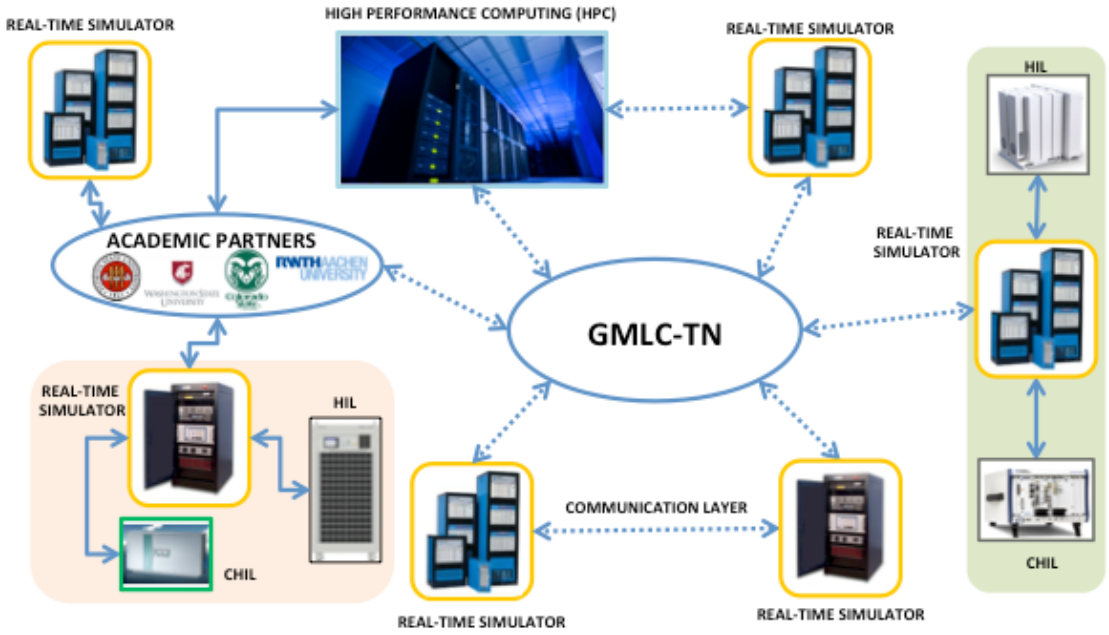
Technical Approach

Technical Approach To Achieve Objectives

- Network experiments between INL and NREL qualify the data latency challenges
- Establish a programmable and reconfigurable network communication layer between two RTDS systems to emulate real world communication events.
- Integrated Phasor Measurement Units (PMU) units with RTDS and communication layers.
- Synthesize power system events using real world events and actual PMU data from other national labs.
- Develop latency mitigation techniques
- Conduct dynamic simulation of large utility system and monitor transient events to demonstrate the value of RT simulation with higher details and better accuracy.

Benefit and Harvest Strategy

- ***New Capabilities***
  - Ability to conduct dynamic and transient analysis of large power systems
  - Research environment that will attract world-renowned researchers to conduct joint research with INL researchers in dynamics and transient analysis of power and energy systems.
- ***New Programs/Work for Others/CRADA Opportunities***
  - In the last 10 months, since the establishments of our stand alone RTDS capabilities, we have been able to attract industry and other academic partners to submit 8 joint proposals and we are constantly been invited to join others in their proposals. Those opportunists will increase with the additions of the proposed unique capabilities.



Benefit and Harvest Strategy

- ***New Collaborations***
  - Academic Colorado State Univ., Washington State Univ., & Florida State Univ.
  - Industrial – RTDS
- ***Publications***
  - We currently have two Journal publications in works based on our early work in this area and we do expect a minimum of two journal publications per year, based on the research and technology dissemination
- ***Intellectual Property***
  - In order to maximize the impact and benefits to DOE, most of the models and technics developed as part of this project will be open to the power and energy community and the information will be disseminated via journal publications.
  - The only technology that could be patented is the data latency mitigation techniques, and we will know more as we start the development.

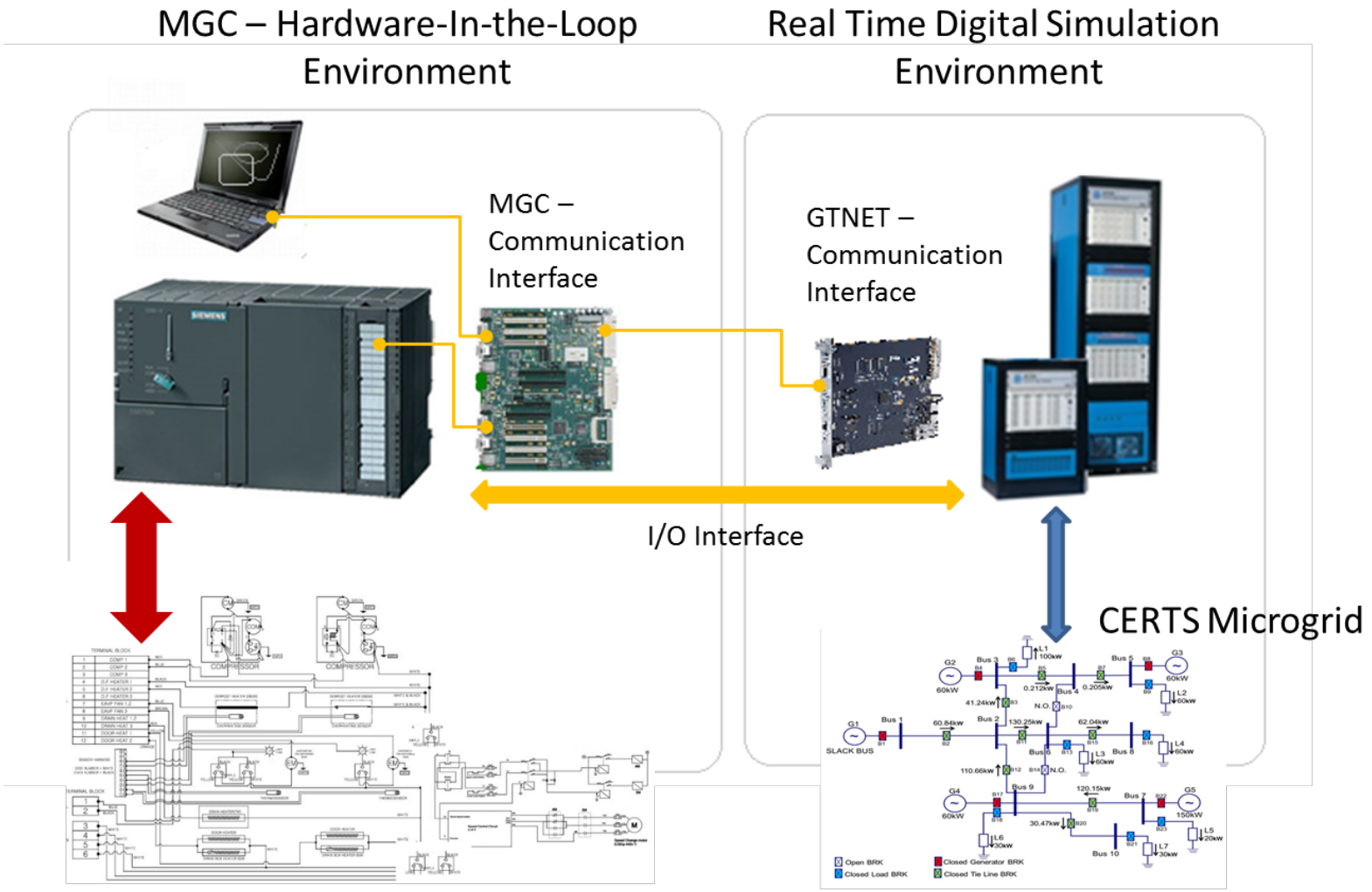
Key Accomplishments

- **Real time simulation conducted on geographically distributed RTDS systems between INL and NREL**
  - Transmission network at INL, and distribution network with electrolyzer at NREL.

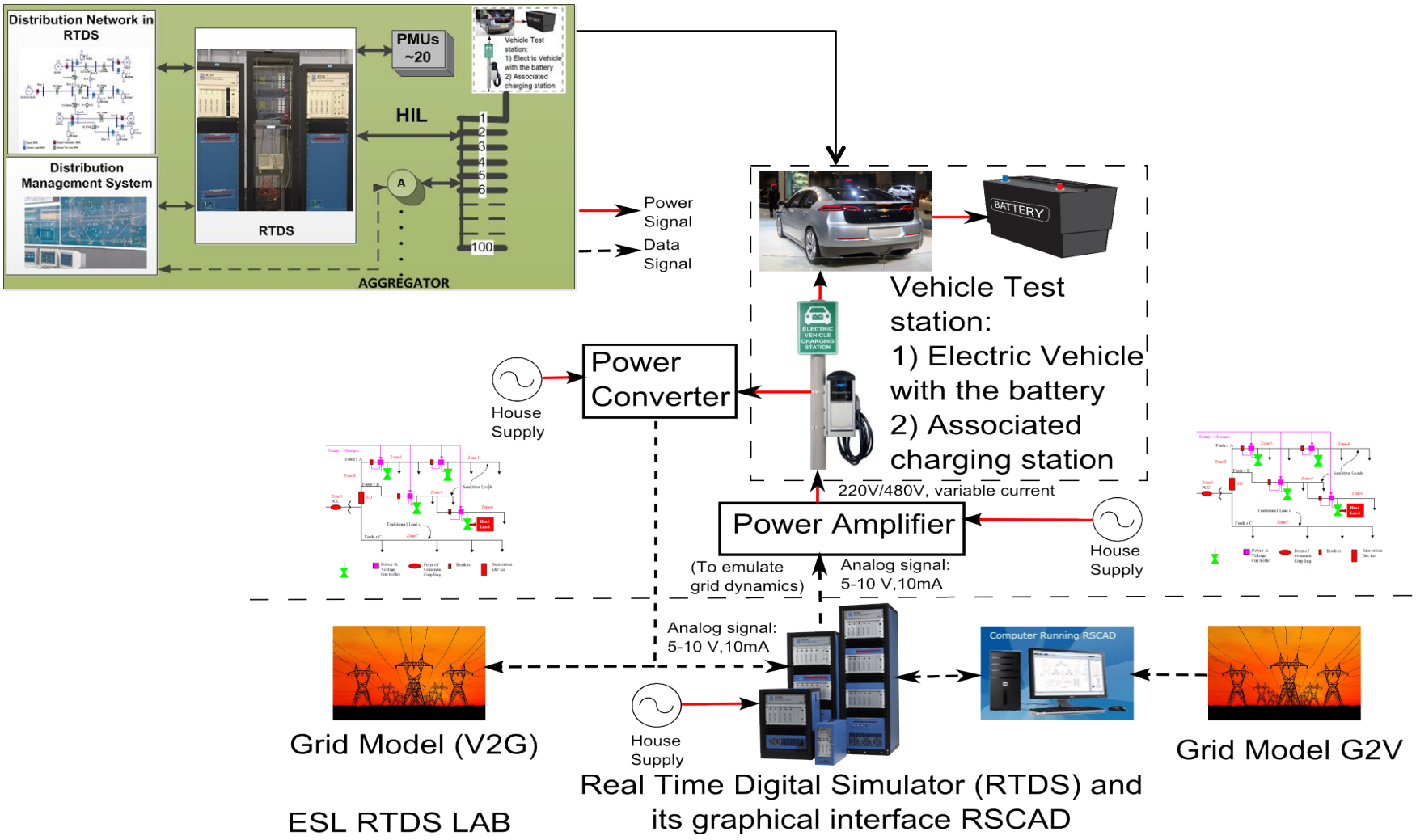
- **INL has been awarded two new projects due to RTDS-RTDS unique capabilities**
  - California Energy Commission's Red Cross evacuation route microgrid
  - Dynamic Modeling and Validation of Electrolyzers to Demonstrate its Value in a Real Time Environment

- **Recent press articles:**
  - Smart Grid News - ***NREL and INL connect power grid technology over the Internet***
  - World of Renewables / Environmental XPRT ***- INL and NREL Demonstrate Power Grid Simulation at a Distance***
  - PHYS-ORG ***- INL and NREL demonstrate power grid simulation at a distance***

Other RTS Research at INL - Microgrid R&D



Vehicle Charging Station and RTDS®



Thank you