Agent-Based Test Beds for the Integrated Study of Transmission-Distribution Operations

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Proposed Talk

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Presentation Outline

- **Integrated Retail and Wholesale (IRW) Power System Test Bed**

  IRW Project Homepage

  www.econ.iastate.edu/tesfatsi/IRWProjectHome.htm

- **HPC Implementation of Case Study**

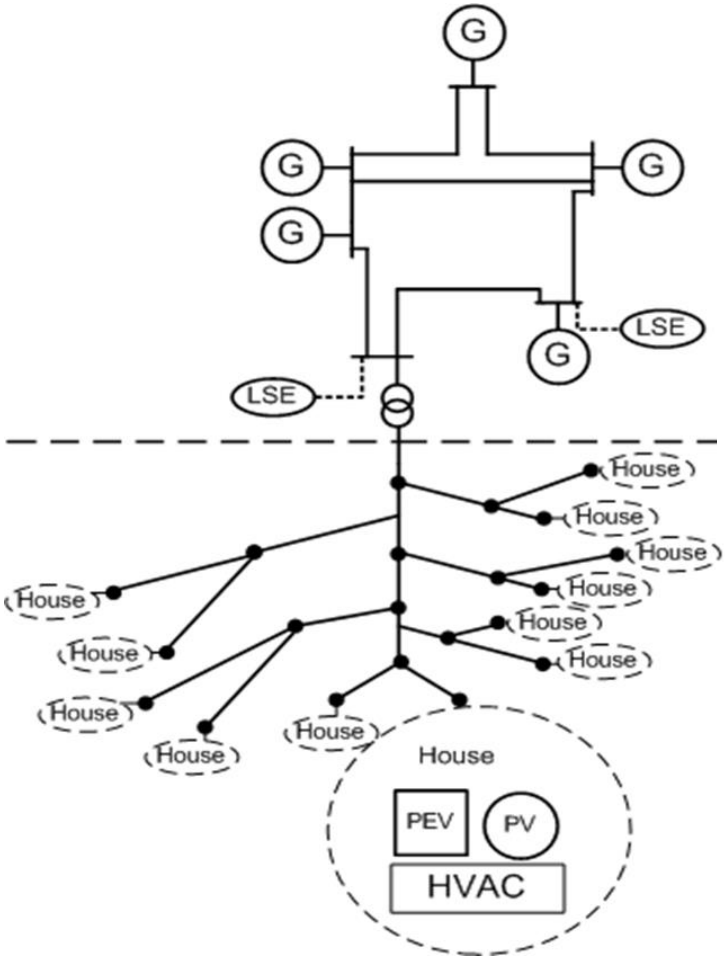
  - IRW feedback loop arising from the Introduction of smart price-responsive A/C controllers for residential households

- **Extended IRW Test Bed**

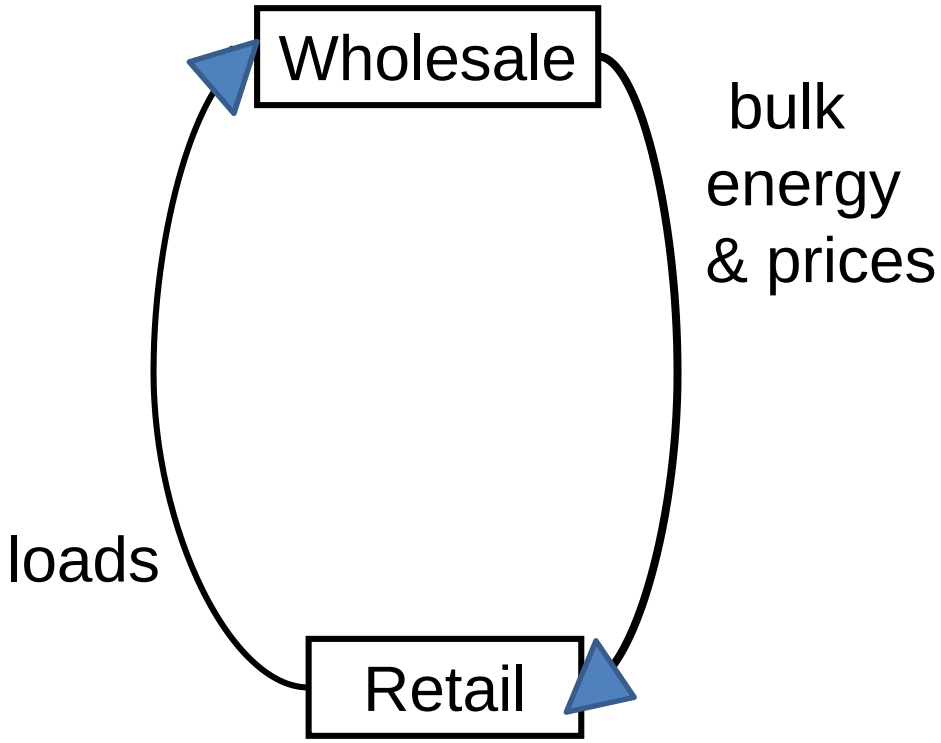
  - On-line integration with GridLAB-D to realistically model the distribution system

Integrated Retail and Wholesale (IRW) Power System Test Bed

5-Bus 1-Feeder Example

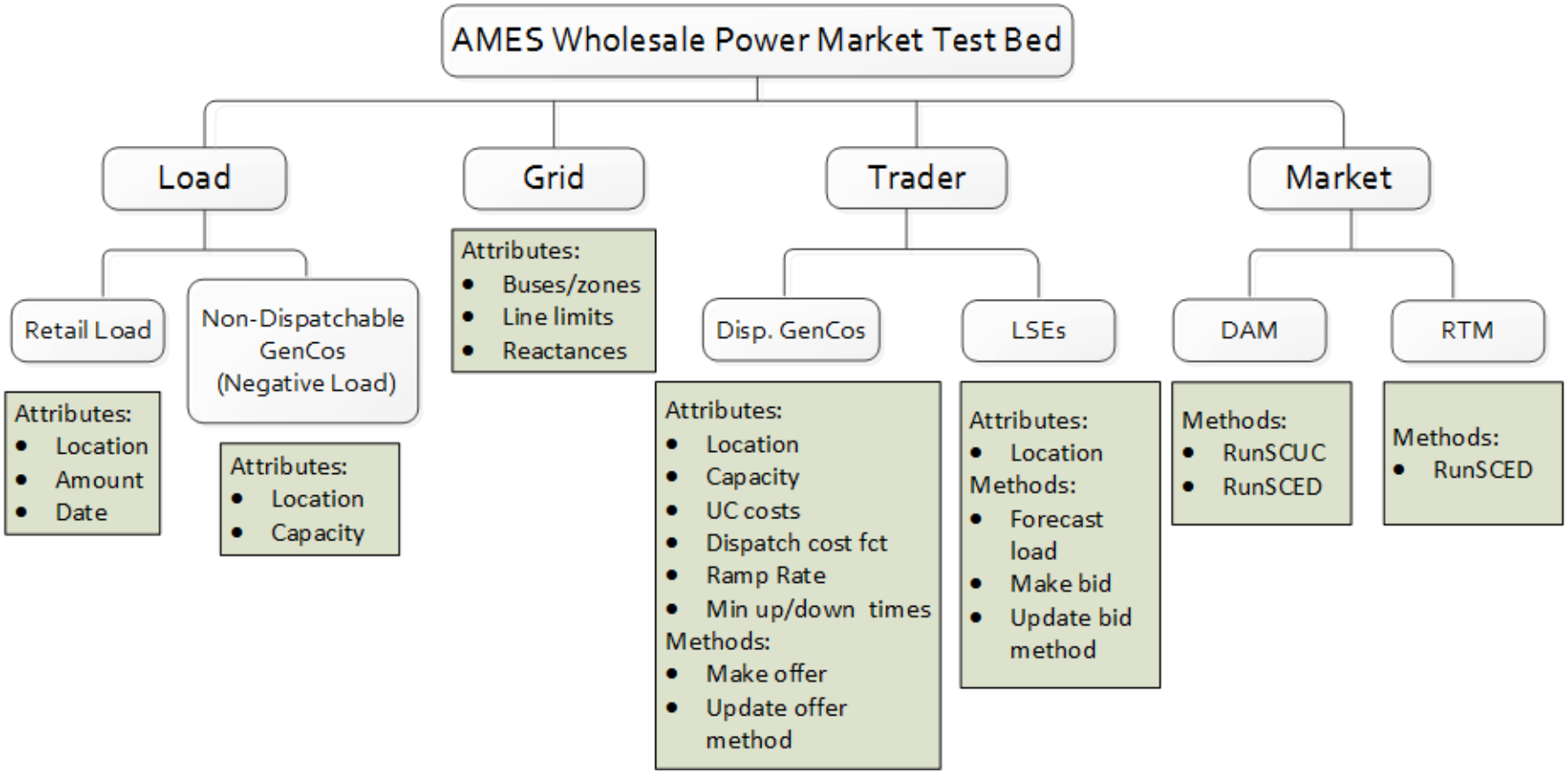


AMES Test Bed



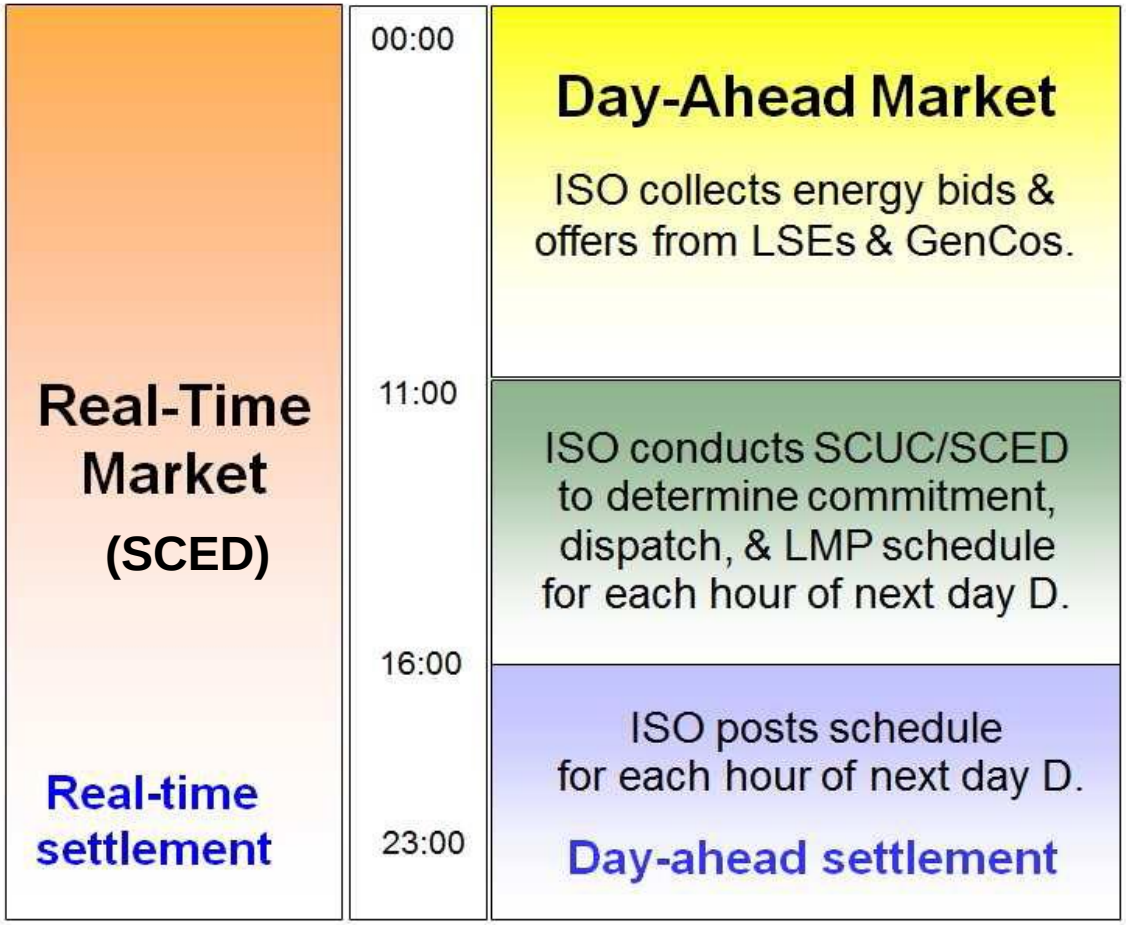
Distribution Test Feeders

AMES Wholesale Power Market Test Bed

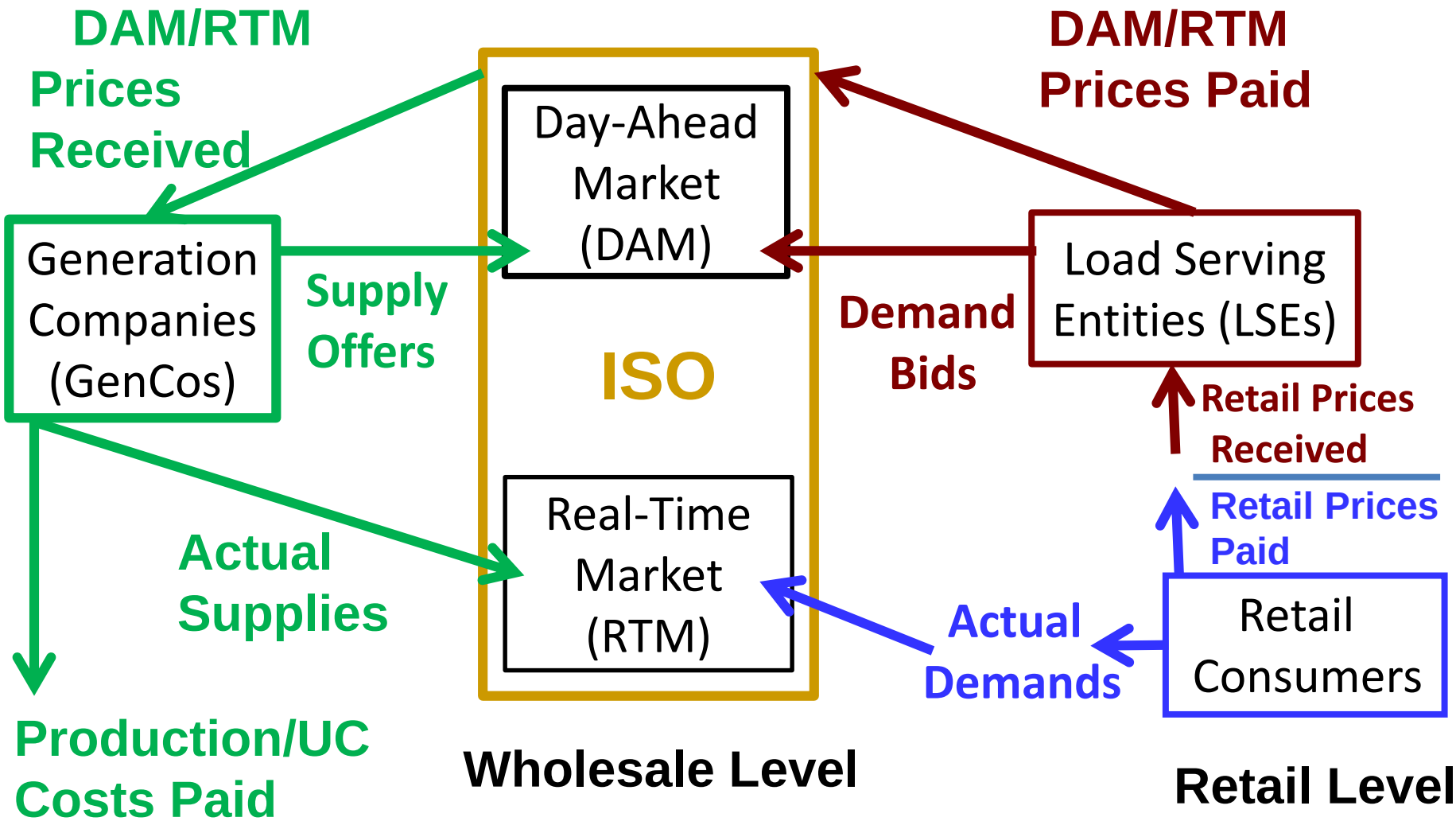


AMES Homepage:
http://www2.econ.iastate.edu/tesfatsi/AMESMarketHome.htm

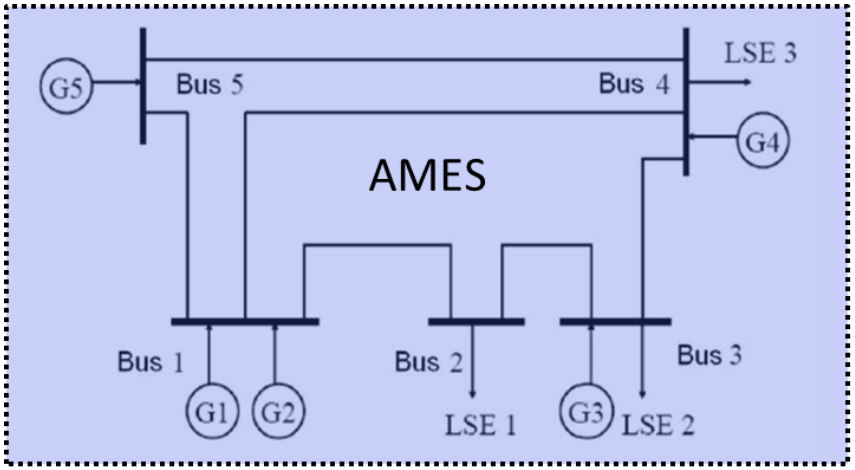
IRW Test Bed Models the DAM/RTM Two-Settlement System

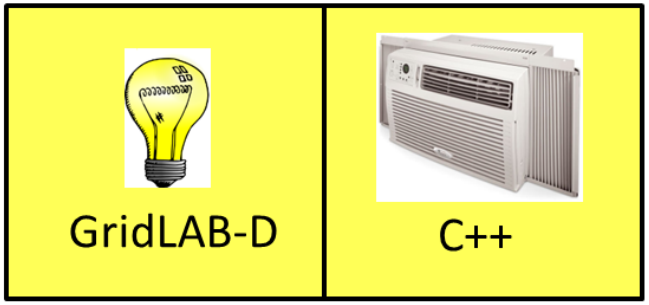


IRW Test Bed Keeps Track of Profits and Losses for Wholesale/Retail Participants



HPC Implementation of IRW Case Study





Conventional Load A/C Load

Modeling of Households

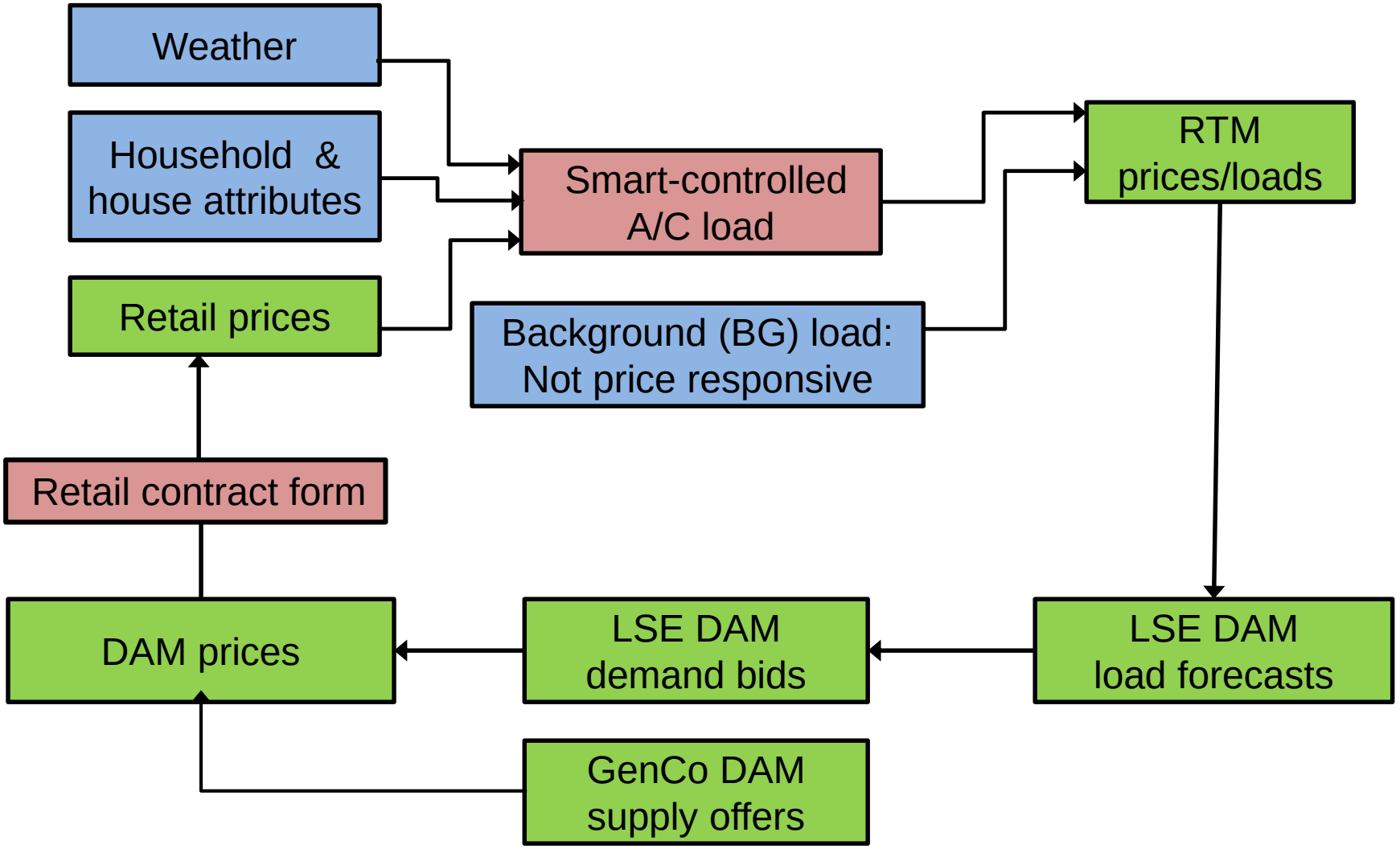
A single ***C++*** application with MPI/OpenMP support for A/C module and GridLAB-D (off-line) used to model conventional load

Choice of Programming Language for A/C Module

- Approximate Simulation Time (12 compute nodes)
  - 1 feeder/1 day → 600 houses → 0.196*30 = 5.88 sec
  - 48 feeders/1 day → 4 feeders/node → 5.88 * 4 = 23.52 sec
  - 48 feeders/100 days → 100 * 23.52 = ~ 39.2 mins

	Platform	Matlab	Python (NumPy)	C	C++ (Armadillo)	C (with OpenMP)	C++ (Armadillo with OpenMP)
20 houses	Simulation Time (sec)	2.477	1.905	1.234	1.101	0.221	0.196
	~Total Simulation Time (min)	495.4	381.0	246.8	220.2	44.2	39.2

IRW Feedback Loop for IRW Case Study



Smart A/C Controller for IRW Case Study

A. Thomas, P. Jahangiri, D. Wu, C. Cai, H. Zhao, D. Aliprantis, and L. Tesfatsion, *IEEE Trans. Smart Grid*, Vol. 3, No. 4, 2012, 2240-2251

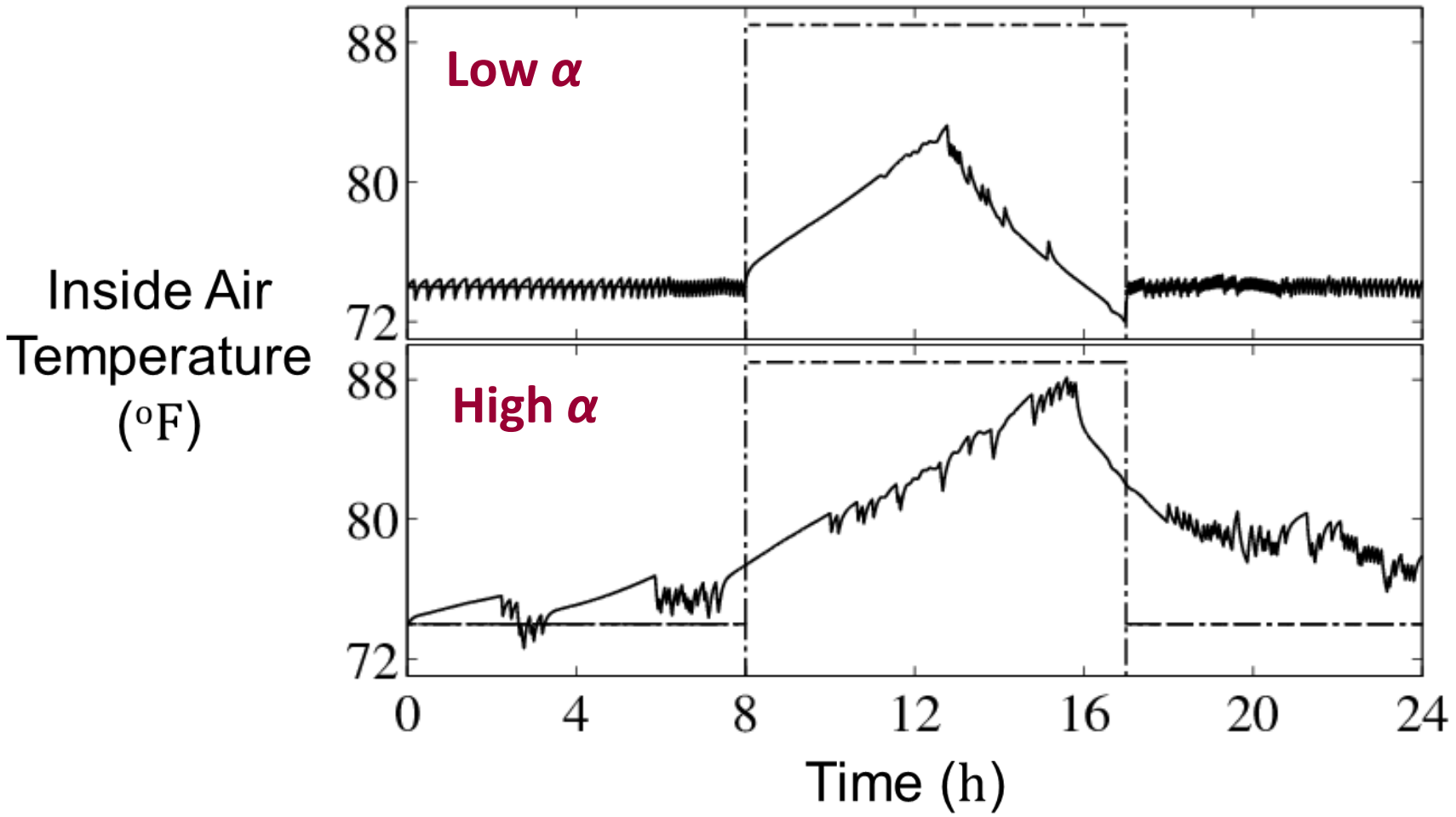
Alpha α

Low → High

Retail Price (DAM Price + Markup) **Weather**	**Household A/C Preference Attributes** **(α setting, set-point temperature, time at home, …)** **House Structural Attributes** **(Btu rating, COP, dimensions, …)**

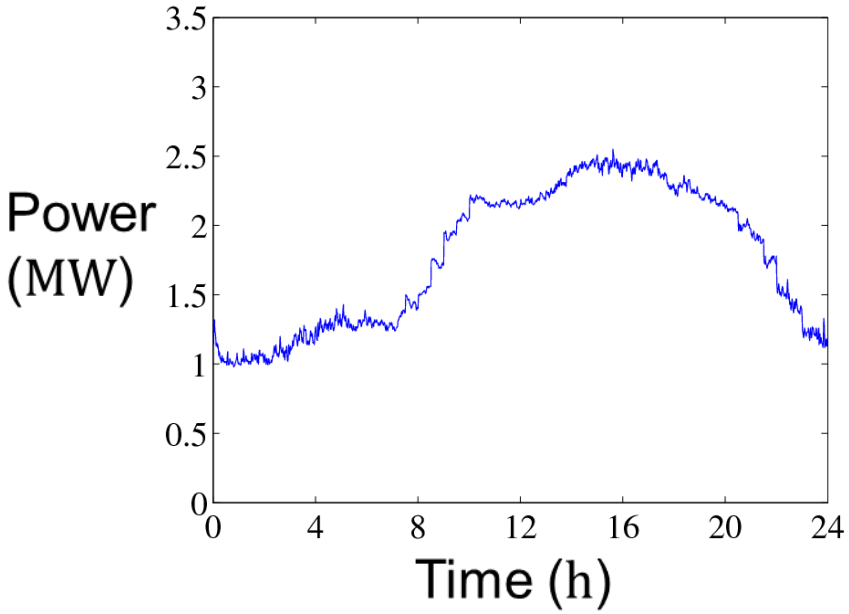
Resident away from home 8am - 5pm

Higher α = Higher concern for cost; Bliss temp = 74ºF

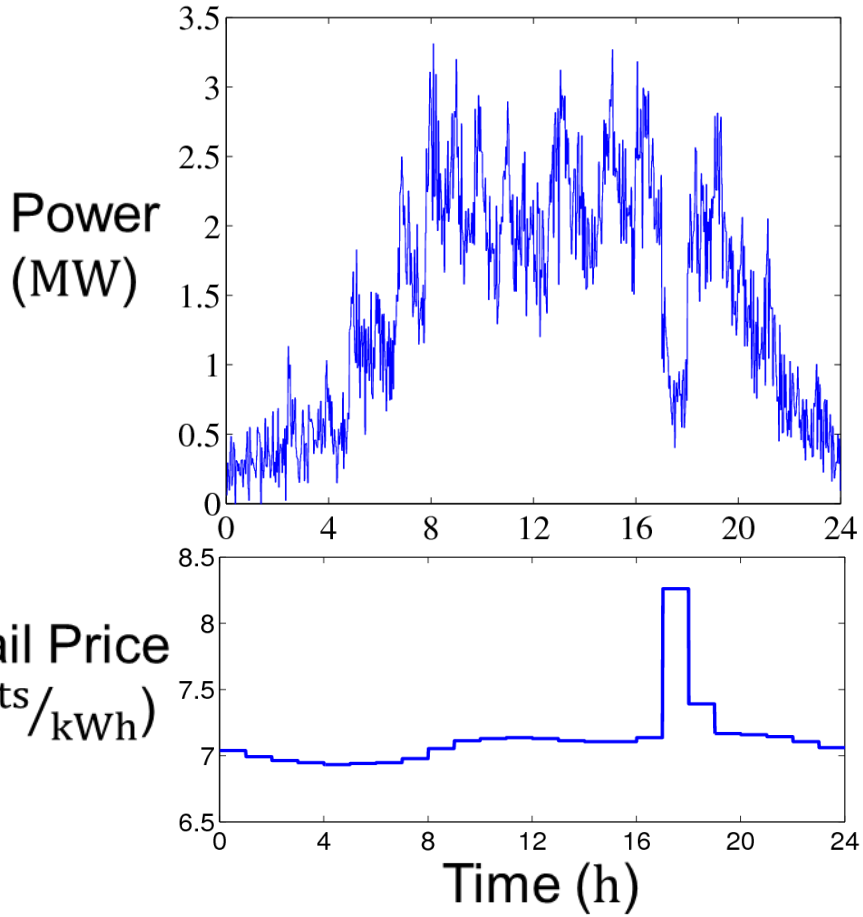


From single-household load to aggregated bus load

Non-Price-Responsive Load



Smart A/C Controlled Load

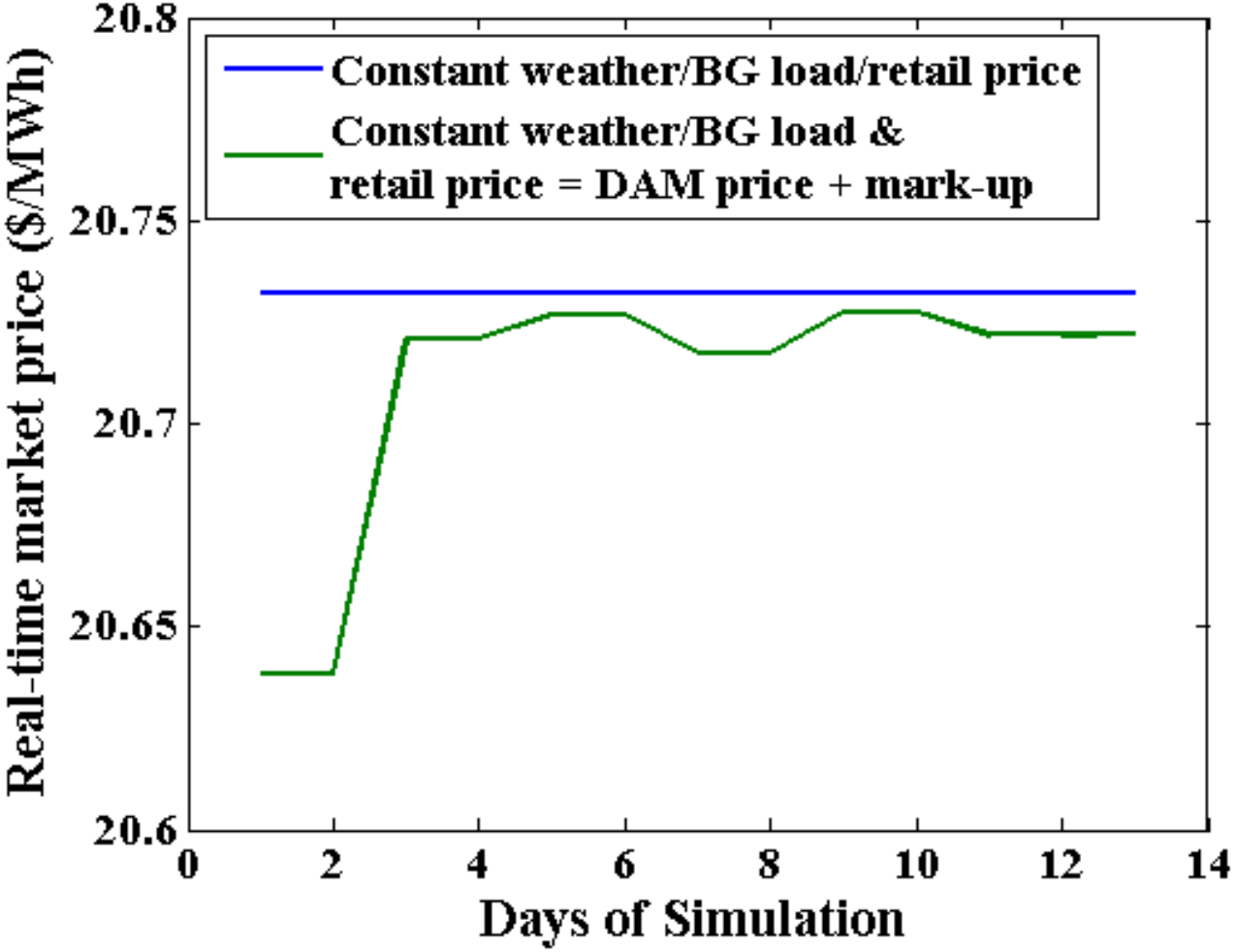


Case Study Specifications …Continued

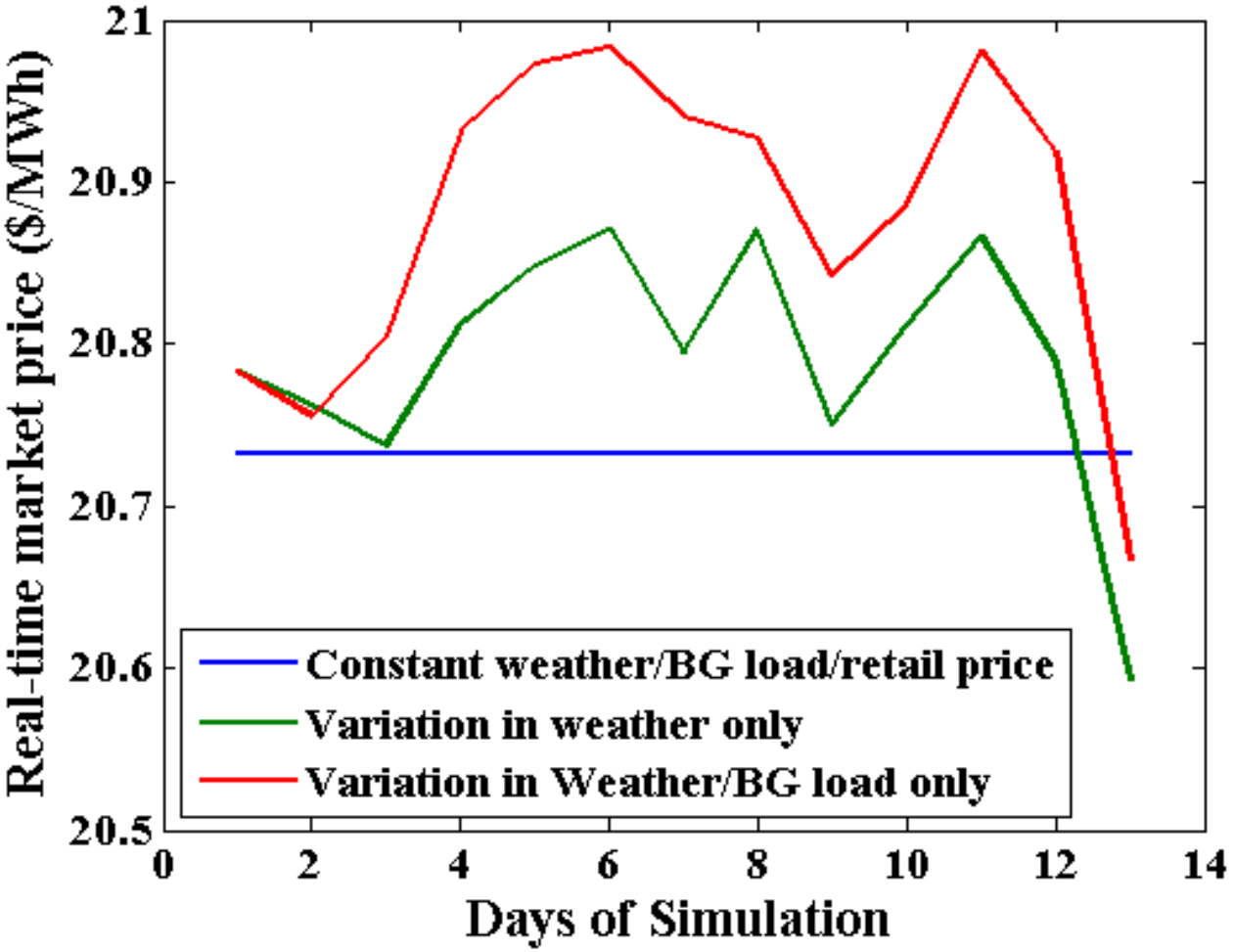
- Exogenously given state vector for each day
  - Weather conditions
    - Outside air temperature
    - Other environmental forcing terms
  - Background (BG) conventional load profile (not responsive to price changes)
- LSE DAM demand bid method
  - Day D-1 actual load ⟹ Day-D demand bid
- Household comfort/cost preference parameters α
  - Set at random (uniformly distributed) values unless otherwise indicated.

Preliminary Results:

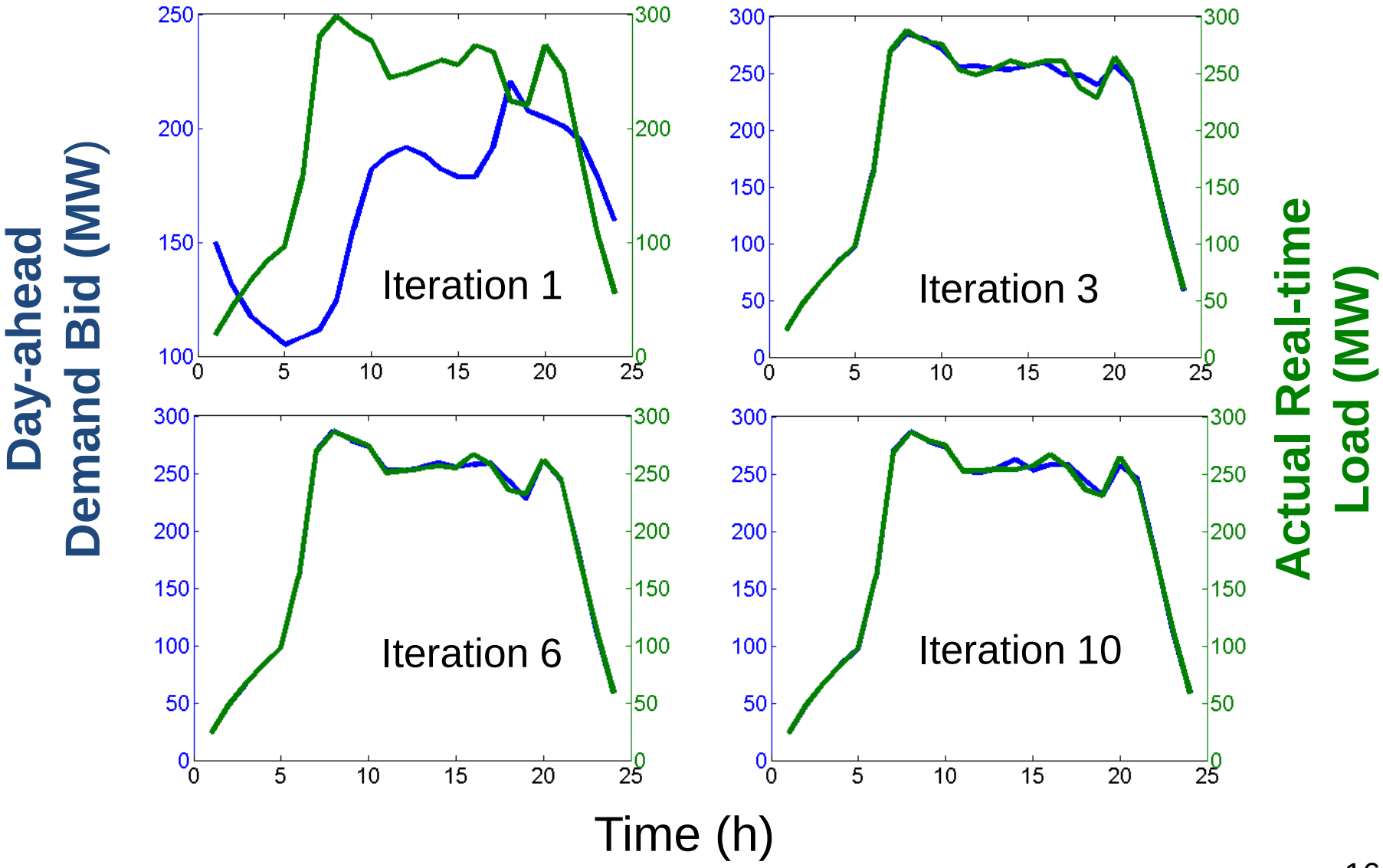
RTM price at feeder bus (peak hour 18) under varied forcing-term and retail-price conditions



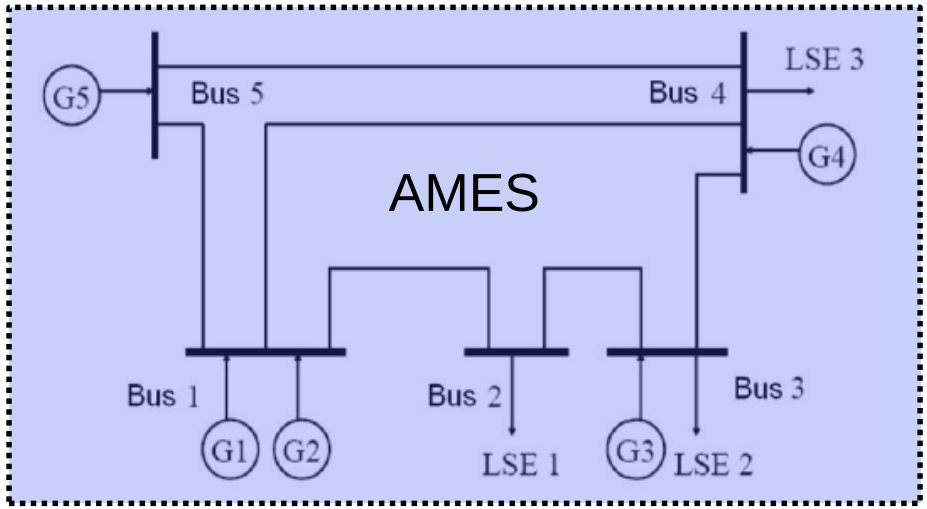
RTM price at feeder bus (peak hour 18)

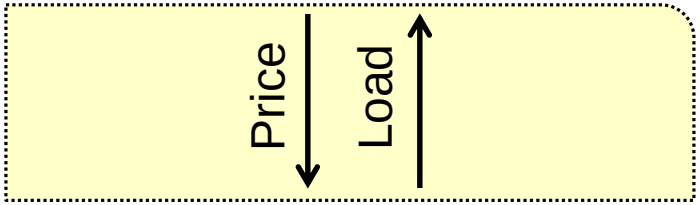


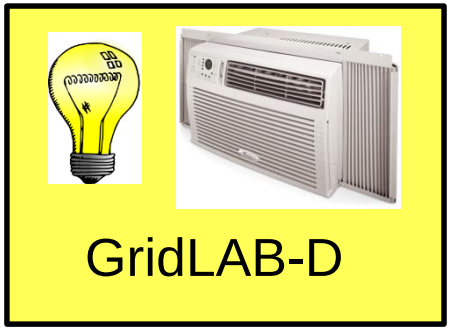
LSE Forecast: Case 1



GridLAB-D Online Simulation







Modeling of Households

Ongoing Research

- Further investigation of IRW feedback loop
  - AMES-GridLAB-D online simulation

- More realistic case studies
  - Use of a High Performance Computer (HPC) cluster to simulate multiple distribution feeders
  - Improved LSE load forecasting methods

On-Line Resources

- **IRW Project Homepage**

  www.econ.iastate.edu/tesfatsi/IRWProjectHome.htm

- **AMES Test Bed Homepage (Code/Manuals/Publications)**

  www.econ.iastate.edu/tesfatsi/AMESMarketHome.htm

- **Agent-Based Electricity Market Research**

  www.econ.iastate.edu/tesfatsi/aelect.htm

- **Open Source Software for Electricity Market Research, Teaching, and Training**

  www.econ.iastate.edu/tesfatsi/electricoss.htm