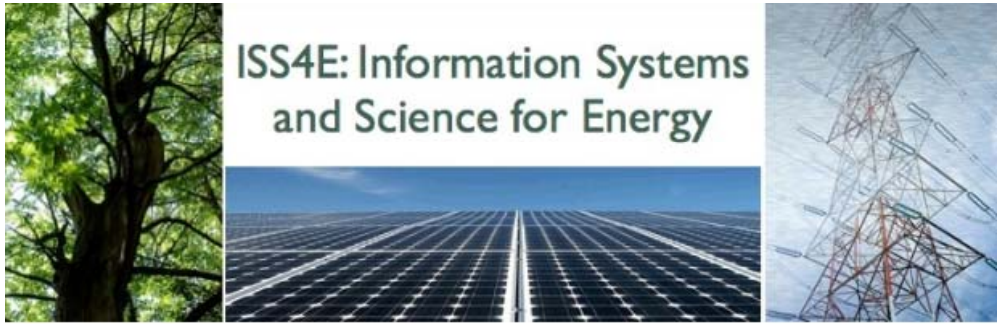
University of Waterloo

WISE
Waterloo Institute for Sustainable Energy



ISS4E or how can the Internet help smarten the grid?

S. Keshav and C. Rosenberg

May 2011

http://blizzard.cs.uwaterloo.ca/iss4e

Smart Grid

University of Waterloo

Bi-directional energy flows

Integration of renewables

Smart Grid

Consumer's Participation

Communication

Elastic Loads: EVs + smart appliances

Storage

Smart Grid: large scale, heterogeneous, distributed system

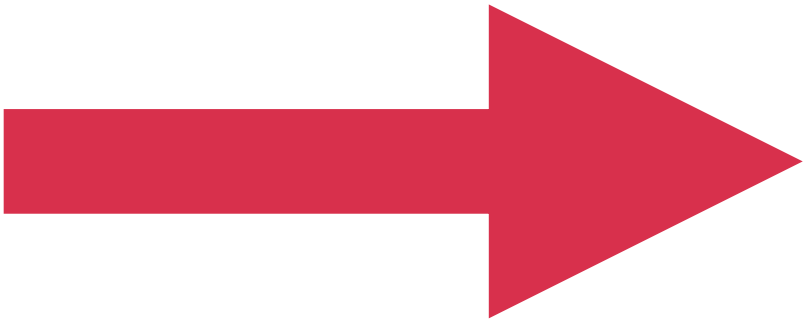
- Millions of sources
- Stochastic sources
- New loads: elasticity, variable demand
- Two-way flows
- Dealing with storage

- Communication
- Maintaining reliability
- Incentivization
- Security
- Non-traditional utility players

The smart grid will require massive change

A relatively static, predictable, stable system with inelastic loads and a few points of control

A highly dynamic system with elastic loads and millions of points of control



A paradigm shift

Our Research

Use Internet **concepts** to smarten the grid

Why Is This Possible: Similarities

- Large-scale
- Heterogeneous
- Critical infrastructure
- Both match geographically distributed demands with distributed generation
- Distributed sources that are highly variables
- Hierarchical
- Balance centralization and decentralization

Differences

- Primarily one-way vs. primarily two-way flows
- Grid has practically no storage
- Consumers are used to see their electrical bill reflect what they really use

Our Vision

*To apply our expertise in **Information Systems and Sciences** to find **innovative solutions** to problems in **energy systems**.*

*We work within **Waterloo Institute for Sustainable Energy (WISE)** in collaboration with*

- *researchers in related disciplines*
- *partners in industry*

Initial focus is ***smart grids***, where energy systems converge with information systems

ISS4E

- **Faculty**
  - S. Keshav, Canada Research Chair, Computer Sciences
  - C. Rosenberg, Canada Research Chair, Electrical & Computer Eng.
- **Post-Doctoral Fellow**
  - Weihong Wang
- **PhD students**
  - Pirathayini Srikantha
  - Tommy Carpenter
- **Masters students**
  - Omid Ardakanian
  - Ryan Case
  - Bo Hu
  - Theodosios Tzoutzas
  - Hadi Zarkoob










- **Laboratory** facilities include sensors for building monitoring, smart power strips for home monitoring and control, ENVI systems for data collection, wireless sensors for solar panel monitoring, etc.

Our expertise

Modeling, mathematical analysis, and system building using techniques from:

- Internet and information technology (planning, design, implementation, deployment, and management)
- Telecommunications (wireline and wireless communication systems)
- Distributed systems
- Stochastic analysis
- Large-scale simulation
- Data mining and machine learning
- Economics and game theory

Ongoing projects

1. ***Modeling and control of grid energy storage and DG***

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2. ***Demand Response: a revisit based on***
   - *Internet views (allows fine grained DR)*
   - *Elasticity*

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   - *GW to appliances (control, measurement)*
   - *Applications*

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4. ***EV Integration***
   - *Charging control*
   - *Billing and roaming*
   - *Fleet integration*

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5. ***Impact of context***
   - *Developed countries vs. developing countries (e.g., smart EPS)*

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5. ***Impact of context***
   - *Developed countries vs. developing countries (e.g., smart EPS)*
6. ***Prototype systems & measurements***
   - *ENVIs, Sensors, I-smart, HomeOS*

Measure

Fine grained

Measure

Fine grained

Measure

Fine grained

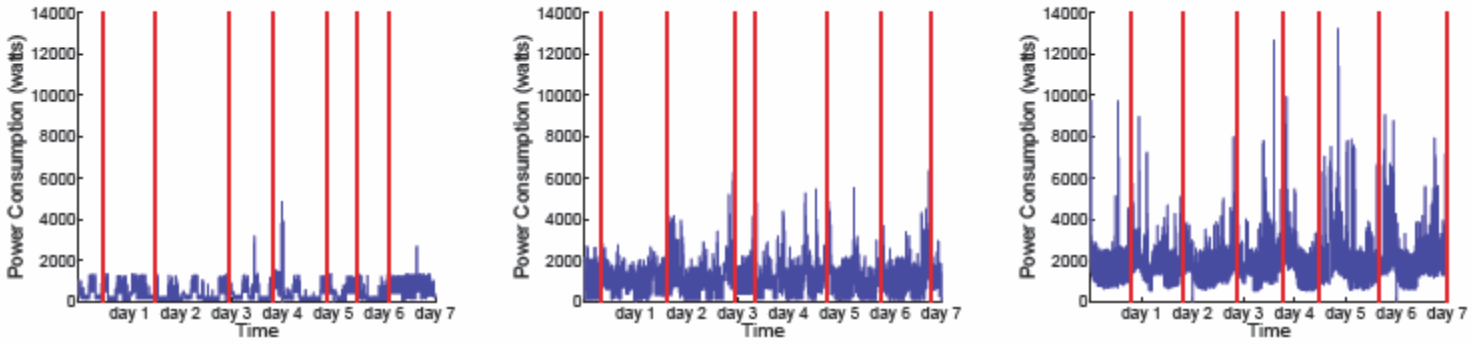


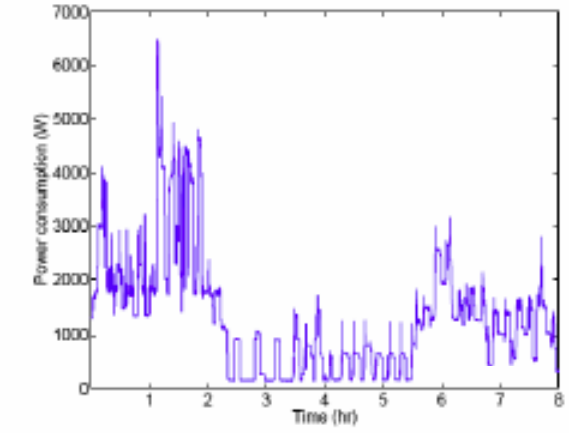
Figure 3: Load measurements from houses in three classes for one week with busy hours marked by vertical lines.

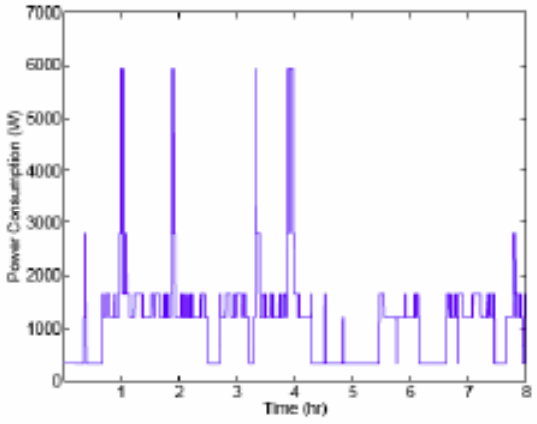
Measure

Model

P =
0.90264 0.00192 0.01080 0.00834 0.07630
0.00103 0.97198 0.00006 0.02210 0.00481
0.06325 0.00110 0.91737 0.00183 0.01645
0.00336 0.01929 0.00028 0.94352 0.03355
0.02448 0.00166 0.00108 0.03038 0.94239

R = 2252 500 4355 1077 1614





Measure

Model

Analyze

Trends
Gain from storage

Measure

Model

Analyze

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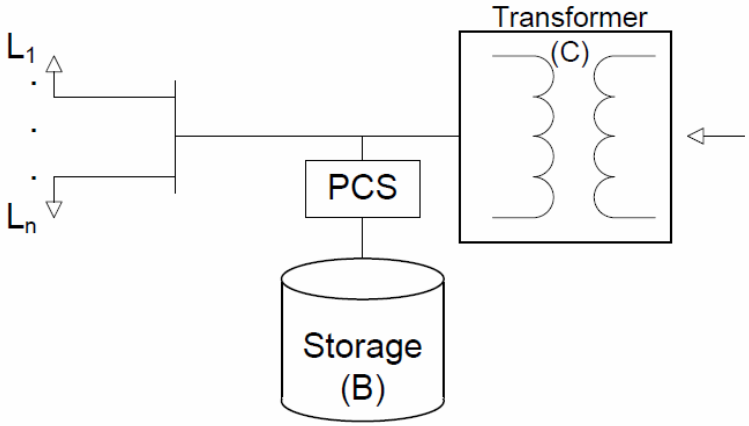
Gain from storage



(a) A branch of the electrical grid with n loads L_i where the capacity of the battery is B Watt-hours and the base rating of the transformer is C Volt Amperes. The Power Conversion System (PCS) drains and fill the store depending on load conditions.

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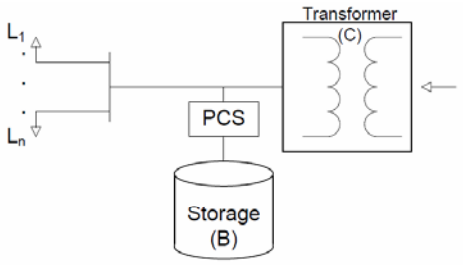

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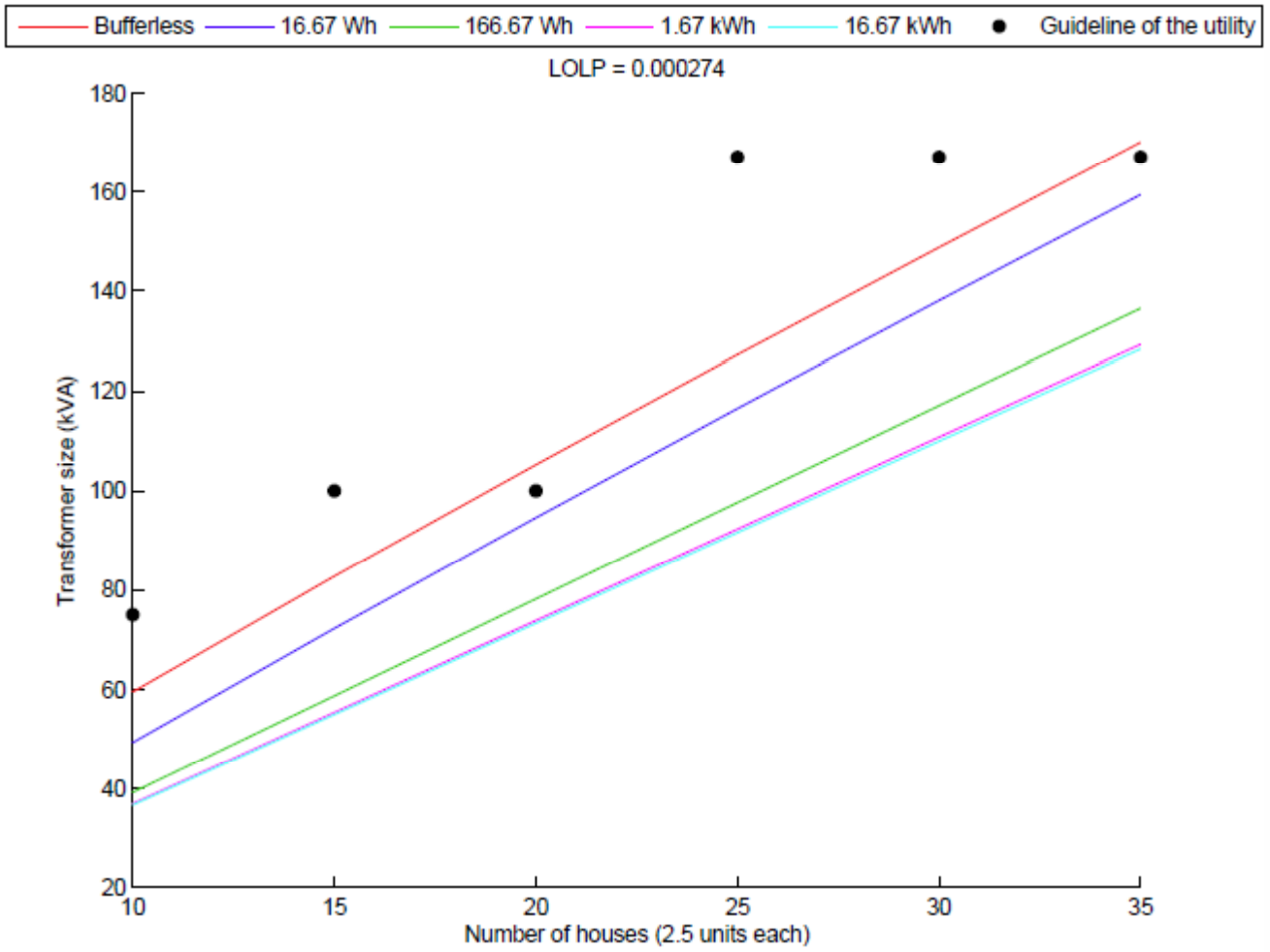


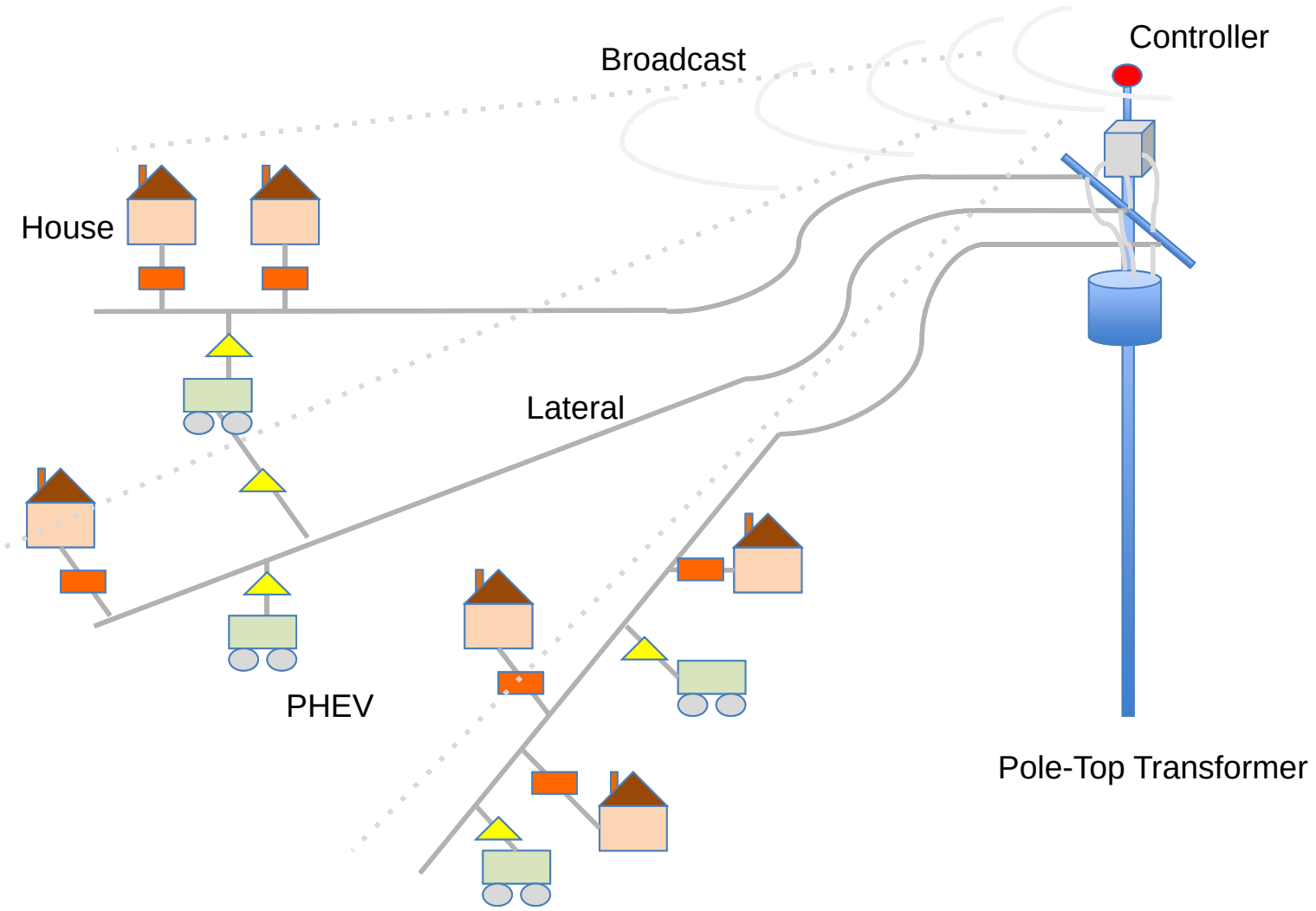
Measure

Model

Analyze

Control

EV charging



Measure

Model

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Control

EV charging
DR:

- Elasticity

Measure

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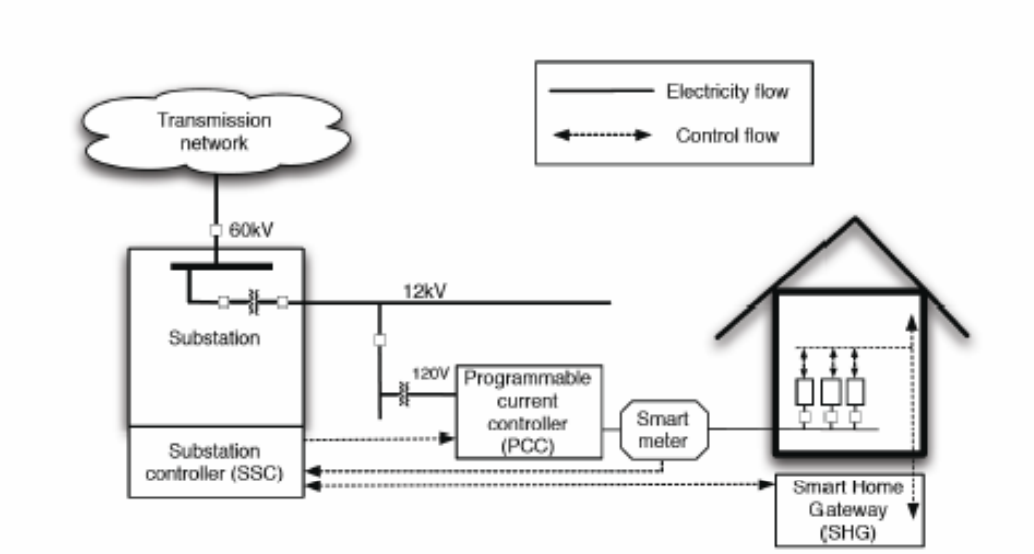

EV charging

DR:

- Elasticity

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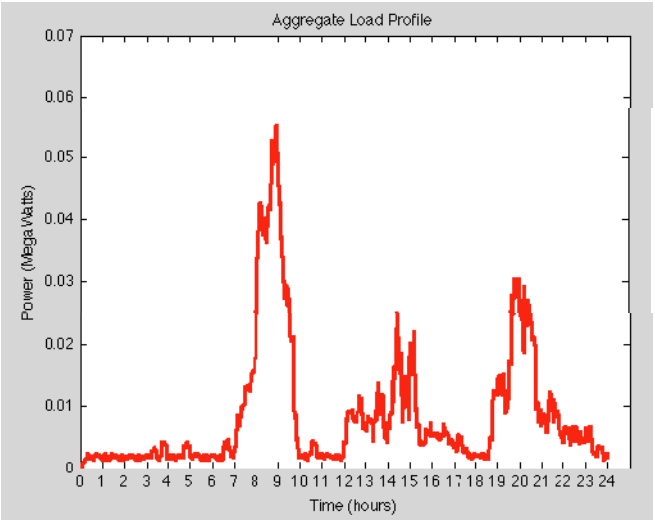

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DR:

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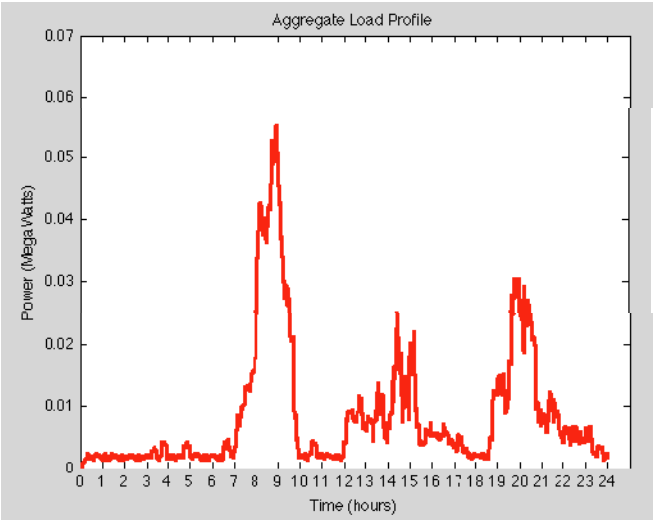
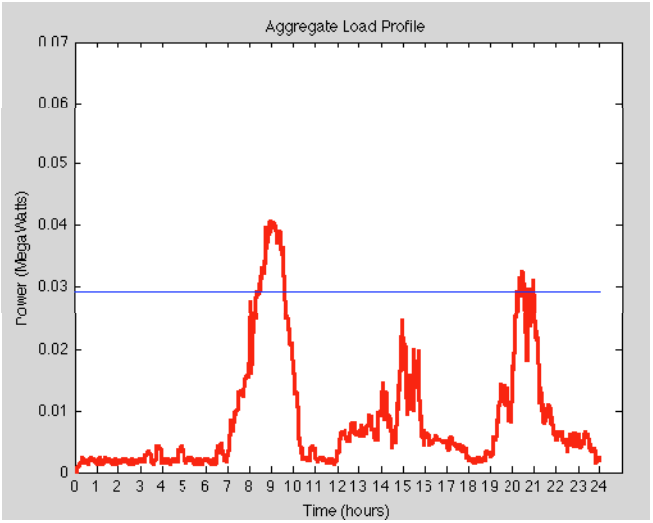




A 15% decrease in peak without noticeable decrease in comfort

Measure

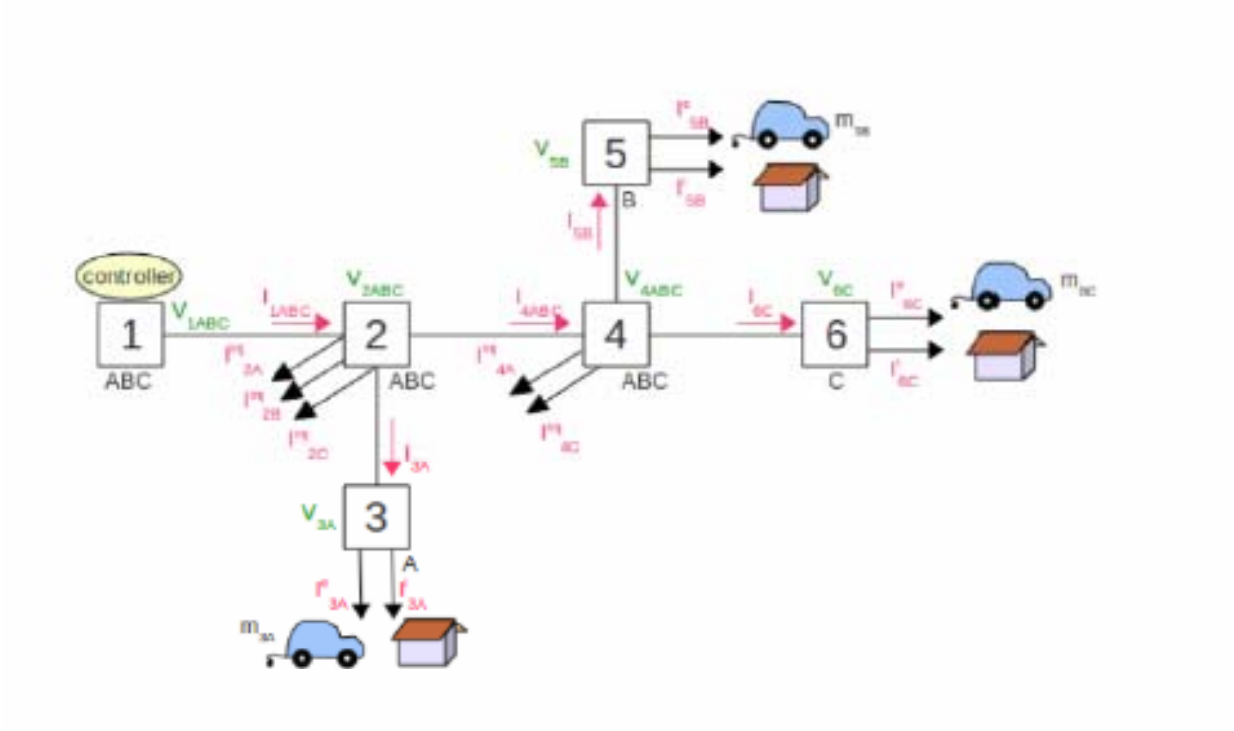
Model

Analyze

Control

Simulate

Gridlab-D



Measure

Model

Analyze

Control

Simulate

Build

Prototype

- Solar panel anomaly detection

Measure

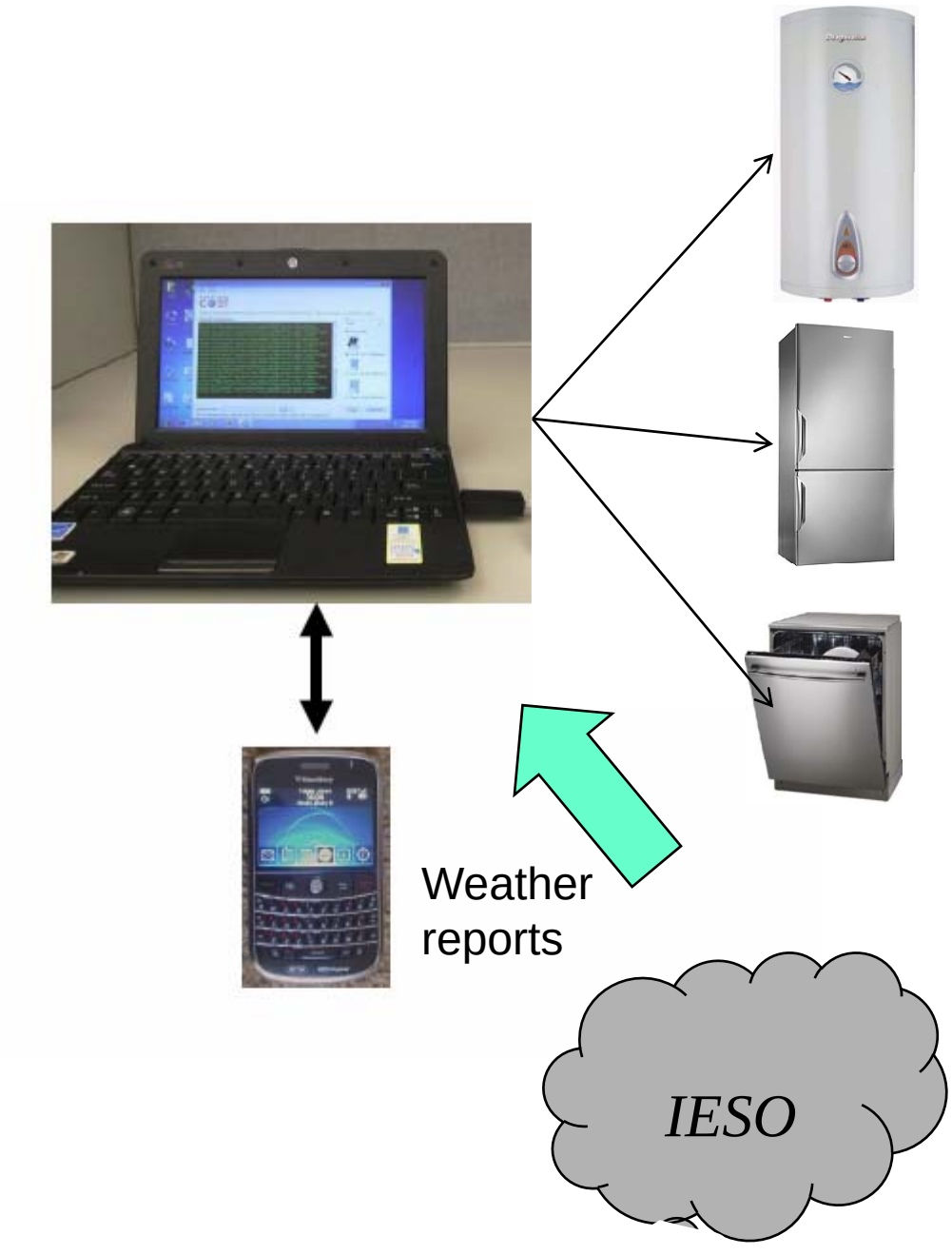
Model

Analyze

Control

Simulate

Build



Prototype

- Solar panel anomaly detection

Applications:

- Alert and weather report

Conclusions

- 2010-2020 will decide the grid of 2120
- Internet ≈ Grid
- 40 years of Internet research {could, should, may} help
- Rich area for impactful research