The Integrated Grid Modeling System (IGMS) for Combined Transmission and Distribution Simulation

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HPC in Power Systems Planning Panel
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The Emerging, Integrated Grid

- Natural Gas Generators
- Nuclear Power Plants
- Hydro power plants
- Transmission System
- Distributed storage
- Distributed wind
- Rooftop Solar
- Wind Farms
- Solar Farms
- T + D...
- Energy Efficiency
- PHEV
- Home Energy Storage
- Commercial Customers
- Solar Farms
- Wind Farms
- Distributed storage
- Smart Meters
- Distributed Generation
- Wireless Networks
- Time of Use
- PMU
- Dynamic Pricing
- Fault Restoration
- AMI
- Smart Appliances
- Home Area Network
- Outage Management
NREL’s Integrated T&D Grid Modeling System (IGMS)

Summary:
A next-generation analysis framework for full-scale transmission and distribution modeling that supports millions of highly distributed energy resources.

End-to-End T&D Modeling Capability
• detailed multi-period wholesale markets (including LMPs)
• generator/reserve dispatch (AGC)
• AC Powerflow (bulk transmission)
• Full unbalanced 3-ph power flow for 100s-1000s of distribution feeders
• Physics based end-use models of buildings and end-use loads.

Example Applications
• **Current**: Analyze distributed PV support for grid operations
• **Future**:
  • Simulate smart grid storage, PV, and demand response
  • Simulate alternative market and service architectures
  • Co-simulation with Hardware via PHIL
  • Connect to Advanced DMS/EMS systems

Status
• **Successful Medium Scale Run(s)**: 118 Transmission buses, 743 Distribution Feeders (PNNL taxonomy), >1M total buses, >600k homes
• **FY15 Development to Date**:
  • Automated output processing and visuals (pull from 1000s of files)
  • Semi-Automated data import from PLEXOS, SynerGEE, & CyME
  • Comparison of IGMS to stand-alone tools
• **Next Steps**: Scale-testing (run time for 10-1000+ feeders), High-Pen PV Scenario development, DGPV for Grid Operations Research
• Day-Ahead Commitment
• Real-time Commitment
• Real-time Dispatch
• AGC reserves
• AC Powerflow (pos-seq, balanced)
• Nodal:
  - Prices
  - Services
  - Voltage

• Return:
  - Power
  - Reactive
  - (Bids)
• 3-ph unbalanced powerflow
• Physics:
  o DERs
  o Load
Often the simulation itself is the “easy” part, compared to set-up and output analysis.
IGMS-Input Data Conversion

Distribution: SynerGEE and CYME to GridLAB-D

1. SynerGEE objects collected
2. Operated via syntax or mathematical conversions
3. Create GridLAB-D text element
4. Create “.glm” GridLAB-D file

POC: Julieta Giraldez

Transmission: PLEXOS to FESTIV – with RPM
IGMS-Populating Feeders with Houses & PV

**Scenario**
- sim start: 4/16/2020
- sim duration: 1 d
- sim timestep: 1 min

**Transmission**
- FESTIV case
- IGMS-FESTIV model rules and configuration
- Startup .mat file

**Distribution**
- Assign feeder models to nodes
- glmgen options for populating GridLAB-D
- LHS sampling

**Core feeder processing built on evolved form of Open Modeling Framework**
IGMS-Output Processing

Load and Voltage

The nodes in the graph are colored by their maximum change in voltage, where darker colors have a greater change.
Current Research Questions

• Can ISO-level visibility of DGPV reduce required bulk system reserve requirements while maintaining reliability standards? How does this change with PV penetration?

• To what extent can high penetration DGPV with advanced inverters contribute to bulk system reactive power and voltage support? How does this change with PV penetration?

• What are the bulk operational impacts of advanced distributed energy scheduling?

• …
Other HPC for planning efforts at NREL

- Time domain parallelization of (very) large PLEXOS production cost—nodal EI: 60k (Clayton Barrows and Aaron Townsend)
- Distributed Energy Scheduler—control framework simulations in IGMS (Emiliano Dall'Anese)
- Energy+ and PLEXOS for DR (Elaine Hale)
Integrated Energy Systems Model (IESM)

- Distribution (GridLAB-D) co-simulation with many home energy management systems (HEMS)
- Retail tariff/market evaluation
- Hardware-in-the-loop
- (Proposed) link to IGMS
Future directions for T+D

• IGMS + IESM = “Prosumer as price maker”
• Enhance economic analysis in IGMS
  o Retail-Wholesale market interactions
  o Customer and utility accounting
• T+D+... Comms, Loads, Markets, etc.
• Large-scale simulations for Power Hardware-in-the-Loop
Questions

Thanks!

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