Commissioning Advanced Lighting Systems

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Synopsis

Lighting is the most visible area of electrical system design, and has been showcased as the centre of many energy efficiency measures, ranging from lower light levels to more efficient lamps and ballasts to more user friendly and adaptable controls. All of these controls and systems make the lighting more difficult to design and commission; but when the designer and commissioning agent work together, the result is an improved final product. Additionally, since lighting is the most visible aspect of electrical design, and is one area of the building design that affects all users, commissioning can be the difference between the acceptance of a more advanced lighting strategy and disconnection of the controls.

This paper focuses on how to commission advanced lighting systems. It starts with the design and specification process, discussing methods of designing with occupancy and daylight sensors, and moves to clarify some of the specifications that can be used to simplify the commissioning process. The roles of both the designer and the commissioning agent are discussed through each phase of a project, from design through construction.

About the Author

Trina Larsen is a senior electrical engineer with the integrated design firm Cohos Evamy. She holds a bachelor's degree in Engineering Physics and a Masters Degree in Electrical Engineering from the University of Saskatchewan. She became a LEED accredited professional in 2002.

Trina's work has focused almost exclusively on sustainable buildings and building energy conservation. She has worked on many LEED buildings along with several green buildings prior to the establishment of LEED. She has experience in all phases of engineering design: from feasibility studies through to detailed design, construction administration, and commissioning.

Specializing in lighting and electrical design, Trina works with clients to develop technical solutions that ensure occupant comfort, ease of maintenance, and low energy consumption.

Introduction

There's been a lot of discussion through the last few years over building commissioning. In many areas of the country, commissioning agents have created businesses specializing in the task and, with the popularity of the US and Canadian Green Building Council's LEED® (Leadership in Energy and Environmental Design) program, commissioning is being required on more new and newly renovated buildings. Mechanical system commissioning is fairly well defined and accepted, as clients have seen the benefits in operating procedures and costs related to this process. Unfortunately, even in LEED projects, electrical and lighting systems often end up undergoing a process more akin to testing than commissioning, with commissioning plans often being the usual testing checklists for electrical systems.

One of the reasons for testing, rather than full commissioning, is that clients (and many designers and engineers) don't understand the benefits of commissioning the electrical systems – so long as the power is available when it's supposed to be, everything is fine. This is similar to the prevailing thought that existed 10 to 20 years ago with mechanical systems. However, like mechanical systems, the benefits of commissioning electrical systems can be far reaching, and include both first cost reductions and operational savings. In addition, systems operate as intended from the start, rather than having ongoing problems in the early stages of occupancy, or even unseen problems that cause occupant discomfort. In a similar fashion to mechanical systems, electrical systems are becoming more complex. No longer do lights operate with simple switches, they now have occupancy and photo-sensors, combined with zone control, dimmers and timers; power systems have peak load shedding and incorporate power from alternative energy sources; audio systems are zoned with override capabilities with multiple inputs; and so on. As the complexity of the system grows, the need for commissioning becomes greater, and simple on-off tests may no longer be sufficient.

Lighting is the most visible area of the electrical system design, and has been showcased as the centre of many energy efficiency measures, ranging from lower light levels to more efficient lamps and ballasts to more user friendly and adaptable controls. All of these features require commissioning, from the appropriate lamp color selection and confirmation of the selection on site, to the ballast selection and confirmation, to operation of the daylight and occupancy sensors and dimmer settings. The commissioning process assists in ensuring the proper operation and acceptance of the complete lighting system. Additionally, since lighting is the most visible aspect of electrical design, and is the one area of the building affecting all users, commissioning can be the difference between the acceptance of a more advanced lighting strategy and disconnection of the controls.

As with overall commissioning, the process of commissioning advanced lighting systems works most effectively when it begins during the design stage, which requires cooperation and interaction between the designer and commissioning agent. As the project moves through construction, the role of the commissioning agent expands while the design team continues to be involved. To move lighting from a testing procedure towards true commissioning requires changes to traditional procedures at each stage of the project.

Designing Easily Commissioned Advanced Lighting Systems

Commissioning lighting systems is most effective when it begins at the start of design and continues through to building occupancy, with the designer and commissioning agent working in tandem. Unfortunately, some projects are too small to warrant a commissioning agent specifically designated to the electrical systems, while on mid-sized projects, the electrical commissioning agent may not have lighting as a specialty. Therefore, it is important for the designer to streamline the commissioning process through design and use the construction documents effectively.

The Design Phase

The design phase sets the tone for the entire project and enables the project to be effectively commissioned. Advanced lighting systems require more design at the outset combined with carefully worded specifications to ensure the final product meets the intent. For an easily commissionable system, the documentation and design intent need to be clear and concise.

The start of the design process involves interactive discussions with the architects as they develop their initial concepts of how the spaces are going to be used, and determine the preliminary building orientation and fenestration patterns. This discussion is significant, as the architects are in control over which areas are day-lit whether this natural lighting will be able to be effectively used. If the benefits of solar shading devices on the exterior of windows and interior light shelves are not understood, rooms may be over day lit when floor to ceiling curtain-walls are provided with no shading. When the benefits are only partially understood, these devices may be installed incorrectly – mounted too high, too shallow or in the wrong orientation for the side of the building. Assisting the architects in their understanding of the impact of daylighting, at the outset, helps to develop the most effective lighting strategies combining both natural and electric lighting in appropriate ways.

Architects also have ideas of how they want the space to be lit. If possible, the early discussions should focus on how the space will look, rather than specific fixtures. This leaves the actual fixture selection flexible for the first while, as the space function settle through the schematic design process. Strategies of up lighting, down lighting, and accent lighting, along with preliminary control strategies are useful at the outset. Client interaction is also beneficial to confirm that their intended use of the space matches the architect and lighting designer's understanding.

Schematic design documentation will be used by the commissioning agent to understand the preliminary design intent. By the completion of design development more details will have evolved, important light fixtures may be selected and the control strategies will be more defined. As with schematic design, the design development documentation will be reviewed by the commissioning agent. Helpful feedback from the agent, at each stage, is desirable, and may revolve around constructability and preliminary documentation requirements so that the designer can tailor the specifications. The commissioning agent will also be involved in confirming that

the client understands the design intent, and that this design intent will actually meet the client's needs.

Lighting Control "Rules of Thumb" for Designers

- Keep the lighting zones as small as reasonably possible. Even without individually addressed controls, people like to have as much control over their environments as possible, whether it's changing blind position or adjusting dimming levels.
- To maximize useable daylighting, work with the architects to place as much fenestration as high as possible so that it penetrates deep into the room. Also work with the architects and interior designers to incorporate light shelves and solar shading as appropriate
    - One of the biggest complaints heard in my practice has been there's too much sun-light, so the blinds are closed and the electric lights are then required, defeating the purpose of the daylight sensors. Properly designed shading and light shelves help with maintaining the proper light level without closing the blinds.
- When using stepped dimming for daylighting:
    - Use the high end of the designed light level (from photometric data), divide this value by the number of lamps, add the designed light level, then add 20%:
        - For a simple on/off (single step) system, double the designed light levels (so 700 lux for an office designed to 300-350 lux) and add 20% to determine the "off level" for the electric lighting. The jump will be a relatively manageable jump of 840 lux down to 490 lux.
        - For a two lamp fixture, the each step would occur at 350/2 + 350 = 525 lux + 20%, which changes the light level from 630 lux to 455 lux.
        - For a three-lamp fixture, turn lamps off one at a time, at 560 lux, dropping the light level from 560 lux to 440 lux.
    - Turn each lamp back on, one at a time, as the light levels drop to the designed light level MINUS 10% (270 lux for the same office, designed to 300 – 350 lux).
- Determine whether combining a photo sensor with a timer or an occupancy sensor will prove advantageous for additional savings.
    - Often offices are appropriate applications for combination daylight/occupancy sensors, while large atria spaces are suitable for the addition of timers.
- In open office areas, provide enough sensors to allow for overlap of their coverage, and place the sensors appropriately for the furniture layout.
    - Reducing the quantity of sensors saves money, but may result in lower performance, and ultimate user dissatisfaction, which leads to the sensor being removed or over-ridden.
- In areas where there are small movements being made (near desks and computer keyboards, over bathroom stalls, etc.) place occupancy sensors as close as reasonable to the small movements to increase the sensitivity of the senor, without making the sensor itself overly sensitive.
- In hallways, good practice involves placing an occupancy sensor at each end, pointing towards the centre. This will provide the best coverage of the corridor, and avoid some of the false triggering.

Specifications to Assist Commissioning

Working drawings and specifications translate the design to those installing equipment and constructing the facility. They are used by the commissioning agent to compare the installation to the design intent and they're used by the owner to determine what is in the building at a later point-in-time. With this range of functions, the challenge for the designer is to make the drawings and specifications as useful as possible for all parties, while achieving the envisioned design.

In addition to the different functions that the documents perform, they are also used differently at different stages in the construction process. During the tender process, in an ideal world each bidder would receive all of the specifications and drawings. In reality, the electrical contractor typically sends the fixture schedule, with counts but no drawings, to the lighting supplier. Further, the contractor then sends the controls specification section, without drawings and often without the light fixture schedule, to the controls supplier. Once the project moves into construction, the ideal world has both the specifications and drawings easily available to the electricians. Unfortunately, the specifications often remain in the foreman's office, with only the drawings actually on-site and readily accessed by the electricians. For the designer, this means that the drawings and the specifications need to work together, yet be developed with insight into how they are used as individual entities.

For advanced lighting systems, the controls and ballasts tend to pose the greatest challenges, as the information for these two items span several sections of the specifications, while other details are on the drawings. One method that has worked well in our office, to alleviate some of the problems on the controls side, is to provide a zoning diagram on the drawings along with a full zoning schedule in the specifications. The zoning diagram includes defined lighting zones and a chart with the control strategies for each area, while the low voltage control schedule in the specifications includes relays, switches, and sensor information, along with preliminary settings for items like daylighting control. In this manner, there is enough information for the controls supplier to bid the project appropriately, while the contractor building the project knows what is expected in each area, and can see the interactions more clearly. For ballasts, specific ballast information (such as suitable for occupancy sensors) should appear in both the luminaire schedule and in the ballast specification. Information on dimming ballasts should also appear on the zoning diagram and low voltage control schedule since dimming ballasts are typically matched to the control system.

Within the general conditions of the specifications, it's a good idea to include a line indicating the requirement of having the commissioning agent involved in shop drawing review. This allows a second set of eyes to see that any changes made by the supplier or contractor still meet the design intent. However, even with this step, sometimes what shows up on site differs from the shop drawings, or the shop drawings don't indicate everything. Ballasts, again, can be a particular problem, as there are occasions when the ballast specified and indicated on the shop drawings does not match what shows up on site. Since the designer is not typically on site when shipments arrive, it is an area where the commissioning agent can be of great assistance.

Specification "Rules of Thumb" for Designers

- Since dimming ballasts are often specific to the controller, provide this information in both the luminaire schedule and the lighting control section of the specifications, and then indicate dimming on the drawings
- Provide counts of low voltage switches and sensor types on a zone-by-zone basis in the lighting control section, with a basic zoning diagram on the drawings
- Include a requirement for the commissioning agent sign-off within the shop drawing section of general conditions
- Add a note on the drawings for manufacturer's input into final sensor placement, since each manufacturer's coverage patterns are slightly different
- Consider allowing BX cable for the final drop from the junction box to the sensor, to allow sensor relocation during commissioning

The Electrical Commissioning Agent's Role

The electrical commissioning agent is part of the overall commissioning team and should be involved throughout the design process, starting during schematic design. As has been found with mechanical systems, to avoid bias and overly optimistic knowledge of the design, it is most effective if the commissioning agent is directly reporting to the end user/client, and not involved with designing the systems. Once construction begins, the commissioning agent should be a signatory on the shop drawing review sheet, and perform site visits to confirm that systems are meeting the shop drawings and are being installed in a manner that will ensure their functional performance, rather than just basic code compliance. The greatest portion of work will come at the end, with testing and verifying all the systems, and then following up to make sure that deficiencies have been corrected.

Design and Specification Phase

At the outset of design, commissioning involves observing the schematic design process to become fully familiar with the facility design intent. Generally, the commissioning agent would attend one or two design meetings, and discuss the design with the designers and client. This role of observer at some of the design meetings will continue through design development and working/construction drawings. Changes occurring between the schematic design and construction documents should be communicated, in writing, from the design team to the commissioning agent, along with rationale for large changes, and will form one section of the final commissioning report. This can be a significant advantage for the design team, as well, as all changes are documented when questions arise from the client. At this point, the role of the agent is simply an observer and questioner, trying to keep the focus on the client's needs and providing electrical systems that most effectively meet these needs.

At the end of the design process, the commissioning agent will be reviewing the drawings and specifications to ensure that they are meeting the client's needs. For lighting systems this involves (at a minimum) confirming that:

- lighting is designed to the proper light levels
- lighting effectively highlights the architectural features
- illumination sources and ballasts are appropriate
- lighting control meets the needs of both the building and the users

In many respects, the commissioning agent's job is to confirm that reasonable alternative possibilities have been considered during the design, make sure that the specifications meet the design intent, and that system interactions are handled appropriately, including system interactions with the architectural and mechanical portions of the project.

Construction Phase

Once construction begins, commissioning becomes a hands-on process that extends beyond the standard construction administration role. Regular site visits play a key role in this process, documenting changes from the original design intent. Typical construction processes involve a construction administer, whose role is to move the facility from construction drawings into concrete, steel and wire. The commissioning agent's role expands on this by confirming that the original design intent is maintained throughout the process, despite deadlines and value engineering. In other words, the inevitable changes that occur during construction need to maintain the spirit of the design, unless the client is fully versed on the impact to their finished facility. Lamp color temperature may be a critical design requirement in certain instances, or the ballast manufacturer due to performance or temperature ratings, while fixture type may be critical for aesthetics. Other items, such as the manufacturer of the lamp may be more or less critical if the final product still provides the functionality of the originally specified system. In addition, since few systems operate independently of the rest of the building, changes to architectural, mechanical or structural systems may impact the electrical systems, resulting in required changes that still require the overall building functionality to remain. An example of this would be a change to the structural system that results in thicker beams, which impacts the down-light locations.

The commissioning agent should be involved in regular site visits and shop drawing reviews to keep abreast of the implementation of the design. Their sign-off on shop drawings may, in fact, be critical in some instances, as the contract administrator may not be privy to some of the design considerations, resulting in their approval of changes that are not in keeping with the spirit and intent of the original system requirements. In addition, some of the actual testing may begin during construction with the commissioning agent overseeing the testing and confirming that corrections are made prior to sign-off. In addition, as was noted earlier, it's helpful if the commissioning agent is available to do a quick check of shipments when they arrive, to confirm that components such as ballasts are actually as specified.

Post Construction

Construction completion marks the point in time where the major component and system testing begins. As in the construction phase, the commissioning agent plays a slightly different role than the contract administrator, in that the agent is involved with ensuring the design intent is met, while the administrator is primarily confirming that the systems work.

A prime example of this difference is exemplified in a test of occupancy sensor operation. Many start-up plans simply document the basic test done in standard construction process which confirms that the sensor turns the lights on and off in an appropriate time frame. A fully commissioned occupancy sensor, however, has a commissioning plan that includes:

- confirmation of the correct type of sensor (infra-red, ultrasonic, acoustic or combination)
- a walk of the coverage area while the sensor is in test mode to ensure full coverage
- a walk outside the coverage area to check the sensitivity settings
- setting the sensor to the appropriate on/off cycle required

Additional connections (such as mechanical fans attached to the same occupancy sensor) can also be confirmed through this process.

When all the testing and verification are complete, the final step in a commissioning process is the final assembly of the operation and maintenance manuals. For the lighting systems, these manuals will include information on lamps, ballasts, fixtures, each sensor and control type, as-built zoning and the initial settings and control strategies.

Conclusions

For any lighting system, the final analysis is left to the end users who ultimately decide whether they like the system, or wish it consisted of simple switches. A well-designed and commissioned system will improve the chances of the end users' acceptance of their lighting. Achieving this ideal requires coordination and interaction between the designer and commissioning agent, along with the architect and the client.

At the design stage, the designer and architect work together to develop preliminary concepts, resulting in the appropriate use of daylighting, suitable light levels for the functions within the spaces, small zones for daylight and occupancy sensors, and suitable use of electric lighting. The commissioning agent confirms that the design intent meets the client's needs and that the control strategies make sense. Moving into working drawings and specifications, the designer should consider the different uses of the documents, making them relatively stand-alone, where required. This means that there will be some duplication of information, necessitating close coordination of the sections to ensure they are consistent.

As the project moves into construction, the commissioning agent will become more heavily involved in the process. From shop drawing reviews and confirmation of equipment deliveries

to the actual testing and verification process, the commissioning agent will be involved. The agent will also confirm the client's objectives for the use of the spaces is kept in mind despite the inevitable changes during construction.

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Appendix 1

Sample Task List for Sensor Commissioning

Design

Confirm appropriate sensor technology	
Occupancy – passive infrared, ultrasonic, dual technology	_____
Daylight – stepped versus continuous dimming	_____
Combined occupancy and daylight	_____
Confirm overlaps of sensor coverage in large areas	_____
Confirm zoning	
Zone size and locations	_____
Zoning in relation to the daylighting simulations	_____
Provide override switches where appropriate	_____
Suitability of on/off light levels to the work done in the area	_____
Confirm that blind corners are provided with coverage	_____
Specs request a zero-delay test setting for occupancy sensors, where appropriate	_____

Shop Drawings

Sensor types confirmed as per drawing and specs	_____
Coverage patterns are confirmed with manufacturer	_____
Site instructions issued as appropriate	_____

Pre-occupancy

Sensor type confirmed	_____
Sensor location appropriate as per manufacturer	_____
Appropriate "lights on" level confirmed and recorded	_____
Appropriate "lights off" level confirmed (including step and dimming) and recorded	_____
Elapsed time has been set and recorded (to prevent over-switching)	_____
Sensitivity adjusted appropriately and recorded	_____
Coverage outside the area has been minimized	_____
Training of maintenance staff completed	_____
Information properly recorded in O&M Manuals	_____