Advanced Demand Responsive Lighting

Host: Francis Rubinstein

Demand Response Research Center
Technical Advisory Group Meeting
August 31, 2007
10:30 AM - Noon
Meeting Agenda

- Introductions (10 minutes)
- Main Presentation (~ 1 hour)
- Questions, comments from panel (15 minutes)
Project History

• Lighting Scoping Study (completed January 2007)
  – Identified potential for energy and demand savings using demand responsive lighting systems
  – Importance of dimming
  – New wireless controls technologies

• Advanced Demand Responsive Lighting (commenced March 2007)
Objectives

- Provide up-to-date information on the reliability, predictability of dimmable lighting as a demand resource under realistic operating load conditions
- Identify potential negative impacts of DR lighting on lighting quality
Potential of Demand Responsive Lighting Control

Typical commercial building peak load profile

Lighting dimmed to 25% power and other loads down 10%

Dimmed lighting

A/C

Other
Dimming Ballasts Becoming More Energy-Efficient

Relative System Efficiencies Compared for Instant Start, Program Start and Dimming Ballasts

Number of Ballast Models

- Dimming (N=53)
- Program Start (N=21)
- Instant Start (N=95)
Project Tasks

• *Testing and certification framework* for lighting control systems

• *Pilot tests* of promising demand-responsive lighting systems in buildings

• *Technology transfer* component
Testing and Certification Framework

Requirements

- System-based
- Performance-based
  - Technical specifications
- Manufacturer-agnostic
- Technology neutral

Initial Focus:
- Demand responsive lighting
- Other lighting control strategies later (daylighting, tuning, etc)
System-based

- Complete end-to-end solutions
- Software matters
- Monitoring and verification “in-the-box”
- Calibration and commissioning
Examples of Performance Metrics

- Lamp-Ballast Efficiency
  - Relative System Efficiency (RSE)
- System Response (Latency)
  - “Spinning Reserve” capability
- Reliability
  - Depth of shed
  - Uncertainty (variability) of shed
What’s Needed for Ballast Efficiency

A **Figure of Merit** that can be used to select ballasts according to lamp/ballast system efficacy
What’s Wrong with Existing Metrics?

• Ballast Efficacy Factor (BEF) is incorrectly normalized
  – Makes it difficult to compare BEFs between different ballasts
  – The units of BEF are awkward (1/watts)
• System Lumens Per Watt (LPW) conflates lamp-only variables (phosphor type) with ballast-only variables (ballast efficiency)
• The electrical efficiency of the lamp/ballast system cannot be easily disentangled from LPW
Ballast Efficacy Factor

BEF characterizes the lamp/ballast system efficacy of a test ballast operating a generic lamp type (T-8, T-12, T-5 etc)

**Definition of BEF:**

\[
BEF \equiv \frac{\text{Ballast Factor} \times 100}{\text{Ballast Input Power}}
\]

where:

\[
\text{Ballast Factor} \equiv \frac{\text{Lamp Lumens on Test Ballast}}{\text{Rated Lamp Lumens}}
\]
Relative System Efficacy

RSE is the BEF, but properly normalized to the rated lamp efficacy

**Definition of RSE:**

\[
RSE = \frac{\text{Ballast Factor}}{\text{Ballast Input Power}} \times \frac{\text{Total Rated Lamp Power}}{\text{Total Rated Lamp Power}}
\]

where:

\[
\text{Total Rated Lamp Power} \equiv \# \text{ of Lamps per Ballast} \times \text{Rated Lamp Power}
\]
Why is Relative System Efficacy Superior?

- RSEs from multiple ballast types can be easily compared on “level playing field”
- RSE easily calculated from data already supplied by lamp and ballast manufacturers

*RSE is ideal metric for distinguishing premium efficiency ballasts from standard*
Relative System Efficiency (RSE) for T-8 Fluorescent Ballasts
(1,092 Ballast/Lamp Combinations)
Relative System Efficiency (RSE) for T-5 Fluorescent Ballasts
(218 Ballast/Lamp Combinations)

Number of Ballast/Lamp Combinations

% Cumulative

Relative System Efficiency

1 Lamp Program Start
2, 3 & 4 Lamp Program Start
% Cumulative

0% 20% 40% 60% 80% 100% 120%
0 20 40 60 80 100 120

Relative System Efficiency

0 0.8 0.85 0.9 0.95 1 1.05 1.1 1.15 1.2
Summarizing

- RSE is superior to BEF for distinguishing ballasts in terms of system efficacy
- It is easy to calculate RSE from BEF without any additional data
Lessons Learned from Lighting Controls Demonstrations

- Evaluating the energy savings from lighting controls is harder than evaluating the savings from electronic ballasts
  - Electronic ballasts save energy simply *because* they are installed
  - Lighting controls only save energy if they positively impact operational performance
- Need independent, third party evaluation of controls savings
  - Manufacturer information not reliable
- Critical to measure energy usage both *before* and *after* installation of controls
  - The baseline matters!
- Demand response should be integrated with energy efficiency strategies
- Lighting controls should monitor and archive energy data as well as control lighting
Reducing the Risk of Installing Lighting Controls

Utilities need a consistent, reliable methodology for evaluating the energy savings and demand shed potential for various combinations of lighting control strategies in different building applications, regardless of networking technology.

With such a database, utilities will be able to appropriately incentivize the installation of energy savings controls in all building types.
Rationale for Pilot Tests

- Energy and demand savings from lighting controls systems must be evaluated under realistic building conditions
- Consistent evaluation of alternative solutions relative to well-defined baseline
- Evaluate changes in luminous environment under different lighting scenarios
Pilot Test Methodology

• Evaluate demand and energy savings under different lighting scenarios
  – Permuting the general and task lighting
• Define fair, consistent baseline against which to compare DR alternatives
• Evaluate changes in luminous environment under different lighting scenarios using High Dynamic Range photometry
Lighting Quality Evaluation

- Lighting quality metrics to be considered include:
- Near-hemispherical, accurate luminance maps of illuminated workstations from key viewpoints, presented as iso-luminance and false color renderings
- Statistical luminance analysis considering luminance ratios, distribution and uniformity of all visible surfaces, including computer monitors
- Detailed glare analysis of all sources including daylight from windows
- Horizontal illuminance distributions at the working plane and vertical illuminance at key viewing directions
- Spectral content, color temperature, S/P ratios
Status of Pilot Tests

• Two workstation-specific lighting control systems at Philip Burton Federal Building
  – Agiliti by Lightolier
  – Edapt by Ledalite
  – Low ambient basecase

• Building 90 flex space
  – LMCS by Lumenergi
  – ZigBee wireless ballasts by RF Arrays (?)
High Dynamic Range Photometry

• Canon 5D with fisheye lens
• Automated image capture
• Analysis of data in Adobe Photoshop CS 3
  – Well-documented, production system for HDR capture and analysis
Sample HDR
Workstation Specific Luminaires I

Agiliti by Lightolier

Two T-5 HO lamps
top-over bottom

DALI-based

User control of
lower lamp

Building control of
upper lamp
Workstation Specific Luminaires II

Edapt by Ledalite

Three T-8 lamps per luminaire

RS-485 network

User control of two outer lamps

Building control of center lamp
Control Panel for Demand Response

Load shedding – Building settings

A. Building control settings
B. Load Shedding Groups (Building default)
C. Add New
D. Load Shedding Mode
E. Loadshed from trigger point
F. % of the entire building load used by lighting system
G. Select load shedding methods to use
Control Panel for Fine-tuning the DR Strategy

### Local load shedding (Fixed trigger options)

<table>
<thead>
<tr>
<th>Select load shedding methods to use</th>
</tr>
</thead>
<tbody>
<tr>
<td>☑ Local load shedding</td>
</tr>
<tr>
<td>☐ External fixed trigger load shedding</td>
</tr>
<tr>
<td>☐ External DR request</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Settings for LOCAL (Fixed Trigger Levels 1, 2 &amp; 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 kW</td>
</tr>
<tr>
<td>□ This load or higher forces shed level 1 (10%)</td>
</tr>
<tr>
<td>□ Don't release this level until load falls below 80 kW</td>
</tr>
<tr>
<td>150 kW</td>
</tr>
<tr>
<td>□ This load or higher forces shed level 2 (20%)</td>
</tr>
<tr>
<td>□ Don't release this level until load falls below 130 kW</td>
</tr>
<tr>
<td>200 kW</td>
</tr>
<tr>
<td>□ This load or higher forces shed level 3 (30%)</td>
</tr>
<tr>
<td>□ Don't release this level until load falls below 180 kW</td>
</tr>
</tbody>
</table>

### Local load shedding (Variable shedding options)

<table>
<thead>
<tr>
<th>Select load shedding methods to use</th>
</tr>
</thead>
<tbody>
<tr>
<td>☑ Local load shedding</td>
</tr>
<tr>
<td>☐ External fixed trigger load shedding</td>
</tr>
<tr>
<td>☐ External DR request</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Select local load shedding method</th>
</tr>
</thead>
<tbody>
<tr>
<td>☑ Use variable load shed based on building load</td>
</tr>
<tr>
<td>☐ Use preset loads to trigger fixed load shedding levels</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Settings for LOCAL (Variable Shedding)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 kW</td>
</tr>
<tr>
<td>MIN - Start shedding when building load exceeds this value</td>
</tr>
<tr>
<td>MAX - Building load for maximum loadshed</td>
</tr>
<tr>
<td>400 kW</td>
</tr>
<tr>
<td>Shedding % to start with at MIN Building load (0 - 100%)</td>
</tr>
<tr>
<td>Shedding % at MAX Building load or higher (0 - 100%)</td>
</tr>
<tr>
<td>Large load shed step change limit (%)</td>
</tr>
<tr>
<td>10 %</td>
</tr>
<tr>
<td>Medium load shed step change limit (%)</td>
</tr>
<tr>
<td>2 %</td>
</tr>
</tbody>
</table>
Commissioning Panel for Daylight Controls
Technology Transfer

- Informed, public-interest TAG guiding research
  - No manufacturers
- Developing the market transformation vehicle
- Setting RSE efficiency targets
- Evaluating potential negative impacts
Impact of Electronic Ballasts and T-8 Fluorescent Lamps on Lighting Consumption


Fluorescent Lighting in Commercial Buildings (2001)

After 20 years, 50% of US lighting still uses inefficient magnetic ballasts


US Bureau of the Census
# Market transformation vehicle

## Table: EBMUD WaterSmart Irrigation Controller Program Qualifying Products

### Table Details:
- **EBMUD WaterSmart Irrigation Controller Program Qualifying Products**
- **Note:** For better assistance, identify yourself as an EBMUD customer when you contact suppliers.

### Table Columns:
- **Brand:** Aqua Conserve, ET Water Systems, Hunter, HydroPoint Weather/TRAK, Irritrol, Rain Master, Toro, Weathermatic
- **Controller Type:** Smart Oval, Smart Oval II, ET Irrigation, ET Irrigation Control
- **Product:** Sensi-TRAK, Sensi-TRAK II, Smart Oval, Smart Oval II, Smart Oval III, Smart Oval IV

### Table Data:
- **Controller:** Sensi-TRAK, Sensi-TRAK II
- **Price Range:** $300 - $800
- **Quantity:** 3 to 10

### Table Excerpt:

<table>
<thead>
<tr>
<th>Brand</th>
<th>Controller</th>
<th>Price Range</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqua Conserve</td>
<td>ET Irrigation</td>
<td>$300 - $800</td>
<td>3 to 10</td>
</tr>
<tr>
<td>ET Water Systems</td>
<td>ET Irrigation Control</td>
<td>$300 - $800</td>
<td>3 to 10</td>
</tr>
<tr>
<td>Hunter</td>
<td>ET Irrigation</td>
<td>$300 - $800</td>
<td>3 to 10</td>
</tr>
<tr>
<td>HydroPoint Weather/TRAK</td>
<td>ET Irrigation</td>
<td>$300 - $800</td>
<td>3 to 10</td>
</tr>
<tr>
<td>Irritrol</td>
<td>Smart Oval III</td>
<td>$300 - $800</td>
<td>3 to 10</td>
</tr>
<tr>
<td>Toro</td>
<td>Smart Oval II</td>
<td>$300 - $800</td>
<td>3 to 10</td>
</tr>
</tbody>
</table>

### Table Notes:
- **Note:** For better assistance, identify yourself as an EBMUD customer when you contact suppliers.

### Table Explanations:
- **控制器**: Smart Oval II
- **价格范围**: $300 - $800
- **数量**: 3到10

### Table Description:
- The table provides a list of qualifying products for the EBMUD WaterSmart Irrigation Controller Program.
- Each product is categorized by brand, controller type, and price range.
- The quantity column specifies the range of quantities available for each product.

### Table Example:
- **Aqua Conserve**
  - Controller: ET Irrigation
  - Price Range: $300 - $800
  - Quantity: 3 to 10

### Table Considerations:
- **Note:** For better assistance, identify yourself as an EBMUD customer when you contact suppliers.

### Table Imagery:
- The table is presented in a tabular format with clear headings and data entries.

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