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Hierarchical Multi-Level Electric Power System Simulation with Smart Photovoltaic Systems using the Functional Mock-up Interface on the Lawrencium Computing Cluster

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Overview

- Project Team
- Functional Mock-up Interface (FMI)
- FMI for Power Systems
- Simulation Setup & Results
- Outlook

Project Team

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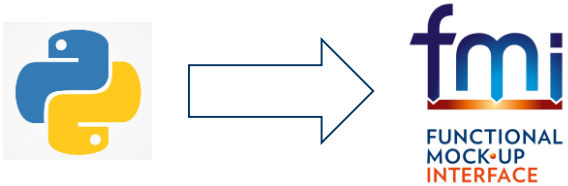
Functional Mock-up Interface (FMI)

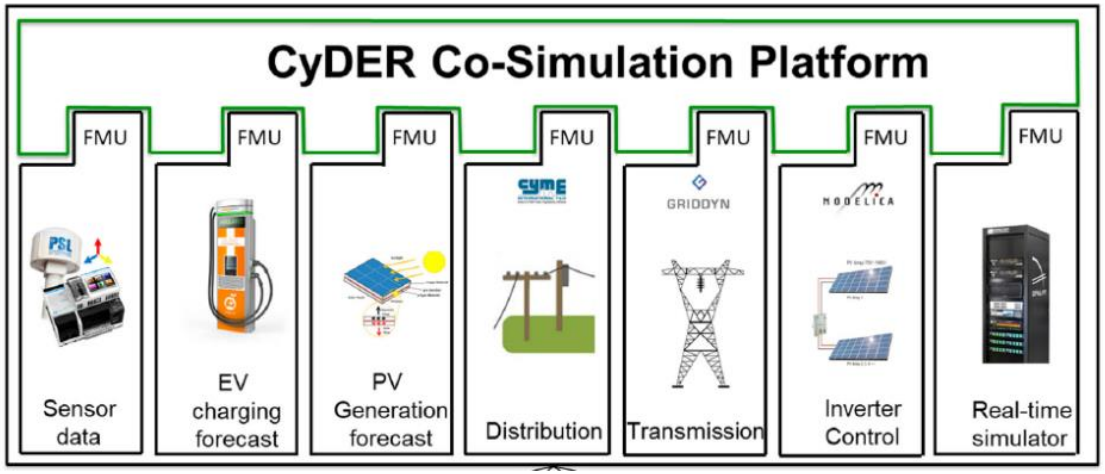
- Standardized functions to export and link simulators

- Widely adopted by industry (100+ supporting tools)
- LBNL developed SimulatorToFMU to export Python code



FMI for Power Systems

- Cyber Physical Co-simulation Platform for Distributed Energy Resources in Smart Grids (CyDER)
  - Make power system simulators more flexible
  - Couple domain specific simulators (T&D)



Nouidui et. al., 2019, CyDER–an FMI-based co-simulation platform for distributed energy resources, Journal of Building Performance Simulation
Gehbauer et. al., 2020, Photovoltaic and Behind-the-Meter Battery Storage: Advanced Smart Inverter Controls and Field Demonstration, California Energy Commission

Simulation Setup & Results (1)

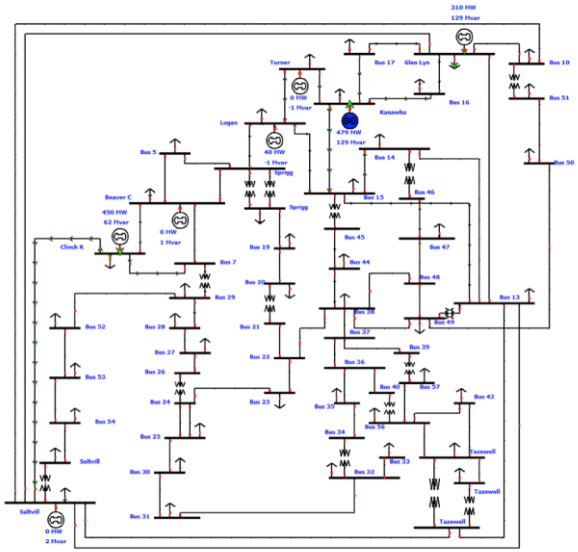
- Demonstrate CyDER and FMI for power systems
  - Couple more than 80,000 individual simulators representing a U.S. state's electricity grid
  - Distribute simulation across multiple compute nodes at LBNL's Lawrencium HPC facility
  - Execute simulation for 24 hours with a variable (continuous) timestep solver (hourly load change)
  - Evaluate feasibility and computational resources

Simulation Setup & Results (2)

42 bus

IEEE 57

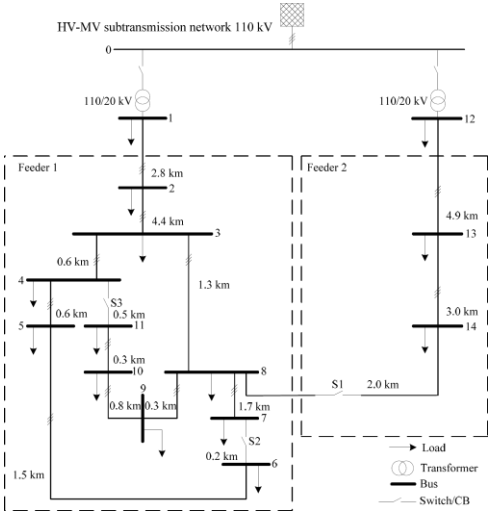
Transmission



13 bus

CIGRE

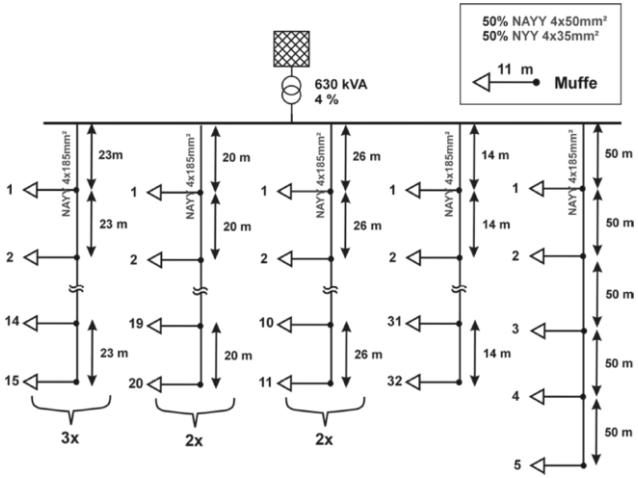
MV-Distribution



146 bus

Kerber

LV-Distribution



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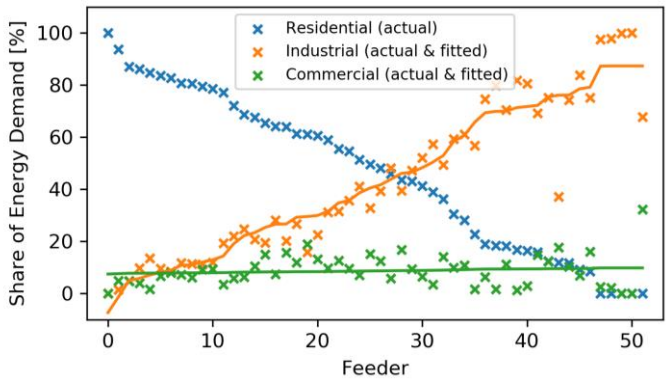
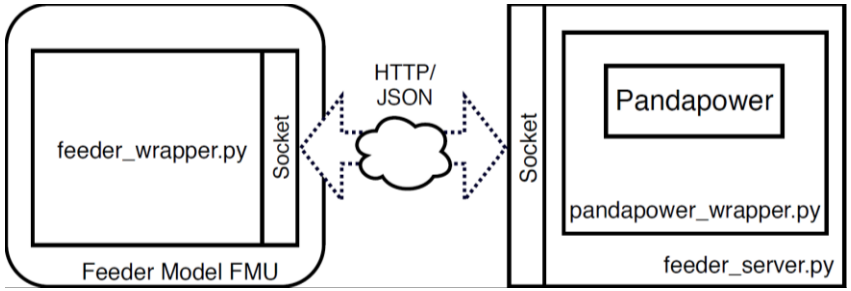
Simulation Setup & Results (3)

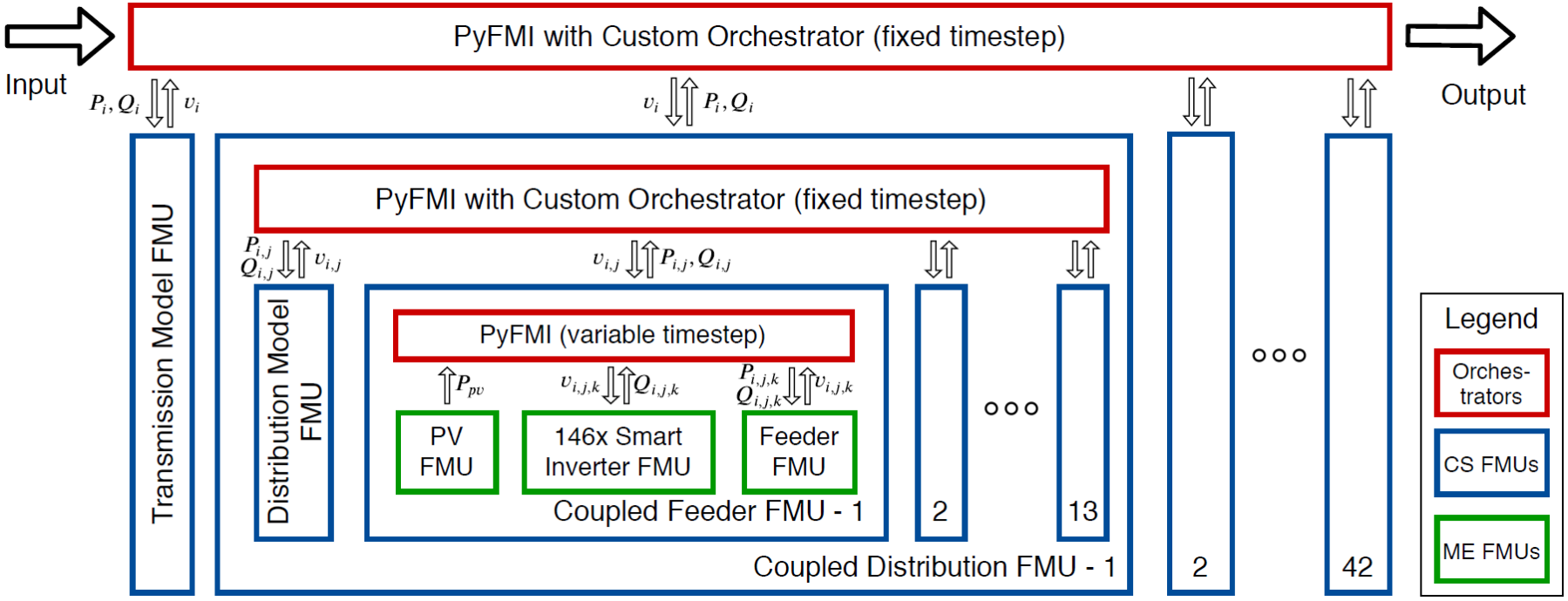
- Individual customers per LV bus, each with:
  - Local PV generation with smart inverter to regulate local system voltage (tight coupling between v, Q)
  - Randomly assigned DOE load profile based on PG&E feeder customer distribution (left)
- Parallelization on 12 Lawrencium nodes (384 cores) with modified SimulatorToFMU wrapper (right)





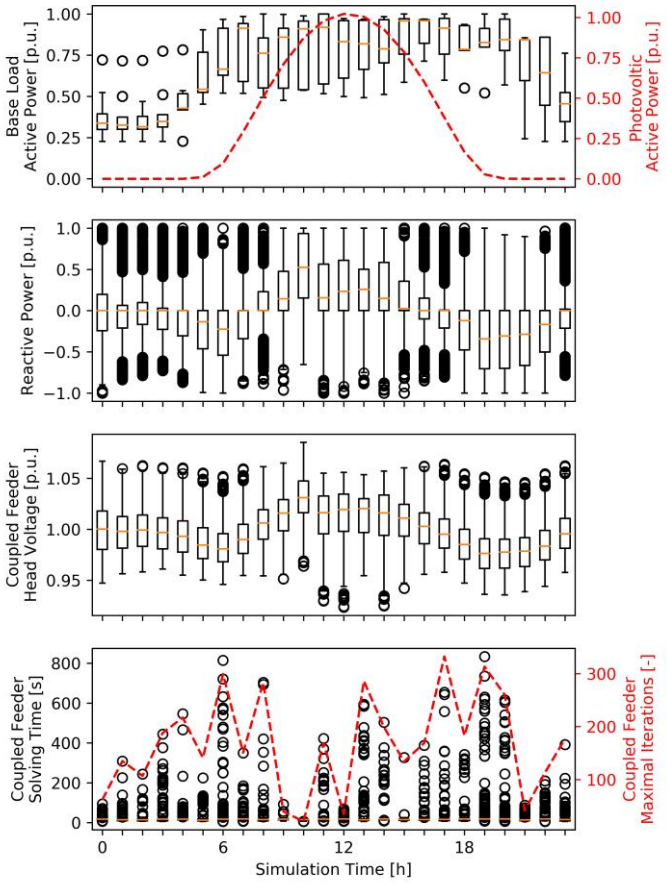
Simulation Setup & Results (4)

- Total of 80,851 individual FMUs
- Coupled through Voltage, Active- and Reactive power



Simulation Setup & Results (5)

- Good distribution of loads (LV bus) from few profiles
- Large variety of reactive power control consistent with feeder head voltages
- Head voltages mostly within bounds of ±5 %
- Most feeders converge fast (<10 iterations) but few increase total solving time



Outlook

- SimulatorToFMU to include state events: Internal state events are currently only captured in Coupled Feeder FMU; propagation to higher hierarchy necessary to simulate switching operations/faults
- Advance orchestrators to handle ME FMUs with variable timestep and rollback functionality
- Validate results with measured data (difficult)
- Integrate platform in ISO operations
- Use platform to develop/evaluate new control schemes

Links

- CyDER: https://github.com/LBNL-ETA/CyDER
- SimulatorToFMU: https://github.com/LBNL-ETA/SimulatorToFMU
- SCooDER: https://github.com/LBNL-ETA/scooder
- MBL: https://github.com/lbl-srg/modelica-buildings
- FMI: https://github.com/modelica/fmi-standard