FALL EDITION

Lighting & Lighting Controls

CONSULTING - SPECIFYING
engineer
eBOOK

Contents

CONSULTING - SPECIFYING engineer eBOOK

Understanding and navigating lighting standards and codes in building design, part 1

Michael Chow and Tony Staub discuss lighting and energy codes, standards and guidelines, focusing particularly on ASHRAE Standard 90.1 and the International Energy Conservation Code

Michael Chow, PE, CEM, CxA, LEED AP BD+C, principal at Metro CD Engineering LLC and Tony Staub, PE, LC, lighting design lead/electrical project engineer at Specialized Engineering Solutions discuss various lighting and energy codes in the Consulting-Specifying Engineer webcast "Lighting and Lighting Controls", standards and guidelines, focusing particularly on ASHRAE Standard 90.1 and the International Energy Conservation Code. They also discuss the importance of understanding and adhering to the requirements of these codes in different jurisdictions, considering that some local codes may be more stringent than the state level.

The following has been edited for clarity.

Michael Chow: When we're taking a look at lighting and lighting control systems, the first place to start is to take a look at the codes, guidelines and standards for lighting. We are going to be focused mostly on ASHRAE Standard 90.1, It encompasses HVAC mechanical, power, lighting is also included in there and we'll talk about that particular standard in a little bit more detail later.

So here are some more codes, standards and guidelines. We'll be talking more about

Back to TOC

Back to TOC

the International Energy Conservation Code and we'll also be talking about the IES. The IES is Illuminating Engineering Society and they have online documentation where they provide recommended foot candle levels for specific tasks and in spaces and also dependent upon the occupant age. The U.S. Department of Energy will talk about that a little bit more as well to the administer the comp check, which most of you should be familiar with that. That is a web-based or application-based system that allows you to show compliance with the energy codes. LEED has certain requirements related to lighting and commissioning. And the well building standard is also one that has a lot of lighting. Lighting as far as the design is concerned and goes into a lot of the quality of the lighting.

There are federal, state and local requirements as well too. ASHRAE 90.1 is updated every three years. And the 2022 update is forthcoming. It's like the IECC. It covers the most aspects of energy efficiency buildings, as we talked about earlier. Lighting is part of that, one of those systems. Some jurisdictions adopt this code and they also published or supplements in amendments.

For example, I'm in Ohio and there is a supplement where certain requirement of ASHRAE 90.1, it is not necessary and that's the 50% receptacle control. Next, we'll talk about the International Energy Conservation Code. And this is published by the International Code Council. It's also updated every three years and the most recent update is 2021 and just like the ASHRAE 90.1, it covers the building systems and lighting. Now it's not a carbon copy of ASHRAE 90.1 when it comes to lighting. Lighting items are very similar as you go across the two documents, but they're not the same. There is a section in the IECC that notice that ASHRAE 90.1 is an acceptable alternate compliance path. So that allows you to use either one.

Back to TOC

Because they're published every three years, typically the IECC allows you to adopt the 90.1 version issue two years before the IECC version. Now, keep in mind that there might be specific requirements. For example, in Ohio the 2012 IECC is in effect, but the ASHRAE 90.1 2007 is also in effect. So that's slightly different from what's stated here.

Next is Title 24 for California. This is one of the energy codes that is not directly based upon either the ASHRAE 90.1 or the IECC. It is also updated every three years. Title 24 is something that some of the items that are in there actually get incorporated in ASHRAE 90.1 or the IECC, an example is vacancy centers. Those are first introducing in Title 24 and they eventually made their way into lead and ASHRAE 90.1 as well. So next, Tony is going to continue the discussions on codes.

Tony Staub: These codes are something that I'm glad to see that we've got quite a few electrical engineers here and these are codes that you should be familiar with regardless then. But going to touch on a few of the lighting specific things that are held within these codes. So

NFPA 101: Life Safety Code is where you find the requirements that layout what is necessary or what is required for emergency operation especially, but for egress as well. There are a couple things in these codes that I see get missed or misunderstood from a lot of people, just because the lighting pieces of these can be a little bit hidden in-depth, from all the other things. At NFPA 101 of the biggest ones there is required illumination levels on stairs. Go take a look, 10-foot candles on every stair tread. That's one that in my experience has commonly been misunderstood or missed.

NFPA 70: National Electrical Code is used every day. Where we're really using that as it applies to lighting, is in how we are setting up the electrical systems to serve specific lighting functions. Depending on what type of building you're in, I personally do a lot of health care engineering and that health care, we are looking at Article 517 a lot, where there are very specific requirements about what lighting can and should be placed on the life safety branch, on the critical branch, on the equipment branch and on the normal branch. It's really telling you how to organize the circuitry for your lighting. It's really a lot of the same language that's used in NFPA 101. It's telling you a lot of the same things. This is where the 90 minutes for emergency egress lighting and things like that are showing up, are between NFPA 101 and IBC. They double cover a little bit. Michael's going to help us determine which codes are applicable for your project.

Chow: As we mentioned earlier that the comp check is available for the Department of Energy and if you go to energycodes.gov, that's a great resource. If you click on that link, it will take you to a website where you can enter the state that your project is in and it will tell you the current year for ASHRAE 90.1 that applies and as well as the IECC. Now, some cities and counties adopt their own energy codes that may be more stringent than the state level. And Tony has an example that he would like to share.

Staub: I'll take just a little short story here with what we deal with, especially in Nebraska. We had a situation where the state code was recently updated to a 2018 IECC and this exemption in Nebraska where if a renovation product or project is under 50% of the insured cost of the building, you're not required to meet the state energy code. We had situations where state energy code was a 2018 IECC and many local jurisdictions had the 2009 IECC. And you really needed to understand both of those things at the same time, because you might have been in a position where I'm in Omaha and a

Back to TOC

renovation project might not have needed to apply with the state code. In many cases they didn't, but there was still a locally enforced code. So really, that's a cautionary tale to make sure that you are looking at both the state and local codes to see which ones are going to apply because the state code might not matter at all, but you might still have a code requirement. Just make sure that you're checking all of those layers of different code requirements and make sure that you're meeting the most stringent code that you're required to meet.

Chow: The owner's project requirements (OPR) contains elements for design and should contain requirements for elimination and related items. This document should be done at the beginning of a project and this is sometimes the owner will give you a list of items that they require and sometimes there are some gaps. It's important to have this dialogue with the owner to make sure that you don't end up all the way at the end of a project and find out that you didn't meet the owner's requirements. And sometimes the owner's requirements, they don't line up with the energy code.

For example, we had a project where the owner wanted all halogen lighting and that did not meet the energy code. We explained this to the owner at the beginning of the project and we were able to work in energy efficient lighting while still meeting the owner's project requirements.

Consulting-Specifying Engineer

Back to TOC

Adopting full electrification for large venue facilities

Buildings of all shapes and sizes must be willing to invest in an all-electrical solution – especially buildings with large energy demands.

Current trends indicate as we move forward with electric vehicles (EV), photovoltaics (PV) and high efficiency heat pumps (COP 2.5 and greater), the overall electrical energy consumed in the United States will rise more than 30%. However, given the forecasted gains in the overall efficiencies of our electrical infrastructure, that consumption will be reduced by more than 50%.

To achieve the forecasted gains, buildings of all shapes and sizes must be willing to invest in an all-electrical solution – especially buildings with large energy demands. This solution requires agreements and investments across all aspects of the electrical infrastructure from the utility plants and electrical grids down to the HVAC equipment within the smallest tenant improvement (TI) space. While this article could dig deeply into all the different facets of that process, what is most important is understanding the implications of electrifying buildings that cause the largest fluctuations of demand on the electrical grid.

Venue facilities are known power and energy hogs. However, most of these facilities are not used more than a few days a week or less, and sometimes only a few times during an entire year. The fluctuations on the grid caused by such facilities can have implications on other buildings utilizing the same utility service. To mitigate these fluctuations, a strategy called Load Shift needs to be utilized. Load Shifting consists of using multiple techniques, like Peak Shaving, to reduce the highs and lows of electrical

Back to TOC

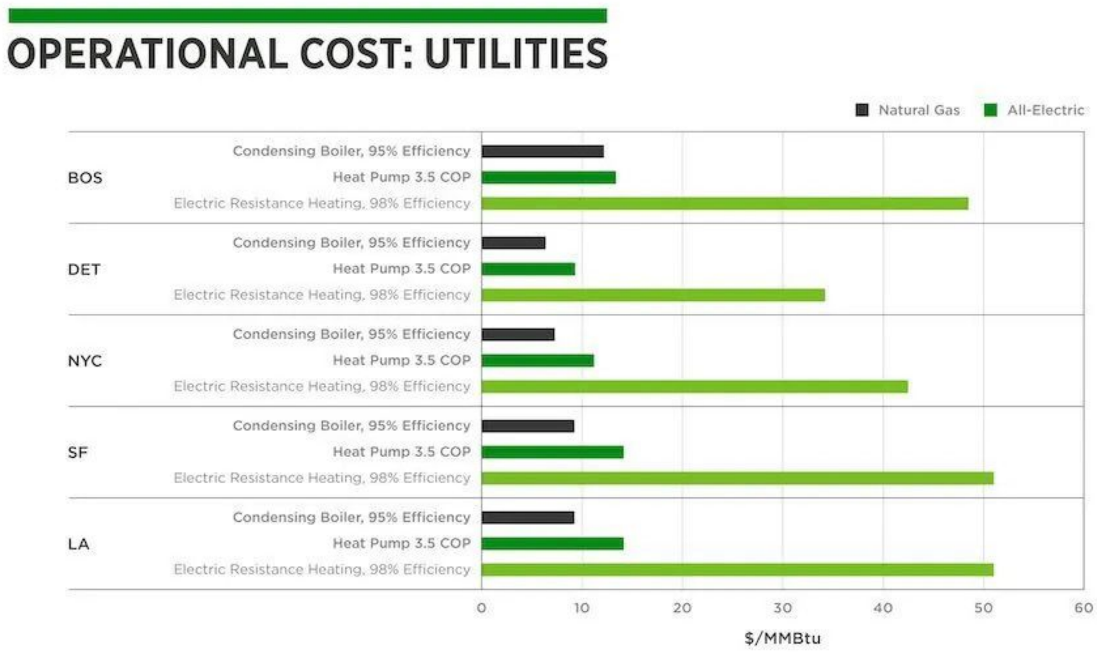
Back to TOC

consumption. By bringing these highs and lows on the grid to a plateau, the overall electrical system can become more stabilized. There are multiple ways to work with utility companies to help stabilize the distribution grid. However, what we are most concerned about in this article is what we can do within facilities themselves.

Grid stabilization approaches for large facilities

Traditionally, Load Shifting is achieved using co-generation or peak shaving diesel/natural gas generators. However, introducing additional energy generation sources from fossil fuels isn't the solution. The key to achieving the stability we are looking for is to use existing technologies that have been improved by the ongoing push toward electrification. Thermal storage, battery storage and demand response building controls are just a few. When it comes to thermal storage, there is often program space that can be repurposed adjacent to central plants, main electrical gear and other energy intensive use equipment that can use that thermal storage capability. Chillers can use cold water or ice storage to decrease power usage during cooling peak times. The same can be said for the boilers and hot water storage. Thermal storage also has some other benefits that we will get into later. For now, though, the next technology that should be implemented is adding battery storage. Batteries and their inherent electrical storage capacity have far-ranging uses within venue facilities. Normally, batteries are used for emergency lighting, UPS systems or PV energy storage. Using batteries is often only discussed for these three applications because of perceived limitations and the general unwillingness to use batteries because of their high maintenance requirements. However, we can adopt using batteries in a similar way as thermal storage by charging them overnight/off peak so as to be used during peak times. With PV gaining even more traction and the desire to reduce overall greenhouse gas emissions, batteries have become a much more viable solution even compared to just three or four

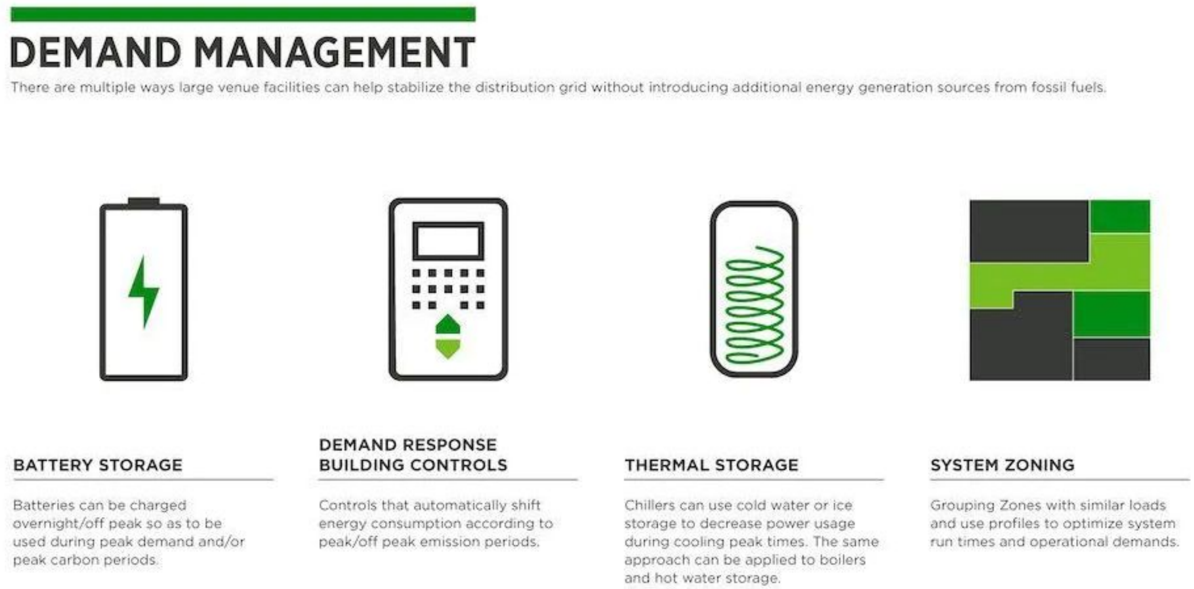
Back to TOC



Courtesy: Henderson Engineers

years ago. As with batteries, demand response controls have been used for years and are incorporated in multiple energy codes and recommended for energy efficient buildings.

Thermal storage is a great way to not only have an energy efficient building, but to also improve grid stability while fully electrifying buildings. But there are other benefits of using thermal storage that are not as obvious, including the reduction of equipment. By sizing thermal storage to offset or even completely supply the cooling and heating for day-to-day operations of a venue facility, you remove the small-scale chillers and boilers that are typically needed. This in turn opens more space for energy efficient storage options and equipment.



Courtesy: Henderson Engineers

While space is always at a premium regardless of building scope or size, it's arguably even more crucial within venues whose highest priority is the fan experience. A fan experience, though, cannot be achieved by a building that is not planned appropriately for energy efficiency and HVAC comfort. It seems odd to think of building efficiency tied to patron comfort, but one does not have to be sacrificed for the other. By planning to use the facility to its full potential, the central plant, thermal storage and other energy efficient equipment can be used to power and condition the day-to-day operations of a sports team, or the adjacent offices, or even part of a university campus facility. Tying administration, office, and training buildings together with venue utility loops allows for an electrified central plant to be used year-round. This decreases electrical loads on adjacent buildings, relieving some of the added load to the grid from the overall electrification effort.

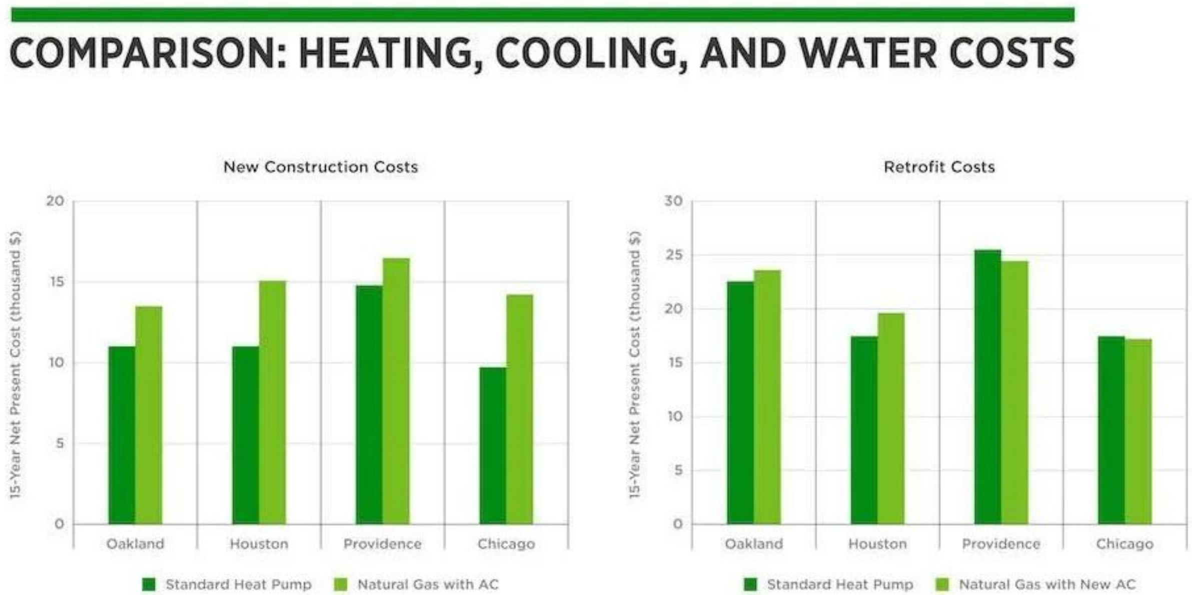
Back to TOC

Back to TOC

Taking these integrated approaches to the design, the project team can examine how to make the overall building better and more efficient. As discussed previously, this space could be devoted to thermal storage for heat/cold energy recovery or set up to hold more interactive building management system interfaces. Using the building management system interfaces, the building can be set up with adaptive temperature control schemes to adjust the supply/set point temperatures in the facility to decrease peak electrical demands. Another technology that can be implemented on the controls side to assist in the electrification of buildings is system zoning. This technique works with the adaptive temperature controls scheme and shifts heating/cooling load to the areas that need it most, helping to decrease demand on the HVAC and electrical systems.

Other ways to decrease the demand on the electrical systems are not traditionally part of the electrical engineer's design. These include a more concentrated effort working with the architect and owner to identify where improvements to the building envelope can be made. Typically, this would include better insulation, glass, and general improvements to mitigate energy losses through the construction of the building. Now, more attention should be paid to using the building mass to store thermal energy. Much like a large concrete parking garage maintains temperature, a building as large as most venue projects can use that thermal mass to its advantage.

With all building energy solutions, regardless of the use of Load Shifting and electrification efforts, there is a large dependency on utilities and the resiliency of the distribution grid. The amount of energy consumed, whether electric or otherwise, requires a partnership between the utility and the venue. It is up to the design team and ownership group to make the efficiency and electrification goals clear at the onset of project design. Design teams need to explore what incentives are available from the utility for



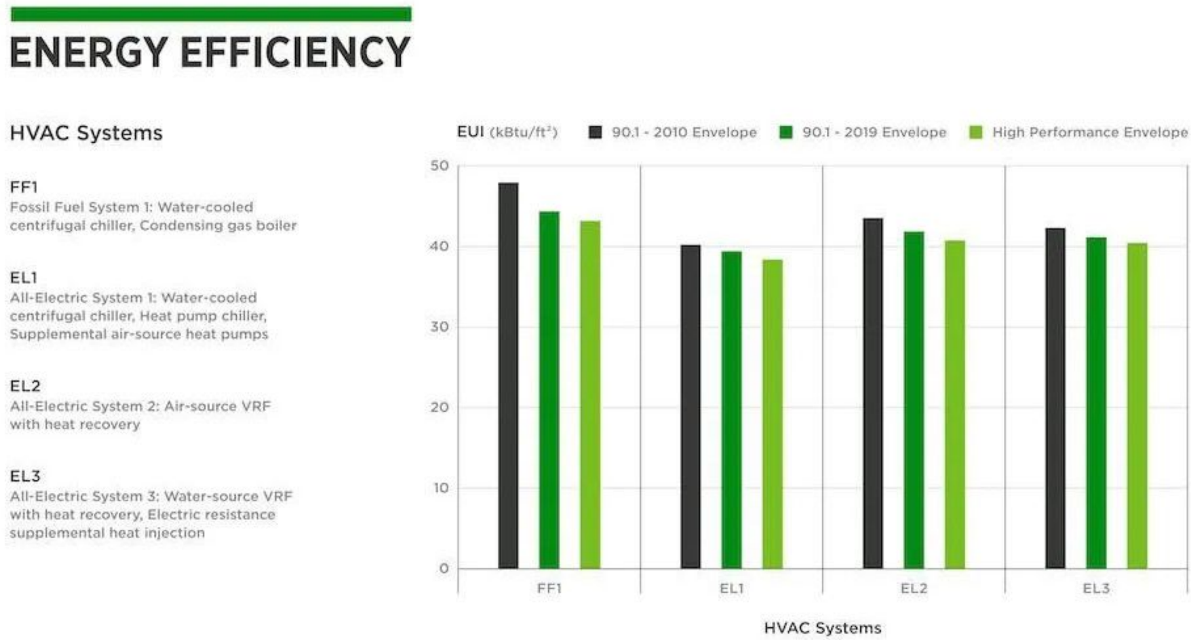
Courtesy: Henderson Engineers

electrification and the utility needs to explore what governmental subsidies will be given to improve the grid to allow for the electrification. Along with the grid improvements, the utility will also see increased revenue due to the electrification effort. With that increase in revenue, the utility may be more willing to work out a more favorable rate and fee structure for the venue facility.

While not directly tied to building electrification, a venue can create other partnerships through branding, working with local trade schools and manufacturers of energy efficient equipment. By partnering with brands in the energy industry, venue facilities actively show how invested they are with being as efficient as they can be. Two drawbacks of being on the leading edge of electrification and energy efficiency is the lack of skilled labor and the limited number of manufacturers who can build the equipment


Back to TOC

Back to TOC



Courtesy: Henderson Engineers

needed. By working with trade schools, either via offering grants or scholarships, the venue facility and utility company can work together to further the goals of training for the future and going fully electric. Helping nurture future skilled laborers needed to further electrify additional buildings will then help incentivize additional manufacturers to reinvest or continue to invest in energy efficient electrical solutions.

Full electrification is worth pursuing

What are the drawbacks for going for full building electrification if the technology is there? We have hinted at a few of these throughout the article, but the main two drawbacks are up-front costs and an unwillingness to change or try new things. While no facility, venue or otherwise, wants to be a guinea pig, venues could benefit more from electrification when compared to a small retail tenant, for instance. It is all about econ-

omy of scale; a retail tenant in a mall may only need 200 amps of power for full electrification whereas a venue facility may need 20,000 amps of power.

This amount of electricity gives the venue much more flexibility to invest in more efficient sources of heating and cooling. It also gives the design team and ownership something – an opportunity to save money for the venue and the utility since less power demand from the venue means less infrastructure and grid improvements. However, the costs to invest in the more efficient electrical equipment must be recognized and discussed at the earliest concept design phases of a venue. It is imperative that all parties understand that electrification is achievable for an NBA arena, NFL stadium or even a smaller collegiate soccer and lacrosse facility.

High efficiency electric boilers, heat pumps and electrical cooking equipment are the first pieces of equipment to investigate in an electrification study. Couple that equipment with point of use electric water heaters and in-duct electric heaters and the venue is almost fully electrified. The costs for these electrified, high efficiency solutions at first glance appear to be higher than having a natural gas equivalent solution.

However, close examination proves otherwise. A great example is cooking equipment. Even the most progressive chef may balk at using anything but natural gas for cooking, but look at all the infrastructure (gas service, meter, pressure reduction equipment, potentially thousands of feet of piping, venting, etc.) that is required to have a char broiler or gas range when an electrified version is readily available. Now think of the savings in piping, flues, etc. for a natural gas central plant scenario. All the equipment needed for a central plant can be replaced with more efficient electrified versions.

Back to TOC

Back to TOC

If large enough equipment is hard to source for the boilers, point of use systems can be provided. The next hurdle to overcome is the shift from the current technology to the all-electric versions. Gas equipment has been used for multiple decades and almost any maintenance professional completely understands how that equipment functions, how it needs to be repaired and where the common points of failure are. The newer electrified equipment is perceived to be much more difficult to be maintained, repaired, or replaced. However, the systems are as easy to replace and maintain as their gas counterparts. The electrified equipment is also significantly smaller than its gas counterparts.

Electrification is possible for all building types right now. As electrification becomes the goal across multiple project types and sizes, but especially for venue sized projects, coordination of expectations and goals becomes the most important part of the design process. The key is for all parties to be on the same page regarding the technologies available now and the future goals of the facility. This gives owners and operators of venues the ability to remove an energy source from their buildings (natural gas), decreases the overall energy consumed and sets the facility up to achieve even more sustainability goals as the efficiencies of boilers, chillers and heat pumps continues to rise.

Venue facilities are known power and energy hogs despite their general limited usage. Building electrification provides an opportunity to deliver energy efficiency and is a key strategy to reduce and eliminate long-term operational CO_2 emissions.

Matt Moore

Matt's *extensive experience in electrical engineering and sports lighting design makes him our go-to expert for venues of any scale. He has worked on Q2 Stadium, the first dedicated MLS stadium to install an entire field lighting system of tunable RGB LED lights.*

How to design human-centric lighting controls

As health care projects become more patient oriented, human-centric lighting design and lighting controls are taking center stage

To achieve the best lighting control strategies, it is imperative to look at each type of space separately and define criteria that is useful for the design. For example, a health care environment involves a plethora of different programs and the individuality of each space affects the lighting control strategy dramatically.

This article has been peer-reviewed.As an electrical engineer or a lighting designer start on a new project, they are usually faced with comments from clients and users about the importance of lighting controls in a health care environment. The ease of controlling lighting is imperative for a great patient experience.

In some existing facilities, the lighting can be harsh and directional. The ability to control the lighting while in bed can be nonexistent. Patients can struggle to walk through a crowded room with the IV pole just to turn the lights on and off.

Human-centric lighting design could lead to a positive patient experience in health care facilities. As building designers embrace technology and the need for net zero, the careful balance between cost, comfort and energy efficiency is the way to the future. Simply providing a lighting controls solution that meets minimum code requirements might not be the best approach, especially when designing state-of-the-art health care facilities.

Back to TOC

Back to TOC

How human-centric lighting uses lighting controls

Figure 1: Caregiver station with central touchpad to control corridors. Courtesy: HDR, Dan Schwalm PennFIRST

How can a lighting designer achieve a human-centric experience using lighting controls? The client and the users must be on board with the design and in tune with the future facility. A health care project involves the interactions of multiple experiences including the patient, visitor and staff experiences. Each experience type carries a diverse set of requirements from the code perspective, and also from the human or user's side.

These requirements should be tailored to the needs of each facility. The complexity of the design requires the proper layering of lighting and lighting controls to achieve maximum comfort for the patient while maintaining a highly technical and functional space for the caregiver.

Let's study each category individually:

Patient experience: It's important for a patient to feel comfortable when coming into a hospital environment. Proper lighting design can play a key role in patient outcomes,

Back to TOC

which is augmented by the lighting control experience. When a patient has personal control, they can feel less stressed in an already-stressful situation. In fact, ANSI/IES RP-29-22: Recommended Practice: Lighting Hospital and Health Care Facilities reinforces the need for flexible patient controls to assure patient comfort and satisfaction.

Increasing patient satisfaction is one important metric hospitals look for to achieve the total performance score (TPS) managed and rated by The Centers for Medicare & Medicaid Services. A low TPS can reduce Medicare payments to a hospital due to poor satisfaction under the "person and community engagement domain" and due to frequent re-admissions. Body of evidence referenced by ANSI/IES RP-29-22 concluded that patient comfort also aids in faster healing and a quick turnaround. This in turn leads to better infection control as the patients' stay in the hospital shortens.

Visitor experience: A visitor's experience is similar, as the goal of controls for that category is to provide intuitive, easy-to-use controls. Providing care for a loved one should not come with the frustration of operating multiple keypads and complicated controls. Incorporating intuitive localized controls into the lighting design for the visitor zone provides localized lighting to the area without disturbing the patient's sleep and respite. This helps reduce the trial-and-error efforts for a visitor to adjust the lighting in the visitor zone.

Staff experience: Staff controls can be used to help increase their efficiency and accuracy. For instance, lighting controls that turn on controlled beam task lights at staff work zones are strongly desirable. These controls should be clearly defined and located near their tasks as well as near the entrance to decrease the need for staff to find the proper switches. Touchless controls for task lighting are also strongly encouraged

to reduce staff contamination as described in the ANSI/IES RP-29-22 Lighting Controls Systems section.

Figure 2: Patient room with lighting keypads on the headwall and in the family zone. Ambient, uplight, charting and family zone on. Shades are up for daylighting and views toward the city. Courtesy: HDR, Dan Schwalm PennFIRST

How to achieve these lighting control strategies

To achieve the best lighting control strategies, a health care case study will be used: Penn Medicine's Pavilion at the Hospital of the University of Pennsylvania. The state-of-the-art facility was designed and constructed by the integrated project delivery (IPD) team PennFIRST, which included HDR, Foster + Partners, BR+A, L.F. Driscoll and Balfour Beatty.

The facility opened in October 2021 after six years of working through an IPD process. During the design — which involved the colocation of the team, including client, designers, engineers, construction managers, estimators and contractors — lighting controls were at the center of multiple in-depth conversations focused on patient experience and comfort. Each area was discussed with the users, client and contractors to achieve the best design solution possible.

Back to TOC

Patient rooms

Figure 3: Caregiver station to override fixtures above patient rooms and linear corridor lighting separately. Charting station window control is on transparent mode to check on patient while the door is on opaque mode for privacy. Courtesy: HDR, Dan Schwalm PennFIRST

For the hospital, the patient room had to achieve maximum comfort: with zones for ambient illumination, patient reading, night light, charting, sink and visitor zones. The IPD team produced a solution that integrated all lighting controls via a bedside touchpad. The touchpad can do the following: control lighting and heating, ventilation and air conditioning (HVAC); achieve digital visual communication with the care team; enable patients to order food; control the TV; and enable communication with loved ones outside the facility.

The controls depended on a visual screen that was easy to read and understand, so patients have an intuitive interface without the need to learn modern technologies. Most lighting zones mentioned above could be controlled and dimmed from the touchpad individually. Each zone is shown on the app, so the patient doesn't have to guess the appropriate zone.

Back to TOC

Back to TOC

From the touchpad, the patient has control over their environment and they can dim the different zones as desired to achieve the best scenario possible for their comfort. They can also control the shades, lowering and raising them as desired. The scenarios are unlimited and flexible so different lighting settings can be achieved when the patients want to watch TV, read, order food, communicate with the care team or just relax.

For the less savvy patients, the traditional integration with the nurse call system was also introduced to control patient-oriented zones, such as the reading and ambient zones. An "all off" button on the nurse call was also introduced in case the nurse leaves the room with some lights on.

The caregivers also control a given set of keypads at localized areas around the room. At the charting station, two buttons control the tight beam chart task light, to not disturb the patient and the uplight in case more lighting is needed. In addition, the bedside station controls the exam lighting, reading light for the patient, ambient illumination and uplights.

At the main entrance, a keypad is divided into two clear sections: the upper section offering easy access for the patients/visitors to control the ambient illumination and uplights, while the lower section allows caregivers to control the charting lights so they can see their way into the room without disturbing the patient with overhead lighting.

The visitor zone has its own keypad for local controls of the lighting in that zone, as well as control for the window shades. All buttons on the patient room keypads are properly labeled with a master raise and lower key to control the lights.

Back to TOC

Lighting controls in patient corridors

Patient corridors are critical spaces, where multiple functions coexist. Patient corridors are used by visitors as wayfinding, for the circulation of patients and as a potential work zone for caregivers in case of emergency. The control system must accommodate each function.

Figure 4: Charting station windows and patient doors on opaque mode for privacy. Courtesy: HDR, Dan Schwalm PennFIRST

The lighting in the space consists of a series of linear lights on the core wall and a wall wash on top of each patient room for wayfinding. The lighting control system schedules the lighting to go on at 100% level in the morning, until 7 p.m. when the linear lights gradually dim down to 30% and the wall washers dim down to 50%. This creates a comfortable, human-centric environment for the patients where they can sleep at night and avoid spill lighting into the rooms.

For the remaining hours of visiting time, there is still ample illumination above the patient bedrooms for proper navigation. In the case of clinical emergency at nighttime, overrides are provided at each nurses' station using an intuitive touchpad. The caregivers then can attend to a patient in need of care, in the corridor with ample illumination.

Back to TOC

Charting stations

Figure 5: Main keypad at entrance for lighting control by caregiver and visitors. Windows and doors are on transparent mode. Sink lighting is on. Courtesy: HDR, Dan Schwalm PennFIRST

Charting stations are also part of the corridor and they are intended for the care-giver to process information and medication locally. One charting station can moni-tor two rooms at the same time. A linear fixture with regressed lens was used to reduce light spill into the rooms. Each charting station lighting is controlled separately for maximum control and to avoid patient discomfort during quiet times.

The doors and windows into the patient rooms include smart glass for patient comfort. The glass can be controlled by the caregiver at the charting station, to turn the window and door separately. This ensures that the patient can keep their privacy with the door on opaque setting, while the caregiver can monitor the patient through the window on the transparent setting. The patient also has control of both the glass and window from inside the patient room unless the care-giver overrides that functionality.

Emergency life safety lighting in the corridors is controlled via a UL 924-rated device that ensures the lighting in the corridors are dimmed and controlled together with

Back to TOC

the regular lighting settings. The days of having dedicated noncontrolled emergency fixtures in a patient corridor are gone. The patient's experience is a primary goal in ensuring their comfort, therefore controlling the spill light into patient rooms at night is critical.

Lighting control challenges

What are the challenges that designers face to achieve a more human-centric experience for a health care environment? Electrical engineers and lighting designers are faced with challenges due to updated, more stringent energy codes. Moreover, they are also challenged with an ever-changing environment of technologies and health care criteria.

The job of the designer is to assess those challenges and establish a set of priorities to meet client aspirations, project goals, budget and code.

Circadian rhythm entrainment

Due to the advancement of tunable white technology, circadian rhythm entrainment became a reality. Tunable white technology is the ability of changing the color temperature of a source following the black body curve by mixing two or more different color sources. Entrainment is a fundamental property of circadian systems by which the period of the internal clock is synchronized to the period of the entraining stimuli.

Research cited in the health and wellness section of ANSI/IES RP-29-22 reinforces the effects of entraining patient's circadian rhythm on increasing patient outcomes, accelerating healing and creating a human-centric environment for the patient to overcome the harsh clinical environment. Tunable white technology research cited by the health

Figure 6: Patient room lighting control scenarios. Courtesy: HDR

and wellness section of ANSI/IES RP-29-20 also suggests the amelioration of the caregiver's health and work environment especially for the ones that work late and night shifts.

However, tunable white technology comes with a slew of challenges to the lighting control system. There is currently little standardization of the technology which creates different comparative color temperature between different fixtures depending on binning. LED binning is a practice carried out to ensure high quality and consistency in the performance of LED light output and color. The technology is also still cost prohibitive in most health care projects and the cost is added to both the lighting fixtures and the lighting controls.

Back to TOC

Back to TOC

To overcome some of these challenges, it is recommended to put different fixture types on separate zones to avoid the difference in color temperature. This way each individual lighting type can be tuned separately to achieve the desired color temperature in the space. Another recommendation is to use the same manufacturer for the tunable white fixtures so the technology and the dimming rate, as well as color consistency, is the same.

Newer Digital Addressable Lighting Interface (DALI) protocols such as DALI DT8 and DALI-2 protocols also currently offer a solution for some manufacturers to provide a good standardization to follow the black body curve and provide another level of consistency.

Emergency lighting

As described in the case study, the future of health care lighting is through using controllable emergency lighting. To provide a human-centric comfortable solution, emergency lighting cannot be left on at night. This can be a burden to the budget, especially if every fixture is provided with a separate emergency module or if they need to be circuited to both the normal and the emergency circuits.

A suggested solution is to put long run fixtures on the same zone and circuit to use the same emergency module. Moreover, keeping the emergency lighting to the required minimum by code and by facility requirements can reduce cost and keep the project in budget. Some wireless lighting control systems can also be conducive since they reduce the amount of wiring.

However, one must keep in mind the requirements by NFPA 70: National Electrical

Code, where some lighting control systems might not meet new emergency life safety requirements. It is also critical to consult with the client as some health care providers do not prefer wireless systems as they can cause electromagnetic interference with their systems and have batteries with short life spans which can also cause a maintenance issue.

Electromagnetic interference

Hospitals are a living structure of devices and equipment. With the advancement of newer wireless technologies, interference between different equipment in a hospital can create a serious challenge. Some occupancy sensors operate on the harmonics of newer real-time locating systems equipment and can interfere with them.

To use the advantages of wireless systems for a human-centric design, a careful investigation of the system frequency and its harmonics is crucial. If the project timeline permits, it is also encouraged to do a mock-up during the design phase with the various hospital and lighting equipment, which can lead to specifying the appropriate lighting control system early in the process.

Integration with BAS

A key element to achieving human-centric lighting controls is the capability to integrate multiple systems together. Because the building automation system (BAS) is often preferred by facility managers as an integration hub for a project's major systems, it is crucial to integrate seamlessly with it.

Standard BAS protocol integration — such as BACnet, Modbus or others — is a feature in most lighting control systems. It is important to have a lighting control system that

Back to TOC

Figure 7: Patient corridor at morning time and nighttime. Courtesy: HDR

uses either no gateway with the BAS or minimal gateway. The former can be achieved using a lighting control system that uses the native BAS protocol.

Hence, control points between the two systems can be minimized and a direct two-way communication can be achieved. If the integration is successful, systems such as shades, smart glass, HVAC and others can be controlled from the lighting control system devices that already exist in the space. Reducing cost and consolidating keypads to lessen confusion in the space. In the case of a nurse call system, it can control lighting zones seamlessly as well.

A careful layout of the sequence of operations and how the system should operate makes the commissioning of the lighting system easier and less time consuming. This operational sequence should include the lighting zones and any integration between these different systems.

Back to TOC

Expandable systems

Because health care projects are projects that last for a long time and since a lot of upgrades can happen to the hospital, the lighting control system should be expandable and future proof. The ability for the systems to receive new products and upgrades is crucial. A distributed smart addressable system is a good approach.

Current lighting control systems are moving away from large, centralized lighting control panels toward more flexible plenum or fixture mounted lighting control modules. Each strategy comes with its own advantages and setbacks.

For instance, integrated controls in fixtures can cause a higher initial fixture cost but provides more flexibility in terms of future zoning. Fixture mounted controls and smart drivers are the way to the future so devices can be added to the lighting control grid seamlessly. A key approach to this is the standardization of both control modules and drivers.

Plenum-rated panels can be challenging in health care environments for maintenance above ceilings. This is why they are typically located in the corridors to avoid patient room shutdown. Plenum-rated panels are great to reduce cost and to zone multiple fixtures together in large areas such as corridors and lobbies. DALI and addressable systems represent about 70% of connected lighting systems according to the EU Joint Research Centre (JRC) and most European manufacturers have it as a standard offering. The technology is slowly making its way into the United States. If those are widely available, a system can be expandable.

The key to standardization is contacting manufacturers early in the process and com-

Back to TOC

Figure 8: Caregiver station at morning time and nighttime. Courtesy: HDR

municating to them the importance of integrating specific drivers into their lighting fixtures. If the quantity is available, manufacturers will certainly be open to use such products.

Given the above-mentioned challenges, the best way to achieve a great design is to tailor it to the user's needs. A strong understanding of what the client requirements are is crucial. Clear communication between the users and the design team is imperative. This communication can be visual, where different control scenarios can be shown or be in the format of a schedule or a diagram to indicate how zones are controlled and what type of devices are used.

Depending on the project timeline and delivery method, at least one meeting per phase for lighting controls is encouraged so the client can see the progress and comment on the changes. On larger immersive projects, the frequency of that review can increase to a weekly basis to ensure proper understanding of lighting controls by the client.

Back to TOC

Back to TOC

It is encouraged to show the different control scenarios to the client visually in the space. Renderings can be used to simulate them and to define how the space will look when built. This accelerates the sign-off process and eliminates future questions and requests for information.

It is also crucial to develop riser diagrams, schedules, details and sequence of operations that are reviewed by the client early in the process. The details and diagrams should be generic in nature to allow showing the intent without locking to a specific manufacturer and to make bidding easier. Documenting this information should be clear and consistent. It should also indicate which zones are dimmed, on emergency and the devices that control each zone.

Finally, a good lighting control system that provides a human-centric environment is critical for patient healing and eventually a better patient outcome. Specifying touchless controls, providing the patient with more controllability and circadian entrainment can promote faster healing, which can increase patient outcomes and reduce infection. This helps having a better return on investment as patient satisfaction and TPS scores increase. It also offers a viable solution for expanding in the future and adding the most current version of the lighting control system.

Paul Daniel

Paul Daniel, LC, LEED AP, *is a senior lighting designer and senior professional associate at HDR.*

Developing lighting control design to compliment standard lighting practices

As a complement to other ANSI/IES lighting practice standards, LP-16 provides a roadmap for documenting lighting control intent and sequence of operations throughout the design process

ANSI/IES LP-16-22, Lighting Practice: Documenting Control Intent Narratives (CIN) and Sequences of Operations (SOO), as its primary objective, provides a standard for documenting lighting control design intent. Once that intent is developed by the designer, in coordination with the owner, user and/or architect, it needs to be translated into contractually enforceable and buildable construction documents that are clear and easy to understand by the contractor, manufacturer and installer.

The inaugural 2022 edition of LP-16, developed in collaboration between the American National Standards Institute (ANSI) and the Illuminating Engineering Society (IES), is not intended to be a standalone document or a design manual. In coordination with ANSI/IES LP-6, Lighting Practice: Lighting Control Systems – Properties, Selection and Specification and ANSI/IES LP-8, Lighting Practice: The Commissioning Process Applied to Lighting and Control Systems, LP-16 is intended to be a reference of best practices for developing and documenting the functionality of the lighting controls systems.

As a result, owners and occupants will be provided with a lighting system that functions as intended with less confusion and errors during the construction process.

Defining the CIN and SOO

ANSI/IES LP-16 outlines two documents that define the lighting controls system.

Back to TOC

Back to TOC

The CIN is meant to outline the requirements of the project and should be written in a format that is easily understood by all parties. The CIN should start with how the project owners and/or users intend the lighting controls system to operate including how the users will interact with the system and how the system should respond to inputs. If the overall lighting controls system is made up of multiple connected systems, the CIN should define how these systems will interact with each other.

The CIN should be written in complete sentences and in plain language and should complement the owner's project requirements (OPR), conveying how the needs of the owners and/or users will be met by the lighting controls system. For example, electrical room lighting narrative might include:

"Electrical rooms should have two manual switches and should not rely solely on automatic shut-off. Normal lighting should be controlled by manual switch and occupancy sensor. Emergency lighting should be controlled by a separate manual switch and shall turn on to 100% upon loss of normal power."

The SOO is meant to be a part of the construction documents and is intended to outline in precise terms and instructions how the lighting controls system shall perform and respond to inputs from individual occupants and connected systems and sensors. The SOO is an enforceable contract document and shall be written in unambiguous instructions to the contractor, integrator and/or commissioning agent.

An example that might be found in the SOO as it relates to electrical room lighting is as follows:

"A manual switch shall be provided to control all normal lights in the space. Ceiling occupancy sensors shall be provided such that all spaces within the room are within the minor motion range of the sensor, on all sides of free-standing equipment and shall be connected to the manual switch. Normal lighting shall turn off after 30 minutes of vacancy. Emergency lighting shall be controlled through a separate manual switch and shall be provided with a UL 924 relay. Emergency lighting shall turn on to 100% upon loss of normal power."

System design

It is important that the design of the lighting control system be considered at all phases of a project. Often, design of lighting controls is deferred to the later phases of the design process. This could lead to missed opportunities for integration or deviations from client or owner preferences outlined in earlier stages of design.

ANSI/IES LP-16 outlines ideal steps to consider at each major design milestone, including review and approval by applicable parties. Both the CIN and the SOO should be developed at different levels depending on the design phase as outlined below.

Schematic design

The CIN should start its development during the schematic design (SD) phase. Developed in conjunction with the OPR, the CIN should translate the overall needs of the owners and/or users into a space-by-space description of the lighting controls system. If the owner and/or user needs remote control or integration with heating, ventilation and air-conditioning (HVAC) or audiovisual (AV) systems, those requirements should be included in the CIN during this phase.

Back to TOC

Figure 1: Install example showing wall controls and combination occupancy sensor/photocell. Courtesy: SmithGroup

Local codes, standards and certification standards that will affect the design of the lighting control system should also be noted in the CIN at this time. Particular attention should be given to the locally adopted energy code. Although the two primary standards adopted as local energy codes, namely ASHRAE Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings and the International Energy Conservation Code, are aligning version by version, understanding the minimum requirements of the adopted version can have significant effects on control devices requirements, control strategies and sequences of operation.

At the end of the SD phase, the CIN should be a thorough outline of the system and the design team should solicit feedback and approval of the approach by the owners and/or users. The SOO is typically not defined during this design phase.

Design development

The design development (DD) phase is the most critical time in the development of both

Back to TOC

Back to TOC

the CIN and the SOO. During this time, the designer will detail out all the spaces in the project and may further describe each space's intent. During SD, the CIN may indicate that conference room lighting controls shall integrate with the mechanical systems.

During the DD phase, this requirement may be refined to indicate that the office lighting controls shall integrate to the building's building automation system (BAS) through occupancy sensor dry contacts for demand control ventilation. The CIN may also detail the differences between large and small conference rooms as well as ones that have integration with shades and AV systems. If the conference room has multiple zones, such as general lighting, conference table pendant and perimeter wall-wash, the designer should detail out how those different zones may be triggered.

DD is also the phase when the SOO starts to detail the system requirements as outlined in the CIN. Each space within the CIN should have a corresponding space in the SOO. At this stage in the design, it may be too early to define exact thresholds and setpoints, but the structure of the SOO should be set up to easily include those later.

In the above multiple zone conference room example (see Figure 2), the SOO may define each zone with multiple setpoints and use a placeholder for the precise values:

- General lighting: a: 0%; b: x%, c: y%; d: z%; e: 100%.

- Conference table pendant: a: 0%; b: x%, c: y%; d: z%; e: 100%.

- Perimeter wall-wash: a: 0%; b: x%, c: y%; d: z%; e: 100%.

Table 1: Lighting setpoints

ZONE	Setpoint a	Setpoint b	Setpoint c	Setpoint d	Setpoint e
General lighting	0%	x%	y%	z%	100%
Conference table pendant	0%	x%	y%	z%	100%
Perimeter wall wash	0%	x%	y%	z%	100%

Figure 2: Preliminary sequence of operations setpoints. Courtesy: SmithGroup

Just as during the SD phase, it is important that the owners and/or users review and provide feedback and ideally approval, of both the CIN and SOO. If the design team works closely with the owners and/or users during SD and DD, the CIN should be essentially complete at this point and the SOO should not need major revisions.

Construction documents

In the construction documents (CD) phase, the SOO turns into a contractually enforceable document. At this point, the exact requirements for each space shall be detailed and aligned with all other documentation such as the specifications, system diagrams, zoning requirements and panel or relay schedules.

If the design team has worked closely with the owners and/or users, this phase should mostly consist of further detailing out each space. If major changes arise during the CD phase, it is important that the OPR is referenced for compliance and the CIN is updated to align with the new direction.

The CD phase is also the last chance to verify that all sequences meet the minimum requirements of the locally adopted energy code. At the end of the CD phase, the CIN, SOO, drawings and specifications shall be in full alignment and the owners and/or users shall approve the complete set of documents before bid and construction.

Back to TOC

Lighting control strategies

Section 5 of ANSI/IES LP-16-22 details several common control strategies, both by strategy and by space type. Within the text, examples are provided for both the CIN and the SOO. It is not the intent of the standard for a designer to copy these examples verbatim but use them as a reference and to tailor them to a specific project.

By reviewing the examples, a designer can understand the difference in language and level of detail between the CIN and SOO. Although not exhaustive, the standard does reference several control strategies, such as high-end/low-end trim, emergency response, room partitioning and spectrum adjustment that may not be found in every project type and therefore provide a level of detail that a designer may not arrive at when first considering how to develop those strategies into the CIN and SOO.

For this reason, it is important to reference the standard for guidance and examples on each new project.

Integration with other systems

As lighting control systems become more sophisticated, some can control or interface with other building systems such as AV, HVAC, security systems or motorized window shade controllers. This interface often involves multiple contractors working together to realize the design intent.

Components that allow for communication with the lighting control system and implementation of the lighting control SOO are not part of the lighting control package, such as touch-panels, thermostats, network switches or communication gateways. When components that interface with other systems are part of the lighting control package, the contractor and integrator need to fully understand what needs to be

Back to TOC

Back to TOC

communicated and how, to achieve the desired functionality.

Clear, concise and complete documentation is necessary, to ensure that all parties understand their scope of work and how the systems need to communicate to achieve the desired result. Section 6 of ANSI/IES LP-16-22 provides examples of how these other systems may integrate with the lighting control system, which system initiates an operation and how each system shall respond.

Lighting control matrix

For large projects with complex control strategies or significant quantities of differently controlled spaces, a written SOO included in the specifications may be the best way to document the lighting control functionality. For many projects, however, having as much information in the drawing set is the best approach to ensure the contractor, manufacturer and integrator have the complete picture. This is where a lighting control matrix can provide a complete and concise representation of the design intent.

The lighting control matrix should still consider all the elements of the SOO. This may require the lighting control matrix to evolve through the design phases to not appear incomplete. For example, in may be useful to include the matrix in an SD drawing set to cover control intent for preliminary pricing but at this point, setpoints and scenes may not yet be defined. To avoid incorrect information or blank cells, it may be advantageous to hide some columns of the matrix, bringing them back at later phases when the intent has been developed.

Section 7 of ANSI/IES LP-16-22 outlines four phases of documentation (SD, DD, CD and installation and commissioning) and provides example matrices showing the necessary information at each phase.

Back to TOC

Note: By the fourth phase, the matrix should have just as much information describing the functionality of the control system as a written SOO included in the specifications. The matrix may include a long list of keynotes to clarify intent that does not fit nicely in a matrix cell.

Integrating lighting controls

Through a detailed process of defining the control intent and translating that intent into a clear and contractually enforceable SOO, the lighting controls system designer can provide documentation to ensure the lighting control system is designed, installed and programmed as required to meet the needs of the space and its users.

Working with the owner, user and/or architect to define how a space should behave and then detailing that behavior in the construction documents into a system that the contractor, integrator and commissioning provider shall turn over will result in a system that is easier to install, use and maintain; is more energy efficient; and complements the architecture and lighting design of the space.

ANSI/IES LP-16, a consensus-based reference standard, is a tool that every lighting controls system designer should use and reference for every project to simplify the design and documentation of the lighting controls system. As control systems become more complex and more building systems become integrated with lighting controls, ANSI/IES LP-16-22 and its future revisions will be an indispensable tool of the design process.

Brandon Stanley

Brandon Stanley, PE, LEED AP BD+C, IES, *is an electrical engineer, lighting designer, project manager and associate at SmithGroup, where he serves as the electrical discipline lead in its Chicago office.*

Existing generators: Extending service life strategies and reuse case studies

Back to TOC

Due to long lead times, maintaining or relocating existing generators is a possible solution to the supply chain problem

There are a lot of standby generators that are in-use in both Level 1 and Level 2 emergency power supply, as defined by NFPA 110: Standard for Emergency and Standby Power Systems, systems that most professionals would classify as "beyond useful life" due to age or number of hours ran.

At the time of publication, lead times for generator sets are beyond 70 weeks due to myriad shortages. Many facilities are looking to extend the life of the equipment they have or find new uses for used equipment. Existing equipment locations can be improved upon, which can extend useful life and improve system reliability.

Improving existing electrical system locations for a generator

The locations of EPS and emergency power supply system equipment as defined in NFPA 110 are typically located in unconditioned spaces, which reduces longevity. If the EPSS equipment room lacks adequate heating or cooling, fan coil or blower coil systems, or mini-split heating, ventilation and air conditioning systems can be added to extend useful life and comply with NFPA 110-2019 Section 7.7.

Environmental factors of concern include the temperature and humidity ranges and dirt and dust accumulation within the room(s). EPSS rooms that lack sufficient HVAC

Back to TOC

shorten useful life of the equipment. Because EPS rooms typically have direct venting to the outdoors, they have the largest fluctuations in temperature and humidity while also having high dirt accumulation.

For a standby generator EPS, these environments affect the useful life of rubber hoses, gaskets, seals and pads. Generators with unit-mounted radiators have enhanced needs for exterior cooling and combustion air and pull large amounts of unconditioned air from the exterior. Even when the exterior louvers are closed, they lack adequate seals.

NFPA 110-2019 addresses the concerns of cold temperatures in Section 5.3.5, which requires maintaining 40°F when the EPS is not operating. If an existing EPS room lacks adequate HVAC equipment, adding supplemental heating and cooling can improve reliability.

The generator starting batteries are an important part of the system, and battery life is heavily impacted by ambient temperature. Best-battery systems, which provide additional redundancy, and high-quality battery chargers can be added to improve system reliability.

Additionally, electrical raceway or conduit is a pathway of air transfer, and it is not common to provide putty seals in conduit located “indoors.” When EPSS equipment is located in rooms with temperature and humidity fluctuations, condensation can occur in the EPSS distribution equipment where feeder raceways serve air-conditioned spaces.

Conversely, in cold climates, cold air can enter from the EPS or EPSS side and travel down raceways and cause condensation in the warm, conditioned spaces served. Both situations are affected by building pressurization, which tends to be more negative than positive due to the energy required to condition ventilation air in extreme cold or

Back to TOC

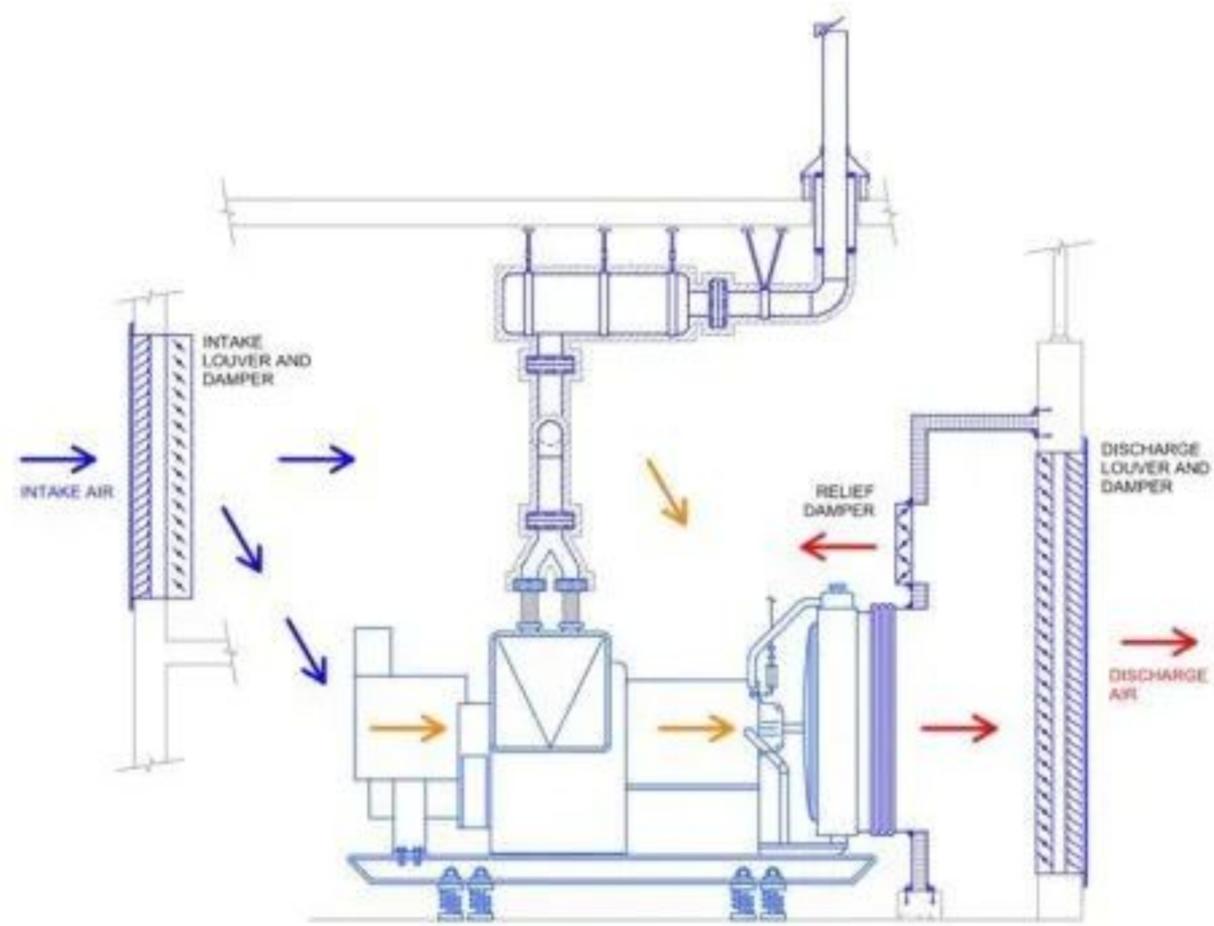


Figure 1: A diagram showing generator cooling airflow pathway and routing for minimal pressure drop and maximum cooling performance. Courtesy: IMEG Corp.

heat seasons. In either case, adding putty to the raceway system(s) can resolve the unwanted air transfer.

The 2020 edition of NFPA 70: National Electrical Code addresses flooding concerns in 700.12(A) and (B), aligning with NFPA 110 Chapter 7 and NFPA 99: Health Care Facilities Code section 6.7.1.2.6. This is a more difficult environmental situation to solve, and the severity of the concern depends on the location of the building.

Note that this section is not limited to natural disasters, but also considers failure of piping for pressurized water systems, such as fire protection, chilled water, stormwater or steam. Where foreign systems are routed in a way that could put the equipment at risk during piping failure event, relocating mechanical piping should be cheaper and quicker than replacing and relocating electrical equipment.

Evaluating existing airflow in a generator

Unit-mounted radiators require a lot more exterior air to be brought into the EPS room than remotely located radiators. While the impacts of temperature and humidity were addressed above, existing airflow restriction also requires attention. The unit-mounted radiator is rated for a maximum pressure drop that can be experienced before generator set de-rating occurs. The preferred arrangement is one in which airflow passes by the generator and engine block before going through the radiator. Some rooms may have intake louvers on side walls where airflow does not pass by the generator and only partially cools the engine block, which shortens useful life. A similar concern occurs with parallel generators and the arrangement of intake air louvers, with concerns that some radiator fans will have less restriction than others, and the pressure drop across intake air pathways increases when all generators are running.

Factors that influence airflow pressure drop, include intake louver free area and design, air pathway configuration, and discharge plenum design and louver free area (see Figure 1). Plans for future growth should include additional airflow for the anticipated systems. Intake air and discharge air pathways can be modified and louver free-area can be increased in existing rooms. One strategy is to replace existing louvers located within the building envelope and providing a new plenum on the building exterior with a new, larger louver.

Back to TOC

Back to TOC

Evaluating existing fuel oil

Because standby diesel generator sets spend a lot of their life waiting to be used, the fuel will need to be routinely cleaned to maintain fuel integrity. It is not common for existing installations to include active fuel polishing systems. These systems are not very expensive and prolong fuel life, save money on third-party fuel treatments, and extend generator fuel filter life and generator reliability. Even existing systems will benefit from cleaner fuel (see Figure 2).

The route that existing fuel lines take can affect system reliability. The ideal scenario is for gravity drainage of returned fuel, as noted in 2022 NFPA 110 Section 7.9.4. This means that fuel storage is routed below the lowest level of the generator and day tank return connections. This arrangement is benefited by recessed trenches for fuel line routing to eliminate trip hazards within the room.

When fuel return piping is routed above the level of the generator and the day tank, then a fuel oil return pump is required, along with solenoid valves and sometimes check valves. It is prohibited by 2022 NFPA 110 Section 7.9.4 to install the day tank at a level above the generator, as additional check valves are required to prevent flooding the engine. Standby generator fuel oil storage systems may be shared with boilers, which provides a secondary fuel source for building heating systems. This additional system increases the complexity of piping, controls and routing. 2022 NFPA 110 Section 7.9.13 prohibits actuated valves on Level 1 EPSS

Evaluating existing generators for reuse

When an existing generator set is available for reuse or repurpose, the design team needs to coordinate with the existing manufacturer and client to determine if the ex-

Back to TOC

Figure 2: Image of fuel polishing system installed on an existing fuel oil system for improved reliability of relocated generators. Courtesy: IMEG Corp.

isting selection is the right equipment for the proposed application. The obvious specifications are voltage and power ratings, fuel type, noise levels and physical dimensions. The existing overcurrent protection needs to be evaluated, and the replacement of the primary breaker may be required to ensure selective coordination with the proposed downstream distribution.

One benefit of reusing an existing generator is knowing the exact dimensions and configuration you have to work with. When specifying a generator with multiple manufacturers, the designer needs to account for all possible configurations. Besides verifying the

physical size, the physical condition needs to be reviewed. Expect that the existing engine controller will need to be upgraded or updated, especially if paralleling is planned.

Generators in exterior controllers should be evaluated for rust or corrosion, and the noise level from the generator needs to be reviewed with the new local noise and emission ordinances. The benefit of knowing what is there can be offset by the downside of being hindered by what is there. For example, heaters and operable dampers may not be present with older, exterior generator enclosures.

When reviewing an existing generator for reuse, it is recommended to go over the maintenance records to evaluate the history of testing, fluid changes, filter changes and fuel treatments. Consumable items include hoses, filters and gaskets, and the generator vendor can assist in evaluating the physical condition of foam or rubber materials.

Engine oil analysis can be a good idea as it can help evaluate the internal condition of the engine by looking for excessive contamination or bearing materials that can indicate potential future failure. Other consumable items include batteries, cables and chargers, all of which should be replaced if they are at or approach the end of useful life.

If the generator is an indoor model, the combustion air and cooling air requirements need careful attention, and the new location needs to accommodate airflow pressure drop and cubic feet per minute requirements.

Richard A. Vedvik, PE

***Richard A. Vedvik** is a senior electrical engineer and acoustics engineer at IMEG Corp. He is a member of the Consulting-Specifying Engineer editorial advisory board.*

Back to TOC

Content Archive

2023 Summer Edition

2023 Spring Edition

2022 Winter Edition

2022 Fall Edition

Lighting & Lighting Controls

Thank you for visiting the Lighting & Lighting Controls eBook!

If you have any questions or feedback about the contents in this eBook, please contact CFE Media at *customerservice@cfemedia.com*

We would love to hear from you!

CONSULTING - SPECIFYING engineer eBOOK