Design and Commissioning of Lighting Control Systems
Rick Miller, PE, LC, LEED AP
RNM Engineering, Inc.
October 18, 2012
Objectives

• Review the Cx process as it relates to lighting control.
• Emphasize the importance of thorough control narratives.
• Stress the need to implement multiple control strategies to achieve maximum energy savings.
Commissioning Misconception

• “A common misconception is that factory start-up is commissioning.”
  by Brian K. Baumgartle, Oct 2012
  Consulting Specifying Engineer magazine
Definition of Commissioning

• “A quality-focused process for enhancing the delivery of a project. The process focuses upon verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the owner’s project requirements (OPR).”

ASHRAE Guideline 0-2005
CA Cx Collaborative
ASHRAE

• Guideline 0-2005,
The Commissioning Process
LEED® by USGBC

• LEED for New Construction
  • Prerequisite (Required)
  • Enhanced (Optional)
Illuminating Engineering Society

- IES DG-29-11: The Commissioning Process Applied to Lighting and Control Systems
Energy Codes

• ASHRAE 90.1
• IECC
• State and Local
• CA Title 24-Part 6
  • Watts per Square Foot - W/SF or LPD
  • Required Controls
Title 24

• Automatic Off
  • Vacancy sensing
  • Photo switch (for outdoor)
  • Time schedule or Curfew

• Reduction or Dimming
  • a/b switching – manual
  • a/b switching - automatic
  • dimming – manual
  • dimming – automatic

• Acceptance Testing
  (By licensed person)
  • Architect
  • Engineer
  • Contractor

Lighting Control Strategies

- Local Controls
- Building Level Controls
- Centralized Controls
Local Control Strategies

• Multi-Level Switching
• Occupancy/Vacancy Sensing
• Daylight Harvesting
• Architectural Dimming
• Personal Tuning
• Lumen Maintenance
• Plug Load
Building Control Strategies

- Time Schedule
- Facility Tuning
- Adaptation Compensation (visual response)
- Adaptive Response (change wrt time)
- Load Shed (initiated by building owner)
- Demand Response (initiated by utility co.)
- Emergency Condition (UL924)
Centralized Control Strategies

- Automated Maintenance
- BMS Integration
- Energy Management
- Energy Dashboards
Daylighting Harvesting

• The selection and placement of the sensor is critical for successful operation.

• **SPOT** (Sensor Placement + Optimization Tool)

• [www.archenergy.com/SPOT/](http://www.archenergy.com/SPOT/)
IES DG-29-11

- Pre-Design Phase
- Design Phase
- Construction Phase
- Occupancy and Operations Phase
IES DG-29-11

• Pre-Design Phase
  • The Cx Team
  • The Cx Plan
  • Owner’s Project Requirements (OPR)
  • Other Pre-Design Phase Activities

• Design Phase
• Construction Phase
• Occupancy and Operations Phase
IES DG-29-11

- Pre-Design Phase
- Design Phase
  - Basis of Design (BOD)
  - Project Phasing
  - Design Criteria
  - Other Design Phase Services
- Construction Phase
- Occupancy and Operations Phase
IES DG-29-11

- Pre-Design Phase
- Design Phase
- Construction Phase
  - Construction Administration & Occupancy
  - Performance Testing
  - Issues Log
  - Systems Manual
- Occupancy and Operations Phase
IES DG-29-11

- Pre-Design Phase
- Design Phase
- Construction Phase
- Occupancy and Operations Phase
  - Ongoing Commissioning
Control Narratives

Storage Rooms and Janitor Closets: Line-voltage wallbox occupancy sensors set for manual on, auto & manual off with time delay set to 5 minutes, and the audible and visible alert functions enabled.
Control Narratives

• Open Office: Local manual bi-level control with step dimming on all fixtures. Scheduled automatic shutoff with 2 hour manual override. Perimeter fixtures within the daylight zone shall include integral photosensor control for local one-step light level reduction of perimeter fixtures.
Control Narratives

• From the New Building Institute:
  • Advanced Lighting Guidelines
  • www.algonline.org
  • 15 different room types are available
Control Narratives

- Lighting Controls Association
- The Lighting Controls Narrative
- http://lightingcontrolsassociation.org/control-design-toolbox-the-lighting-controls-narrative/
Beneficiaries of Narratives

• Designer — better chance to satisfy the Owner
• Contractor — clear direction for bidding
• Installer — less chance of making error
• Manufacturer — speeds submittal & startup
• Cx Authority — knows what to test
• Owner — more likely to maintain the system
• User — increase likelihood of acceptance
# Lighting Control Design Matrix

Performed by Designer

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<th>MANUAL OFF</th>
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<th>MULTI LEVEL SWITCHING</th>
<th>KEY SWITCH</th>
<th>TIME SCHEDULE - ON</th>
<th>OVERRIDE SWITCH</th>
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Commissioning Specification

• SECTION 260800 – Commissioning Of Electrical Systems And Lighting Controls
Spec Section 260800

• Submit a floor plan or spreadsheet table checklist that indicates each local lighting control device, occupancy sensors, daylighting controls, system component.
Spec Section 260800

• Submit the system sequence of operation fully describing the equipment components and functionality, including setpoints and alarm functions.
Spec Section 260800

• The detailed sequence of operation shall be provided regardless of the completeness and clarity of the sequences in the controls specification and/or drawings.
# LC Submittal Matrix

Performed by LC Vendor, submitted to CxA

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<th>ROOM NUMBER</th>
<th>ROOM NAME</th>
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# LC Installation Verification

Performed by Installer, submitted to CxA

## LIGHTING CONTROL INSTALLATION VERIFICATION CHECKLIST

| ROOM NUMBER | ROOM NAME                  | LUMINAIRE MANUF & TYPE | LUMINAIRE LOCATION & HEIGHT | BALLAST TYPE | LAMPS BURNED-IN (SEASONED) | WALL SWITCH LOCATION & TYPE | OR SWITCH LOCATION & TYPE | POWER SUPPLY & RELAY TYPE | OCC SENSOR LOCATION | OCC SENSOR TYPE | OCC SENSOR SETTINGS | PHOTOCONTROL LOCATION | PHOTOCONTROL AIMING | PHOTOCONTROL OPEN LOOP | PHOTOCONTROL CLOSED LOOP | PERSONAL TUNING | ADAPTIVE RESPONSE | UL 924 EMERGENCY RELAY | PLUG LOAD | EXTERIOR PHOTOCELL LOCATION | WIRING DIAGRAM REFERENCE | SEQUENCE OF OPERATIONS |
|-------------|---------------------------|------------------------|-----------------------------|--------------|-----------------------------|-----------------------------|---------------------------|------------------------|---------------------|----------------|---------------------|-----------------------|---------------------|-----------------------|------------------------|----------------|-------------------------|-----------------------|----------------------|
| 1001        | Open Offices              |                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| 1002        | Private Offices           |                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| 1003        | Meeting Rooms             |                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| 1004        | Break Rooms               |                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| 1005        | Kitchen                   |                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| 1006        | Pantry                    |                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| 1007        | Cafeteria                 |                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| 1008        | Corridors                 |                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| 1009        | Restrooms                 |                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| 1010        | Storage Rooms             |                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| 1011        | Ground Floor Lobby       |                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| 1012        | Reception Areas           |                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| 1013        | Electrical/Mechanical Room|                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| EX1         | Exterior Parking Lot Lighting|                     |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| EX2         | Exterior Grounds Lighting |                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
| EX3         | Exterior Security Lighting |                        |                             |              |                             |                             |                           |                        |                    |               |                     |                       |                     |                      |                        |                |                        |                       |                      |
## LC Component Test Matrix

Performed by Installer, submitted to CxA

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<td>EX3</td>
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Dimming Saves Energy

(Three brands of DALI dimming ballasts)

Courtesy of LBNL
Perceived vs Measured Light

Courtesy of IES Handbook, 9th Edition
Dimming Control Protocols

• ANALOG
  • Line-Voltage Phase Control Dimming
  • 0–10VDC Dimming

• DIGITAL
  • DALI Dimming & Control
  • DMX512 Control
Lighting Control Systems

• Wired Digital
  • DALI
  • Digital Components
  • Powerline Carrier

• Wireless Digital
  • Mesh Network vs Star Network
  • Micro Power
  • Mixed Protocols
A Life Cycle Cost Evaluation of Lighting Control Strategies
Commissioned By: Daintree Networks
Prepared By: Clanton & Associates, Inc
   Dane Sanders, PE, LEED™ AP
   Darcie Chinnis, EI, LEED™ AP
With Contributions by:
   Group 14 Engineering
   &
   Energy Products Associates, LLC

Courtesy of Clanton & Assoc and Daintree Networks
Systems Evaluated

• 1 – Localized Control (Code compliant)
• 2 – Relay Panel for Switching
• 3 – Relay & Dimming Panel for Daylight
• 4 – DALI Dimming everywhere
• 5 – Wireless Dimming near windows (D.H.)
• 6 – Wireless Dimming everywhere

Courtesy of Clanton & Assoc and Daintree Networks
Relative Capital Cost

![Bar chart showing relative capital cost for different systems and technologies: Sys 1 Title 24, Sys 2 Relay Panel, Sys 3 Dimmer Panel, Sys 4 DALI All Dim, Sys 5 Wireless D.H. Dim, Sys 6 Wireless All Dim. The x-axis represents the different systems and technologies, while the y-axis represents the percent cost. The chart is courtesy of Clanton & Assoc and Daintree Networks.]
Annual Energy Use

KWh/sf

Sys 1 Title 24
Sys 2 Relay Panel
Sys 3 Dimmer Panel
Sys 4 DALI All Dim
Sys 5 Wireless D.H. Dim
Sys 6 Wireless All Dim

Courtesy of Clanton & Assoc and Daintree Networks
Relative Life Cycle Cost

![Bar chart showing relative life cycle costs for various systems. The x-axis represents different systems: Sys 1 (Title 24), Sys 2 (Relay Panel), Sys 3 (Dimmer Panel), Sys 4 (DALI All Dim), Sys 5 (Wireless D.H. Dim), and Sys 6 (Wireless All Dim). The y-axis represents the percent cost.]

Courtesy of Clanton & Assoc and Daintree Networks
LA Engineering Office

• System:
  • Wireless, addressable
  • EnOcean protocol
    • Wall Switches, Vacancy Sensors, Photosensors

• Strategies
  • Daylight harvesting, Vacancy, Multi-level
  • Task/Ambient Lighting (each controlled separately)
  • Occupancy sensor informs HVAC to change setpoint
  • Demand response
  • Personal control
  • Energy dashboard

Courtesy of The Lighting Quotient
Real Measured Data

Title 24 Baseline 1.18 W/SF
Connected Lighting Load 0.83 W/SF
Lighting Controls Credit 0.66 W/SF
Actual Performance Max 0.25 W/SF

Courtesy of The Lighting Quotient
Control Narratives

• Required for system commissioning
• Must be thorough
• Needed for each scenario
• Include adaptive parameters
• Needed for components and system
Control Narratives

- Required for system commissioning
- Must be thorough
- Needed for each scenario
- Include adaptive parameters
- Needed for components and system

**Required to achieve maximum energy savings!**
Credits

• Enovity, Inc.
• Greg Cunningham, AIA
• Illuminating Engineering Society
• Lighting Controls Association
• Clanton & Associates, Inc.
• Daintree Networks
• The Lighting Quotient
• Consulting Specifying Engineer
The End