Establishing Credibility for Load Coordination at Scale

Super Session: Grid Edge – Devices, Control, Applications, and System Operation

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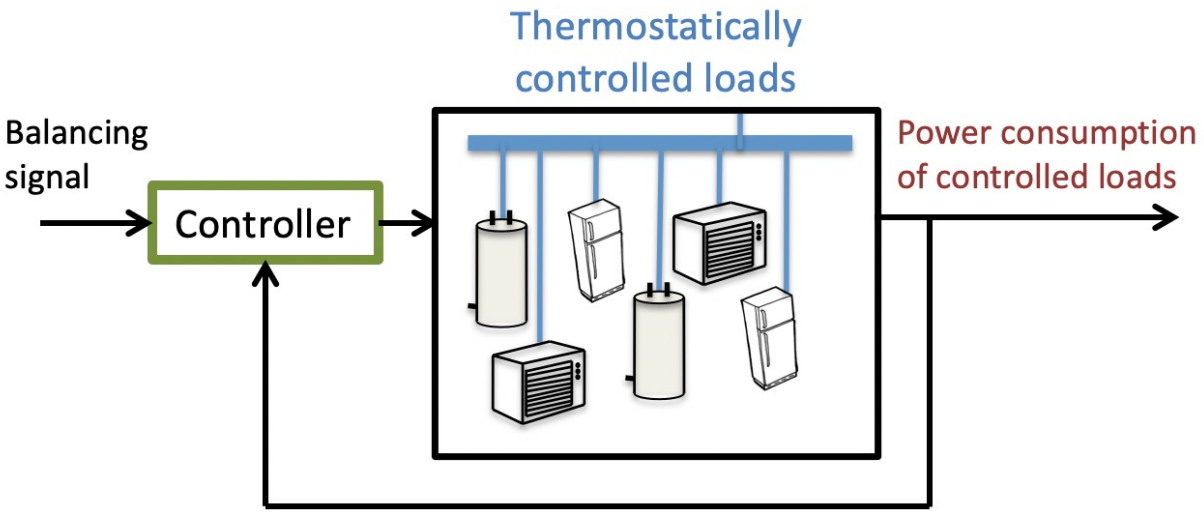
Collaborators

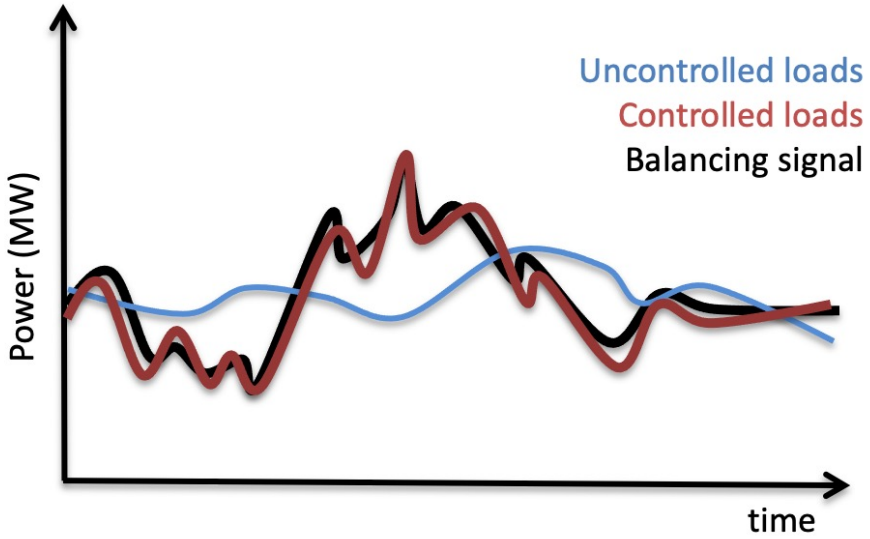
Funded by:

Electric Load Coordination

Feedback Control



Tracking a Balancing Signal



How is this different?

- Lots of research, demos, pilots on load coordination for balancing services
- Why hasn't load coordination become standard practice?

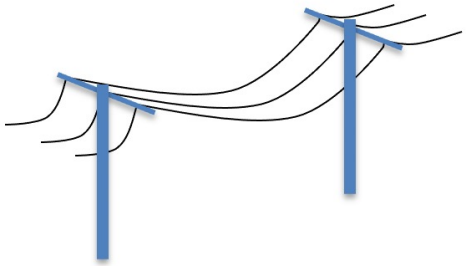
- **Goal:** Establish credibility for load coordination at scale.
- **Approach:** Identify technical issues and develop solutions to address those issues such that consumers, utilities, system operators, aggregators, and regulators trust the technology and understand its capabilities and limitations.
- **Anticipated result:** Resolve fundamental technical obstacles to widespread adoption and large-scale deployment of load coordination for balancing.

Technical Issues

- **Distribution network impacts**
  - over- and under-voltages
  - transformer overheating
- **Control over imperfect communication networks**
  - Control over imperfect communication networks
  - Trade-offs between quality of control and comm network sophistication
- **Stability**
  - Synchronization leading to oscillations

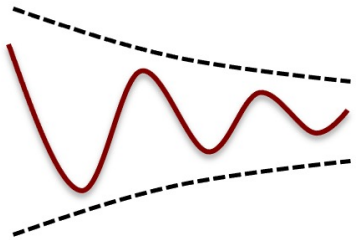
Overall Goal

Network-Aware



Communication-Constrained

Stability Guarantees



Controllers that enable aggregations of air conditioners (ACs) to provide frequency regulation with sufficient quality to meet an ISO's performance requirements

…with no stability or distribution network issues

…utilizing low-cost communication network(s) and controllers

…in a way that is completely non-disruptive to customers

…AND cost/benefit analysis shows profitability for aggregator and consumers

Why frequency regulation?

- It's really hard – if we can demonstrate frequency regulation, we should be able to do any balancing service.
  - Requires coordination amongst loads
  - Requires closing the loop fast (2-10 seconds)

Approach:
Test Load Controllers in 3 Testbeds

Simulation Testbed
1000 ACs (high-fidelity models)
+ distribution network (GridLAB-D)
+ comm network (fully configurable)

Experimental Testbed
20 real ACs at LANL

Field Testbed
100 real ACs at Pecan Street

Experimental Testbed at LANL

- Validated against data from real ACs
- Critical for pushing the system to its limits and discovering controller failure modes – we can't do these experiments in a field testbed!

Each box is a "model house" with an AC

Controller Testing + Development

- Identified 3 promising controllers from literature
  - 2 top-down controllers (Aggregator sends coordination signals)
  - 1 bottom-up controller (AC request power)
- Tested them in nominal and extreme conditions in the high-fidelity simulation testbed
  - Observations: temperature excursions, poor tracking performance, transient transformer overloads, over- and under-voltages, oscillations
- Will next test them in experimental testbed

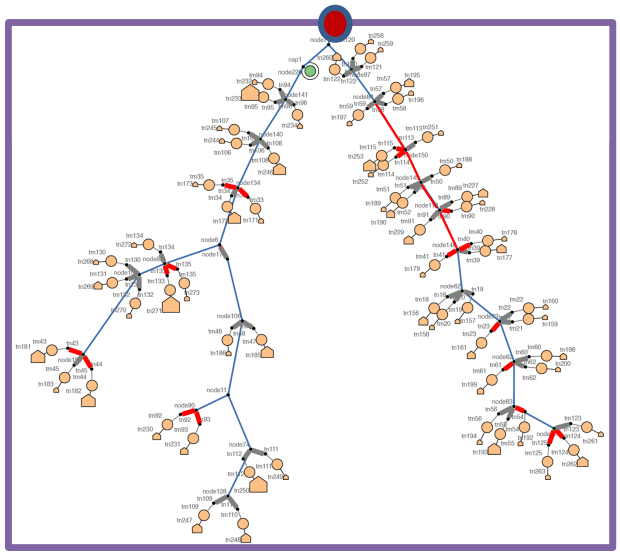
Innovations: Control + Modeling

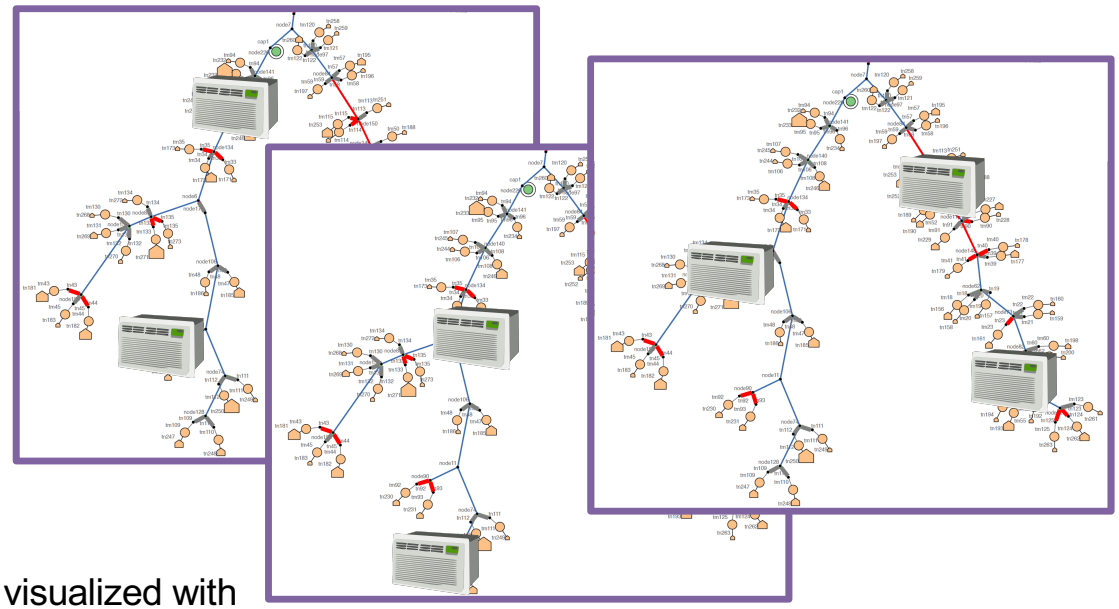
- Most controllers from the literature can't be directly applied to ACs
  - On/off switching
  - Compressor requires long periods of being off (lock-out)
  - → Extensions to existing controllers, for example:

    A. Lesage-Landry, J.A. Taylor, D.S. Callaway, "Online Convex Optimization with Binary Constraints" IEEE Trans on Automatic Control. 2021
- Existing AC models ignore some important physics
  - Power draw isn't constant but a function of temperature and voltage
  - Compressor/transport delay dynamics
  - → Extensions to existing AC models

Final Thoughts: Control Architecture

regulate the feeder vs. control the ACs





GridLAB-D unbalanced distribution feeders visualized with
http://emac.berkeley.edu/gridlabd/taxonomy_graphs/

To be continued…

- Though we're 2 years in to this project, most of the exciting results are yet to come.
- Looking for collaborators in industry and academia
  - Contact: jlmath@umich.edu
- Thanks to the organizers for inviting me to participate in this Super Session!