Distributed Real Time Simulations Using RTDS®

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

Presenter – Manish Mohanpurkar, Ph.D.
Scientist, Energy Storage and Transportation, INL
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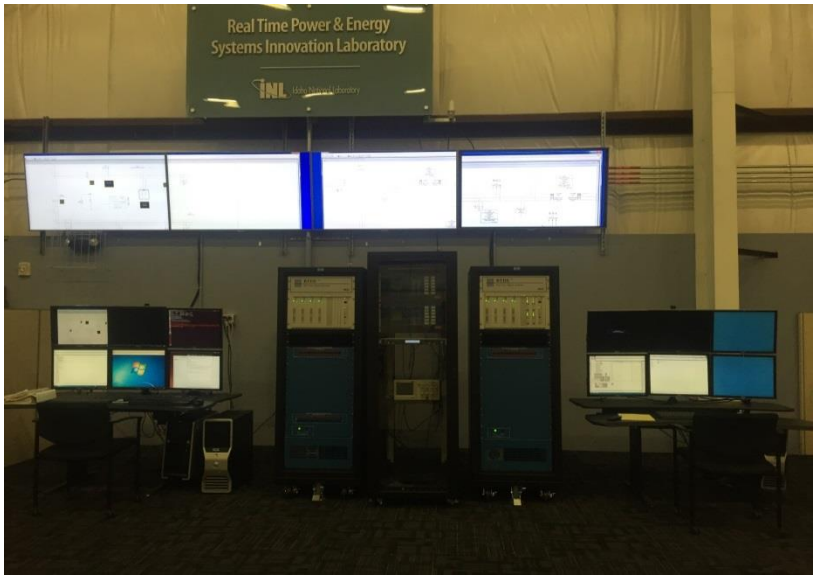

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

www.inl.gov

INL
Idaho National Laboratory

Team Members

Idaho National Laboratory

- Rob Hovsapian, Ph.D.
- Manish Mohanpurkar, Ph.D.
- Yusheng Luo, Ph.D.
- Mayank Panwar
- Eric T. Whiting

National Renewable Energy Laboratory

- Vahan Gevorgian, Ph.D.
- Ed Muljadi, Ph.D.
- Mohit Singh, Ph.D.
- Susan Bond

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- Press release: http://www.nrel.gov/news/press/2015/17498.html

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

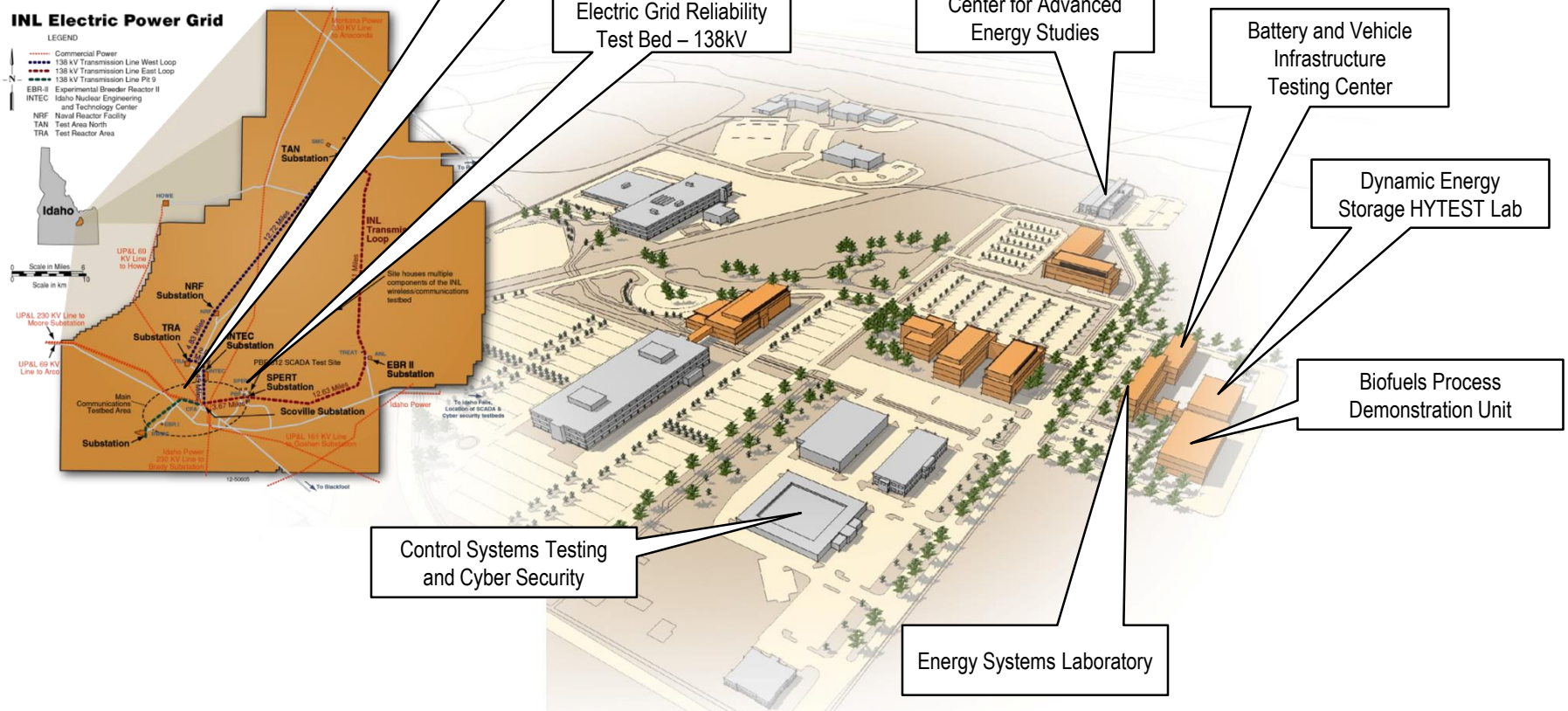
13+
Number of grid-related test ranges, user facilities and laboratories at INL

10+
Grid-related software programs created at INL

>85
Number of staff working on grid-related projects

20+
Grid related software intellectual property

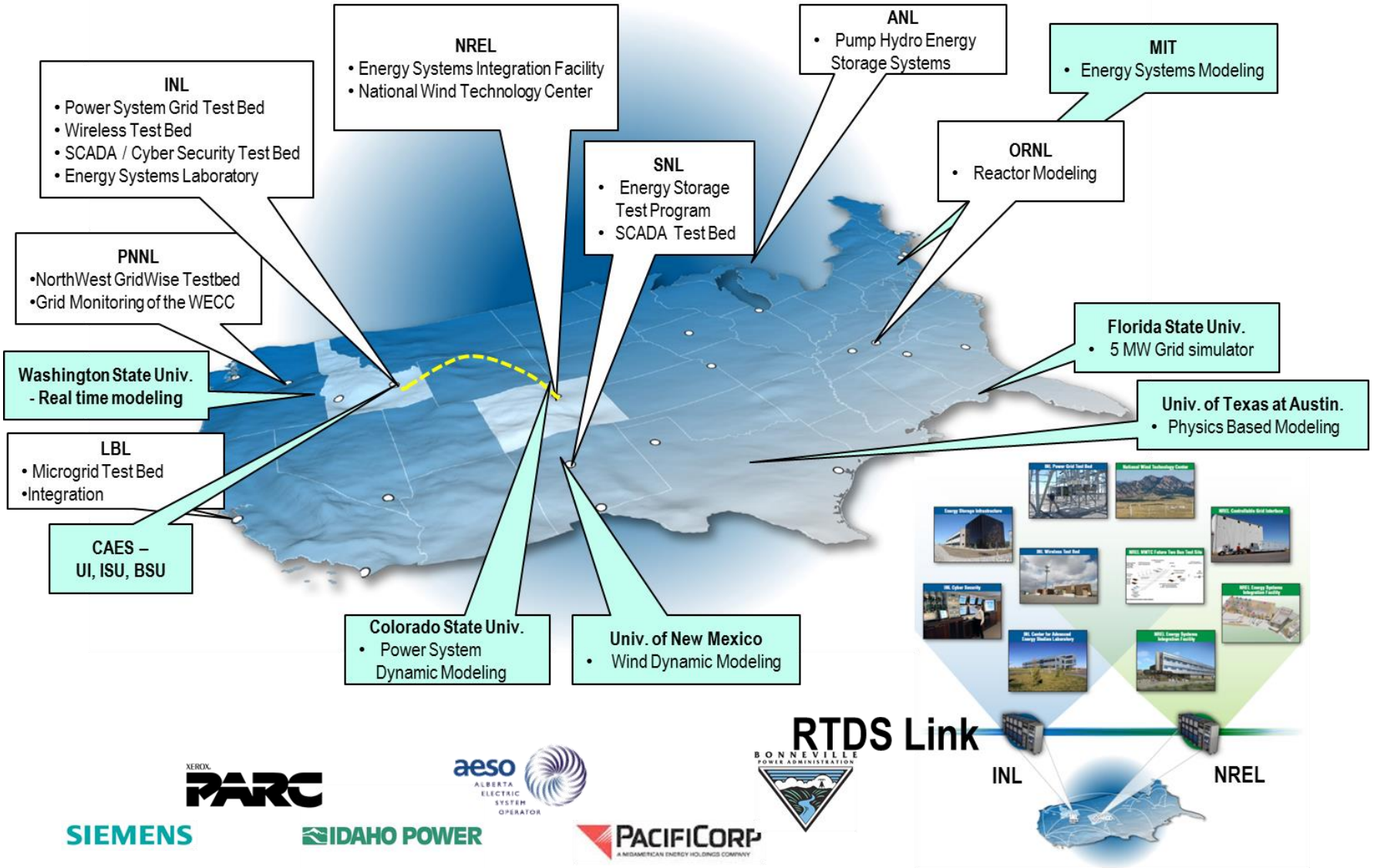
Grid-Related Physical Infrastructure



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

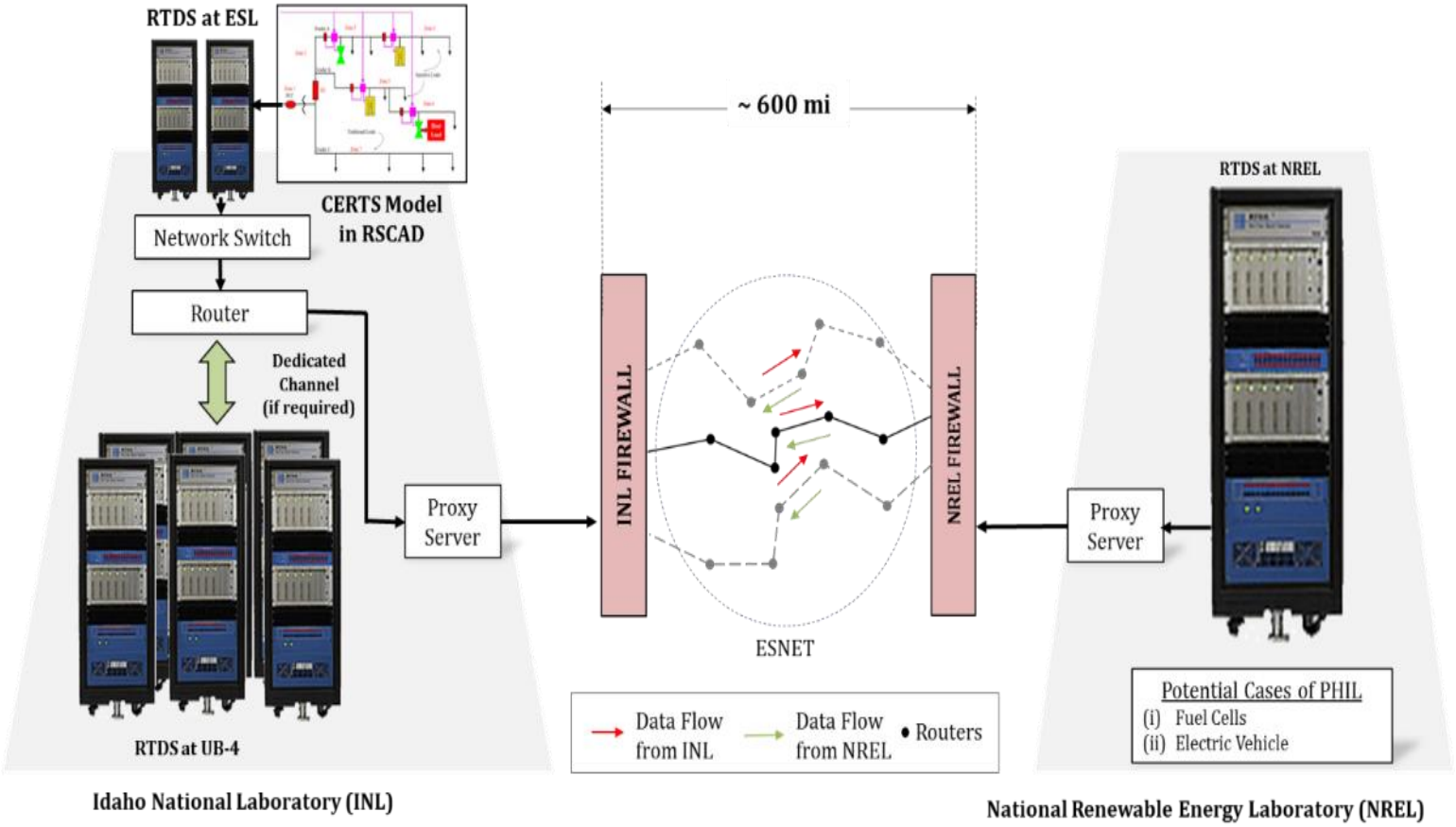
Super Lab Concept



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



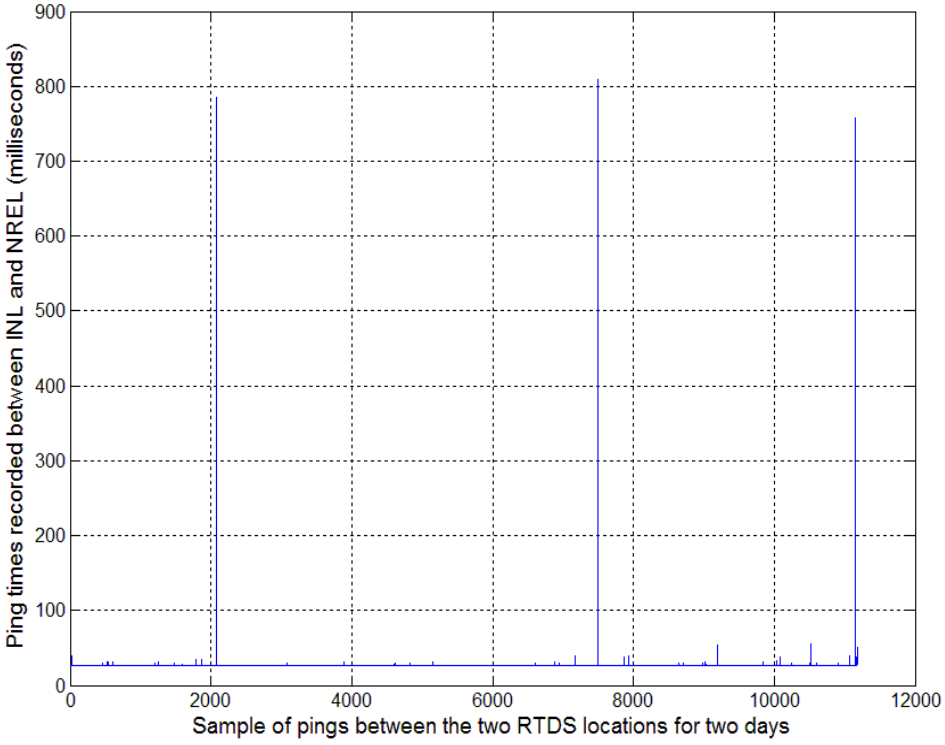
INL Assets

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

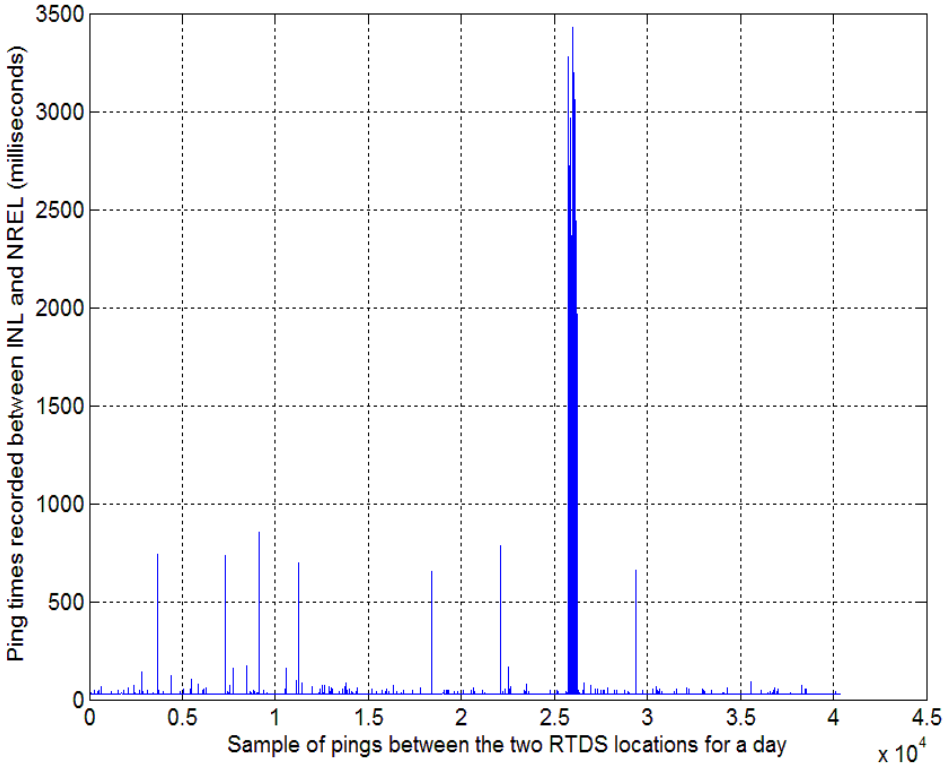
NREL Assets

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

Ping Test Results



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

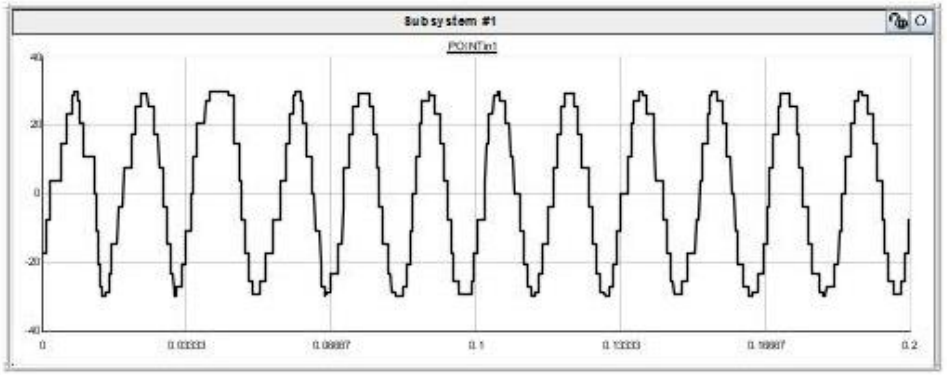


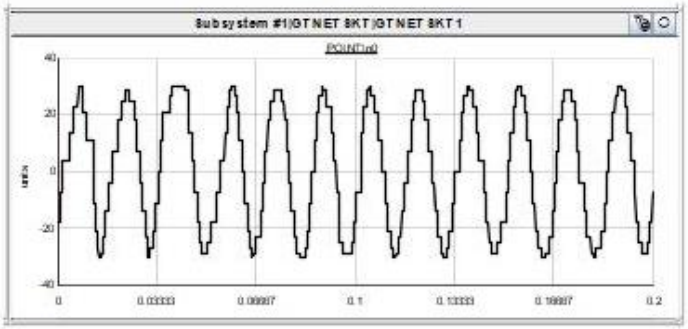
- Maximum = 3433 milliseconds
- Minimum = 26 milliseconds
- Average = 34.7855 milliseconds
- Data drops = 43

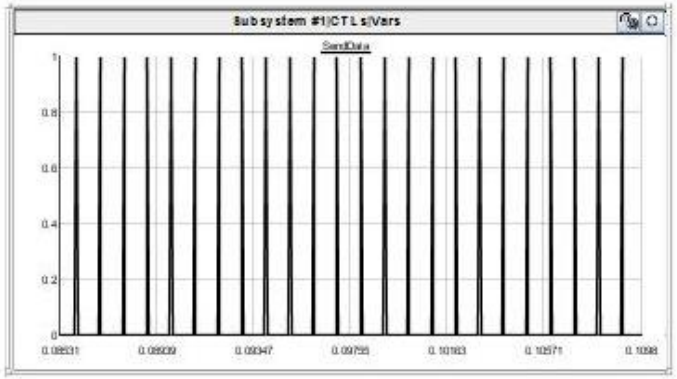
Distributed RTS

- 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

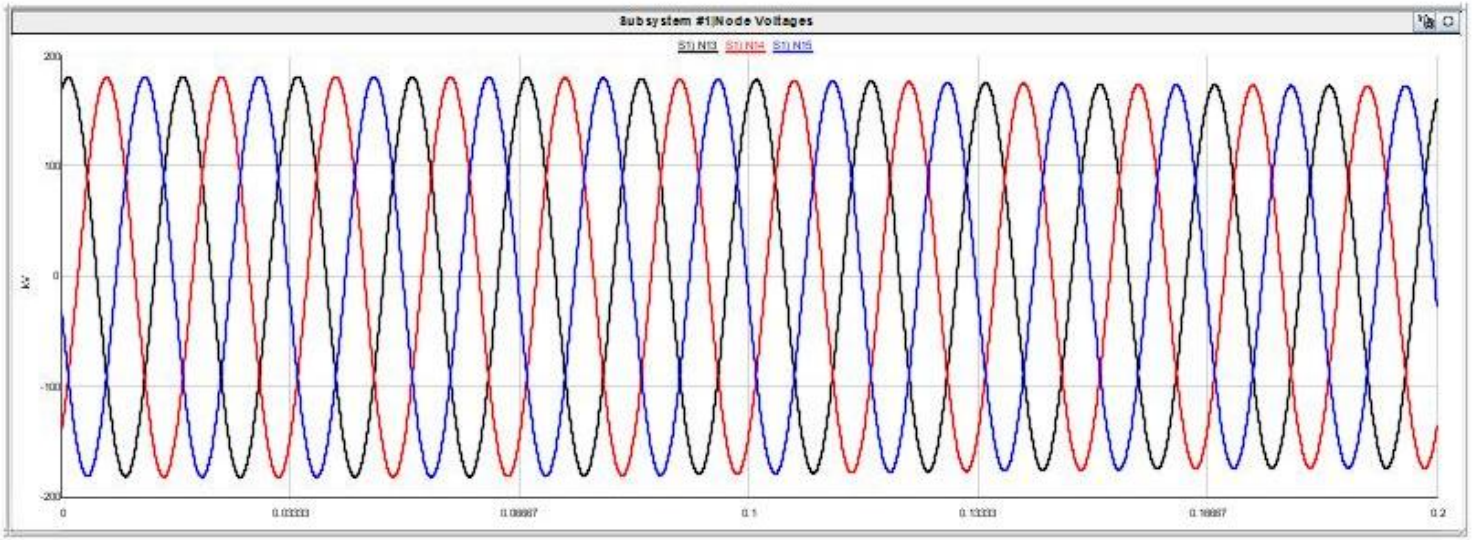
Data Stream Exchanges

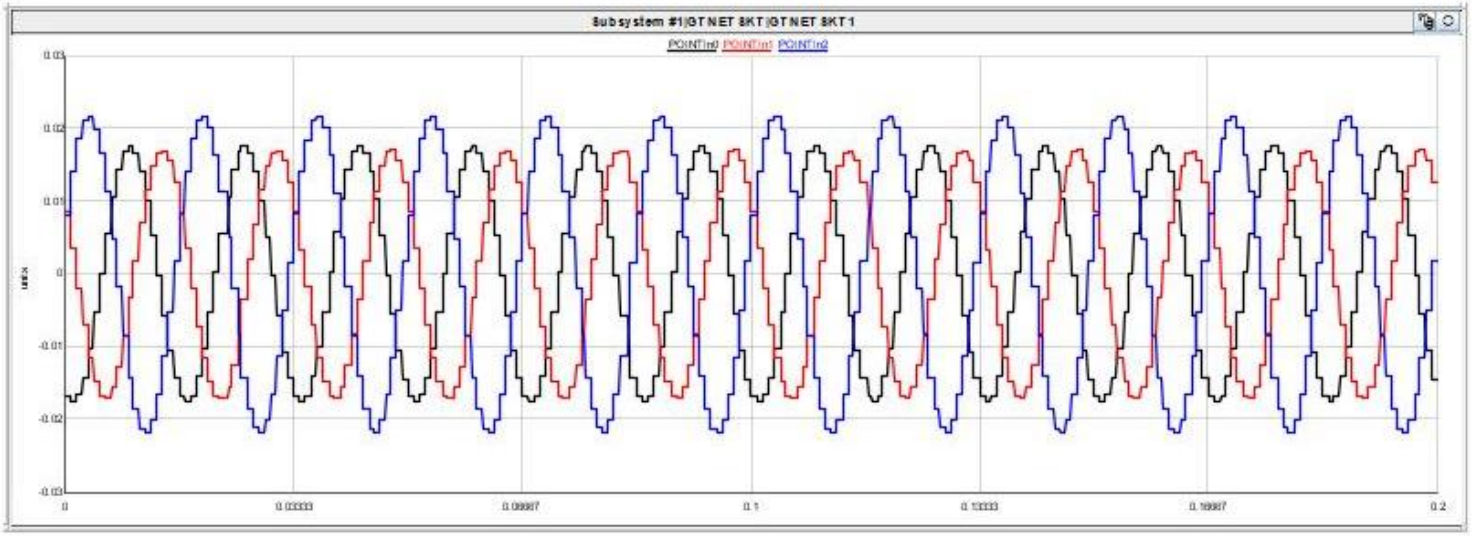




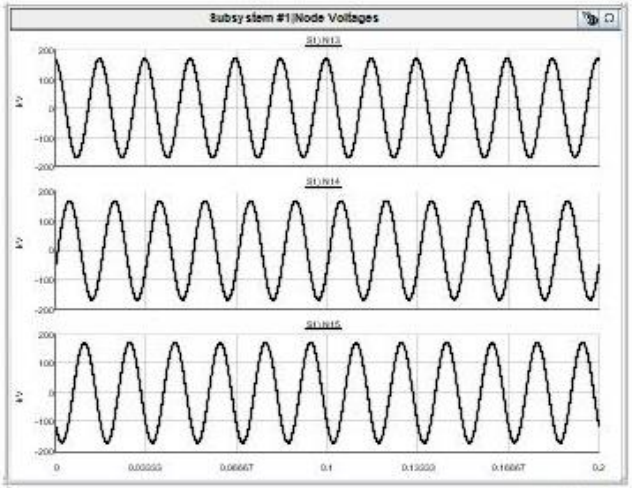


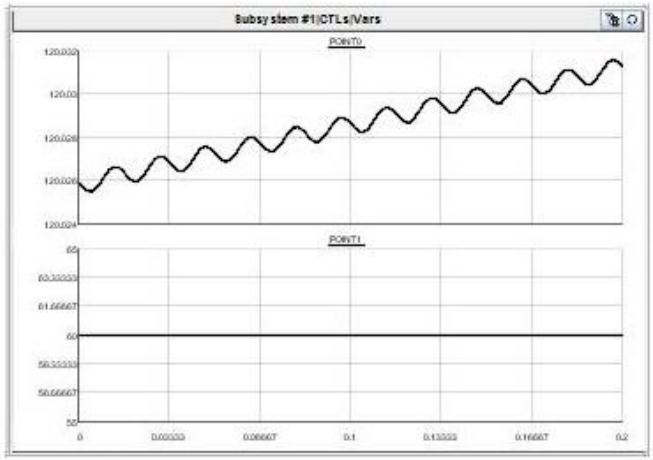
Results - I

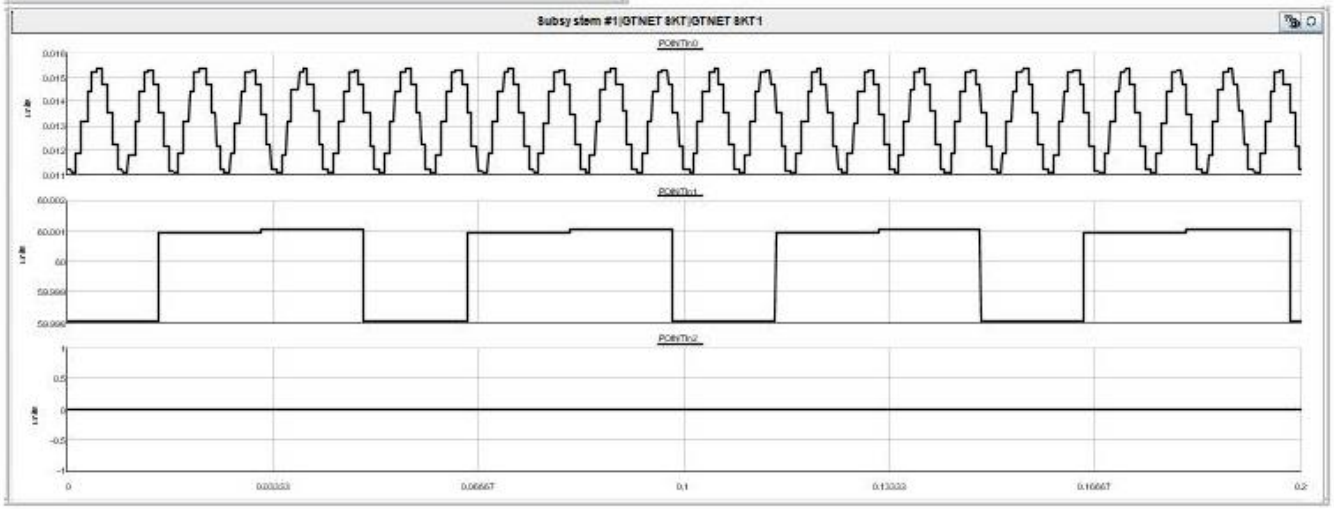

Subsystem #1|Node Voltages
STUN3 STUN4 STUN5
kV


Subsystem #1|GTNET-SKT|GTNET-SKT1
POINTin0 POINTin1 POINTin2

Results - II

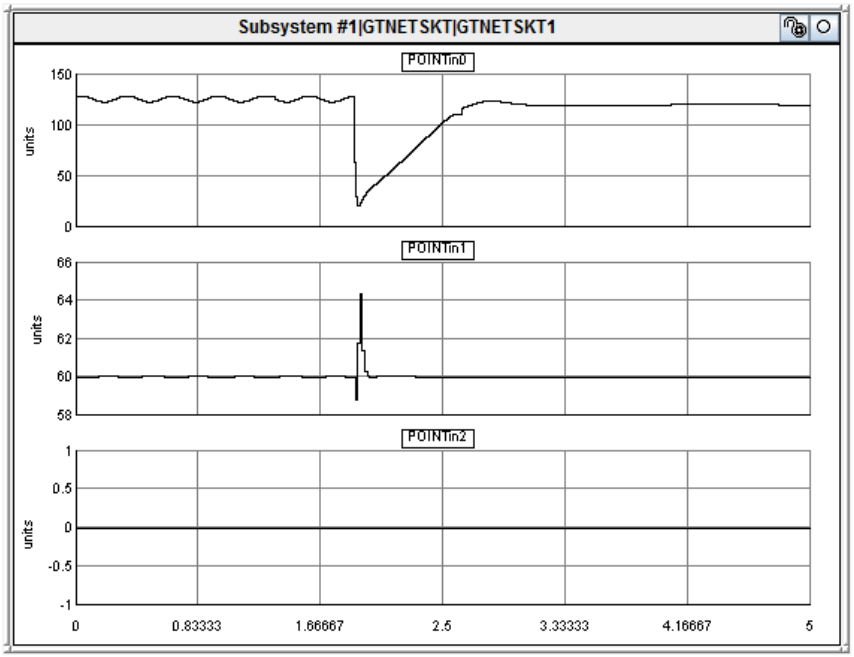

Subsystem #1|Node Voltages
BUS13
BUS14
BUS15

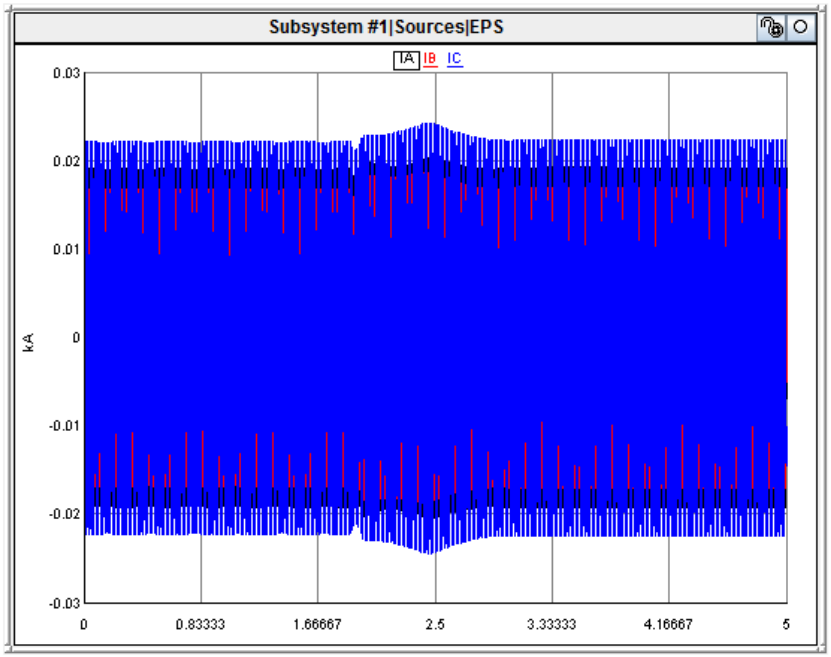

Subsystem #1|CTLs/Vars
POINT0
POINT1

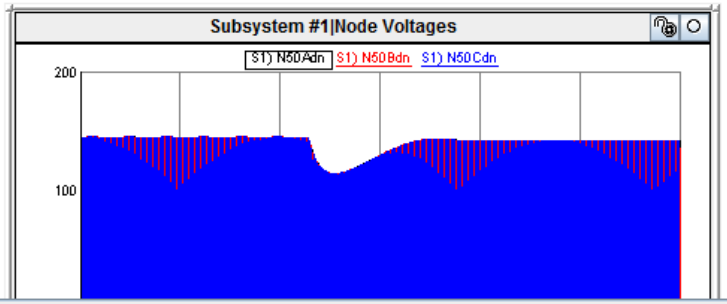

Subsystem #1|GTNET SKT|GTNET SKT 1
POINTn:0
POINTn:1
POINTn:2

Results - III

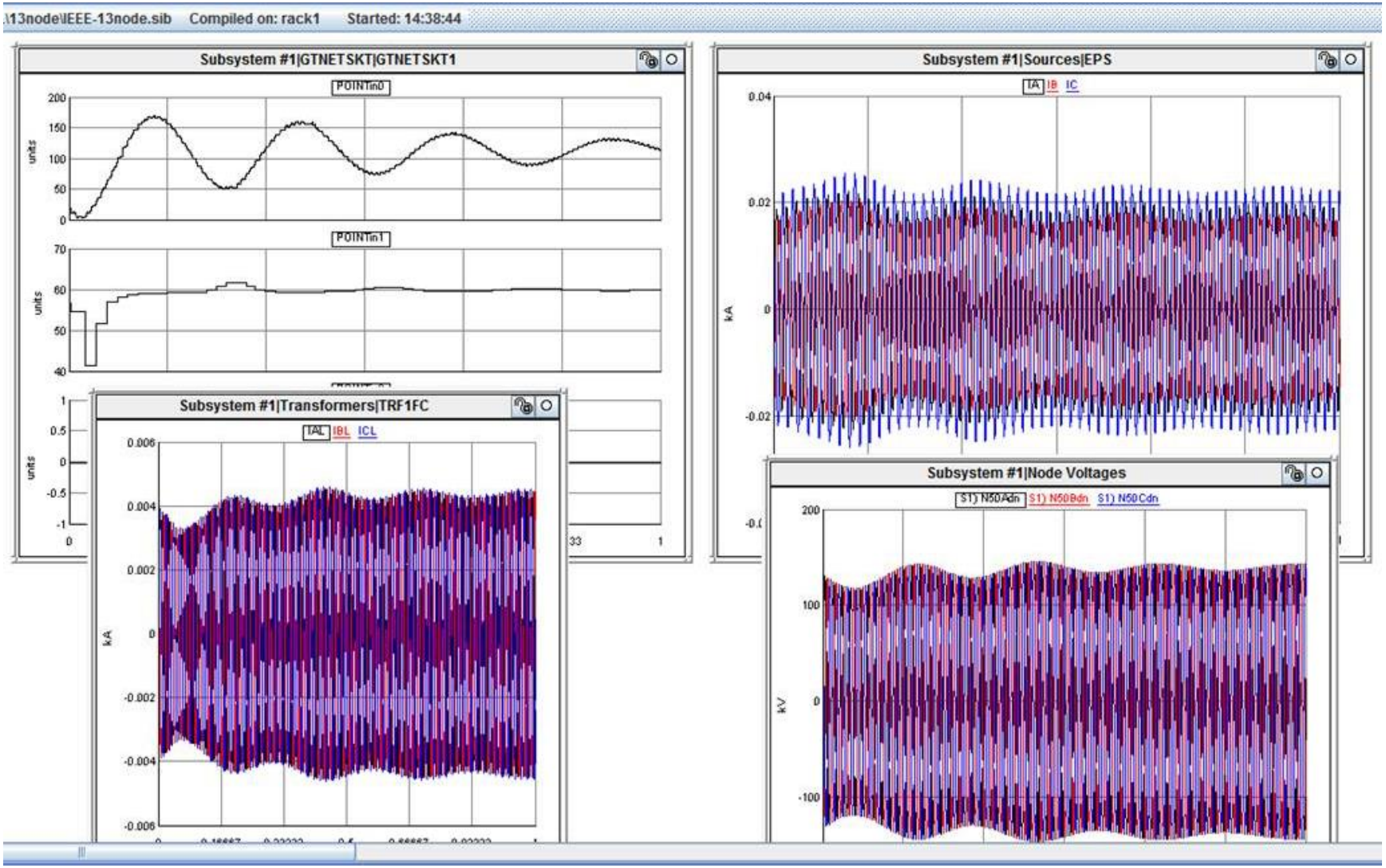
L\13node\IEEE-13node.sib Compiled on: rack1 Started: 12:17:28



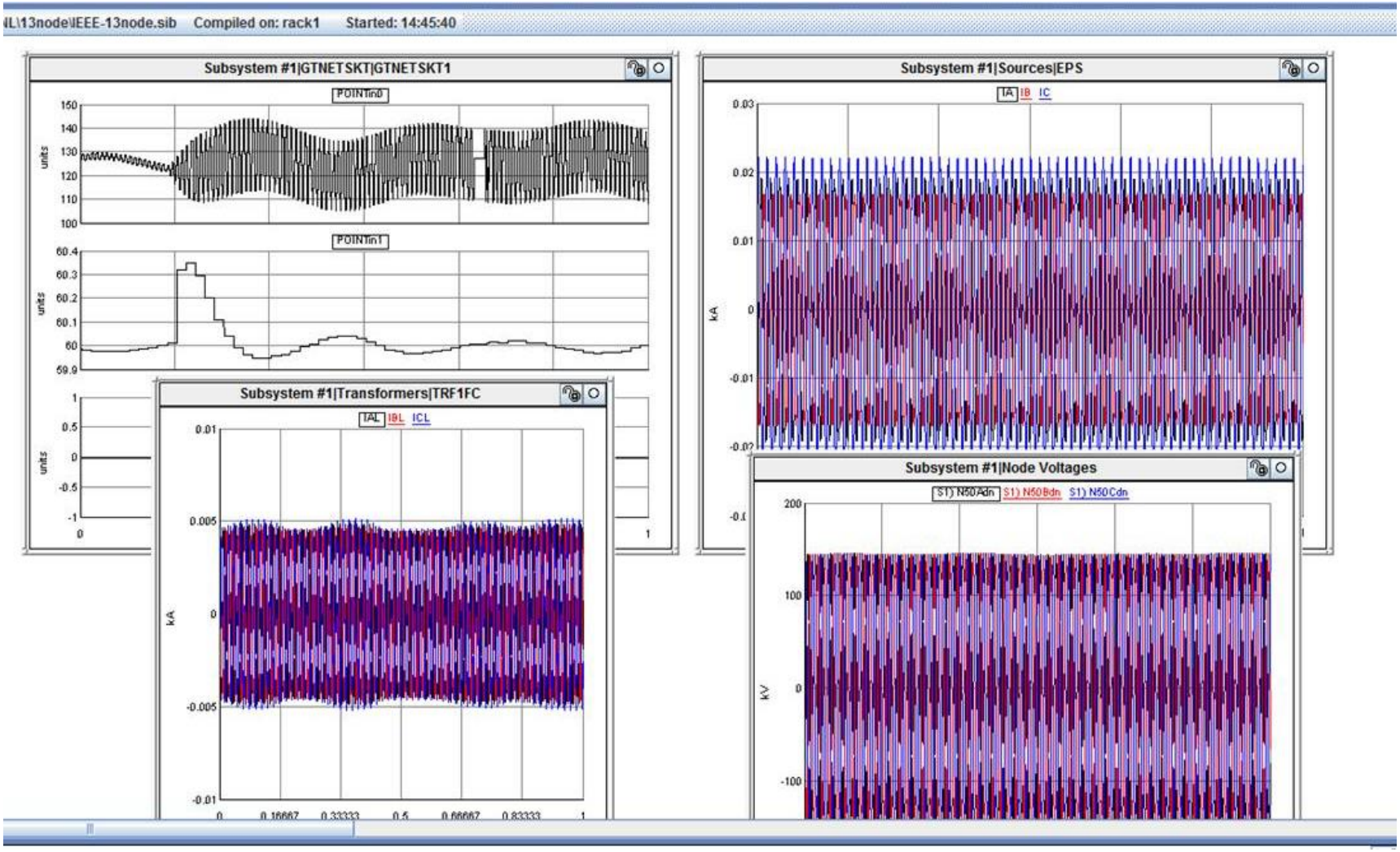




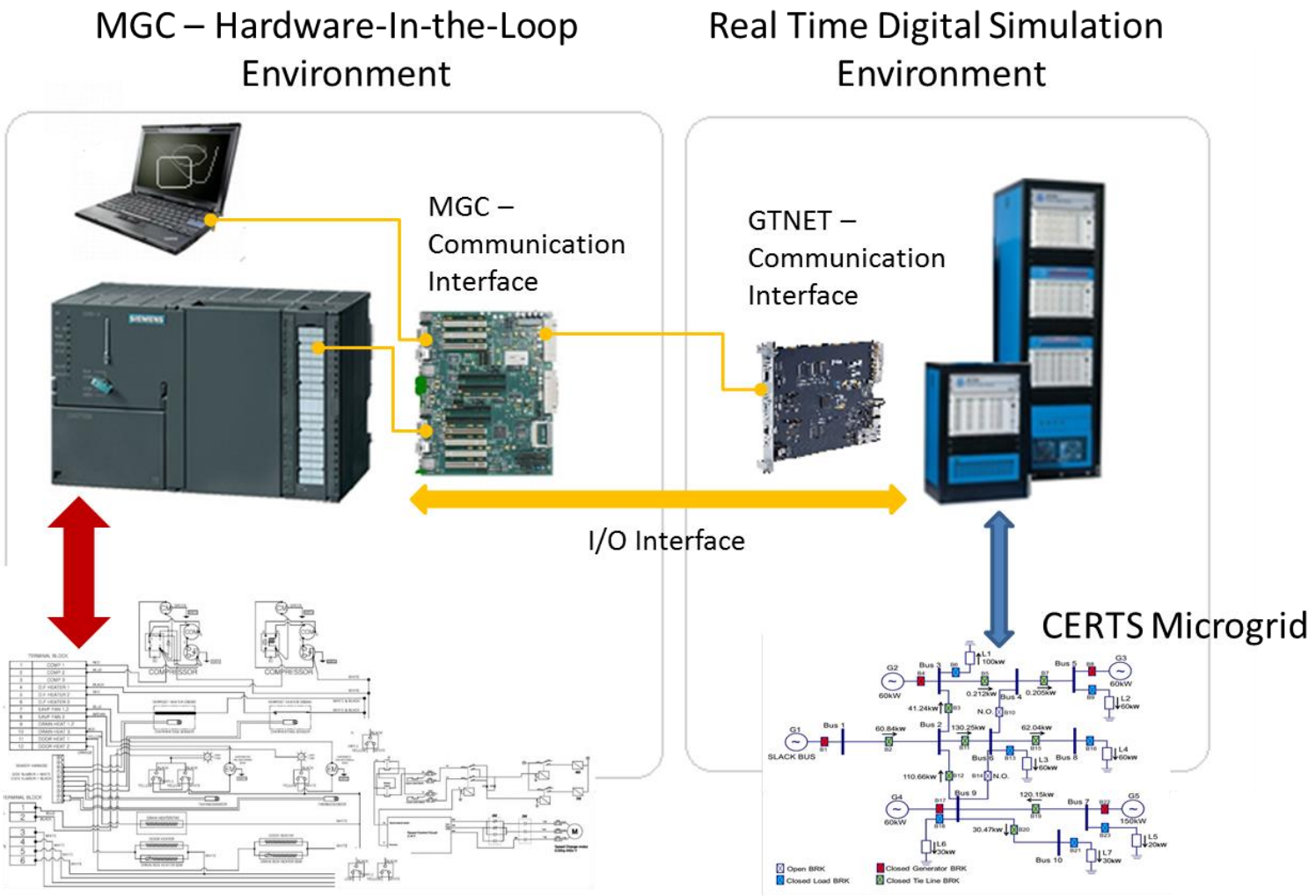
Results - IV


\13node\IEEE-13node.sib Compiled on: rack1 Started: 14:38:44
Subsystem #1|GTNETSKT|GTNETSKT1
POINTin0
POINTin1
units
Subsystem #1|Transformers|TRF1FC
IAL IBL ICL
kA
Subsystem #1|Sources|EPS
IA IB IC
kA
Subsystem #1|Node Voltages
S1) N50Adn S1) N50Bdn S1) N50Cdn
kV

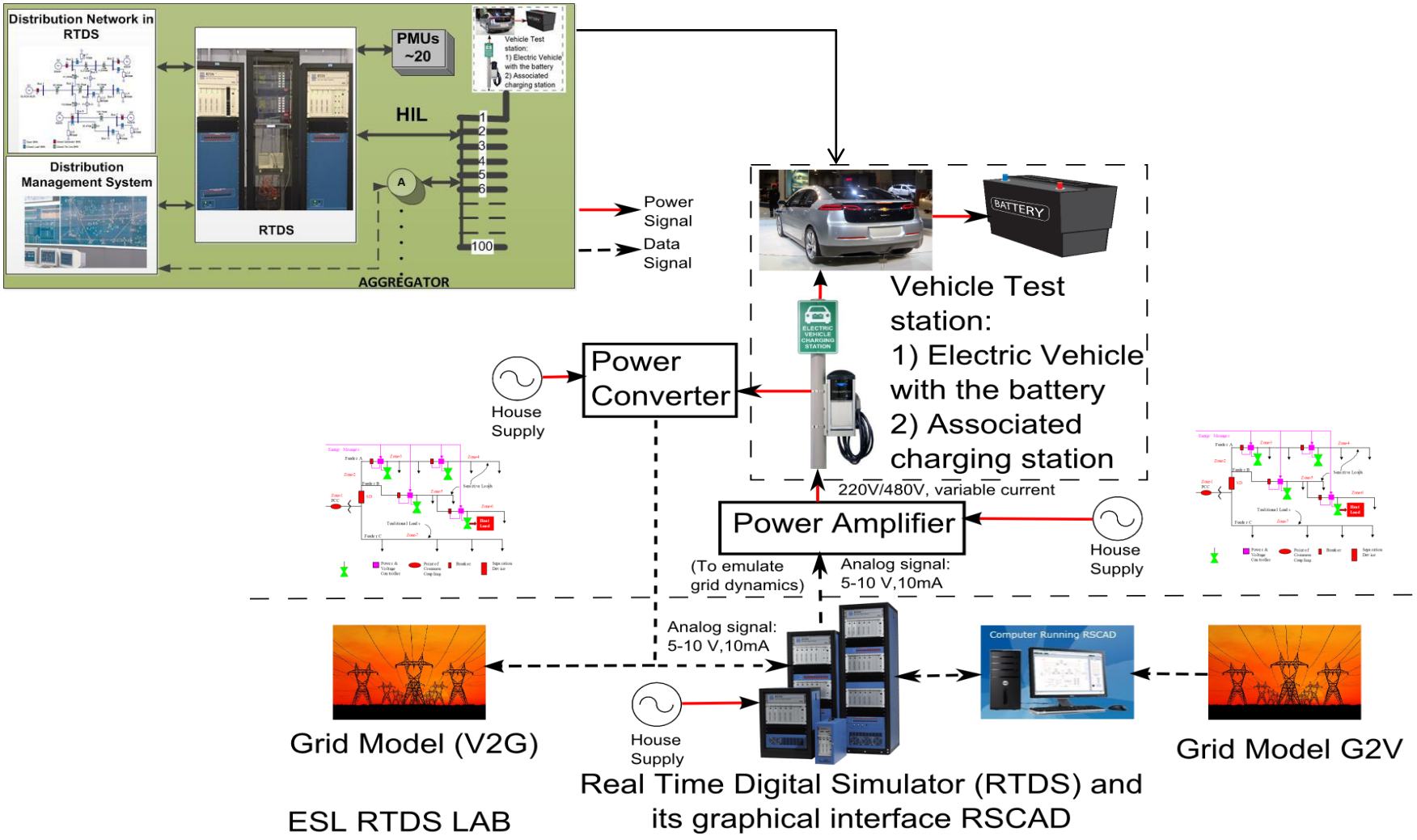
Results - V


\13node\IEEE-13node.sib Compiled on: rack1 Started: 14:45:40
Subsystem #1|GTNETSKT|GTNETSKT1
POINTin0
POINTin1
units
Subsystem #1|Transformers|TRF1FC
TAL IBL ICL
kA
Subsystem #1|Sources|EPS
TA IB IC
kA
Subsystem #1|Node Voltages
S1) N50Adn S1) N50Bdn S1) N50Cdn
kV

Microgrid R&D

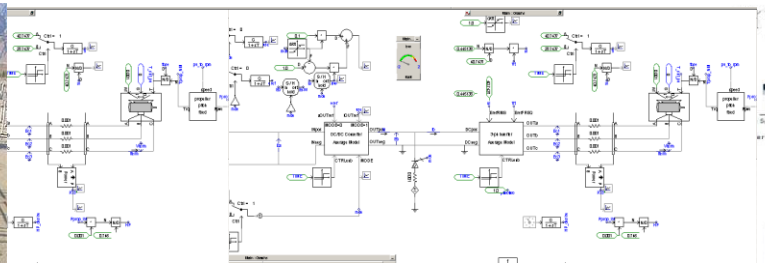
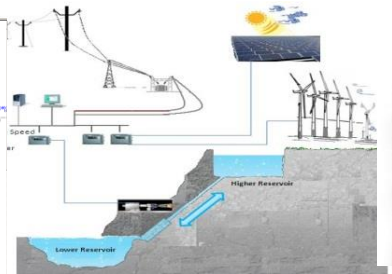


Vehicle Charging Station and RTDS®



Key Research Questions

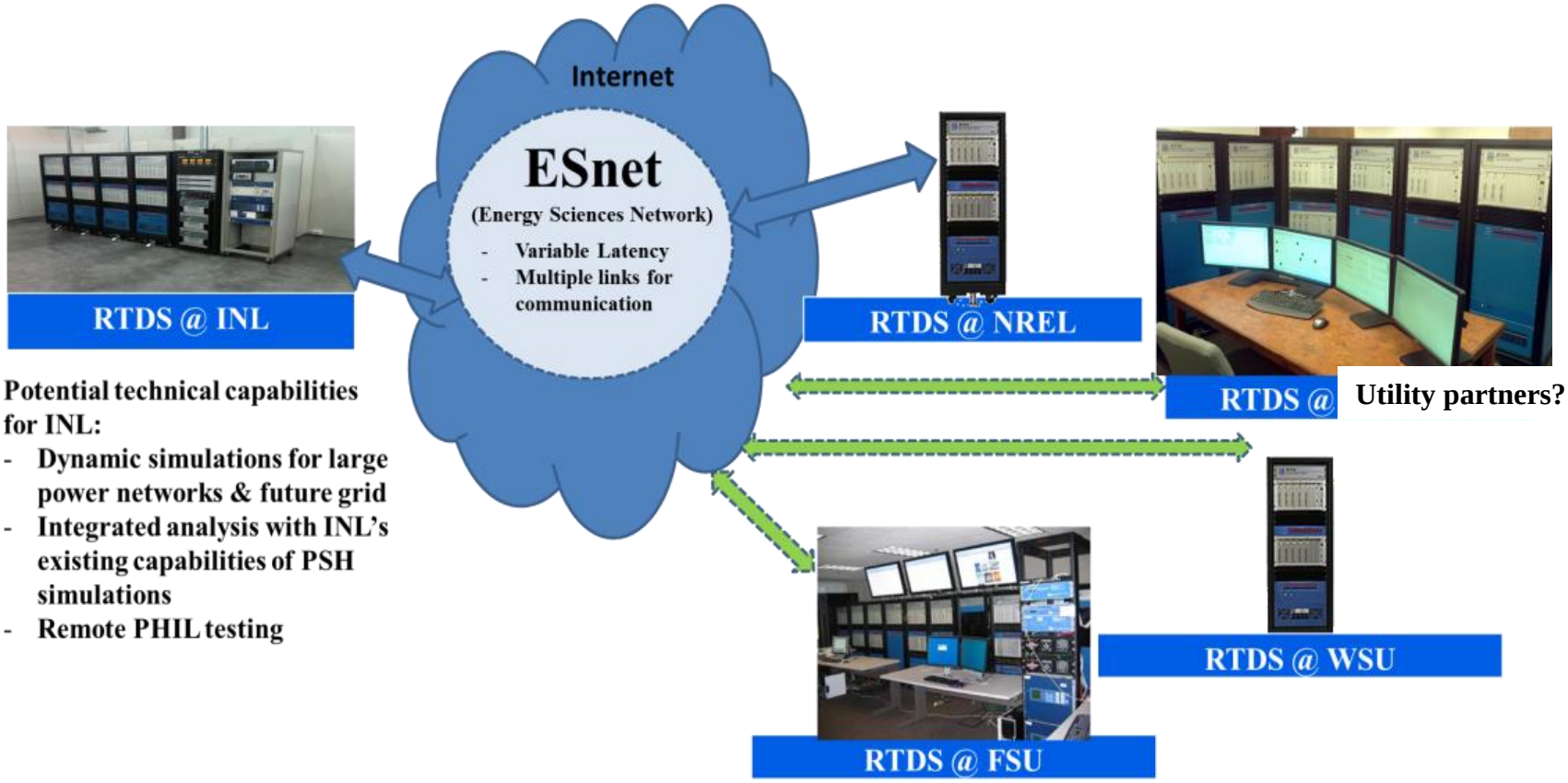
- How are ancillary service provided by variable generation
  - How can they contribute into grid reliability improvement and cost of energy reduction
- How smart grid technologies can be implemented and expanded in “Large Grid” applications
- How much renewable penetration can be supported by the existing 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**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