INL Grid Simulation and Scenario Planning Capabilities

Power & Energy Systems

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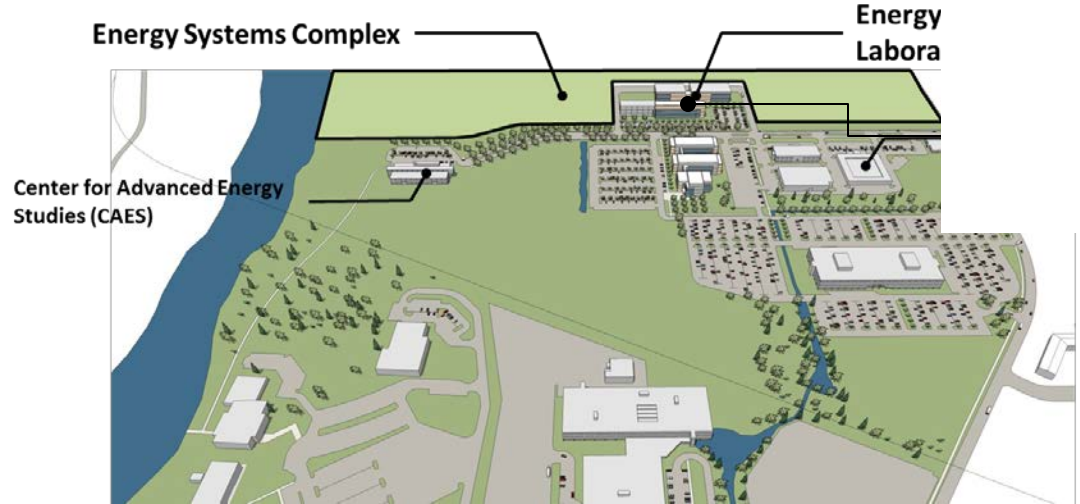
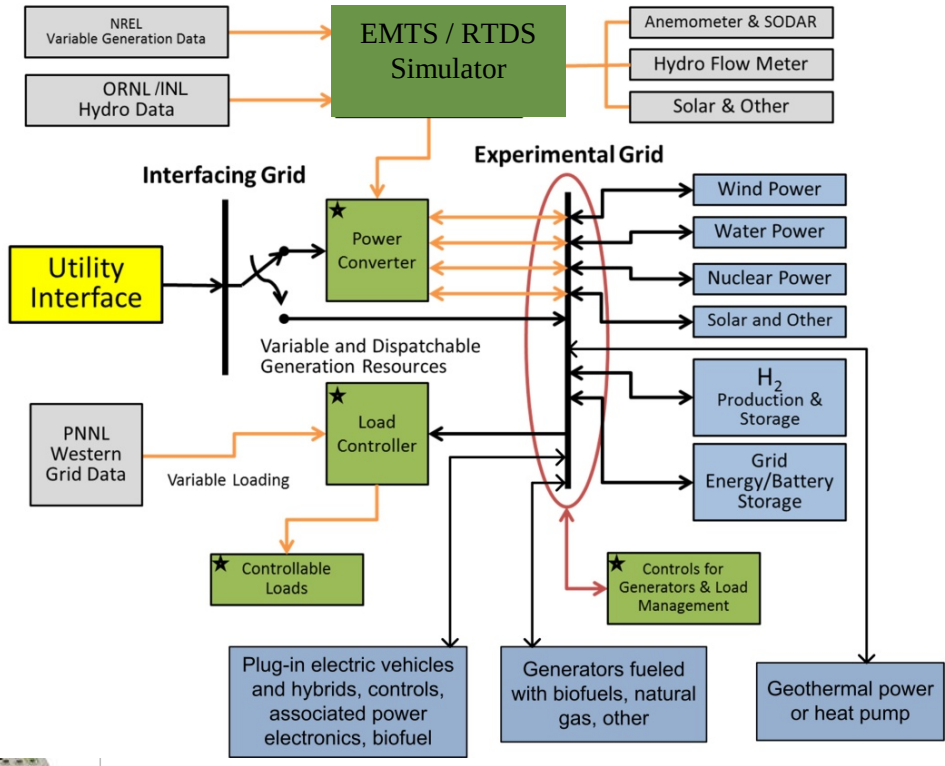
www.inl.gov

Idaho National Laboratory

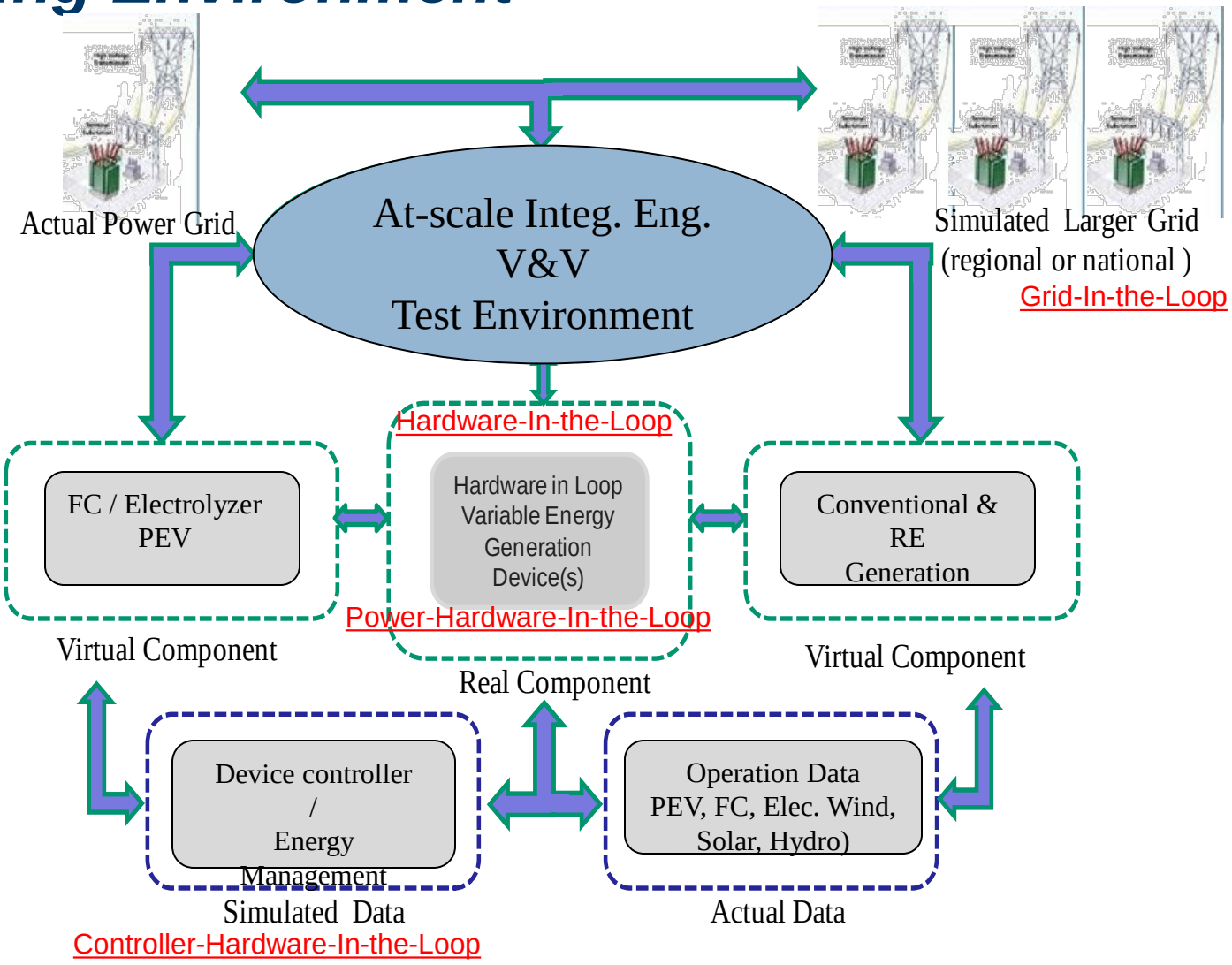
INL Real Time Energy Systems Laboratory's Demonstration Complex and Test Bed

- Power and Energy Integration Test Environment
  - Real Time Emulation Test Bed - hardware-in-the-loop capabilities for demonstrations and dynamic analysis
    - Power system devices
    - Integration with HES
    - Control and integration strategies
    - Coupling with energy storage



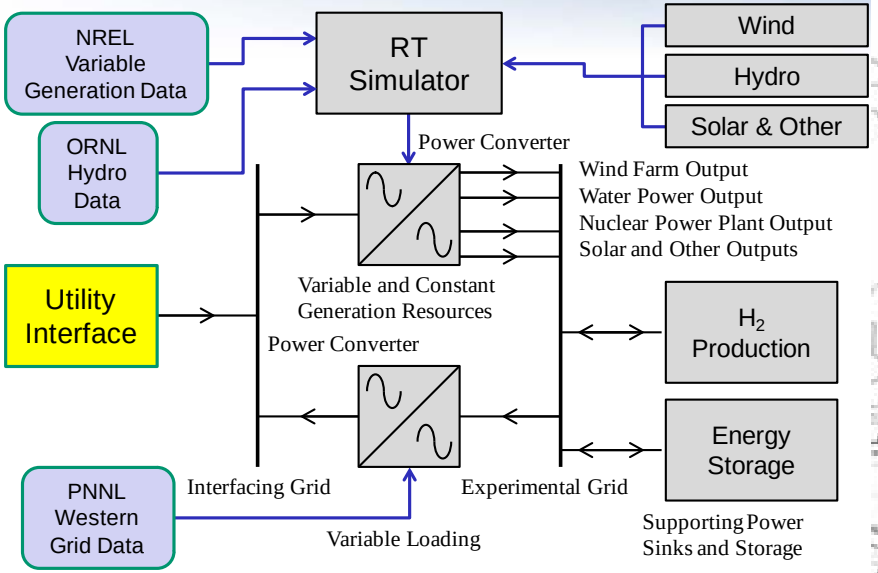


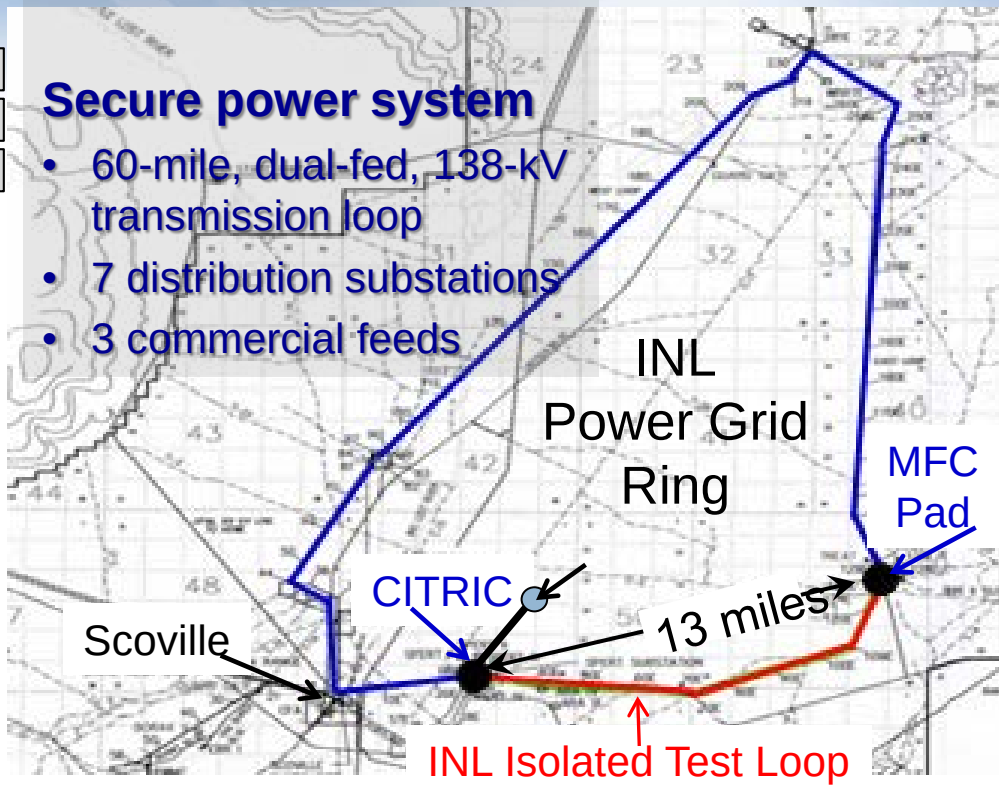
Real-Time Hardware-In-the-Loop Modeling and Testing Environment

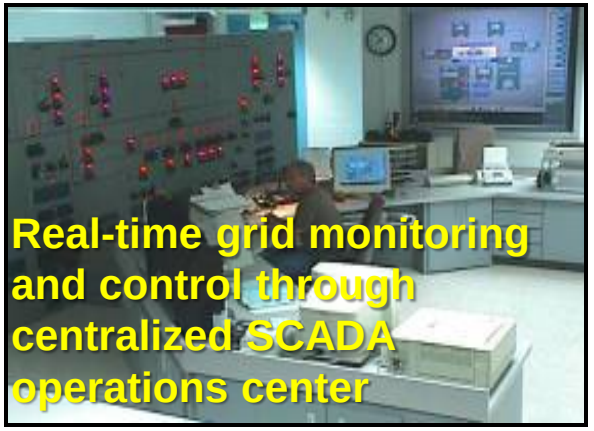


The Energy Demonstration Test Bed

Idaho National Laboratory



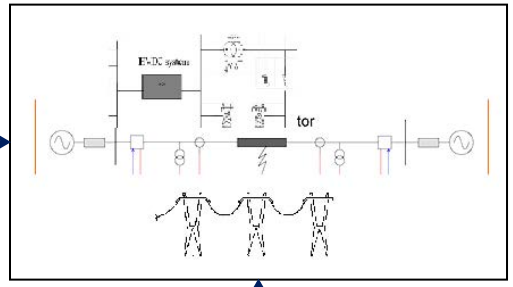




Integrated Grid Environment - Electrical / Mechanical / Thermal Co-Simulation

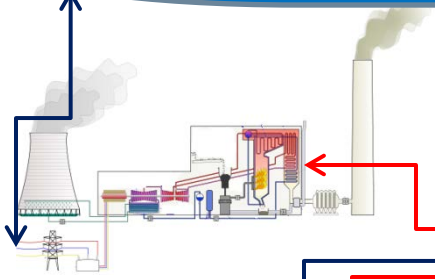
RTDS/ (Other Sites)

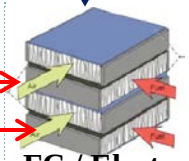
RTDS/INL



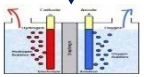
Power System Models

finite state machine

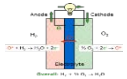




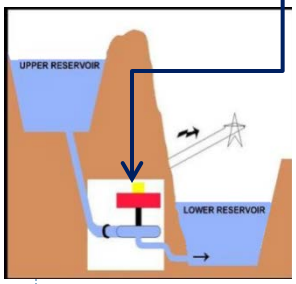
HT – FC / Electrolyzer

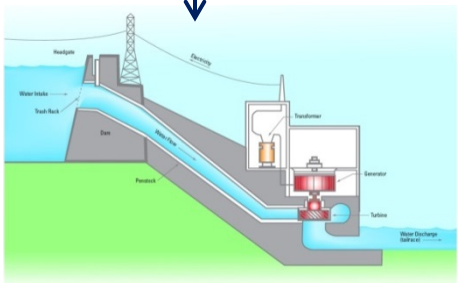


Electrolyzer

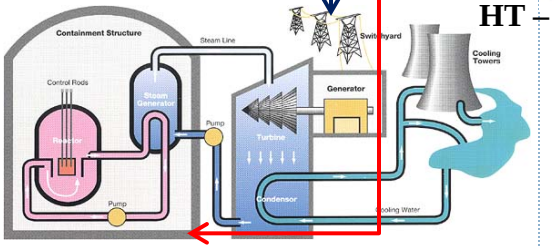


Fuel Cell





Hydropower Plant Models



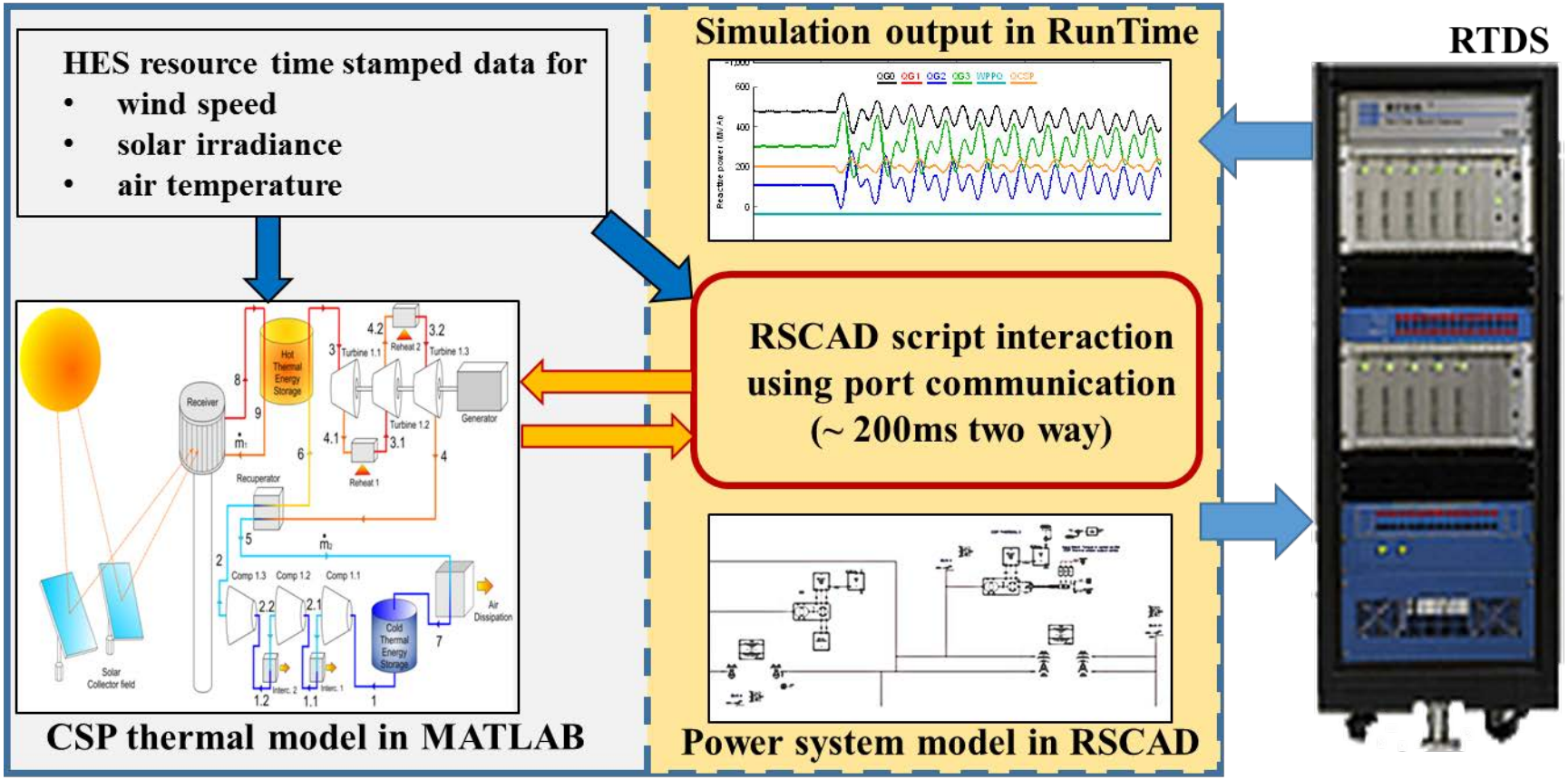
Thermal Power Plant Models

Energy Storage Models

V2G

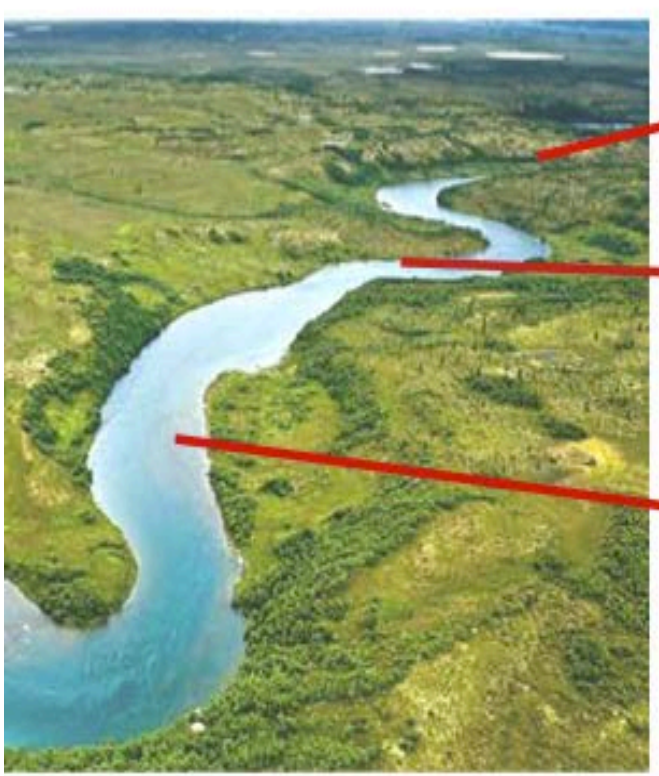
INL's Current Projects Related to Grid Simulation and Scenario Planning

Real Time Thermal Electrical Co-simulation



RT co-simulation of electrical-thermal-mechanical systems with physics based models

Multi-time Scale of Energy Storage Devices



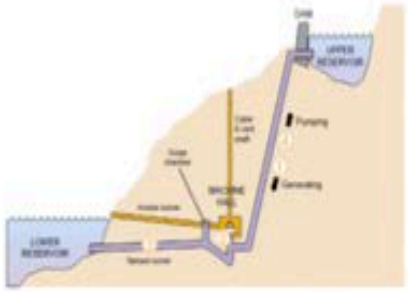
RIVER BASIN

ROR 1

ROR 2

...

ROR *n*



Supercapacitor

Decommissioned Coal Plants

Grid Level Storage

Pump-Storage Hydro (PSH)

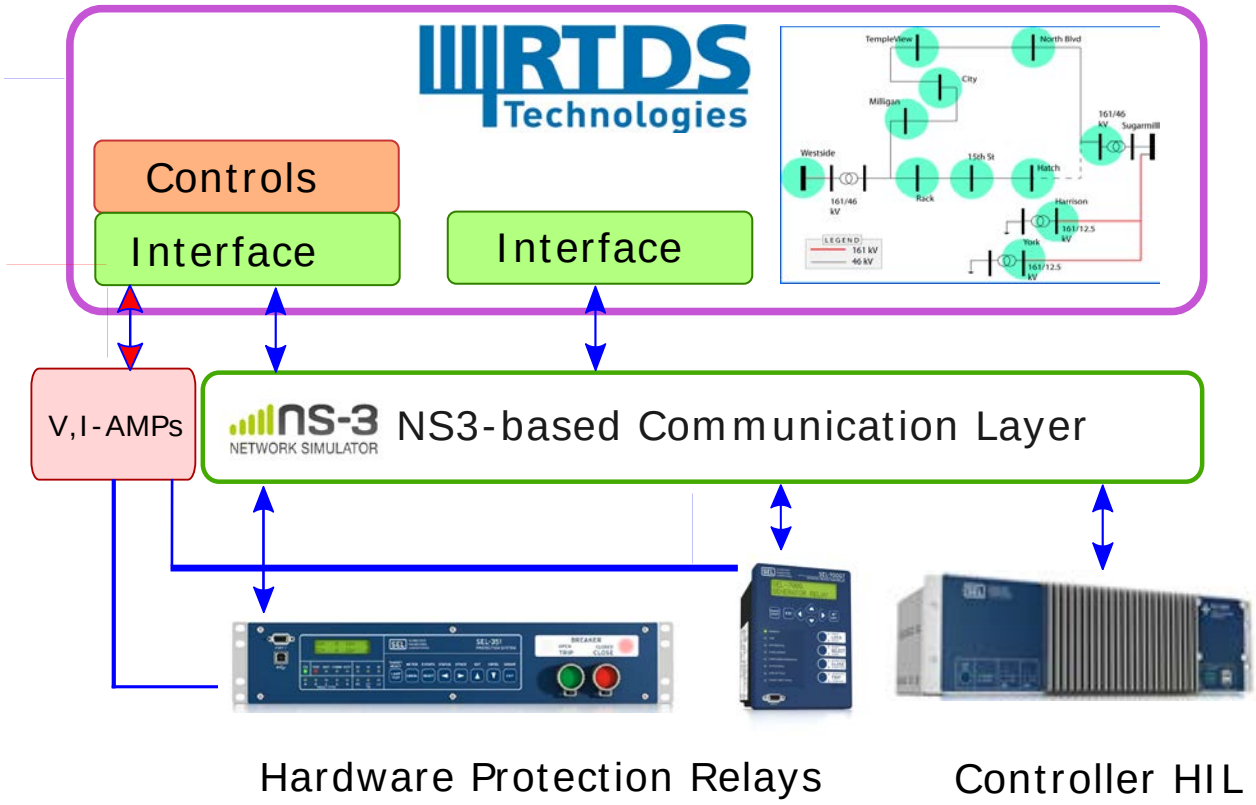
Utility Scale Battery

Front-end Controller (FEC)

Power Transmission Sytem

GMLC 1.3.9 – Smart Reconfiguration of Idaho Falls Power Distribution Network

- NS3-based communication layer is emulated for co-simulation of power systems and control/communication network between RT models and hardware devices



NS3 communication layer-based setup for RT HIL Testing

CEC Microgrid Project – Blue Lake Rancheria, CA PG&E Grid

- Black Start with Diesel generator
- Automatic reconnect to grid when islanded with Diesel generator
- Transition to Islanded Operations with MGMS Unresponsive

Microgrid Went Live 04/28/2017

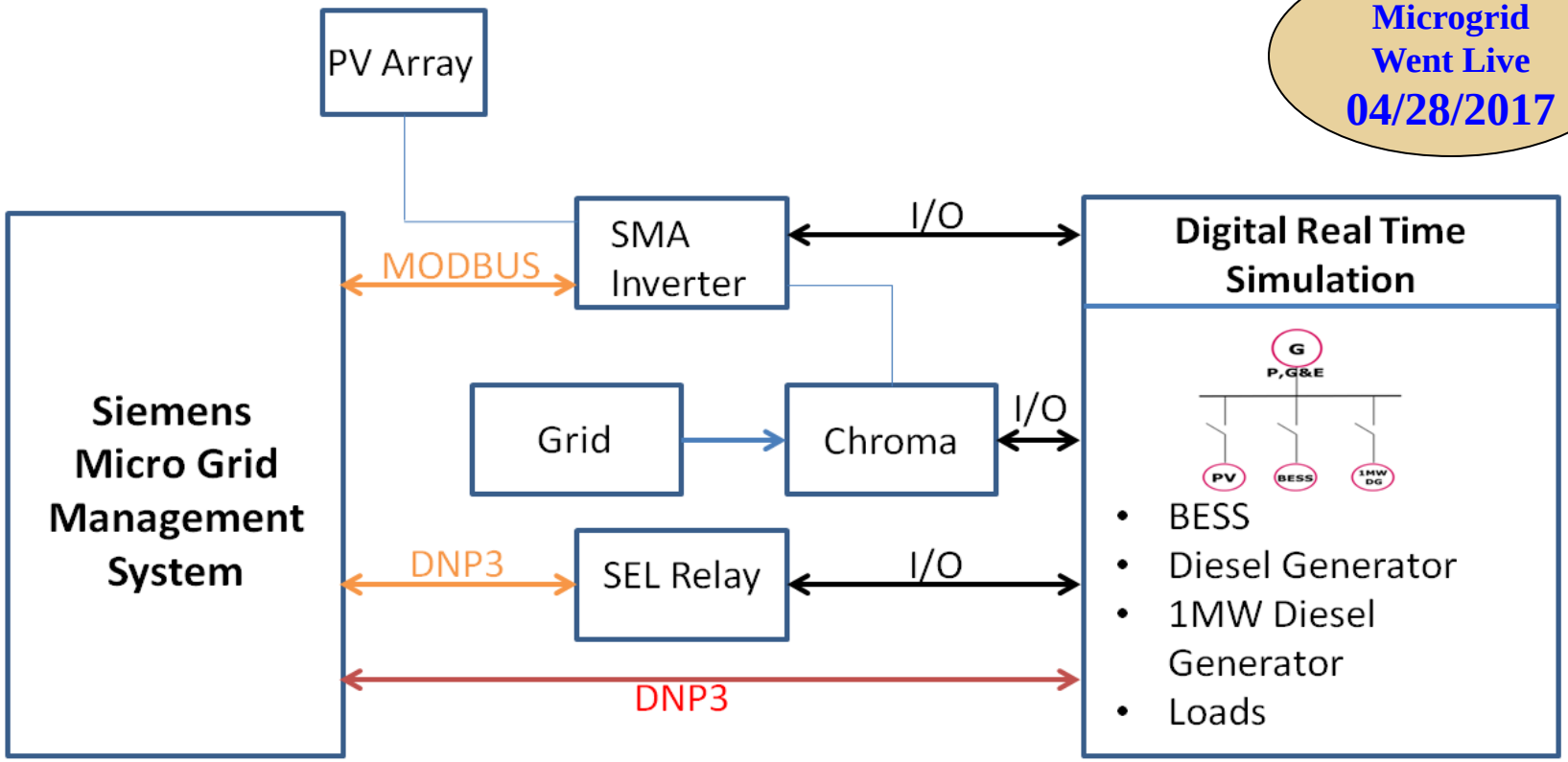
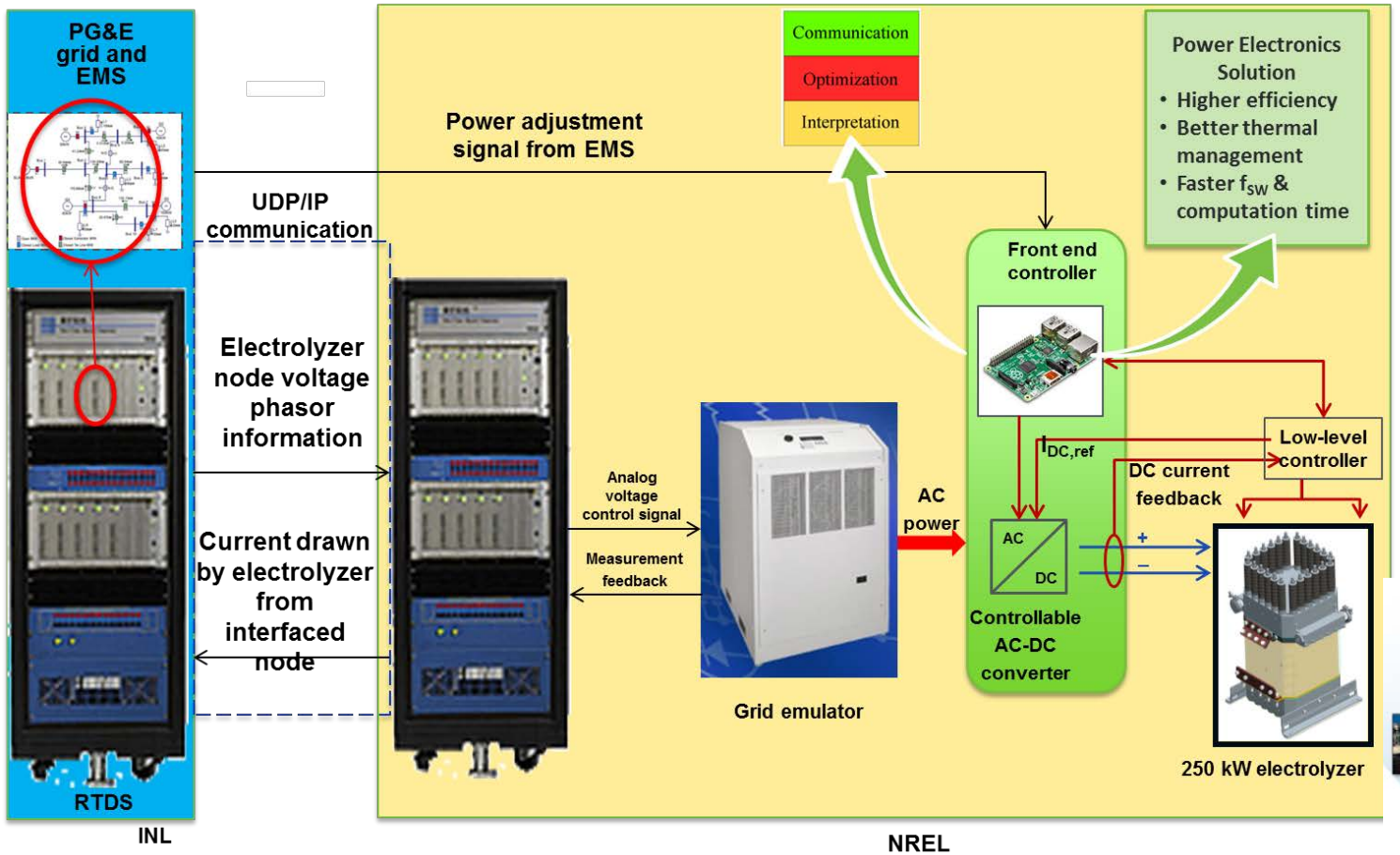


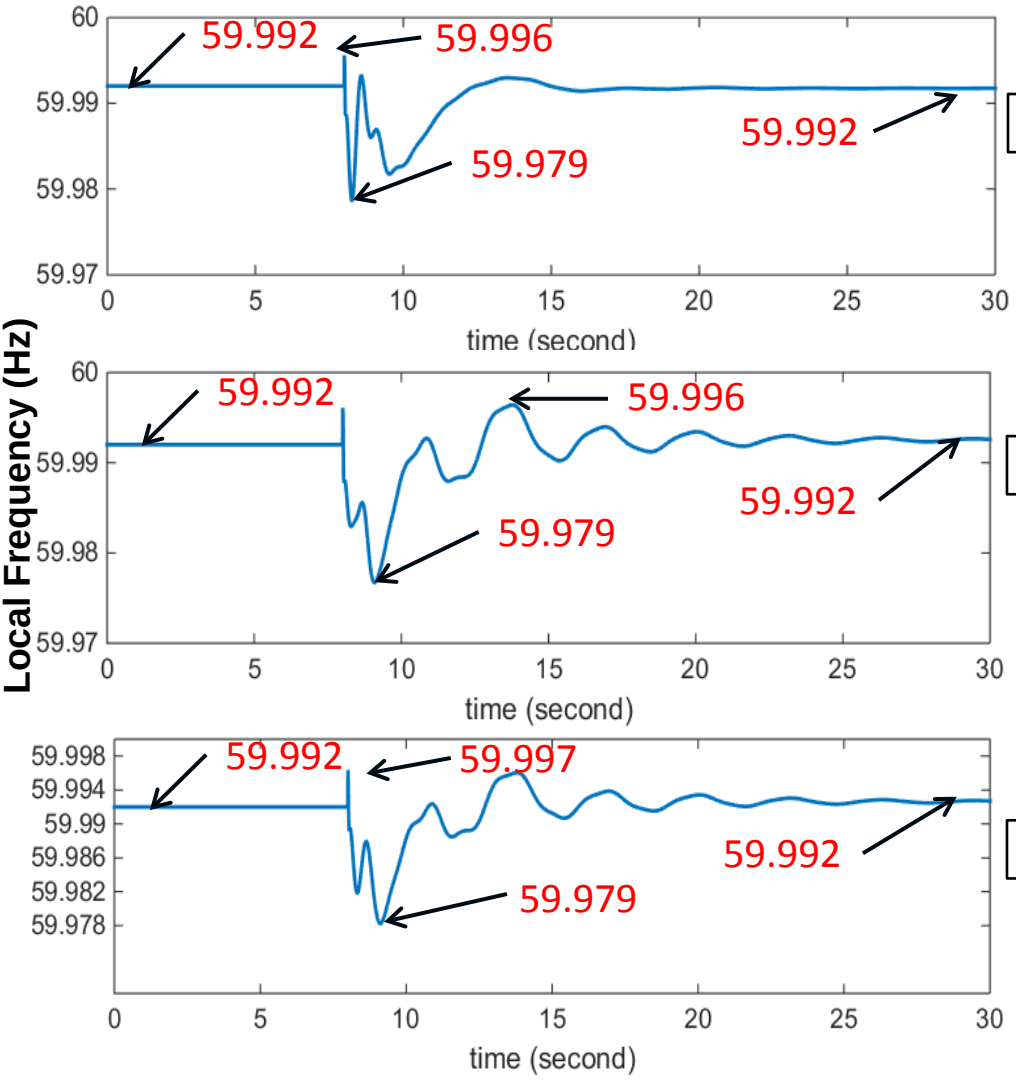
Fig. 5 BLR Microgrid Setup and HIL Testing

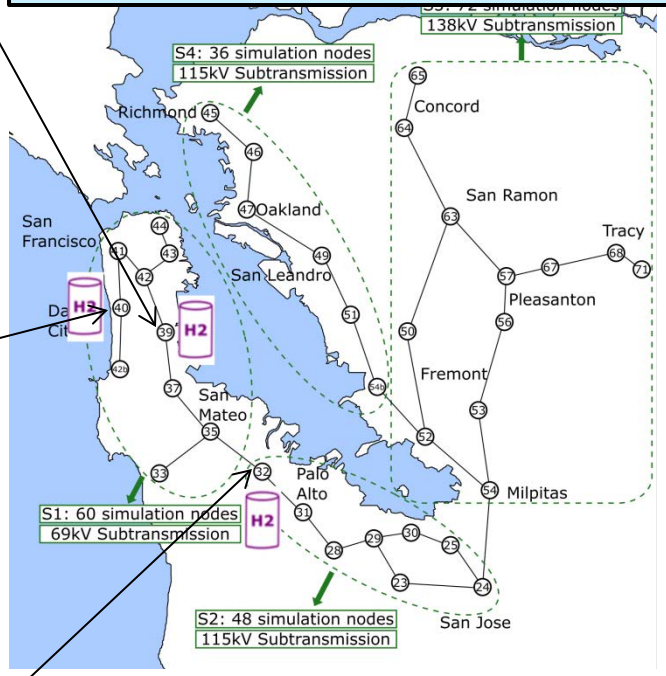
Dynamic Modeling and Validation of Electrolyzers in Real Time Grid Simulation



Frequency Support by Multiple Electrolyzers

Multiple electrolyzers controlled by Front End Controller can enhance overall grid stability by limiting frequency excursions





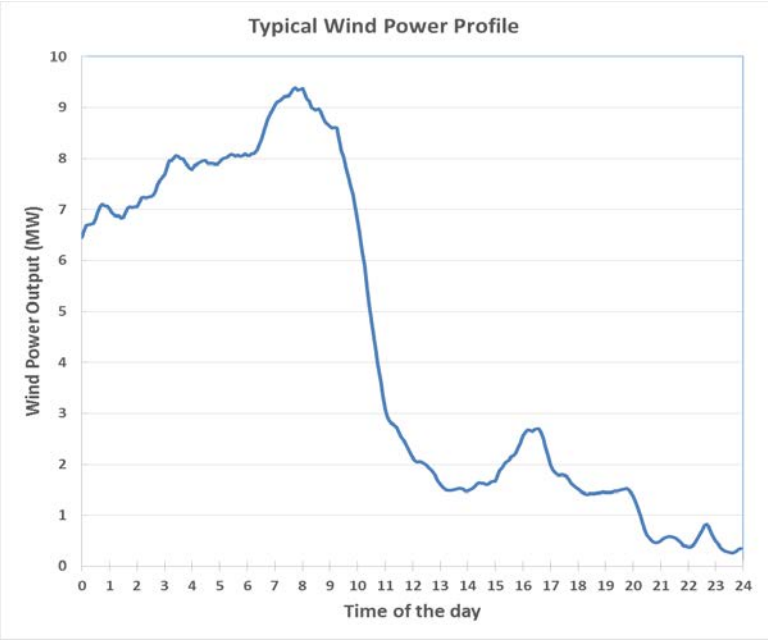
Fault location: Node 39

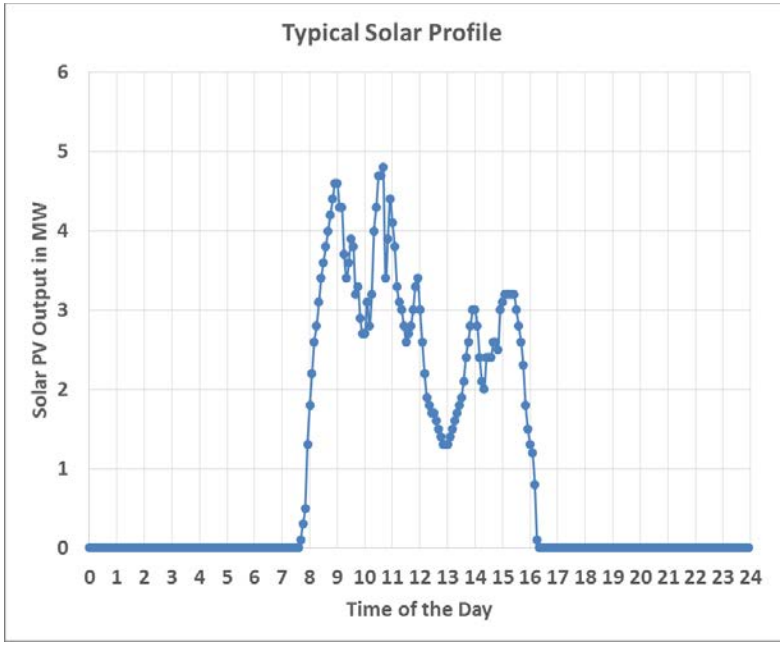
Fault type: Three phase balance

Fault duration: 0.1 seconds

Variability of Renewable / Hydrogen Refueling Stations

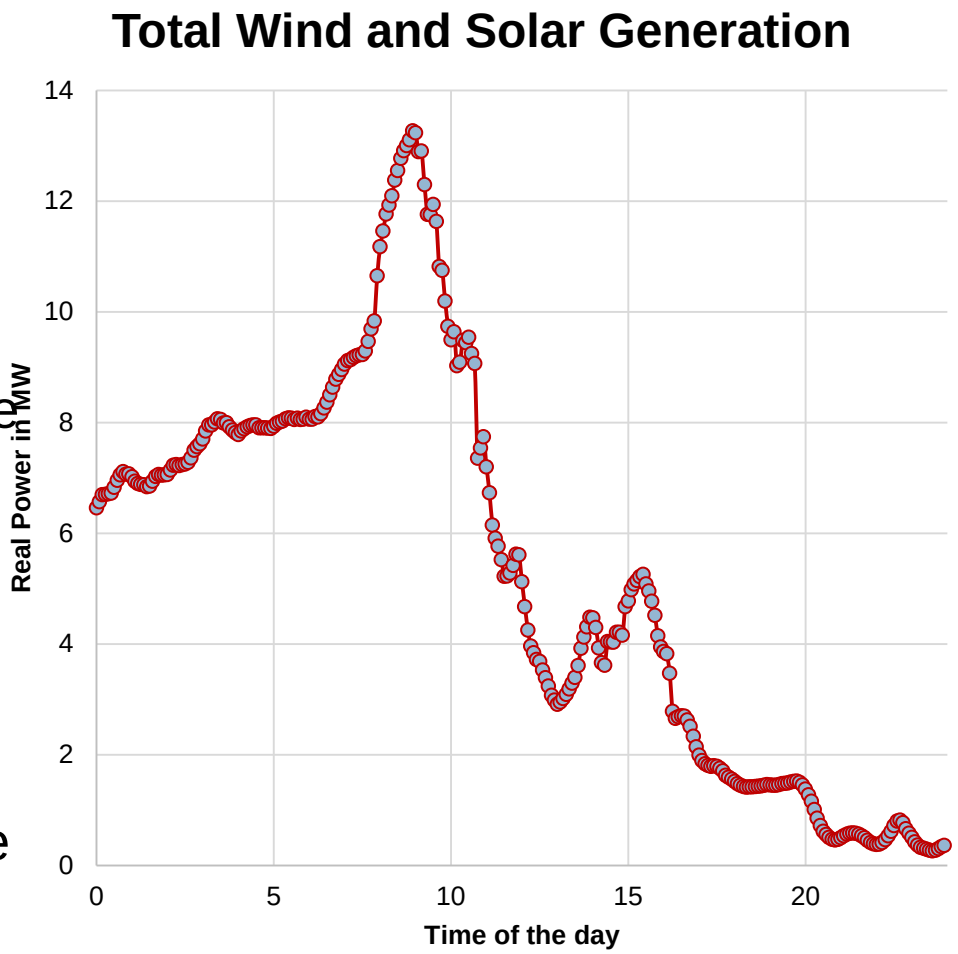
- Renewable Energy sources such as wind and solar demonstrate high degree of time dependent variability i.e., seconds to minutes to days…
- Electrolyzers have an innate capability to respond in seconds to follow control set points
- How can electrolyzers offset the variability observed by the power?
  - Grids expected predictable and non-varying generation sources
  - Hydrogen demands per day for different years are used as a constraint





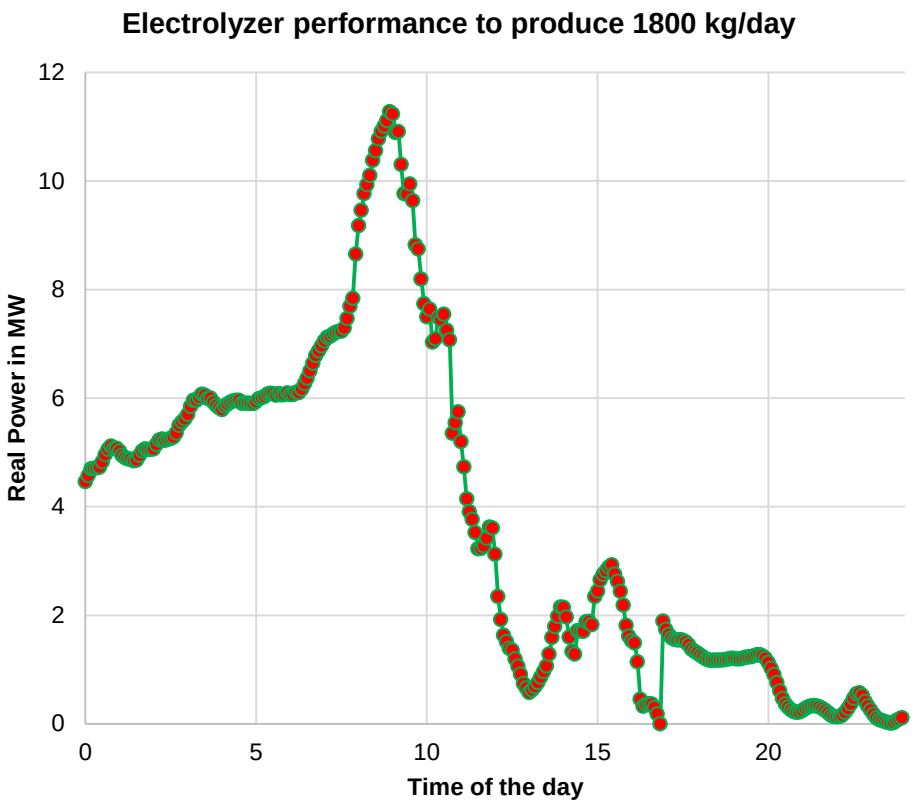
2018 Case with 7,200 FCEVs

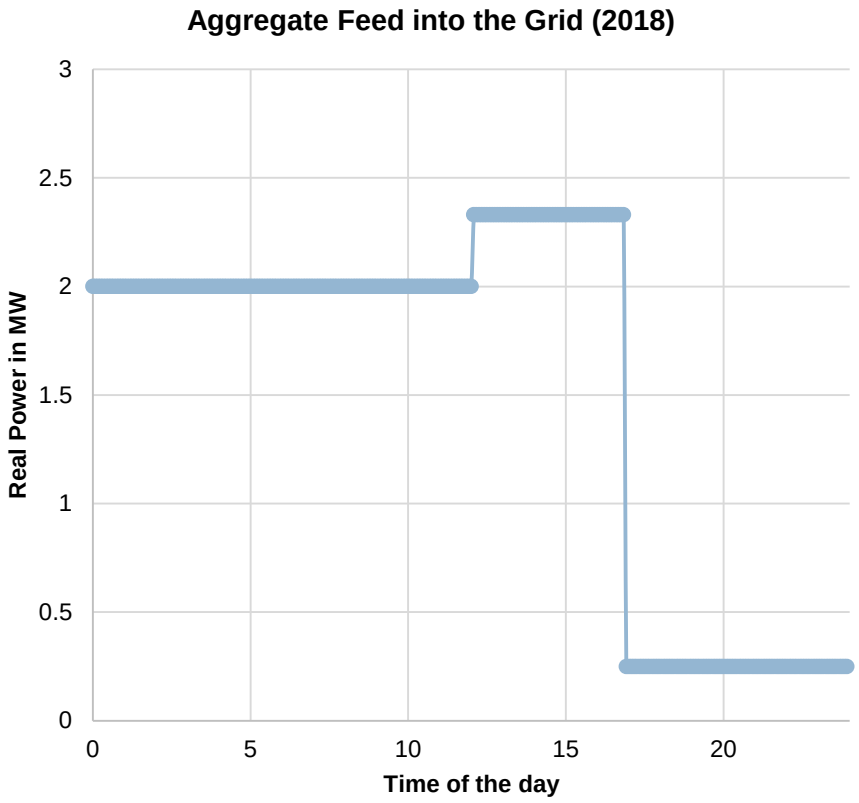
- Objective: Offset time-dependent, aggregated variability of solar and wind power using electrolysis
- Total of 13 MW electrolyzer plant is used for this example
- 2018 test case projections from ARB on vehicle fuel use to generate 1,800 kg/day of hydrogen for 7,200 FCEVs
- Approximate fuel dispensed in Santa Clara, Sacramento, San Francisco, Marin, Contra Cost and Alameda county
- Total energy consumed to generate this hydrogen demand 90.28 MWh/day



Wind, Solar, and Electrolysis

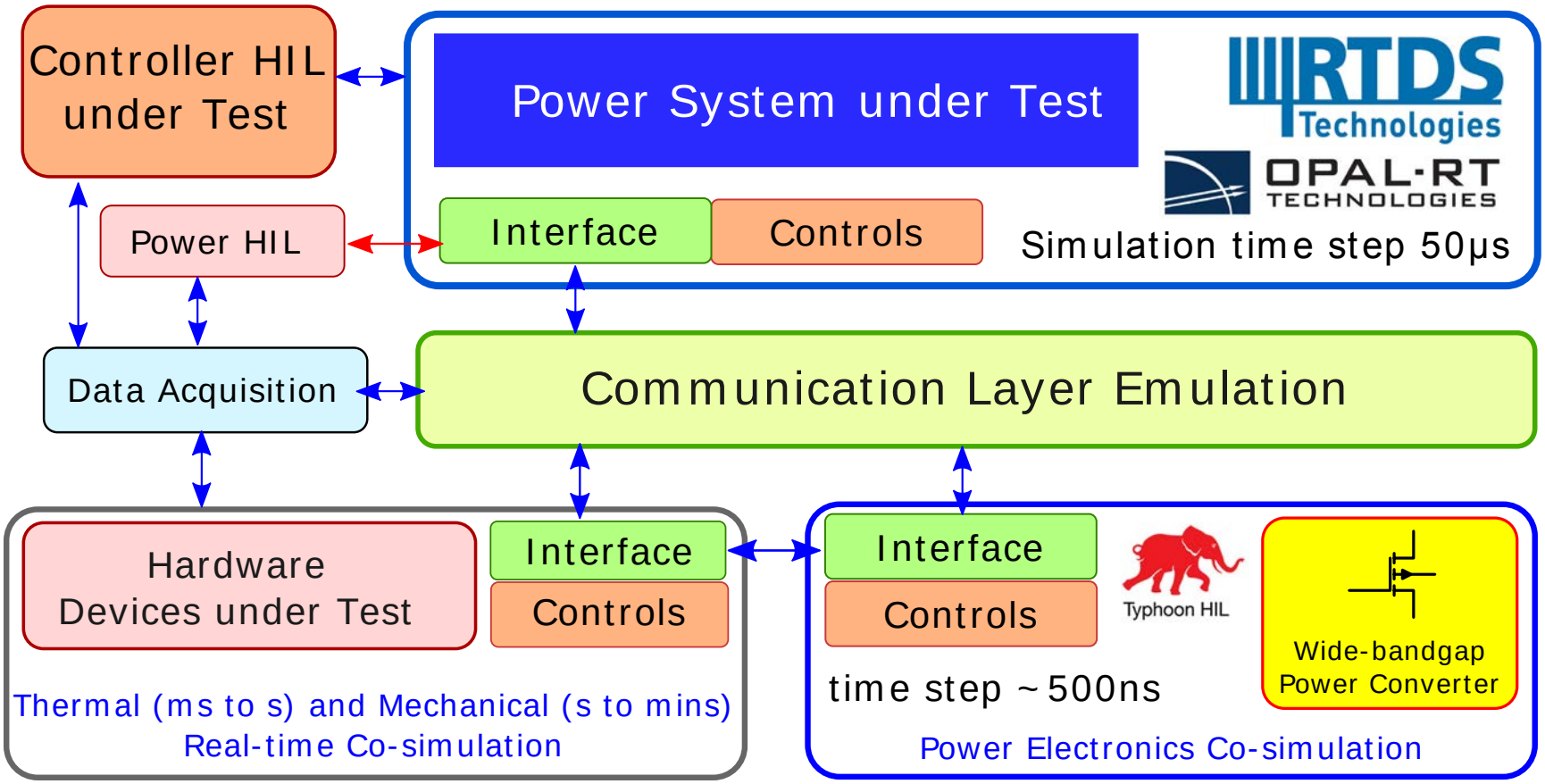
- Advanced control of a 13 MW electrolysis plant to offset variability of wind and solar power
- A fixed and predictable power injected into the grid from solar and wind plant due to coordinated operation with electrolyzers





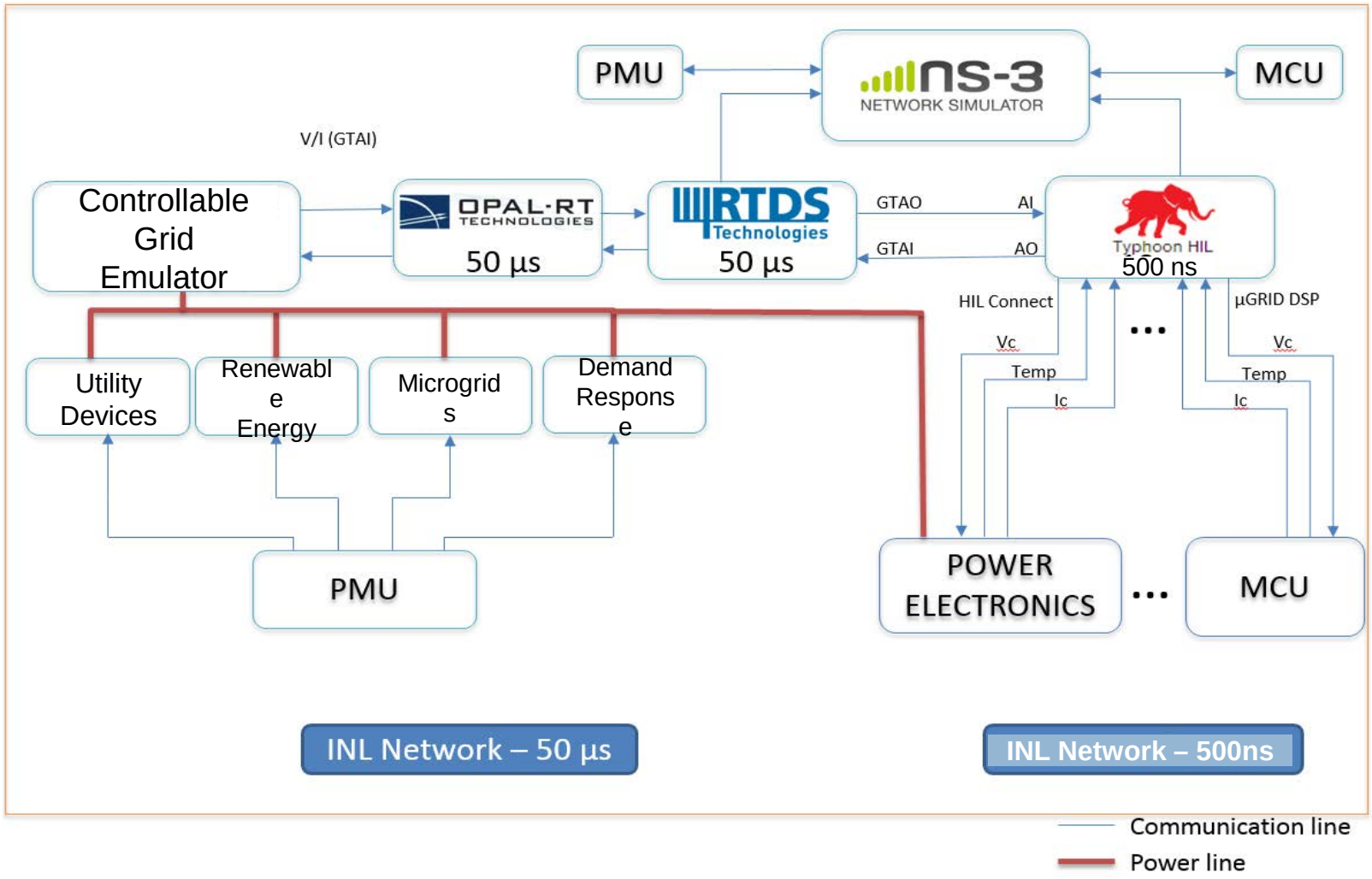
INL's Capabilities Related to Related to Grid Simulation and Scenario Planning

Integrated Multi-time Scale Real-Time Simulation Test-bed



Real-time Simulation with Communication Emulators

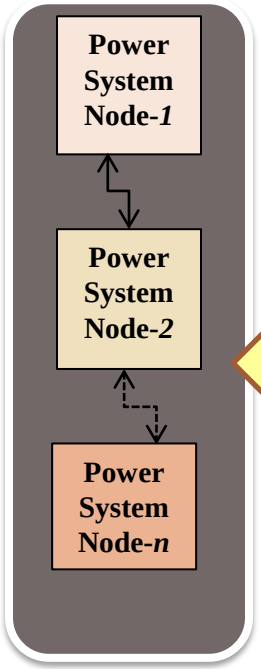
With the integration of modern and legacy utility devices, it is imperative to co-simulate communication with power system devices



Distributed Architecture for Simulation, Testing and Visualization using HIL

- Power System Simulated in Virtual Real-time Platform

- Graphical work Instruction
- Operator Training
- Real Time Situational Awareness for Grid Operator

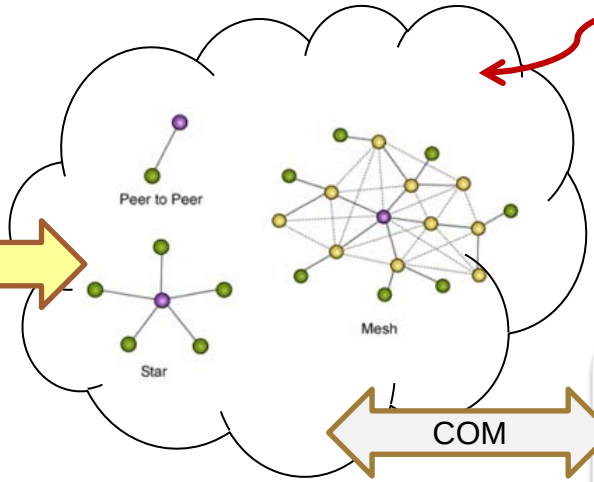


Virtual Real Time Power Systems

Data link

Visualization facility at INL*

COM



COM

COM

System Under Test (Power Hardware)

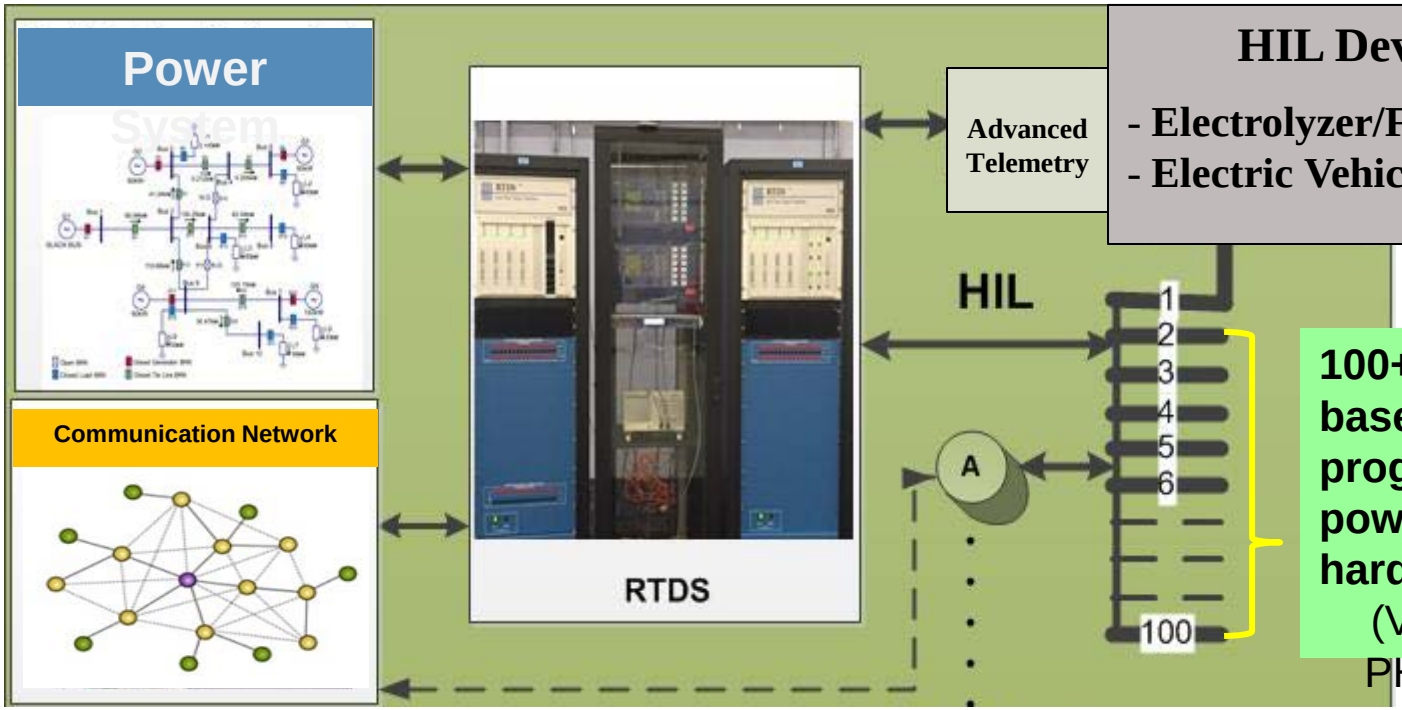
Actual Hardware Power Systems

Communication Layer (multi-protocol, multi-topology)

COM Communication network 1-10Gb/s

* Source: *Center for Advanced Energy Studies at Idaho National Laboratory*

Scalable Hardware-In-the-Loop (HIL) Co-simulation



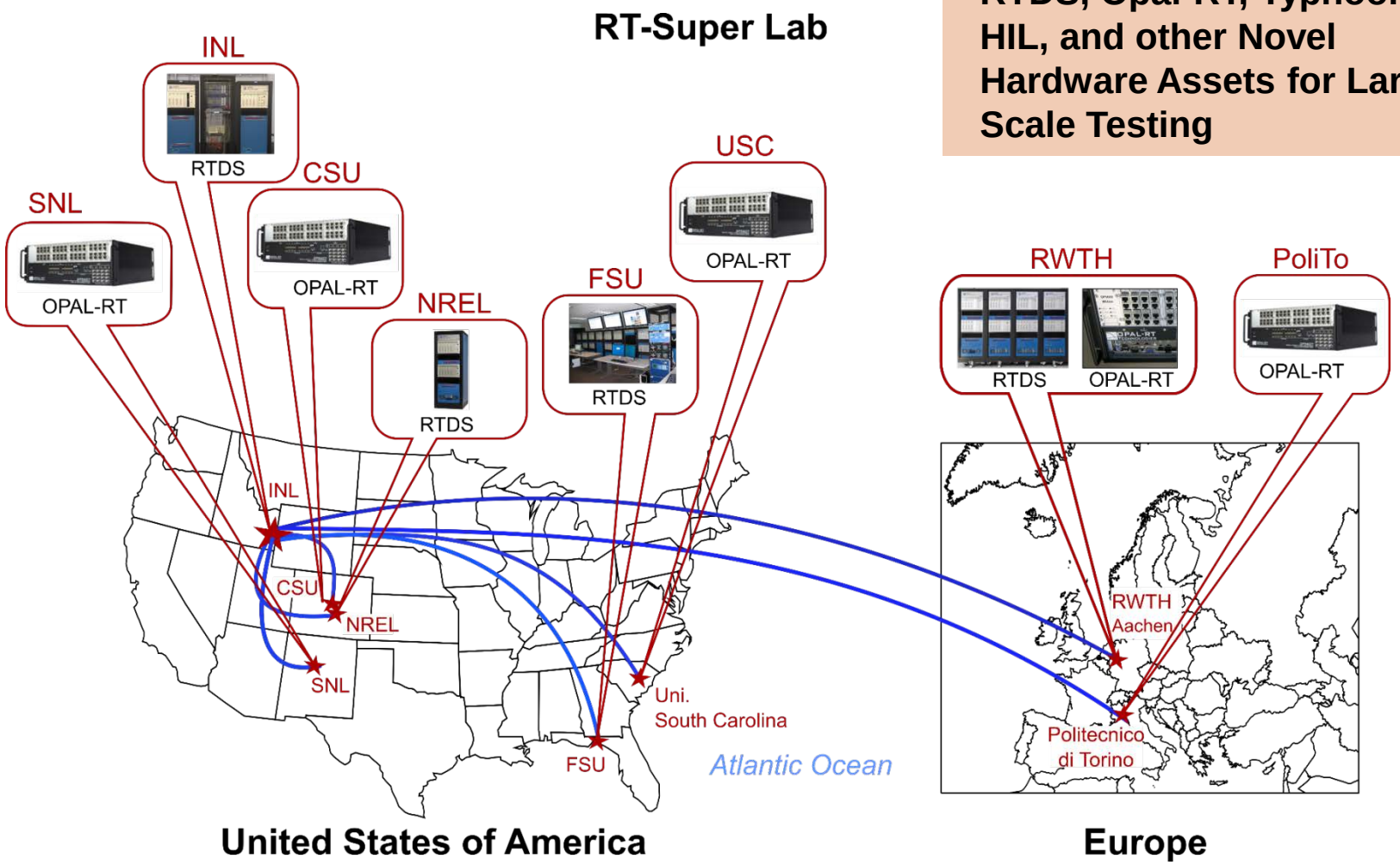
Potential scenarios testing

- Power System Issues
- Communication Issues
- Interoperability
- Data Latency
- Operations under
  - Harsh Environments
  - Degraded Conditions
- Survivability operations

Real-time Connectivity Across Organizations

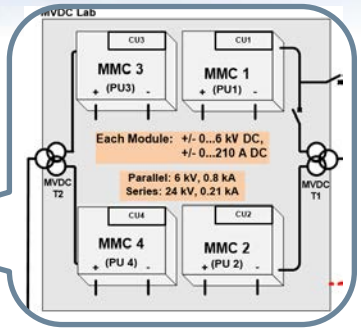
- RT-Super Lab for the Futuristic Grids
- Collaboration with Academia, Research Labs, Utilities

Real-time Connectivity with RTDS, Opal-RT, Typhoon HIL, and other Novel Hardware Assets for Large Scale Testing



Multi-Lab Co-simulation and (P)HIL- Grid Testing

Controller-In-the-Loop



MMC-based MVDC Test Bed

FSU-CAPS

(MT)DC

DS 5

USC

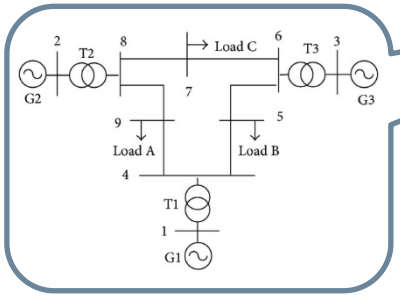
INL

TS 2

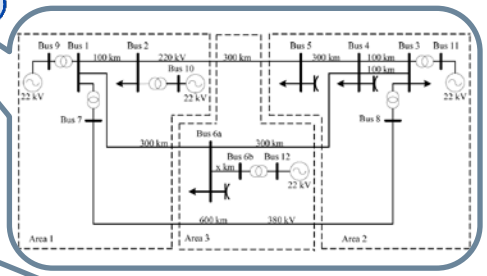
HVDC

RWTH-ACS

TS 1



Western System Coordinating Council (WSCC)
9-bus system approximation



European HV transmission network benchmark (CIGRÉ)

DS 2

DS 3

DS 4

DS 1

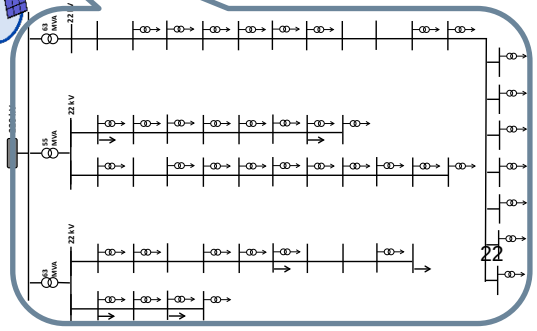
POLITO

Electrolyzer

SNL

NREL

CSU



Distribution system – a portion of Turin City, Italy

Thank You
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Questions

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