# Online Integration of Modular Smart Grid Test Beds

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# Outline

- Major problems requiring integrated smart grid test beds
- Smart grid characteristics and performance measurements
- R&D needs
- **Centralized** simulation of modular smart grids
- **Distributed** simulation of modular smart grids
- **Co-simulation** of modular smart grids within cyber-physical systems

# Challenges of Integrating smart grid test beds

- Why integrate?
  - System-level performance improvements at distributed-level choices
- Major problems to solve
  - Integrating (operation and planning) new technologies at value
  - Avoiding unexpected operating problems

# R&D needs

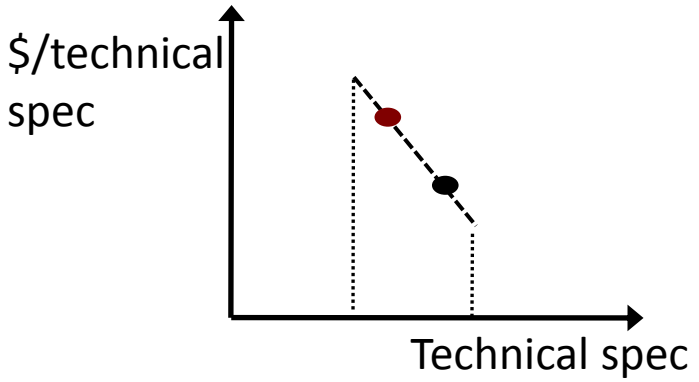
- Systematic framework for designing and online testing of inter-connected test beds
- **Information exchange protocol** definitions
  - That align multi-layered distributed performance measurements with system-level performance
  - That support data-driven and model-based decision making; academic work in progress
- **Communication protocol** definitions for temporal and spatial information exchange to ensure theoretically provable observability
  - Specification of sensing, communication delays, estimation accuracy, security needs

# Design and Development Evolution

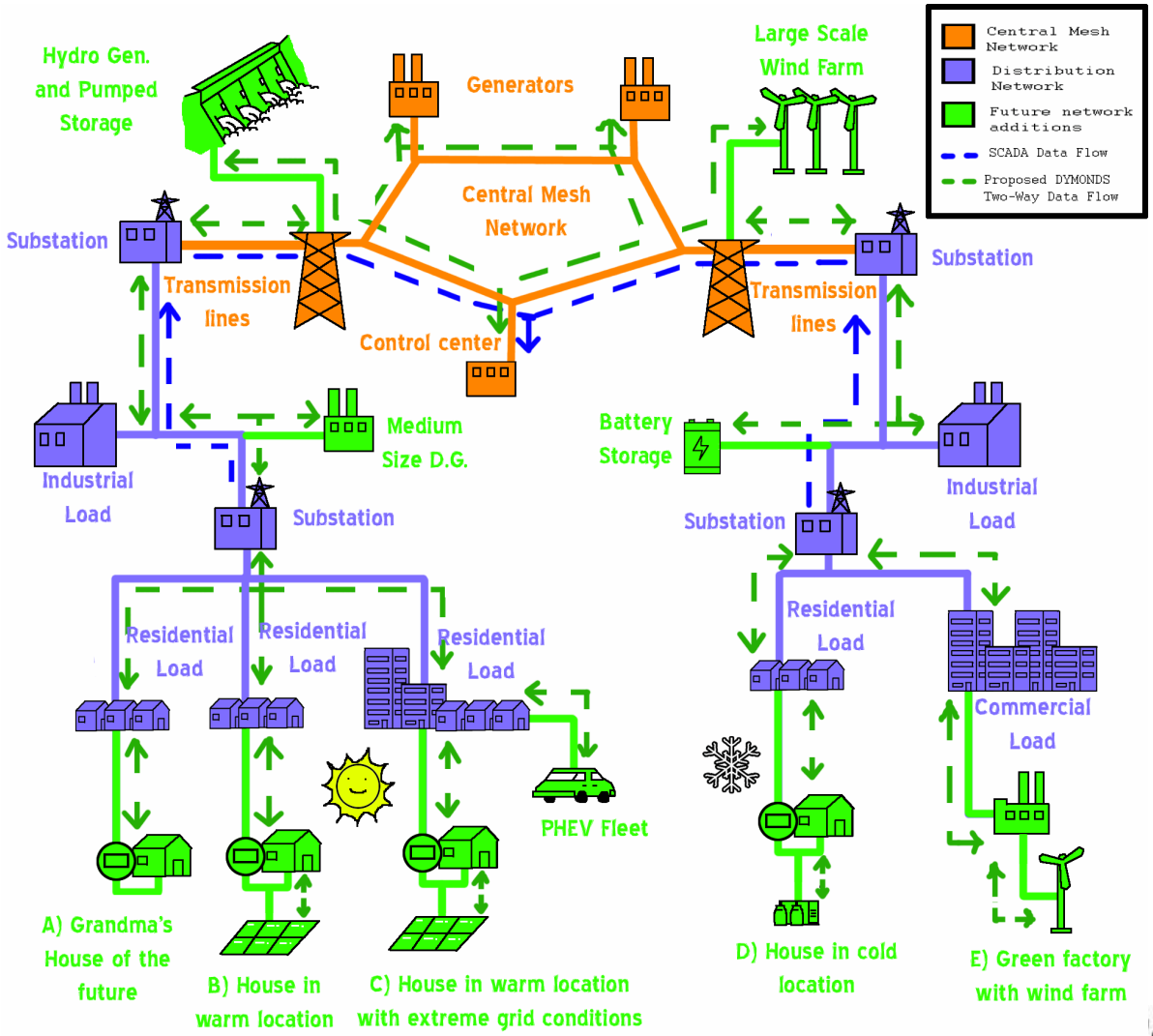
- World is a collection of distributed objects
- Model the systems as close as needed
- Centralized, single processor simulation
- Simulate on a distributed computational platform by replacing communication method
- Replace some of nodes with measurements
- Explore proposed data flow standards; collaborating with the industry

# SG features and performance measurements (basis for information protocols)

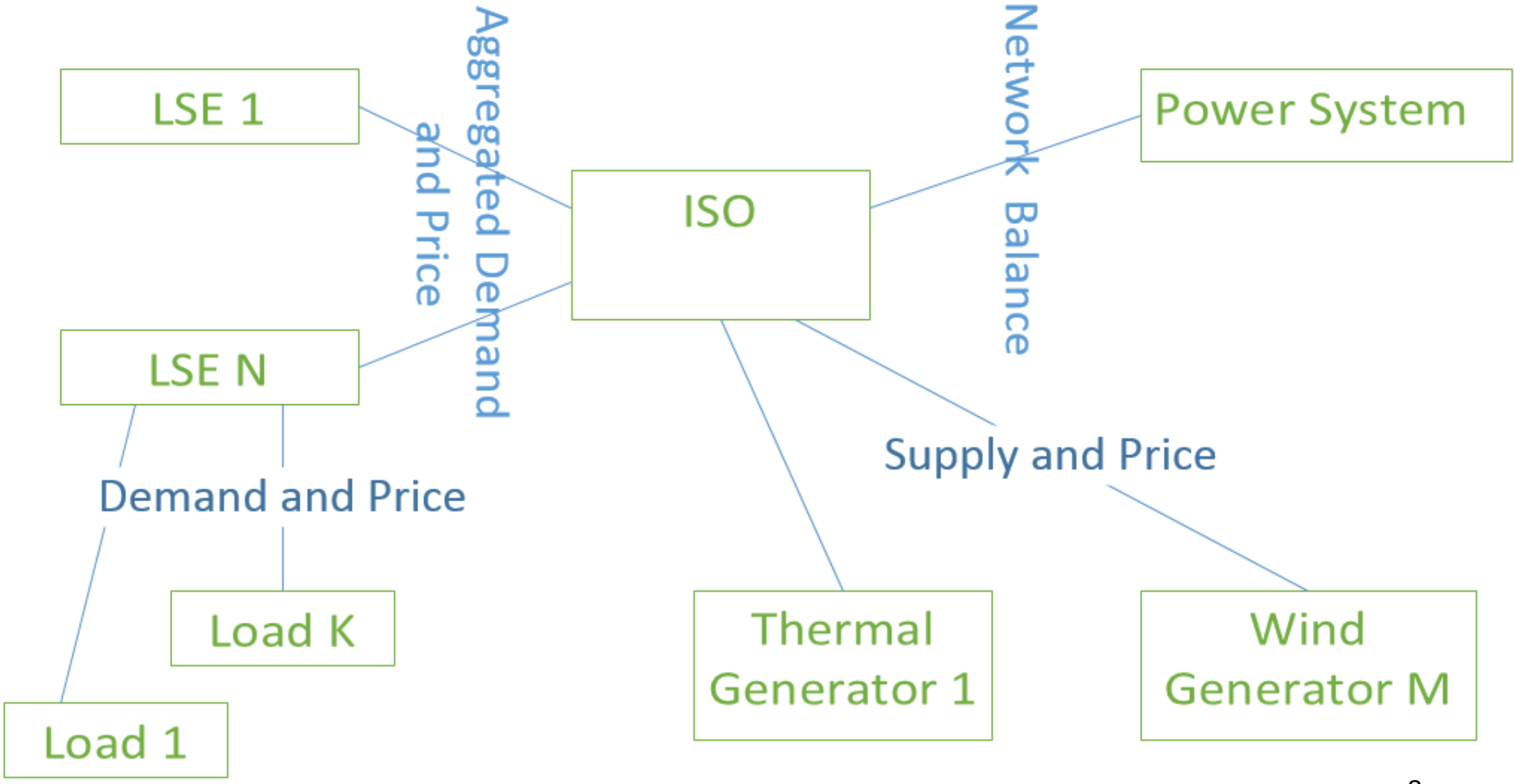
- **Well-defined protocols** (technical, $$, interoperability)
  - Over a wide range of time scales (planning; scheduling; load following; stabilization)
  - Over a wide range of geography/hierarchy (small customers, LSEs, ISOs, TOs, DOs, GENCOs)
- **Performance measurements**
  - Distributed multi-party (demand side, renewables, conventional GENCOs, LSEs, ISOs, ...)
  - Functional performance specs
  - Time-varying



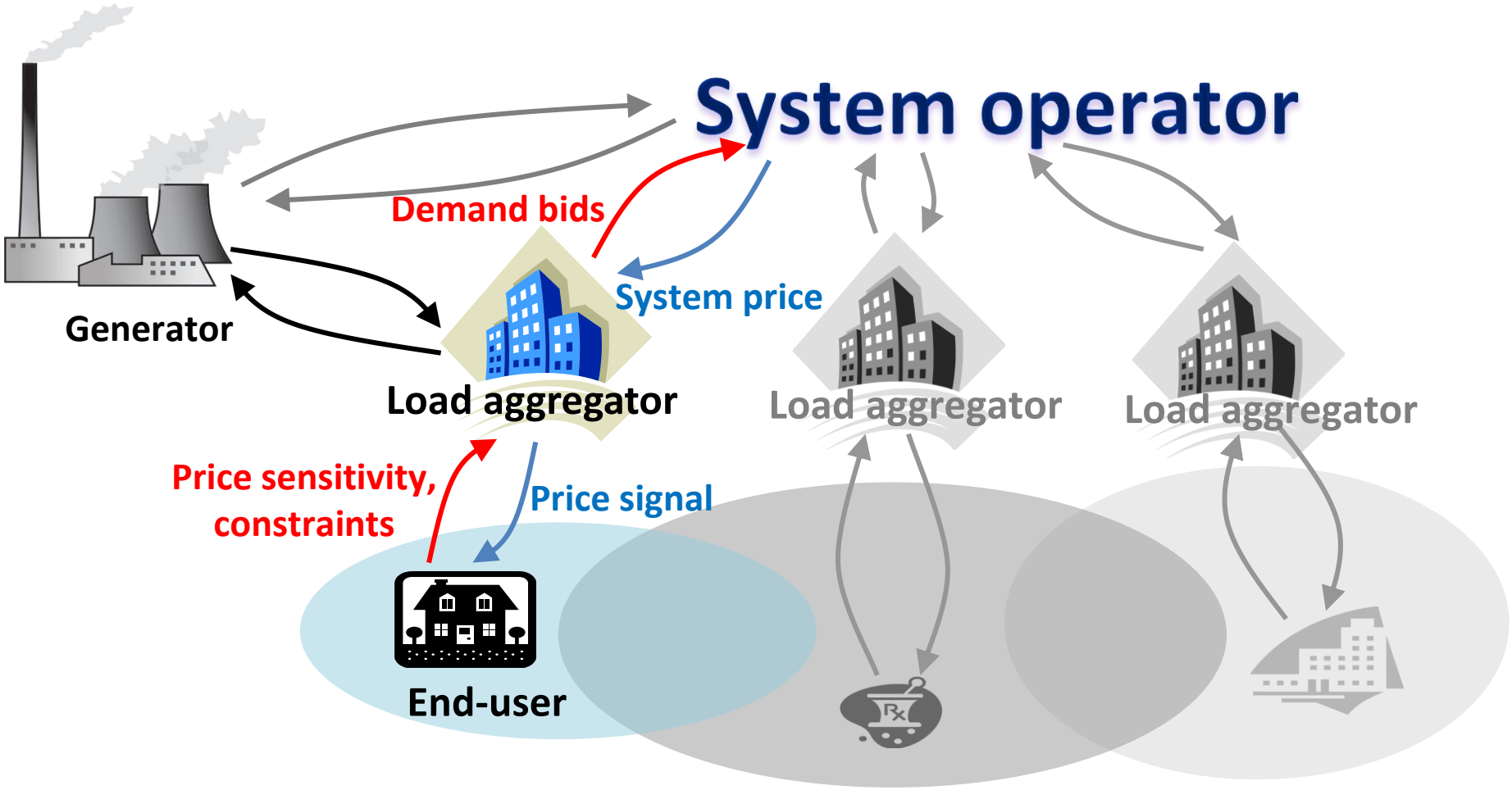
# DYMONDS – Aligning distributed and system-level performances



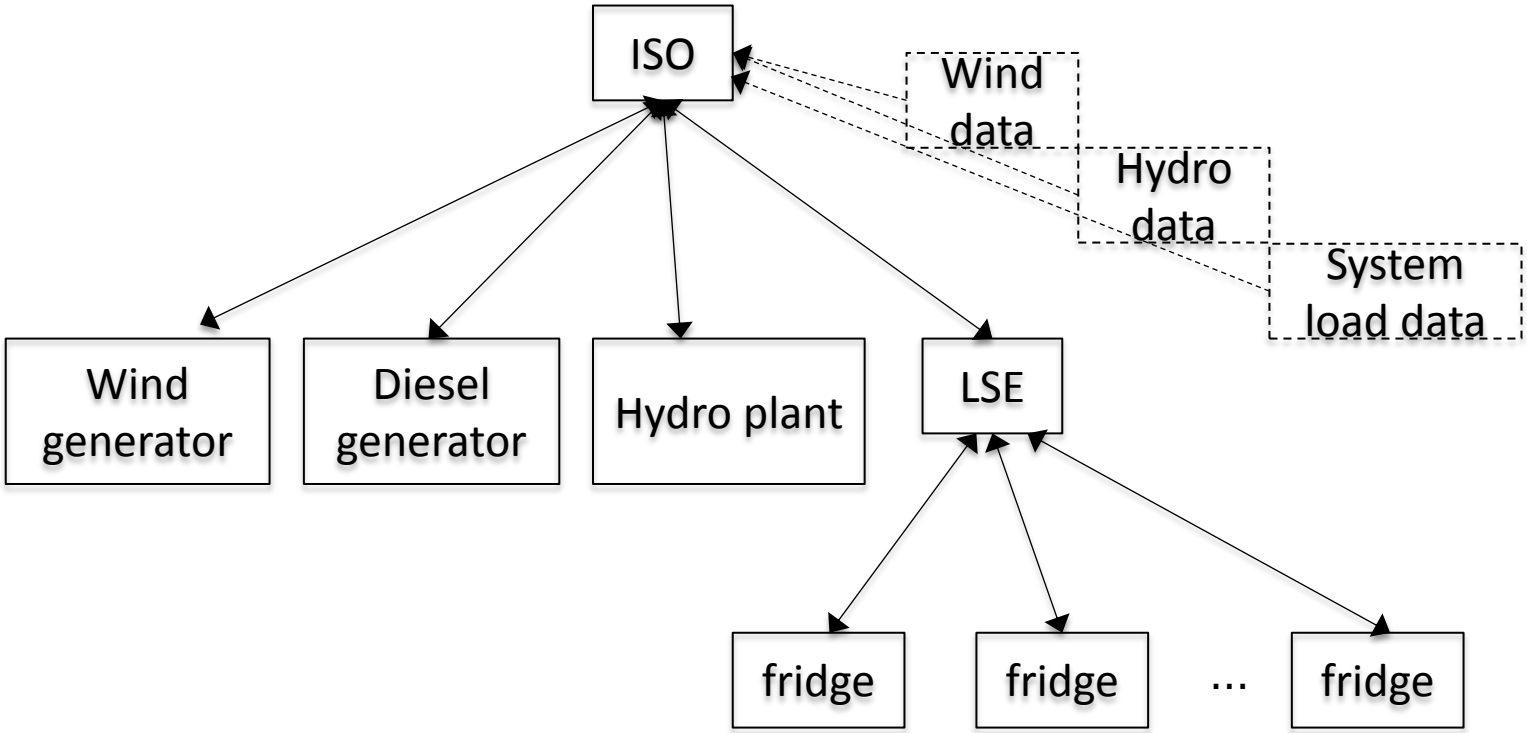
# Centralized modular smart grid simulation



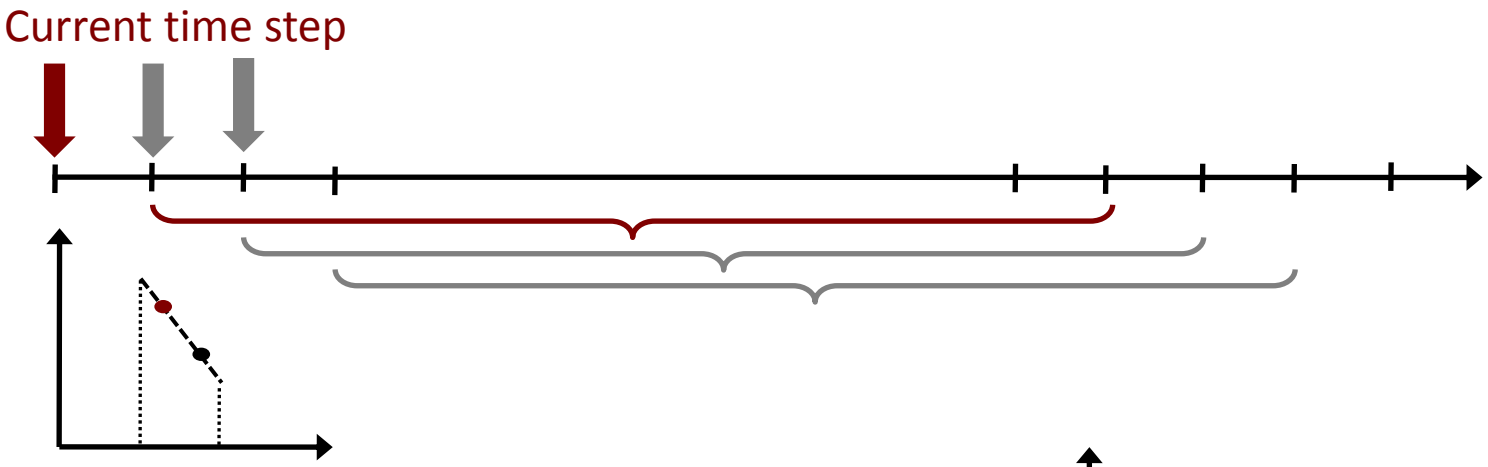
# Adaptive Load Management

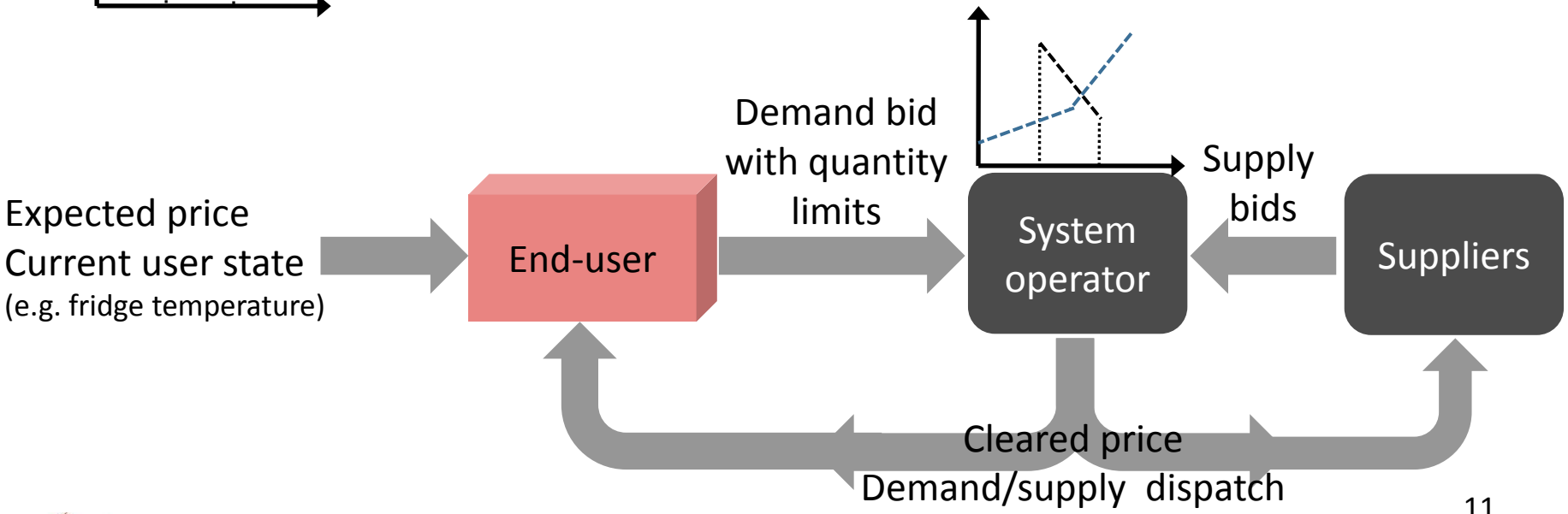


# Example of scheduling – Flores Island, Azores, Portugal



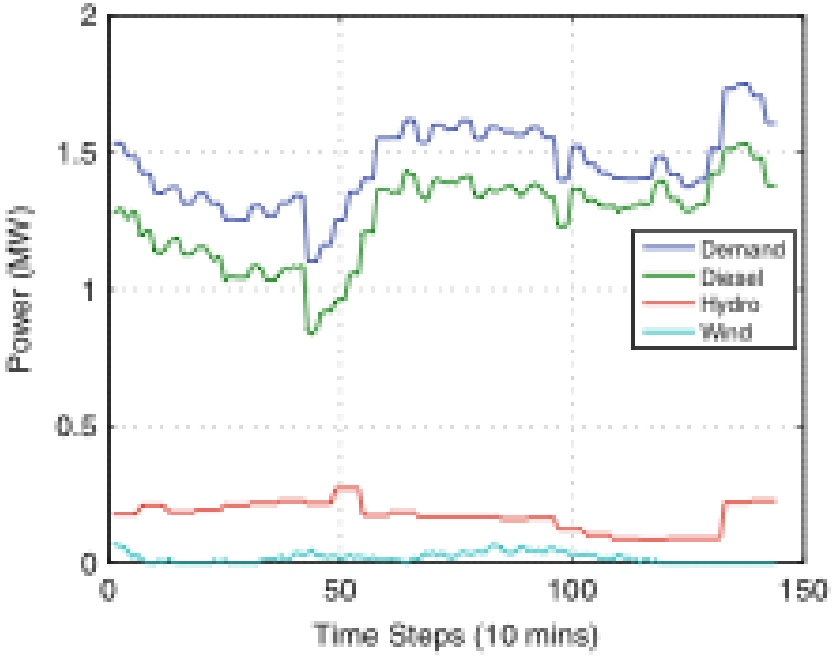
# Interactive moving-horizon dispatch



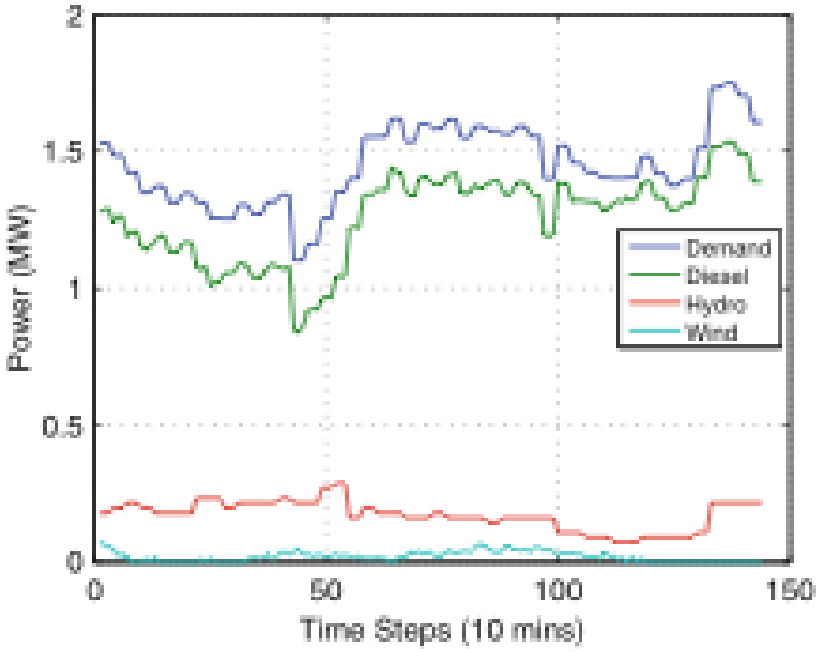



# Proof of concept: distributed vs. centralized

Flores Island, July 16, 2008




Centralized

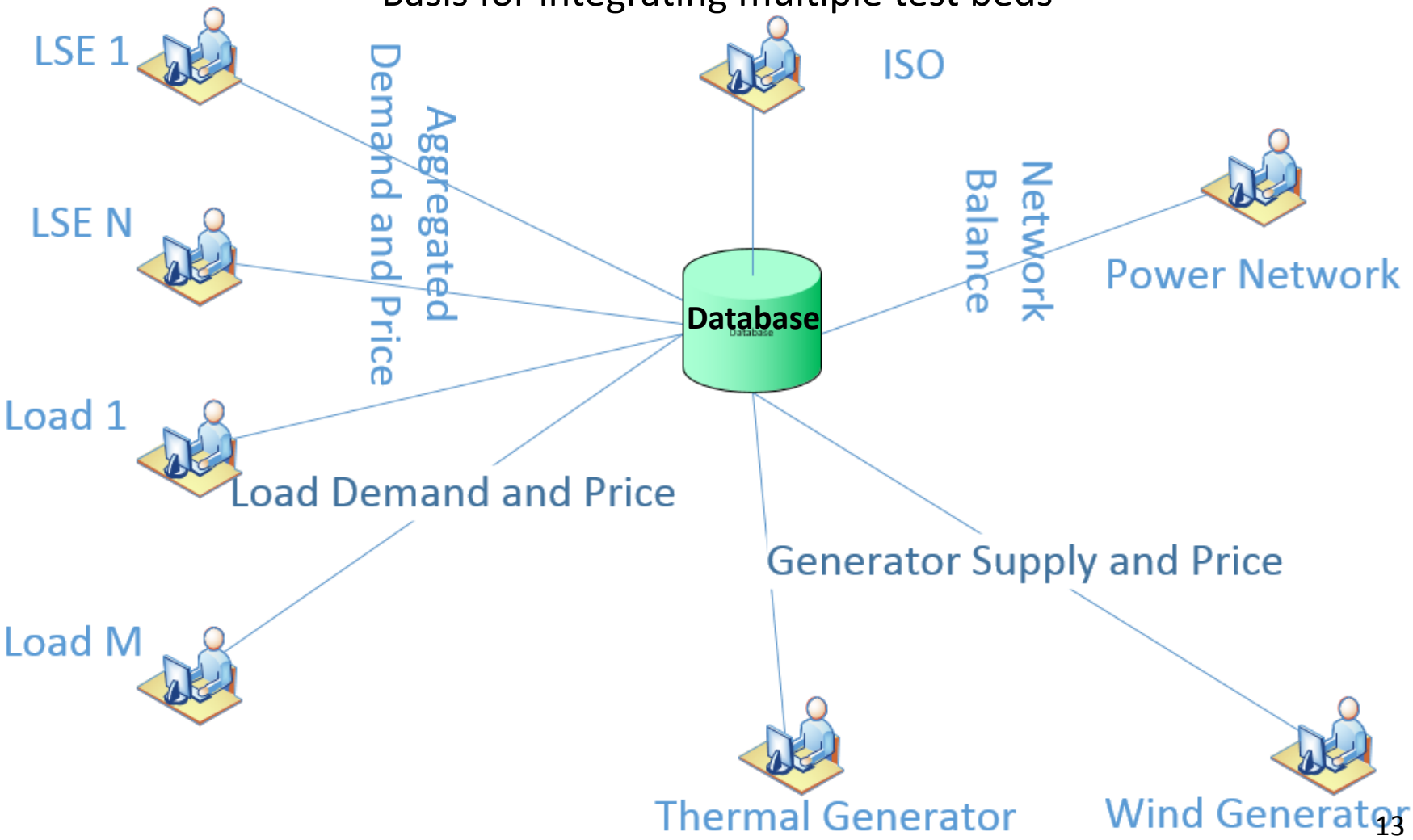



Distributed

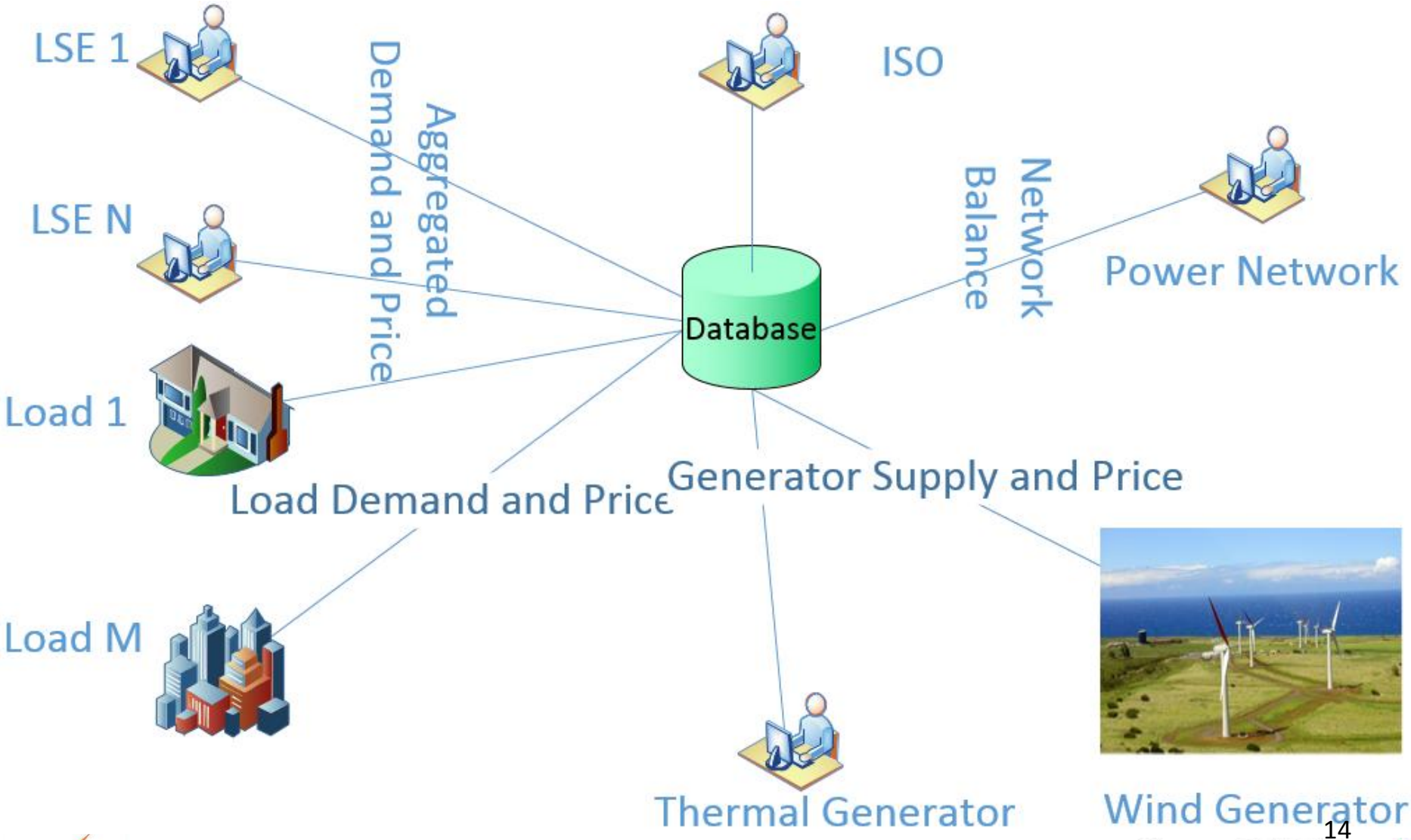
Reference: Engineering IT-enabled Sustainable Electricity Service: The Tale of Two Low-Cost Green Azores Islands, Springer, 2013

# Distributed modular smart grid simulation

Basis for integrating multiple test beds



# Co-simulation of modular smart grids within cyber-physical systems



# Concluding remarks

- Smart Grid In A Room -- NIST-CMU collaborative project, is pursuing simulation of modular smart grids integration
- Model-based and data driven demonstration of provable performance based on proposed information protocols
- Next phase:
  distributed co-simulation to demonstrate communication protocols
  - Directly relevant to integration of existing physical test beds
  - Collaborating with Microsoft and OSISoft on Smart City initiative

# Thank you

# Networked Database System

- Interoperable with power system entities
- Secure with well defined access control
- Capable of storing large amounts of data
- Available API to interface with various data sources and formats (SQL, CIM, text, etc.)
- APIs for different programming languages (C/C++, Matlab, Python, etc.)
- Free for academic research

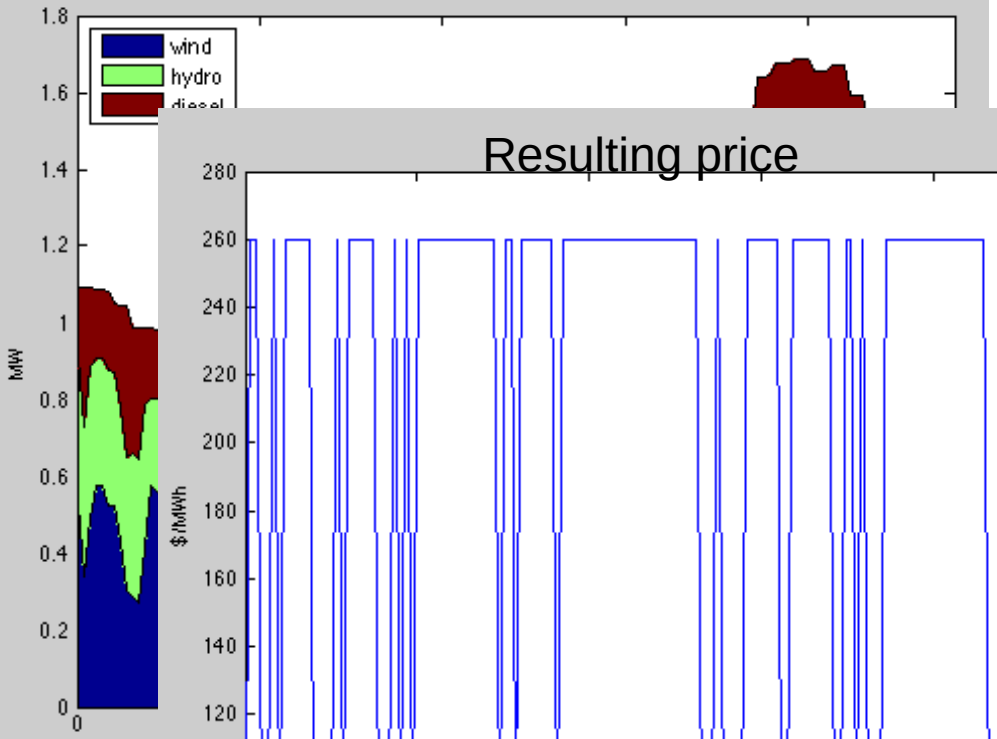
# Implementation Outcomes

- Designing better dispatch and control algorithms
- Defining what information needs and can be exchanged for higher efficiency algorithms
- Deciding on communication standardization efforts

# Flores Island, Jan 15, 2008

Distributed interactive protocols approach system-level performance

Generation dispatch




Resulting price




Refrigerator consumption and temperature