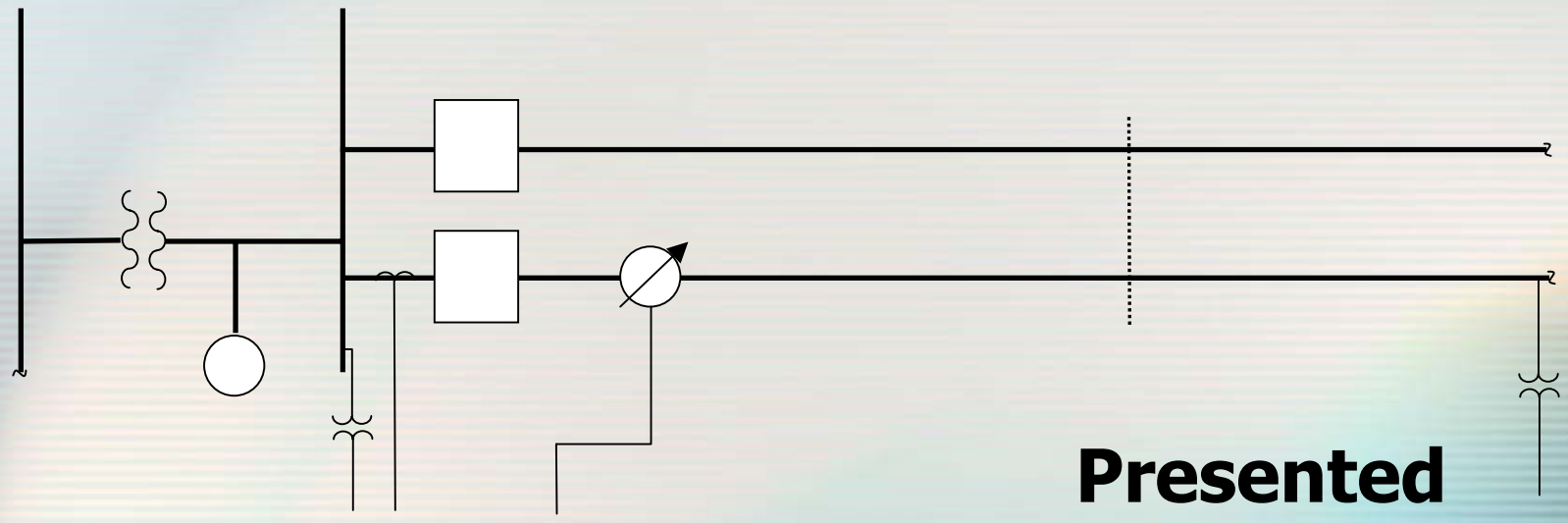
Verification Protocol
for
Automated Conservation Voltage Regulation Systems



Presented by PCS UtiliData

February 10, 2004

Background

PCS UtiliData has deployed its Adaptive Voltage Control (AdaptiVolt™) systems at:

- Inland Power and Light Company
- Clatskanie PUD
- Avista Utilities

Planned Future Deployments:

- Everett Naval Station
- Hydro Quebec Distribution
- Kimberly-Clark Corporation
- 94 Local Distribution Companies (LDCs)
- Others

Background

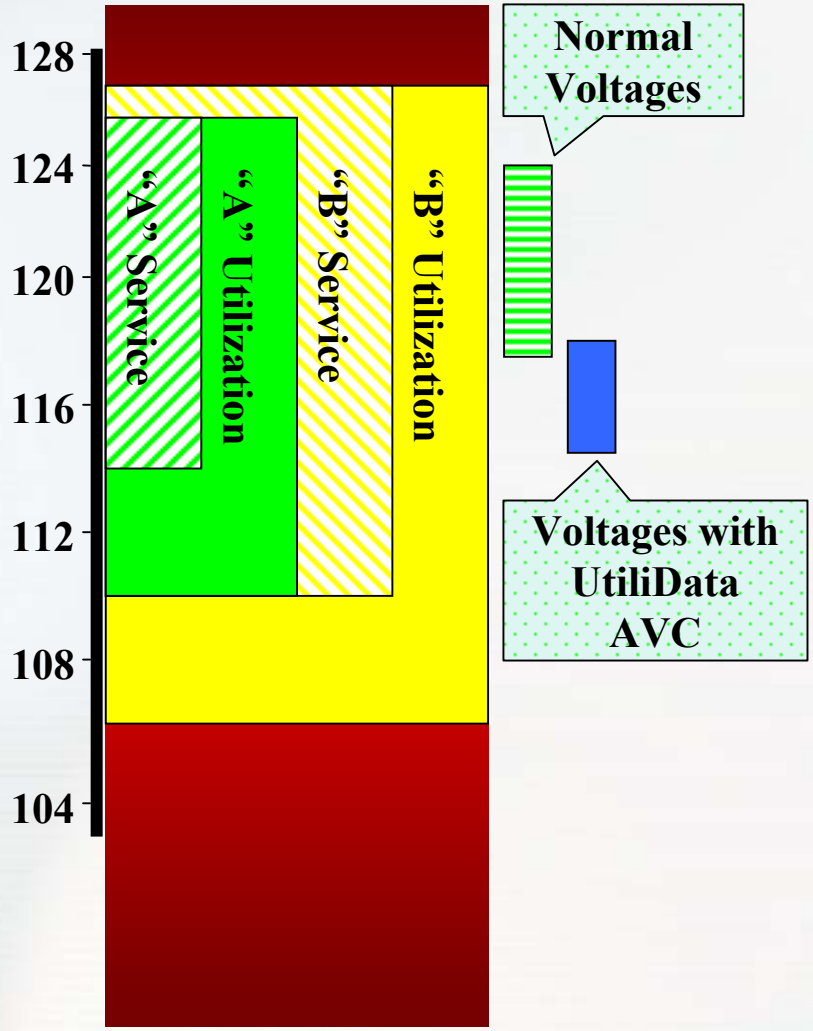
PCS UTILIDATA

Currently negotiating a Third Party Agreement with BPA to deploy an energy conservation technology (AdaptiVolt™) that saves Kilowatt Hours for both customers and distribution utilities

Actively pursuing Market Transformation in the Pacific Northwest and other areas, in cooperation with:

- **Bonneville Power Administration**
- **Northwest Energy Efficiency Alliance**
- **US Navy**
- **FERC**
- **State and Regional Regulatory bodies**
- **Government agencies**

Allowable Voltage Range?



ANSI Standard C 84.1 – 1995 "Electrical Power Systems and Equipment – Voltage Ratings"

Nominal 120 VAC – Range A (Normal Operation)

- **Service Voltage 114 v – 126 v**
  - Voltage at which utility delivers power to home
- **Utilization Voltage 110v – 126 v**
  - Voltage at which equipment uses power
  - Most Motors rated at 115 v
  - Incandescent Lamps rated at 120 v

Nominal 120 VAC – Range B (Out of Normal Operation)

- **Service Voltage 110 v – 127 v**
- **Utilization Voltage 106v – 127 v**

Why Implement Automated CVR?

- Assurance that all customers receive ANSI standard voltages at all times
- Ability to dispatch and control in real-time
- Provide accurate and extensive metering capabilities
- Fully optimize energy savings

Aim

To seek the approval
of the
Regional Technical Forum
for
Verification Protocol:
Automated CVR Protocol #1

Why Automated CVR Protocol #1?

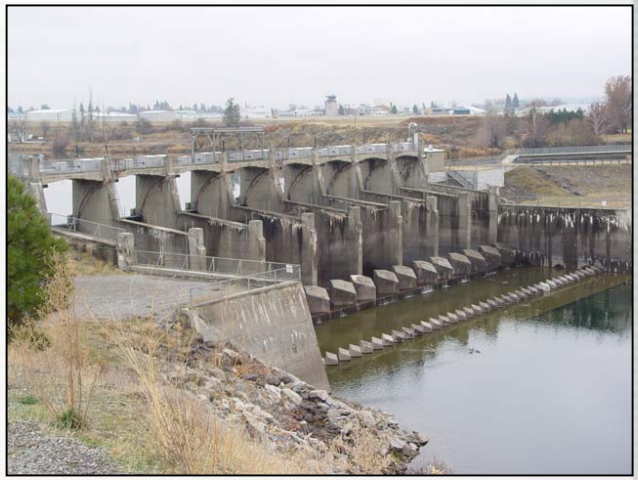
Application Specifications*:

- **CVR system must be able to turn on and off in accordance with a set automated pattern**
- **Must have voltage set-points that can be changed quickly**
- **On a per feeder basis, must have the ability to measure and record period:**
  - **Bus Voltage**
  - **End-of-line voltage**
  - **kWh**
  - **kVARh**
  - **Temperature**
  - **Other variables**

* The method is applicable where no previous energy usage information is available

Savings available through CVR?

- In Washington State
  - An estimated 274-372 average MW
  - Equal to 21 Spokane Upriver Dams or 14 Spokane Waste to Energy Plants



- In the United States
  - An estimated 14,500 average MW
  - Equal to 9 “Four Corners” coal fired generating plants

Our Team

- Bruce Cody
- Ken Keating
- Nelly Leap
- Don Fay
- Steve Fucile

BPA

- Tom Eckman

RTF

- David Bell
- Tom Wilson
- Ken Hemmelman
- Jeremy Wilson
- Paul Dionne

PCS UtiliData

Basis for our request

- Deployed AdaptiVolt™ - Halfmoon Substation
- Collected 2002 data
- Built a CVR_f and kWh prediction model
- Collected 2003 data
- Continued to refine the model using 2002 data
- Applied the model to 2003 data
- Compared CVR predictions to actual data
- Proposing a Verification Protocol
- Pursuing coordinated Market Transformation with a technology that works, i.e. saves energy
- Want to provide a prediction tool to Utilities

Automated CVR Protocol #1

- **Suitable for determining energy conservation on distribution feeders and substations feeding residential, commercial and industrial loads.**
- **Also applicable for industrial or commercial customers that have the ability to implement automated CVR in their facility.**

Automated CVR Protocol #1

- The goal of the protocol is to derive a CVR_f (coefficients) that can be used to verify savings
- $CVR_f = \%\triangle E / \%\triangle V$ over a period of time
  - For example, a system with a CVR_f of 1 would save 1% of load with each 1% decrease in voltage

Inland Power & Light Halfmoon Substation

kWh Savings at Halfmoon Substation

- Mostly rural/suburban type loads
- Substation is rated at 8 MW peak load
- An estimated 1,262,000 kWh saved between November 2002 and 2003
- Approximately 3.4% of load.

Actual 2002 Forecast for Feeder 1 and 3

- Using coefficients developed from 2003 data, we forecasted daily savings for April 2002
  - Feeder 1
    - Forecasted daily savings: 343 kWh
    - Estimated (actual) daily savings: 340 kWh
  - Feeder 3
    - Forecasted daily savings: 660 kWh
    - Estimated (actual) daily savings: 679 kWh

Actual 2004 Forecast for Feeder 1 and 3

- Using 2002 data to develop coefficients to determine 2004 daily savings for January 2004
  - Feeder 1
    - Forecasted daily savings: 539 kWh
    - Estimated (actual) daily savings: 518 kWh
  - Feeder 3
    - Forecasted daily savings: 787 kWh
    - Estimated (actual) daily savings: 691 kWh

Comparative CVR_f for 2002 and 2003

Overall CVR_f

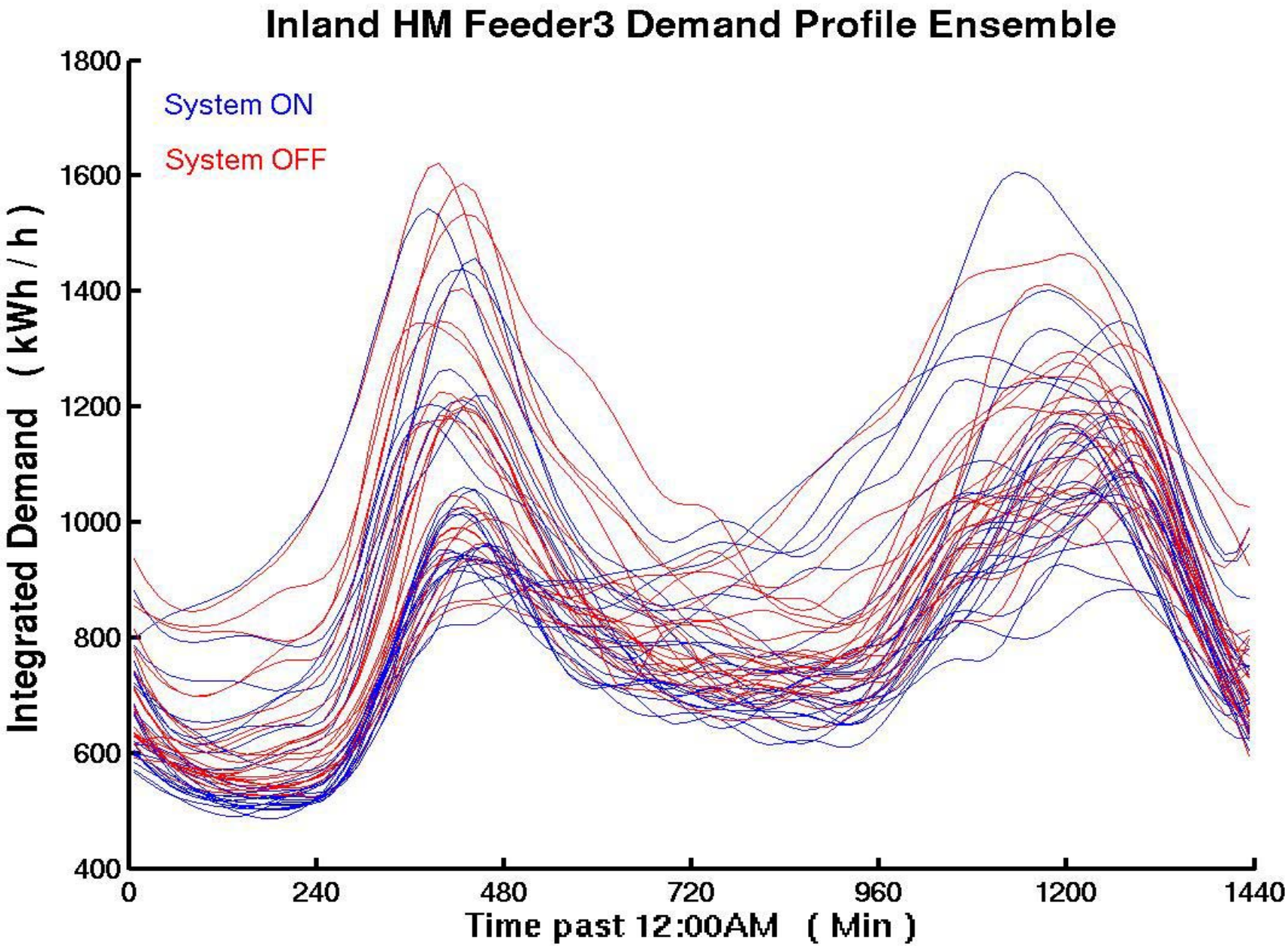
- **For combined 2002 test period : 0.953***
- **For combined 2003 test period : 0.914***

* **Percent of energy consumption per volt**

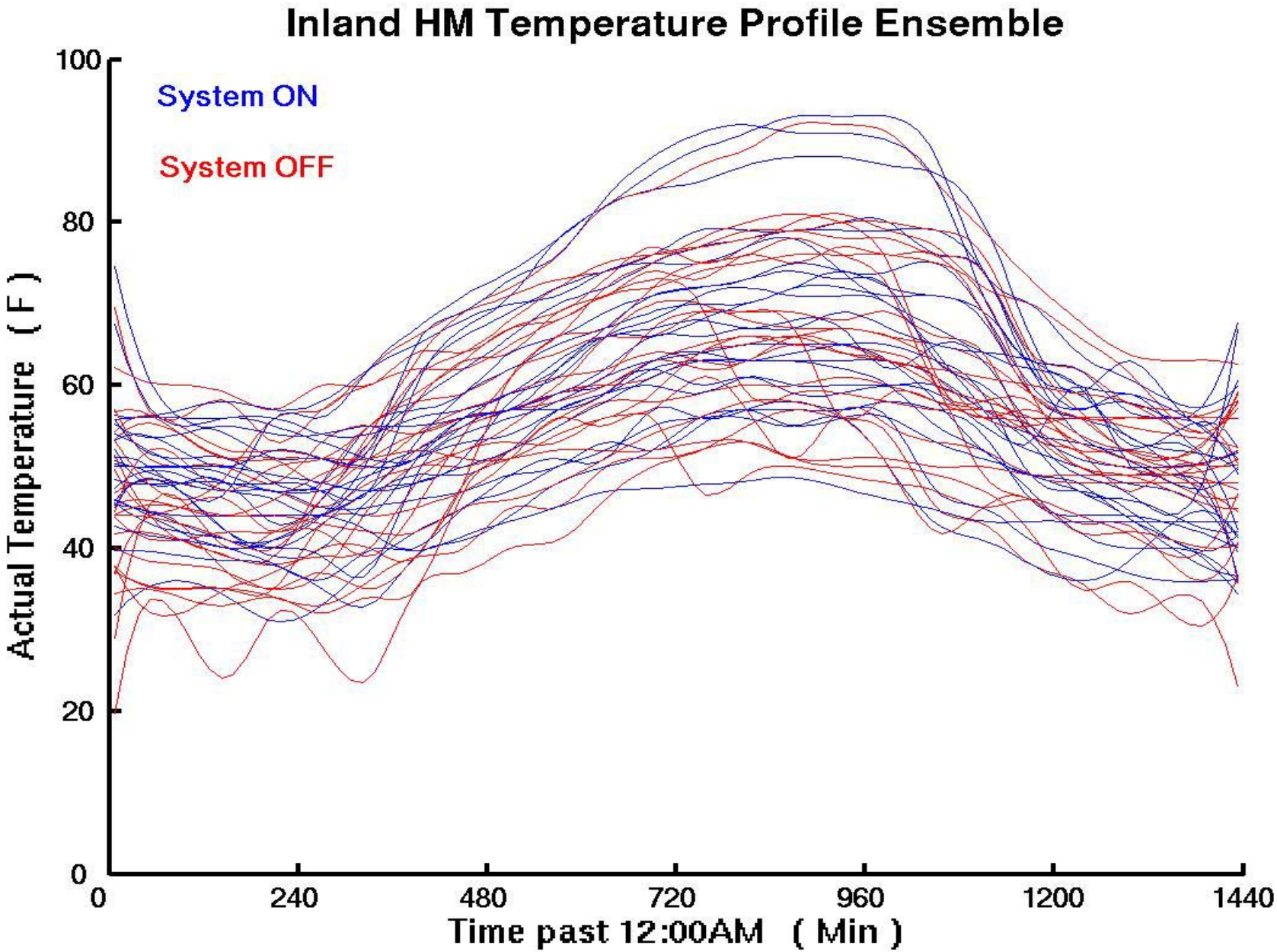
Traditional methods of analyzing energy Savings

- Conventional regression analysis
  - Gaussian distribution
    - Least squares methods
    - Confidence level
    - Sample size
    - Precision
    - Variance
    - Population - Customer classes
- Days on “energy used” and days off “energy used”

Time Series - Demand Profile



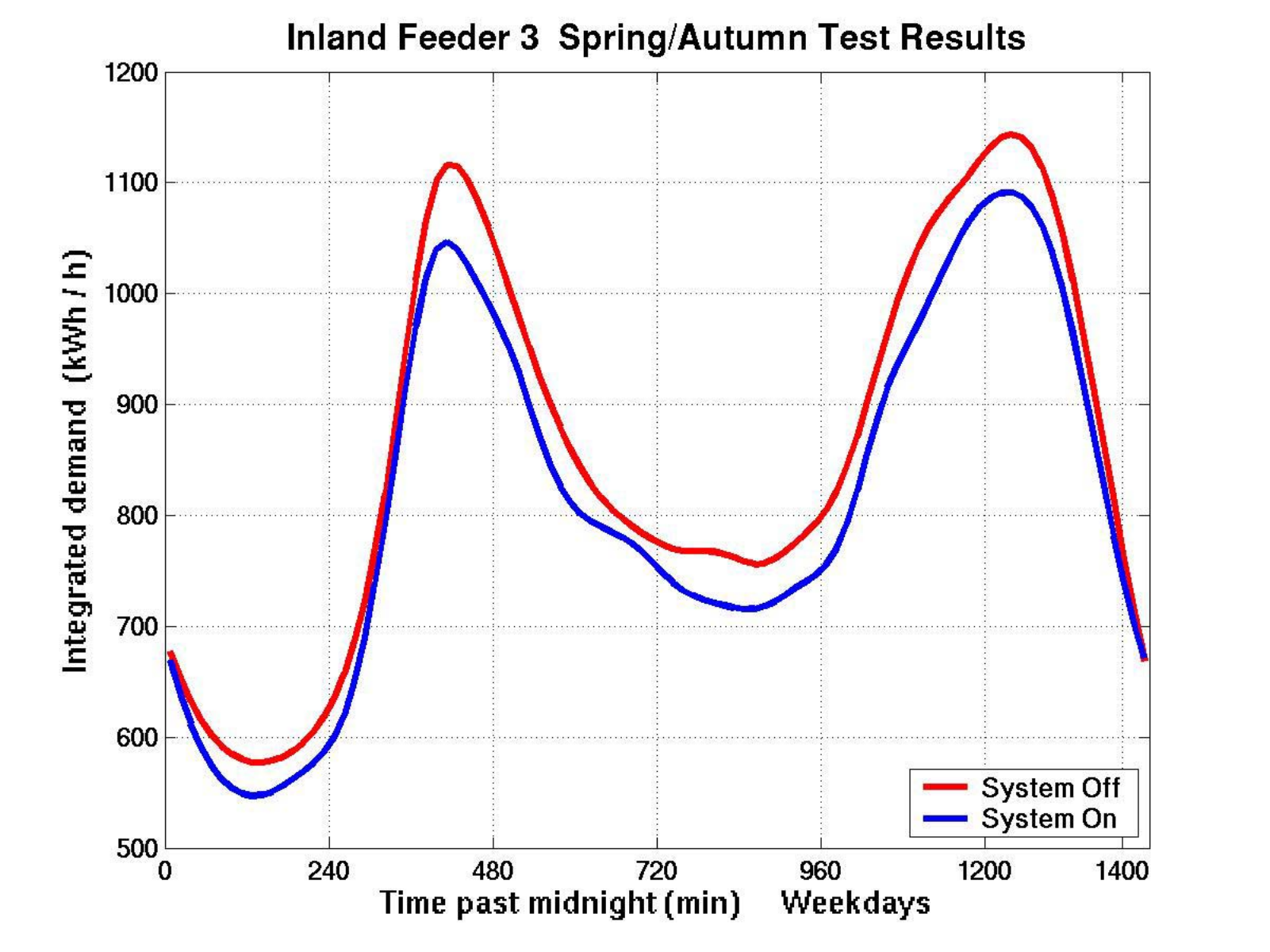
Time Series - Temperature Profile



UtiliData Estimation Method

- **Suggested energy analysis model and procedures**
  - **Linear model for energy consumption:**
    - **Linear dependence on delivered voltage**
    - **Asymmetric linear dependence on ambient temperature**
    - **Stochastic customer behavior, average & random components**
  - **Time Series approach**
    - **Analysis of demand profile ensembles (Matched hours)**
    - **Establishment of 24 ensembles/coefficients of temperature and load profiles in hourly time segments**

Inland Feeder 3 Spring/Autumn Test Results

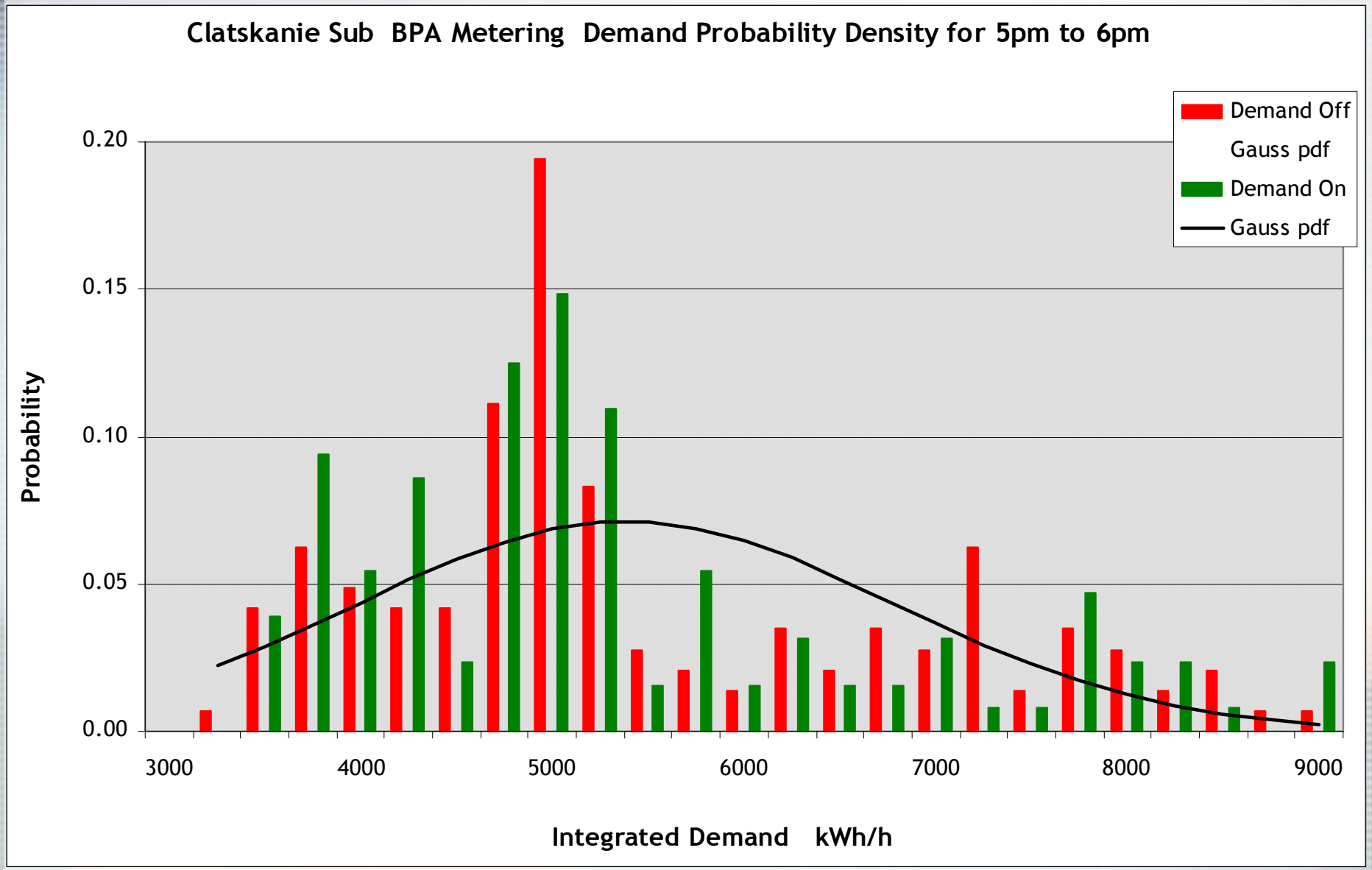


Robust analysis - Motivating Factors

- **Real observations of energy demand are not Gaussian**
  - **Conventional estimates of:**
    - **Confidence level**
    - **Variance**
    - **Required sample sizes**

    <u>are no longer valid</u>
  - **Least squares regression estimates are sub-optimal**

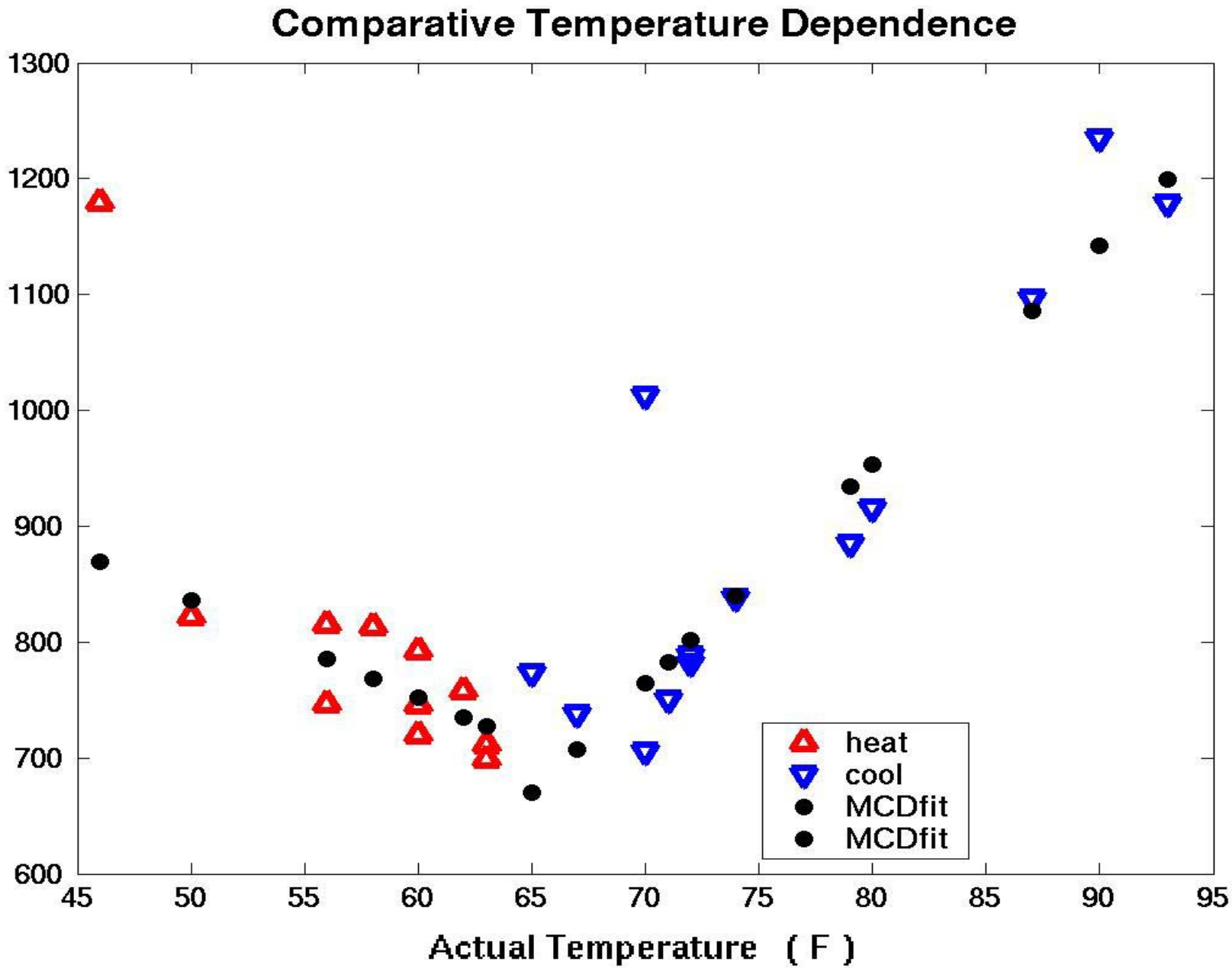
Robust analysis - Motivating Factors



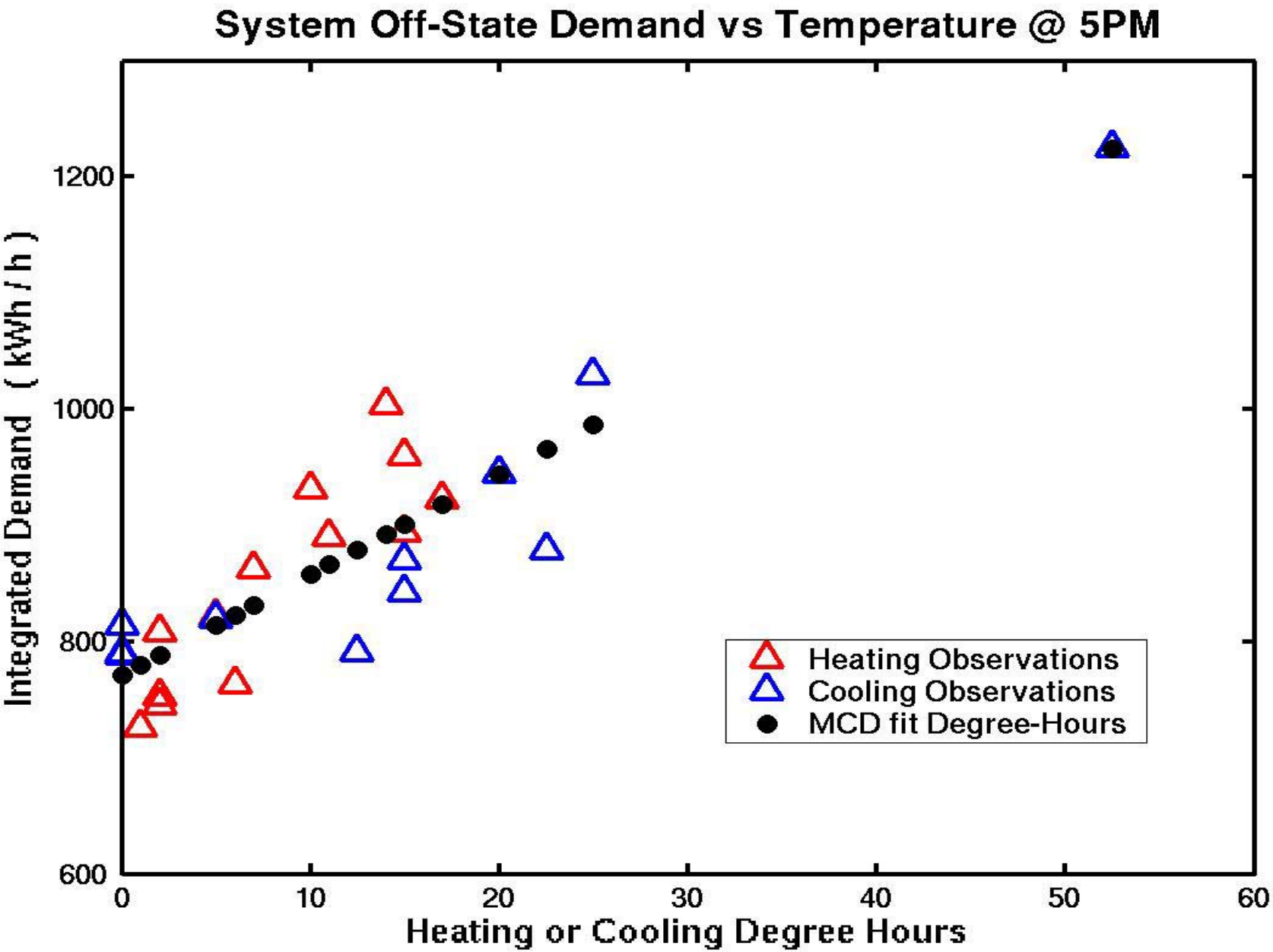
Robust analysis - Motivating Factors

- **Benefits of Robust Statistical procedures:**
  - **Better suited for small sample sizes**
  - **Assumes no probability distribution**
  - **Structured rejection of outliers and leverage points**
  - **Handles cases with non-homogeneous variance (Heteroscedastic)**

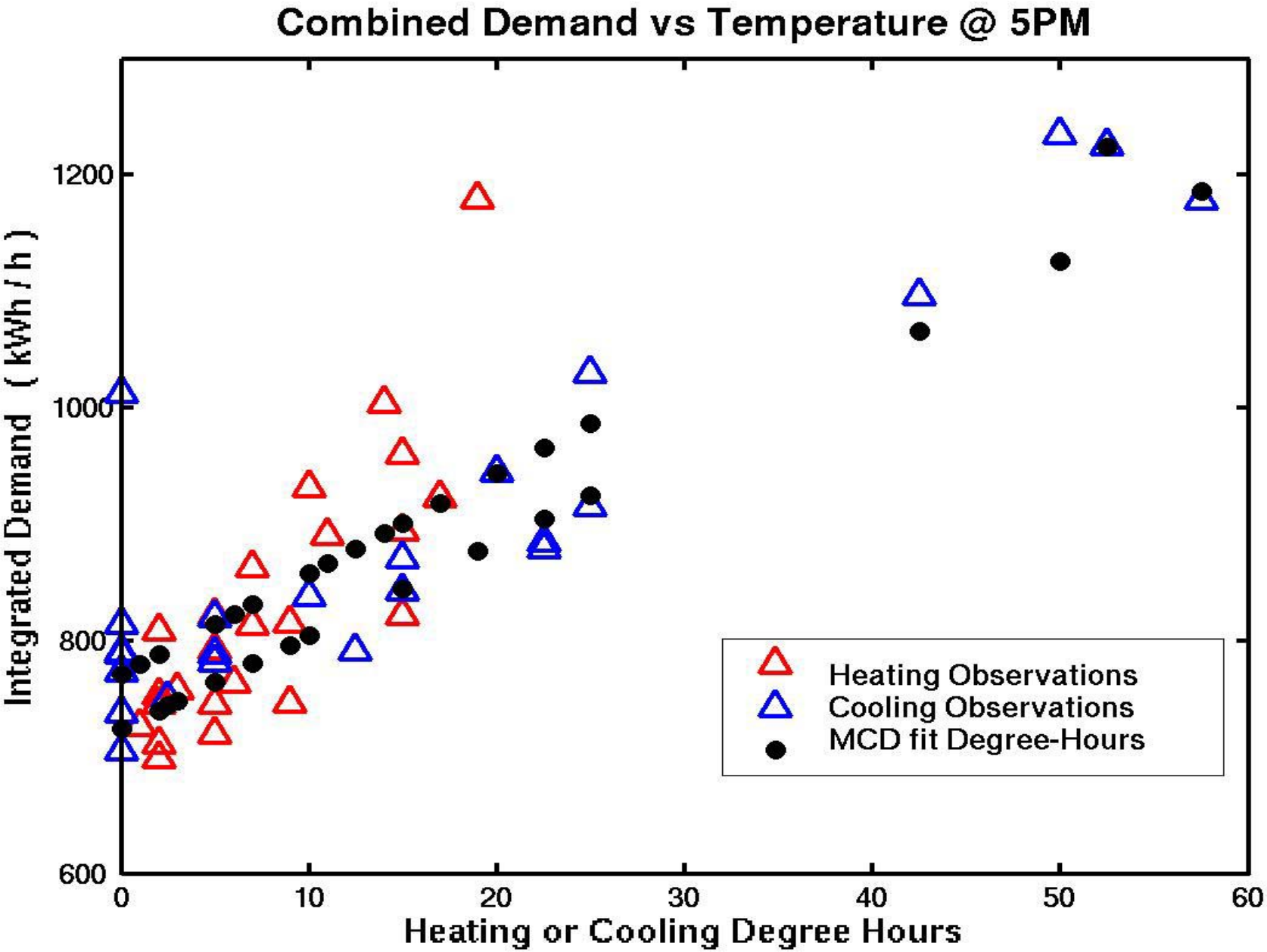
System On-State Demand vs. Temperature @ 5 PM



System Off-State Demand vs. Temperature @ 5 PM



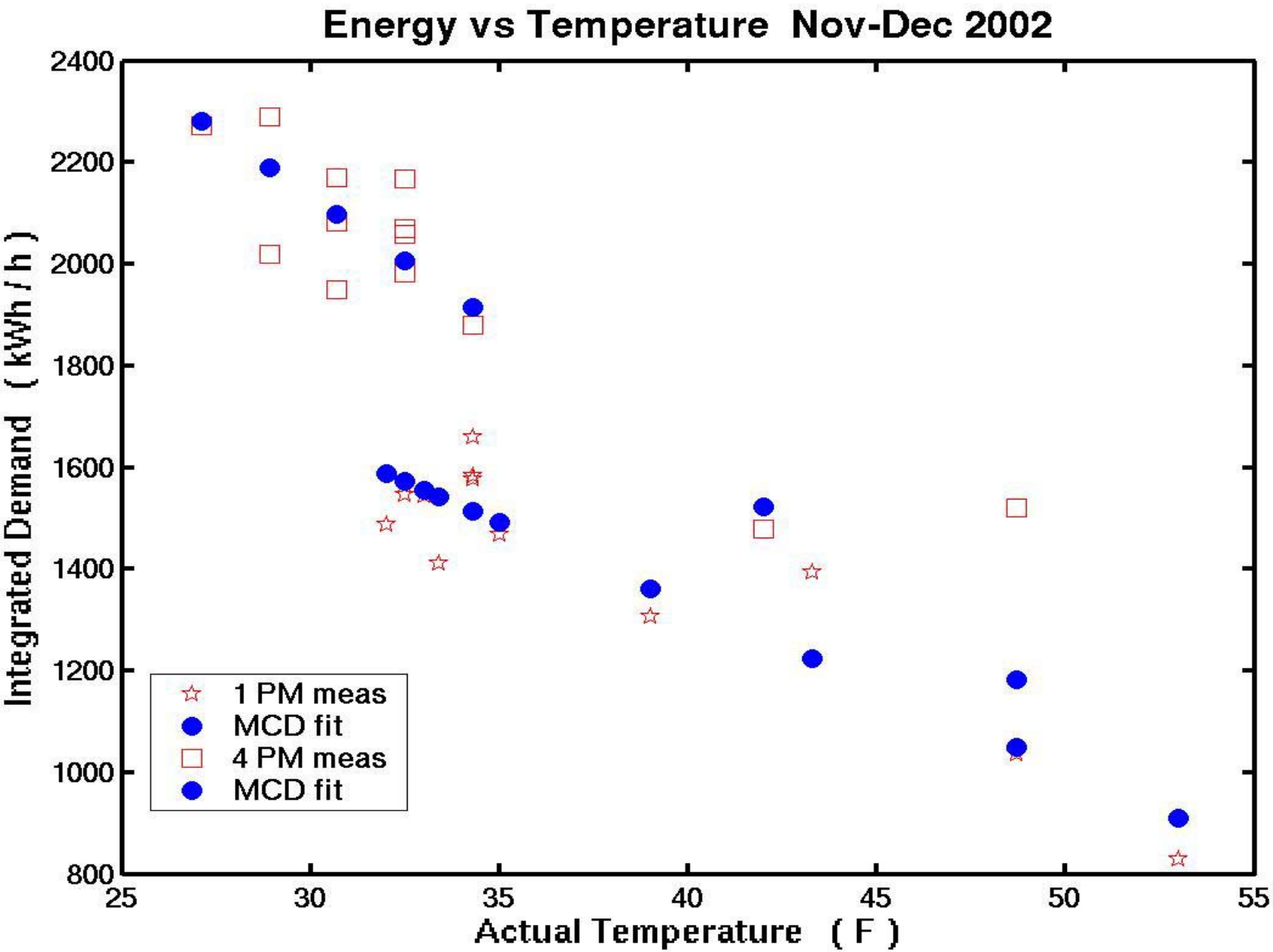
Combined Demand vs. Temperature @ 5 PM



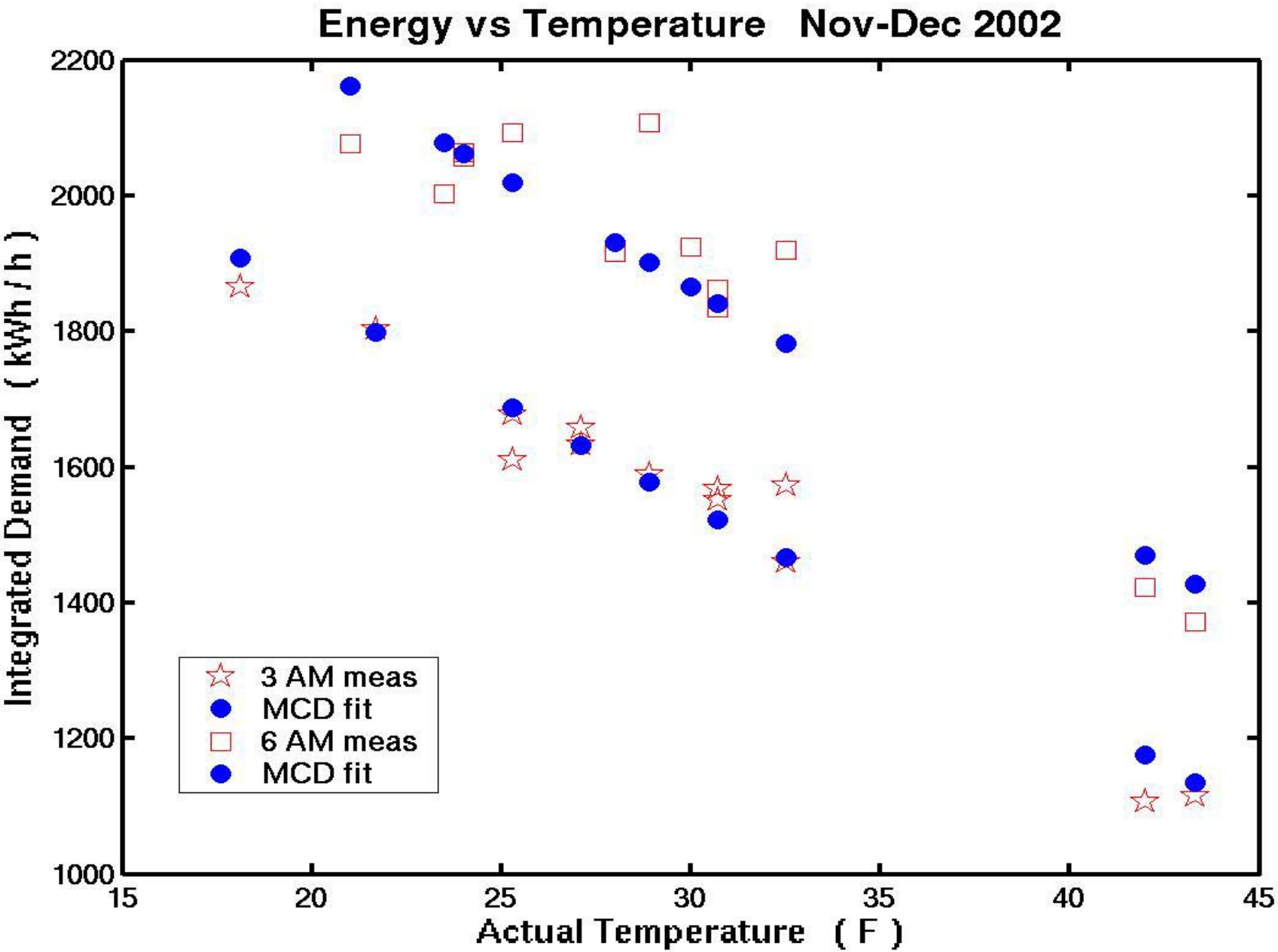
UtiliData Estimation Method

- Compare demand on a uniform basis
  - Operation on alternate days
  - Exposure to same environment
- Exploit prior knowledge of the demand processes and the resulting signals, such as:
  - Daily periodicity
  - Utilization devices efficiency versus voltage
  - Customer demand behavior
- Demand processes are locally linear
- Apply results only within bounds of observations

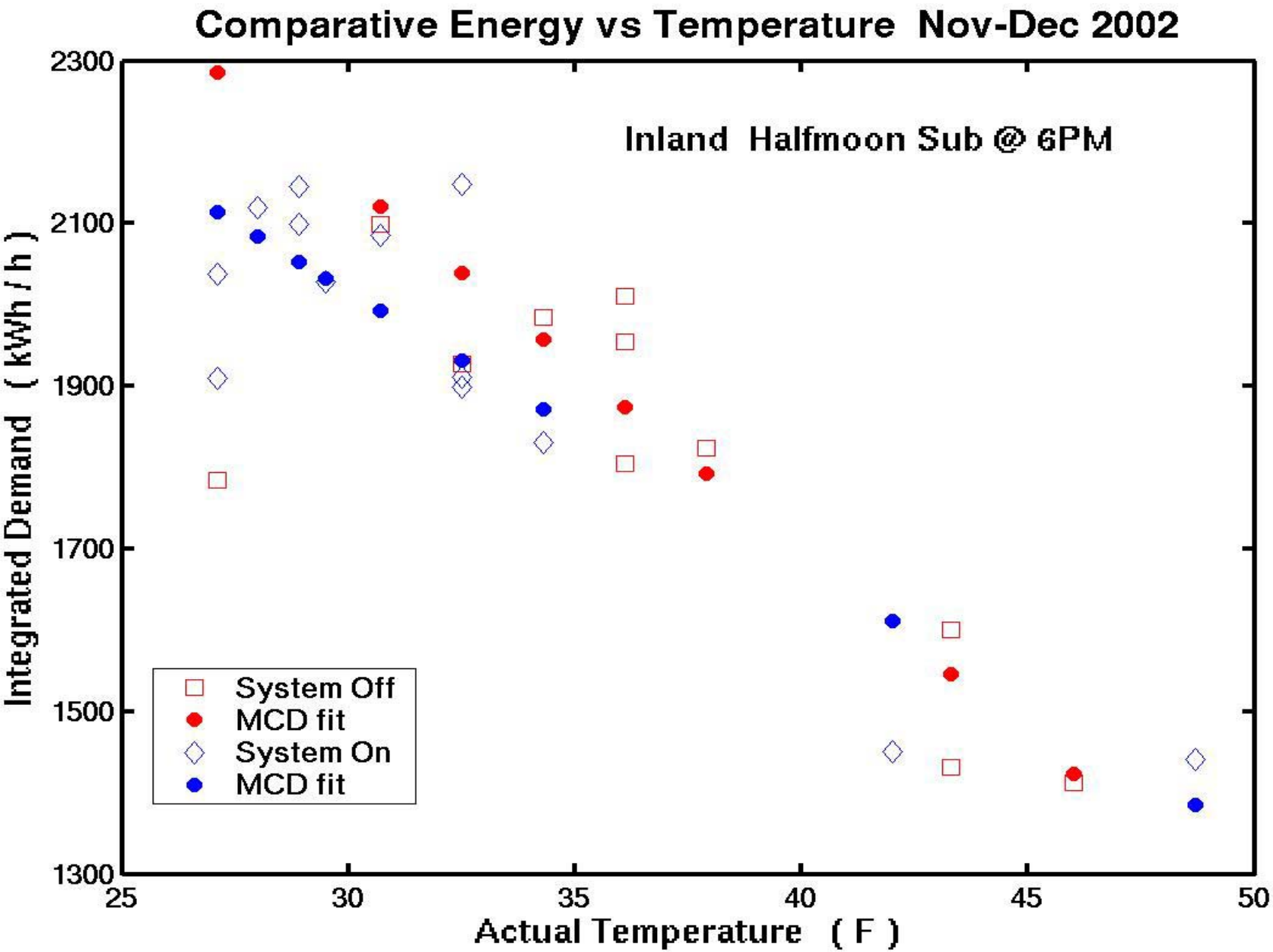
Demand vs. Temperature @ 1 PM and 4 PM



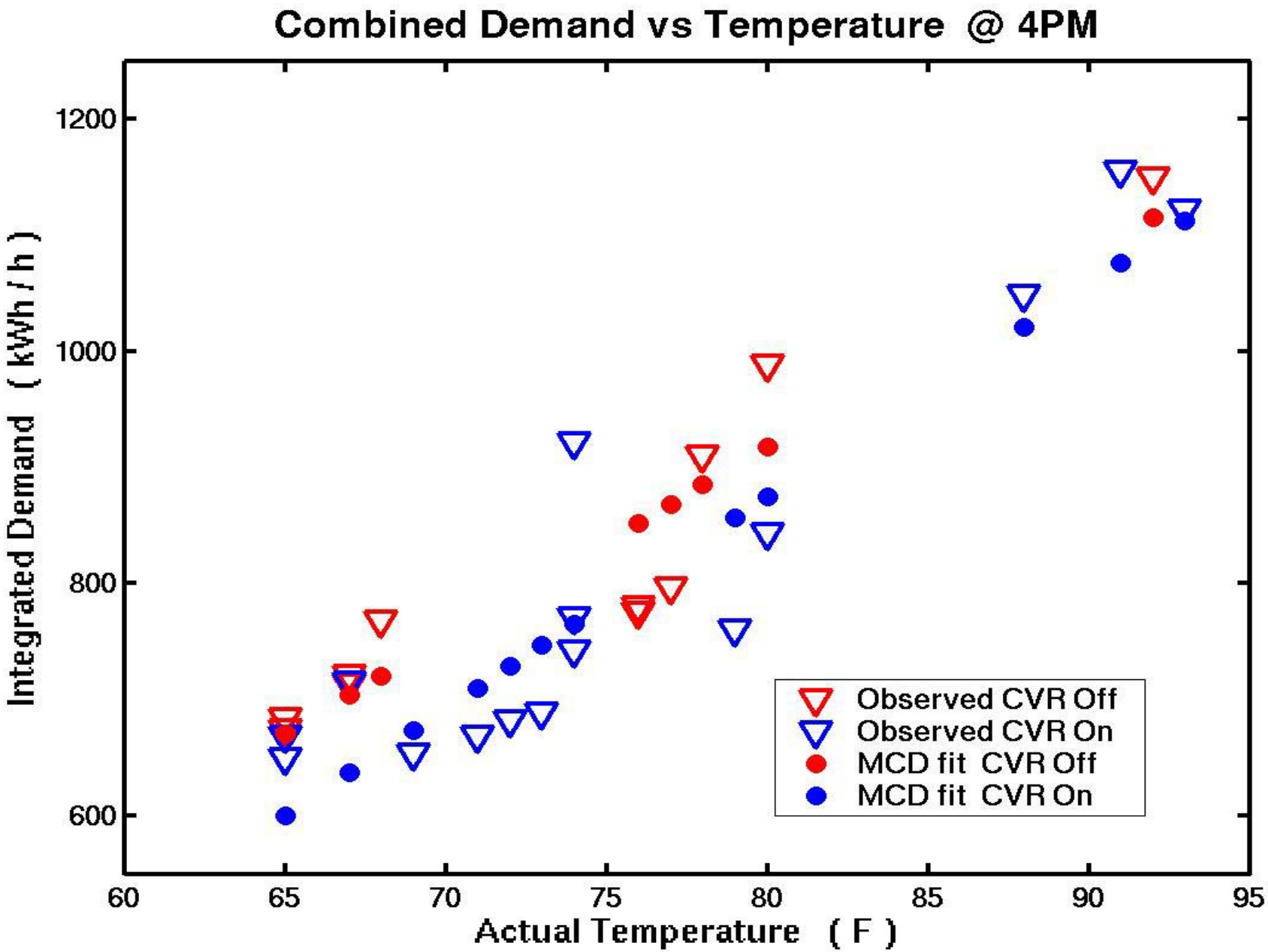
Demand vs. Temperature @ 3 AM and 6 AM



System ON vs. System OFF @ 6 PM



System ON vs. System OFF @ 4 PM



Protocol - Primary Verification Method

- Initial testing would last one year
- Operate system at different voltage levels on alternate days
- Statistical methods are used to verify energy savings, and estimate future savings on each feeder
- Re-verification triggered or upon request

Protocol - Testing Period

- First 90 days (after commissioning) of operation consists of running the system alternating days on full CVR on, at a controlled nominal midpoint above full CVR and then CVR off
- Three more months will be selected during the verification year, based on seasonal patterns, in which the system will alternate days between full CVR on, and CVR on at the controlled nominal midpoint

Protocol - Verifying Energy Savings

- Time series analysis.
- Robust Statistical methods.
- Temperature compensation.
- Only similar days compared.
  - Winter weekends vs. winter weekends
  - Summer weekdays vs. summer weekdays

Protocol - Special Considerations

- Temperature Data
  - Substation are usually located centrally to the feeders
  - Micro climates may exist, therefore additional temperature monitoring may be necessary
  - Should be collected on same period as load data

Protocol - Special Considerations

- Data accuracy and integrity
  - Power Meters
    - Do not need to be revenue certified
    - Must have revenue class accuracy
  - Voltage Meters
    - Metering equipment needs to be within 0.5% linear and less than 0.5% drift over -40C to +65C
  - All metering equipment should be shop calibrated
  - Field inspections will be necessary to verify correct installation and accurate readings
  - Data recording procedures should be auditable

Protocol - Control Group / Baseline Data

- With alternate day testing and variable voltage set-point, the application group acts as its own control group
- Pre-installation voltage levels must be measured to ensure accurate baseline measurements
- Historical regulator/LTC data records must be part of verification data records

Recommended Model and Tools

- **CVR_f Estimation Method**
  - **Available at www.pcsutilidata.com**
- **MatLab®**
  - **Automated CVR performance forecasting and estimation tools for this program are available from PCS UtiliData**

Variance Identified to Raise R^2 Levels

- Solar incidence (i.e. hours of daylight)
  - affects lighting, heating and air conditioning loads
- Additional Metering Points
  - Metering on secondary systems
- Other variables

Acknowledgements

- Kevin Tomsovic, Ph.D., Washington State University
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- Richard Damiano, Inland Power & Light
- Art Robare, Clatskanie People's Utility District

Thank You

Presented for your consideration

Automated CVR Protocol #1