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

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Grid modernization requires integrating multiple infrastructures...
And we have many, well trusted tools to model each...
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*.
**HELICS™:**
Hierarchical Engine for Large-scale Infrastructure 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

**Use Case Requirements**

**New Platform Design**

**Best of Existing Cosim**
- IGMS/ FESTIV
- FSKit/ GridDyn
- FNCS/ GridLAB-D

**Co-simulation Engine**

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

Co-modelling is “where 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

Slide adapted from Dr. Wes Jones, NREL

Co-Modeling

SIIP Optimization
Julia-JuMP

Simulation based Optimization

Optimize
Gradient Descent
Genetic Algorithm

Simulation

Optimize
Sensitivity
Uncertainty
Artificial Intelligence
Visualize

Integration Pipelines

Simulation
Simulation
Analysis
ReEDS2PLEXOS2MAGMA
Luigi

IGMS
HELICS/CoSim

“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

**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

Legend
- Voltage Regulator
- Capacitor Bank
- PV Inverter
- Recloser
- Controller
Keeping the wires uncrossed
... 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++, SCEPTRRE, etc.

- No changes to domain models

Protocol/Full-Stack Performance

*Ex: SuNLaMP Hybrid Comms*

*Ex: Power-Comm. Emulation*
Some Other Use Cases

Large-scale DER-Market Sim

- 35k feeders
- WECC-240 trans.
- 25M homes
- Simplified CAISO-style Market

T&D frequency stability with high DER

ADMS Testbed and other PHIL

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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