HELICS for Integrated Transmission, Distribution, Communication, & Control (TDC+C) Modeling

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Grid modernization requires integrating multiple infrastructures...

Transmission

Distribution

Control & Communication

Transportation, Water, Gas, etc.
And we have many, well trusted tools to model each...

Transmission
- PSLF
- PSS®E

Distribution
- CYME
- WindMill
- Synergi
- GLD

Control & Communication
- CPNET
- MNeT++
- SCEPTRE
- MATLAB

Transportation, Water, Gas, etc.
- BEAM
- Inverware
- SAInt
However they are largely used within their own silos of excellence.
HELICS enables easily bringing together two or more existing tools, exchanging data as time advances, to form a tightly integrated co-simulation.
Scalable, High-performance co-simulation to combine best-in-class tools for breakthrough grid modernization simulation and analysis

**Capabilities:**
- **Scalable:** 2-100,000+ Federates
- **Cross-platform:** HPC (Linux), Cloud, Workstations, Laptops (Windows/OSX)
- **Modular:** mix and match tools
- **Minimally invasive:** easy to use lab/commercial/open tools
- **Open Source:** BSD-style.
- **Many Simulation Types:**
  - Discrete Event
  - QSTS
  - Dynamics
- **Co-iteration enabled:** “tight coupling”
- **APIs:** C++, C, Python, Java, Matlab, Julia, FMI

v2.0.0 available now at https://www.github.com/GMLC-TDC/HELICS-src

Co-modelling is “w[h]ere models are described in a unified language, and then simulated.”[1]

Co-simulation “consists of the theory and techniques to enable global simulation of a coupled system via the composition of simulators. Each simulator is a black box mock-up of a constituent system, developed and provided by the team that is responsible for that system.”[1]

Computational Integration Workflows

Co-Modeling

SIIP Optimization
Julia-JuMP

Simulation based Optimization

Optimize Gradient Descent
Genetic Algorithm

WISEDEM MDAO

Co-Simulation

Simulations

IGMS
HELICS/CoSim

Integration Pipelines

Simulation
Simulation
Analysis

ReEDS2PLEXOS2MAGMA
Luigi

Optimize

Sensitivity
Uncertainty
Artificial Intelligence
Visualize

Analysis

“Cyber”-Physical Simulation

e.g. Transmission-Distribution-Market

- Physical Data (Values)
  - Voltage, Frequency, Current
- Market Data (Messages)
  - Measured Load, LMPs

Large-scale DER-Market Interactions

NREL’s Integrated Grid Modeling System (IGMS) provides a full-scale co-simulation with transmission-level markets, 1000s of distribution feeders, and 1Ms of DERs
Adding Controllers…

*e.g. Control Architecture Scaling & Performance*

- **Physical Data (Values)**
  - Voltage, Frequency, Current
- **Market Data (Messages)**
  - Measured Load, LMPs
- **Controller Data (Messages)**
  - Sensor Readings, Control Signals

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**Novel T&D Control Architecture**

*Design:* Predictive State Estimation & Machine Learning Control

*Grid Sim:* Entire Island of Oahu, HI with >1M electric nodes.
Keeping the wires uncrossed

Actual Deployment

Software Simulation

Controller

Legend

Recloser

Substation

Inv 1&2

Voltage Regulator

Capacitor Bank

PV Inverter

IEEE 8500u: Power
Keeping the wires uncrossed

Actual Deployment

Software Simulation
… and Simple Communication
e.g. Design-stage Cybersecurity Evaluation

► Built in “Filters” for
  ❖ Delays
  ❖ Random drops
  ❖ Other message effects (e.g. packetization)
  ❖ And more

► No changes to domain models

**Novel T&D Control Architecture**

*Design:* Predictive State Estimation & Machine Learning Control

*Grid Sim:* Entire Island of Oahu, HI with >1M electric nodes.

1. Control signal spoofing
2. Control node compromise
3. Sensor data spoofing
4. Communication Denial of Service
5. Communication Latency Margin
Or Detailed Communication  
e.g. Protocol Comparison for Situational Awareness

- Full communication simulation:
  - Shared bandwidth
  - Network Specific Vulnerabilities
  - Potential Tools: ns-3, Opnet++, SCEPTRE, etc.
- No changes to domain models

Project Ex: SuNLaMP Hybrid Comms

Ex: Power-Comm. Emulation
Some Other Use Cases

T&D frequency stability with high DER

Large-scale DER-Market Sim
- 35k feeders
- WECC-240 trans.
- 25M homes
- Simplified CAISO-style Market

Figure from Trevor Hardy, PNNL
Growing mix of tools
Enable large-scale interdependency all-hazards studies: scale to 100,000+ domain simulators
Diverse simulation types:
- Continuous, discrete event, time series
- Steady-state/dynamic/transient
- Any energy system
Support standards: HLA, FMI, …
APIs: C++, C, Python, Java, Matlab, Julia, FMI

Not exhaustive lists.
Thank You

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