Mitigating Renewables Intermittency Through Nondisruptive Load Control (3.2)

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Notes: Callaway is the Task leader, dcal@berkeley.edu. Mathieu is currently a postdoctoral scholar in the Power Systems Laboratory at ETH Zurich. Dyson was not funded by the project, but contributed to the resource assessment.

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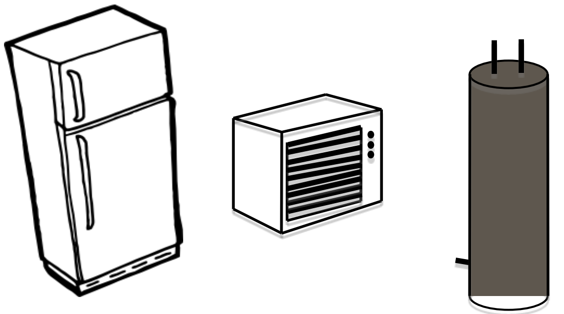
Context

- Renewables integration requires power system flexibility (e.g., managing frequency response and energy imbalances)
- Centralized control of load resources could be a low cost solution: the grid connected resources exist already
- But the costs could be pushed upward by:
  - Communications & metering infrastructure requirements (system operators need high quality telemetry data in certain applications)
  - Customer payments (if end-use function has to be seriously compromised)

Research Goals

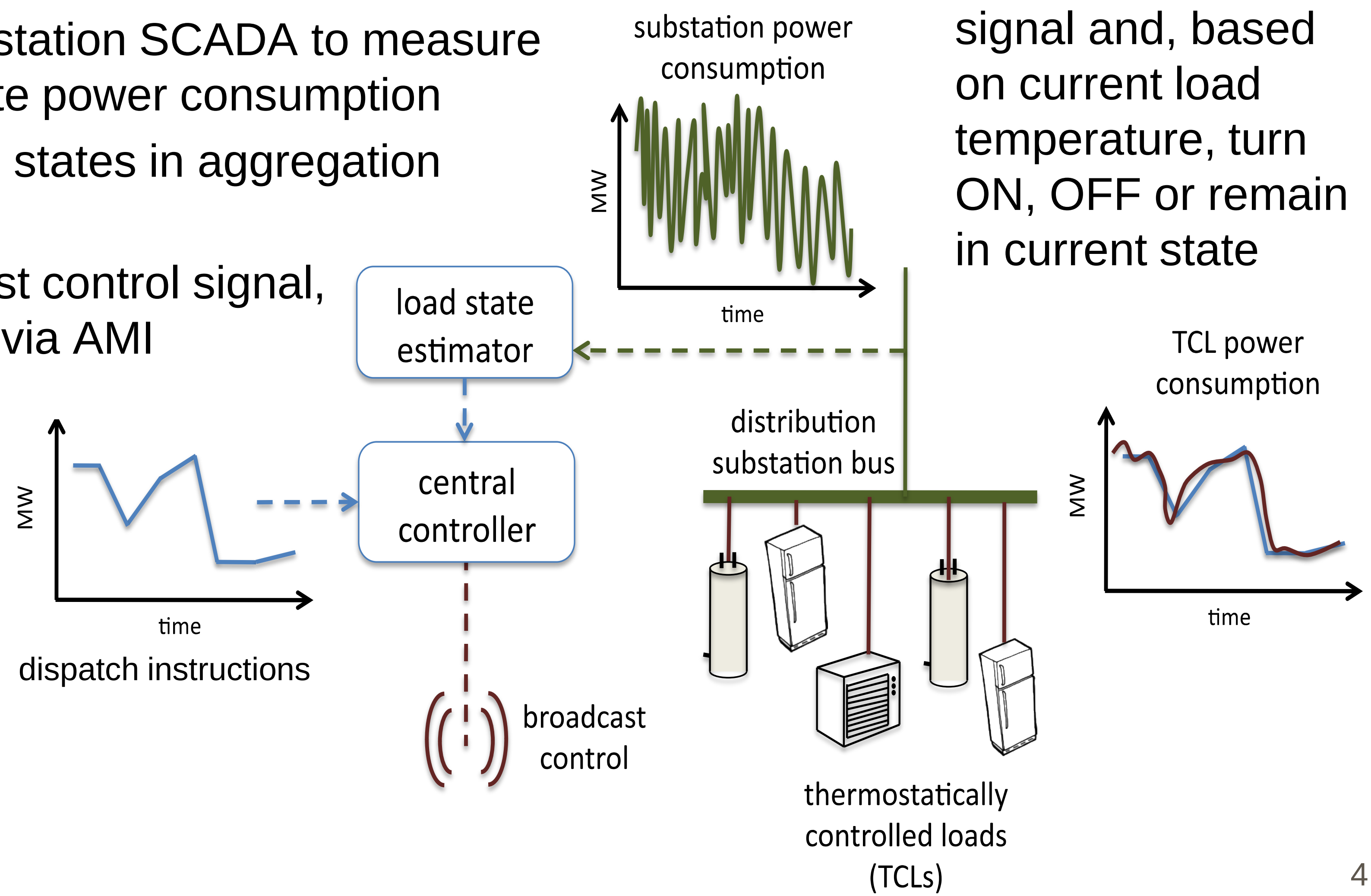
- New methods to model and control aggregations of thermostatically-controlled loads (TCLs) that
  - Reduce communications and power measurement requirements
  - Minimize temperature deviations
- Evaluate how different real time communications abilities affect
  - Ability to accurately estimate local temperature and ON/OFF state of loads
  - Controllability of load resources
- Analyze TCL resource potential, costs, and revenue potential associated with TCL control



Basic Residential TCL Control Architecture

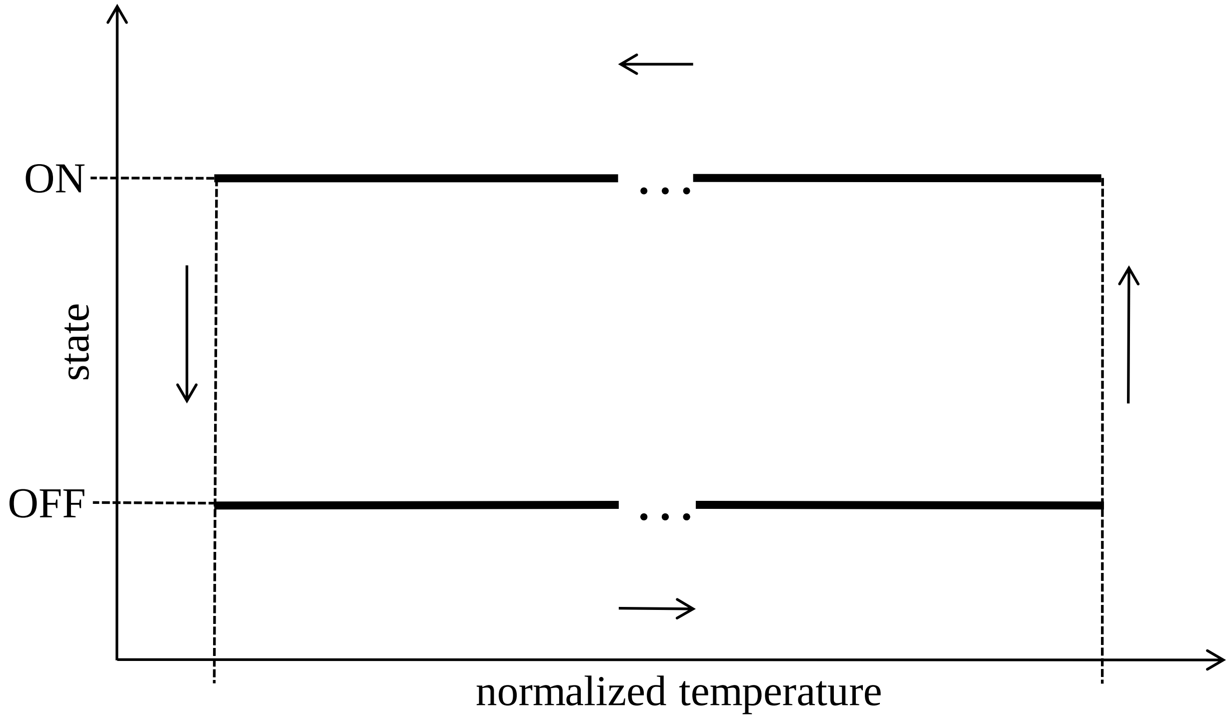
- All control occurs within existing TCL temperature deadband
- Use substation SCADA to measure aggregate power consumption
- Estimate states in aggregation model
- Broadcast control signal, possibly via AMI

- Loads receive broadcasted control signal and, based on current load temperature, turn ON, OFF or remain in current state



Aggregated TCL Model
'State bin transition model'

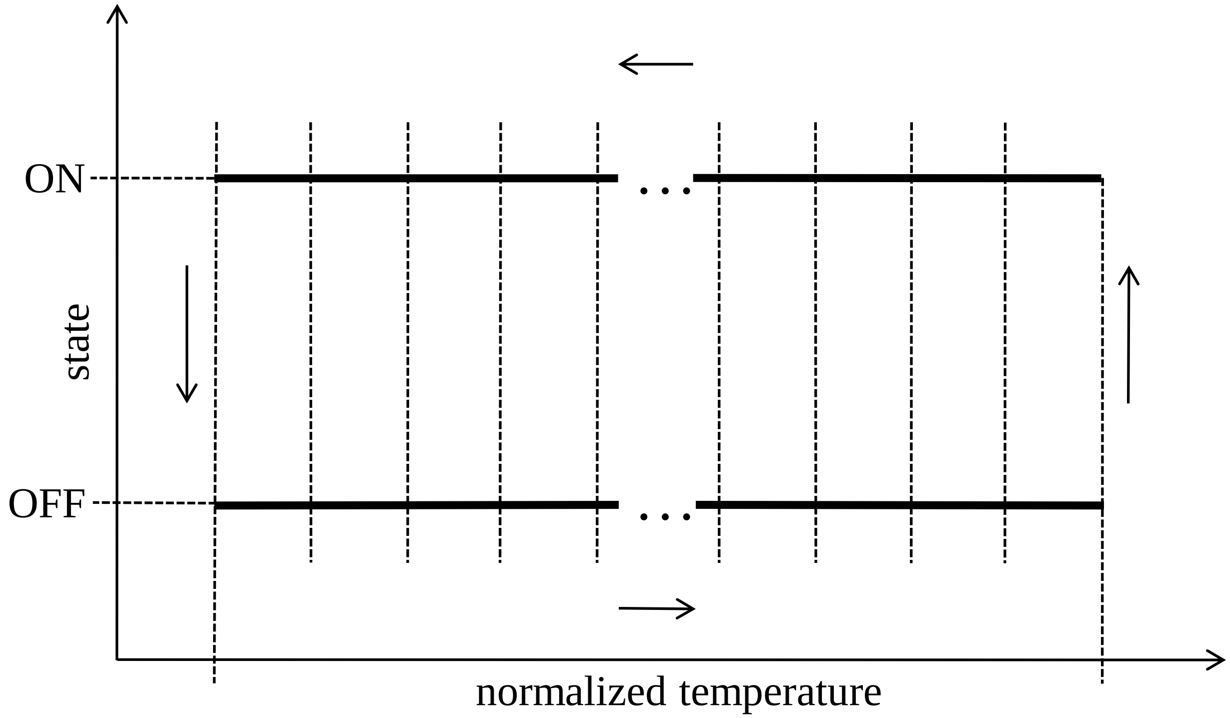
[Similar to that proposed by Lu and Chassin 2004; Lu et al. 2005; Bashash and Fathy 2011; Kundu et al. 2011]



Consider thousands of TCLs traveling around a normalized temperature dead-band.

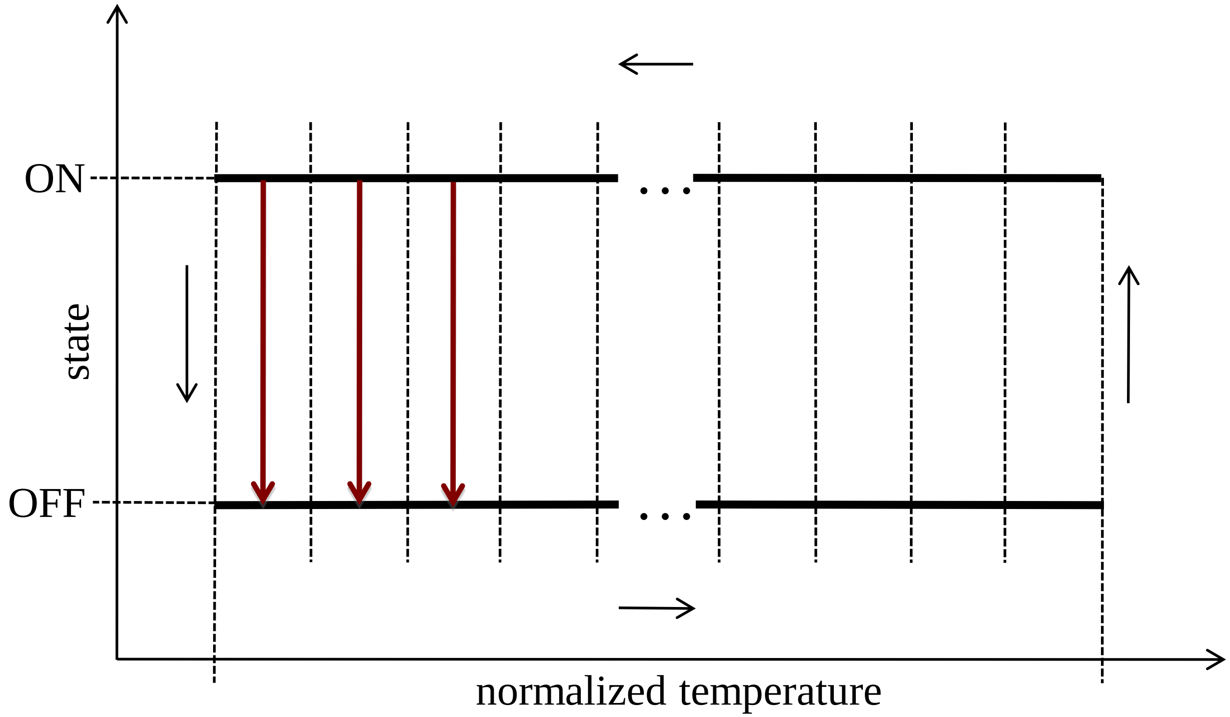
Aggregated TCL Model
'State bin transition model'

[Similar to that proposed by Lu and Chassin 2004; Lu et al. 2005; Bashash and Fathy 2011; Kundu et al. 2011]



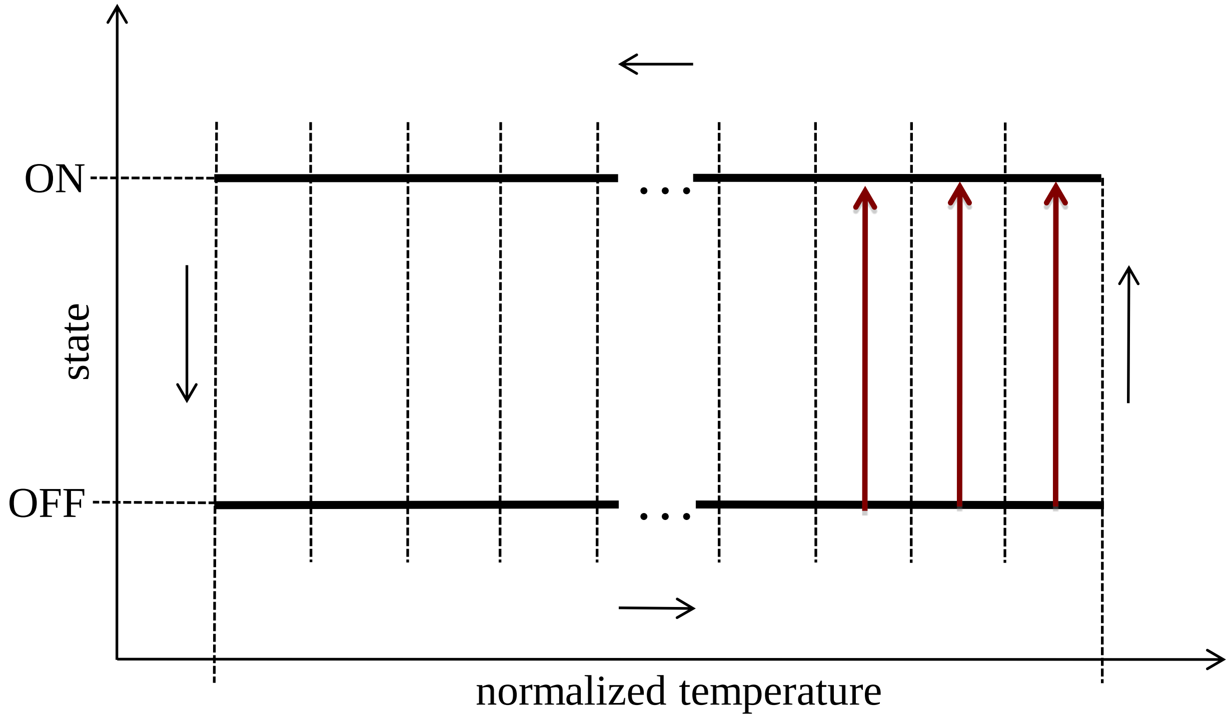
Divide it into discrete temperature intervals.

Aggregated TCL Model
‘State bin transition model’



Forcing the system: decreasing aggregate power.

Aggregated TCL Model
'State bin transition model'



Forcing the system: increasing aggregate power.

Question: How important is real time metering?

- Reference case: Meter power and temperature at all controlled loads, error following dispatch signal = **0.6% RMS** (smaller is better)
- Case 1: Meter the ON/OFF state at all loads, measure aggregate power at the distribution substation.
  Result: error = **0.76% RMS**
- Case 2: Meter only aggregate power at distribution substation. Result: error = **5% RMS**
  - Note, this error compares favorably to conventional generators

Answer: Not important; state estimation works

All results assume:

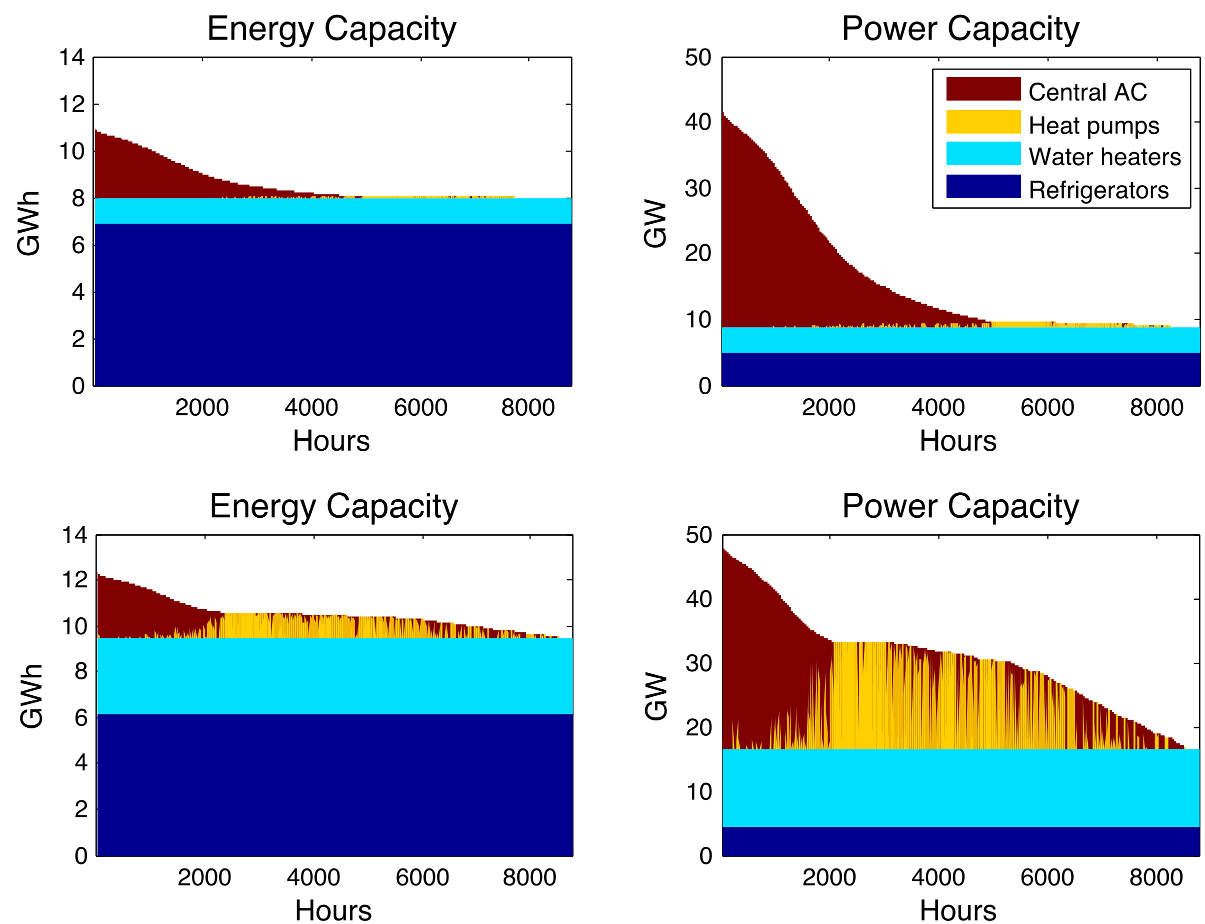
- 17 MVA substation load
- 15% of load (1,000 TCLs) is controlled
- Aggregate power measurements include *all* loads on substation
- Total substation load can be forecasted with 5% average error on a one minute horizon

How LARGE is the Resource Potential?

Estimates for most of California (5 largest utilities) based on Renewable Energy Certificates and California Energy Commission data.

2012 Resource Duration Curve

2020 Resource Duration Curve, assuming increased efficiency and 30% of water/space heaters converted to electric



Potential Revenues for Regulation and Load Following (per TCL per year)

	Regulation	Load Following
Air conditioners*	$9-79	$2-9
Heat pumps*	$100-170	$9-14
Combined AC/HP*	$160-220	$16-18
Water heaters	$61	$35
Refrigerators	$25	$14

*Results depend on the climate zone

Note: cost requires a separate analysis!

Uses and Potential Benefits of Results

- Reduced cost to deploy centralized control of loads on distribution circuits
  - AMI could broadcast control signals
  - Substation SCADA may be all that is required for real time measurement
- Roadmap for which loads are best for fast demand response
  - Electrification of heating has big benefits
- Results lay groundwork for demonstration
  - Currently in discussion with several load aggregators to run a pilot

References

- Mathieu, J.L.; M.E. Dyson, and D.S. Callaway. *Using Residential Electric Loads for Fast Demand Response: The Potential Resource, the Costs, and Policy Recommendations*. To appear in the Proceedings of the 2012 ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA, August 12-17, 2012.
- Mathieu, J.L.; S. Koch, and D.S. Callaway. *State Estimation and Control of Electric Loads to Manage Real-Time Energy Imbalance*. IEEE Transactions on Power Systems (in press), 2012.
- Mathieu, J.L.; and D.S. Callaway. *State Estimation and Control of Heterogeneous Thermostatically Controlled Loads for Load Following*. Proceedings of the 45th Hawaii International Conference on System Sciences (HICSS45), Wailea, Hawaii, January 4-7, 2012.