HELICS – Co-simulation Framework for the Smart Grid

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**Need:**
Enable large-scale TDC interdependency studies through a flexible and scalable, open-source co-simulation platform for the following industry drivers:

- Current gap in simulation and modeling technology that inhibits integrated planning across multiple domains
- Integrated studies needed for maximum flexibility and resilience in grid operation and planning

**Our Objectives:**
- Provide foundational capabilities for grid planning, operation, and control
- Engage and educate grid developers on the value of multi-domain planning

Image from smartgrid.ieee.org
Leverage existing tools with co-simulation

**Standing on the Shoulder of Giants**

- Lots of effort has gone into (sub) domain-specific tools.
  - (So use them)
  - Trusted by stakeholders
  - Continue to improve
- Allows focus on the “glue-ware”
  - Faster
  - Many frameworks
- Encourages Modularity
  - Swap/add models as needed

HELICS™: Hierarchical Engine for Large-scale Infrastructure Simulation

Best of Existing Tools

IGMS/FESTIV

FSKit/GridDyn

FNCS/GridLAB-D

Use Case Requirements

New Platform Design

“TDC Tool”
1. Impacts of DER’s on Bulk Systems Reliability
2. Impacts of Distributed Energy Resources on Wholesale Prices
3. Regional Coordinated Electric Vehicles Charging
4. Real-time Coordination of Large-Scale Solar PV and Energy Storage
5. Evaluate modeling adequacy of composite load model under high penetration of DERs
7. New Control Paradigm – Centralized vs Distributed to Prevent Voltage Stability Collapse
8. Wide Area Monitoring, Protection, and Control (WAMPAC)
9. Real-time Co-simulation of Power Systems and Communication Networks for Transient Assessment
10. Communications Architecture Evaluation for High-Pen Solar
11. Adaptive Voltage and Frequency Ride-Through Settings for Smart Inverters
12. Wide Area Voltage Stability Support Using DERs
Identified “must have” features

- Tool/platform released open source with (nearly) all use cases accessible via open-source
- Types of Simulation: Discrete Event, Time Series, Quasi-Static Time Series, Phasor (Dynamics)
- Reiteration (within timestep convergence)
- Compute Systems: Laptop -> HPC Class
- Problem Scale: 2 - ~100,000 federates
- “Easily” incorporate existing tools/elements
  - From other labs
  - From industry/commercial
  - Open-source & commercial
- Standardized interfaces (HLA, FMI)
- Documentation and Examples
- Support stand-alone control/optimization “agents”
The need for a new platform

- Existing implementations have limitations that would prohibit meeting design goals
  - Types of simulation
    - Co-iteration
  - Programming Language
  - Scaling
- Licensing issues
- Platform Limitations
- It isn’t totally new:
  - Take Lessons learned from existing tools
HELICS layered design

- **Layers**
  - User Interface
  - Simulators
  - Application
  - Core
  - Platform

- **Components**
  - Scenario Gen.
  - Configuration
  - Automation
  - Visualization
  - Griddyn (Other-T)
  - GridLAB-D (Other-D)
  - ns-3 (Other-C)
  - FESTIV (Other-M)
  - Other Misc.
  - TDC-Optimized Interfaces
  - Federate/Object Management
  - Event Communication
  - Scheduler/Time Synchronization
  - Serialization
  - Distributed Object Store
  - Distributed Time Synchronization

- **Interfaces**
  - HLA
  - FMI

- **Communication**
  - MPI
  - Linux/Unix
  - ZeroMQ
  - Windows
Transport mechanisms

“test”

“IPC”

“MPI” for interconnected clusters

“ZMQ”, “TCP”, “UDP”
Types of federates

Value Federate

Transmission

Control signal packets

Data packets

AGC Controller

Message Federate

Transmission

A combination Federate has both interfaces in a single federate
Often the simulation itself is the “easy” part, compared to set-up, output processing, and analysis.
Many more use cases need TDC integrated simulation

Support a variety of simulation types:
• Discrete Event
• Time Series
• QSTS
• Dynamics
• Transients

Evaluate systems of unprecedented scale:
• 2-100,000+ Federates
• HPC, including cloud
• But also workstations and laptops

The test case will analyze a combined T&D test system with and without advanced distributed systems with high penetrations of distributed solar PV. Studying the impact on reliability metrics such as the NERC Control Performance Standards 1 and 2 as well as other main metrics can quantify the impacts of advanced distribution systems.

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<td>Impacts of DER’s on Bulk Systems Reliability</td>
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- DER’s on Bulk Systems Reliability
- Load Modeling under high penetration of DERs
- Wide Area Voltage Stability Support Using DERs
- Voltage and Frequency Ride-Through Settings for Smart Inverters
- Real-time Co-simulation of Power Systems and Communication Networks for Transient Assessment
- Communications Architecture Evaluation for High-Pen Solar
- New Control Paradigm – Centralized vs Distributed to Prevent Voltage Stability Collapse
- Wide Area Monitoring, Protection, and Control (WAMPAC)
- Impacts of Distributed Energy Resources on Wholesale Prices
- Mitigating T/D Interface Congestion Through Demand Side Management
- Regional Coordinated Electric Vehicles Charging
- Real-time Coordination of Large Scale Solar PV and Energy Storage
Study at 50% solar and 150% base load

Comparison of different smart inverter control strategies – unity power factor, Volt-VAR and adaptive Volt-VAR

- Unity PF - voltage at buses 5 and 9 are below 0.95 PU at peak load.
- Volt-VAR - voltage at bus 9 is below 0.95 PU at peak load.
- Adaptive Volt-VAR - no voltage violation.
Models

- A combined T&D test system
  - IEEE 39 bus system + simple radial distribution system model
Further engage users to refine and expand API capabilities

Expand HELICS core capabilities to federate with domains beyond T, D, and C.

Continue community engagement through workshops, tutorials, webinars, web forums, etc.

Build open-source community support of HELICS development

Testers are welcome!
Technical Review Committee (academia and industry experts)

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<tr>
<th>Name</th>
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Further reading

www.github.com/GMLC-TDC/HELICS-src

www.helics.org

tdc-helics channel on YouTube