Testbed and Simulation of Household Energy Consumption

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Introduction

Many inefficiencies in residential energy stem from the lack of consumer knowledge and involvement. Home energy consumption analysis is needed to:
- Reduce the overall load curve
- Provide transparency in electricity bills
- Reduce emissions from peak-power generation sources

"Green Button": Common sense initiative to provide consumers with their kWh meter data.
- Enable informed energy decisions
- Optimize size and ROI of solar installations
- Monitor energy efficiency investments
- Recognize abnormal usage patterns
- Detect appliance malfunctions

The Issue: How can this raw data be made useful to consumers, electric utilities, and third parties?

Project Objectives

Monitor electrical appliance power consumption: single devices and aggregated signals.
- Use Data Mining and Disaggregation techniques to extract useful information from a single measurement point.
- Identify limitations set by sampling rate, load characteristics, and meter constraints.
- Focusing on the potential of meter data

Methods

Testbed: Campus data collection site that displays the consumption characteristics of a residence.

Simulation: Testbed data imported into a computer program, establishing a database of device activities, patterns, and consumption scenarios for use in signal disaggregation.

Research: Load Metering Experiments and Data
- NILM (Non-Intrusive Load Metering): extracting individual device consumption data (kWh) from the aggregated power signal.
- Publicly-Available NILM Datasets.

Residential Appliance Classification

Function: Entertainment, Lighting, Environment Conditioning, etc.

Load Type: Resistive, Inductive, Capacitive, Rectifier Loads, Motor Loads, Combinations.

Operational Modes: ON/OFF, Multiple States, Variable Power Draw, Base-Load Devices.

Testbed Configuration

Sampling Rate Flexibility: 15 minute sampling rate for low resolution data (feasibility of power meters)
- Adjustable metering settings to allow entry point and individual/grouped appliance monitoring
- Nominal operating conditions of equipment

Objective Data: 100% GROUND TRUTH
- All user and appliance activities simultaneously recorded to provide a complete overlap of test bed activity and raw data. Outright ground truth allows for an in-depth analysis of the connection between user behavior and energy consumption.

Hardware
- Yokogawa CW-240 Power Meter (pictured)
- 2A/20A Current Transformer Probes (4)
- Agilent E4980AL-030 Precision LCR Meter
- Surge Protectors (striped for isolated (+) wires)
- 100 Amp-hour 12V Deep-Cycle Battery
- 12V DC to 110V AC 1500W Power Inverter
- Power Source Transfer Switch
- 10 AWG Stranded Copper Wire
- 40" LCD Display, RS-232 VGA Cable

Future Work

- Real-time demonstration of testbed
- Power source switching (grid/battery power)
- Power quality (on/off-grid) examination
- Device interference experiments
- Video demonstration

Simulation

Using testbed appliance data to simulate user-defined consumption scenarios
- Set time-of-day and duration
- Set device array
- Generate aggregated waveform
- Algorithm disaggregation

Simulation will provide a platform for other experiments to contribute data, increasing the overall load database and disaggregation accuracy

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