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Spectacular events increasingly often use equipment that requires undimmed AC mains power. Remotely turning on and off that power becomes the new technical challenge.

How new LED and power distribution technology is changing performance space design

BY MARK BISHOP AND CURTIS KASEFANG

WITH THE RAPID TRANSITION TO LED LUMINAIRES in performance spaces already underway, several considerations must be taken into account when it comes to lighting and power system design and distribution. Theatre designers and technicians are now faced with decisions that will affect the efficiency, architecture, and workflow of their installations. The following discussion will provide an overview of the current trends in both LED lighting and power distribution while offering best-practice considerations that will facilitate the transition to the new technologies.

Transitioning to LED

Today, a variety of LED luminaires are coming onto the market while fewer conventional luminaires are being introduced. Tungsten incandescent lamp plants are closing, and there is little movement in the development of dimmer racks. As the tungsten lamp supply decreases and demand changes, instability in lamp pricing is likely, with the eventual outcome being markedly higher lamp prices and poor availability. All of this points to a world migrating away from tungsten-based lighting.

The question for the entertainment industry, therefore, is not if but when it will be compelled by these external forces to change. Although many existing LED luminaires are less than ideal, largely because of their inherent discontinuous spectrum and optical challenges, manufacturers are working hard to solve these issues and are developing new luminaires that are very acceptable. Now system designers are faced with the dual challenge of designing for today's users and preparing for an uncertain future, although it's becoming clearer.

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Presently, LED luminaires can satisfy most lighting requirements. Taking into account the vast improvements in intensity, spectral continuity, color variation, performance, reliability, and affordability, installers are beginning to realize that a conversion to the new technology can result in vastly improved efficiencies within a number of areas.

Conventional lighting sources such as halogen luminaires equipped with filters have traditionally consumed large amounts of power and produced a net luminous efficacy of as low as 0.4% in the case of luminaires with saturated color filters—essentially making them small heaters that generate a little colored light. Conversely, LED luminaires have at least 20% net luminous efficiency, giving designers the same or more light while using much less power. These efficiencies, combined with on-board dimming, are particularly interesting since they present new possibilities for power distribution.

LED advantages and opportunities

In addition to lower power consumption, LED luminaires reduce heat loads within installations, providing savings in installed electrical distribution, ventilation, and cooling as well as the elimination of the dimmer room. These savings allow facilities to reclaim much-needed space since ducts, fan units, and chiller sizes can be smaller. When viewed as a whole, the cost of LED luminaires can be almost entirely offset by initial cost savings in other areas during new construction or major renovation.

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The extended lifespan of LED luminaires also produces advantages. Rated between 30,000 – 50,000 hours, LED luminaires eclipse the service expectancy of traditional luminaires, which only average between 300 – 2,000 hours. While the initial investment can be quite significant, this additional cost can be offset by the infrastructure efficiencies noted above as well as operational efficiencies. Without any bulbs to replace, LED luminaires mitigate potential labor and material maintenance costs. Additionally, color-changing LEDs remove the need to purchase and maintain plastic gels, further reducing labor and waste.

On the power side, the self-dimming capabilities of LED light luminaires eliminate the need for conventional dimmer racks. This is because LED luminaires require a clean, constant power source. Many will not function properly or at all if connected directly to an SCR dimmer—even when the dimmer is continuously set to full power or to non-dim mode. Consequently, system designers are becoming increasingly interested in a distribution of switched, as opposed to dimmed, circuits. This is leading to the deployment of direct feeder topographies, with localized luminaire dimming providing more granular control.

Power trends

Power control is an important consideration for LED luminaire installations. In many facilities, users leave their LED luminaires energized 24/7 while only using them for a couple of hours each day. However, LED technology is susceptible to damage from power anomalies. Regardless of their lifespans and performance ratings, internal components can become damaged, resulting in malfunctioning LEDs whenever lights are not powered off. Without switched power control, maintenance costs in LED installations can begin to rise in as little as 12 months. Additionally, while the quiescent load (the load the electronics draw when idle) for a single luminaire is minimal, it can be significant in the aggregate for a facility with a relatively large lighting plot that is only active a few hours each day.

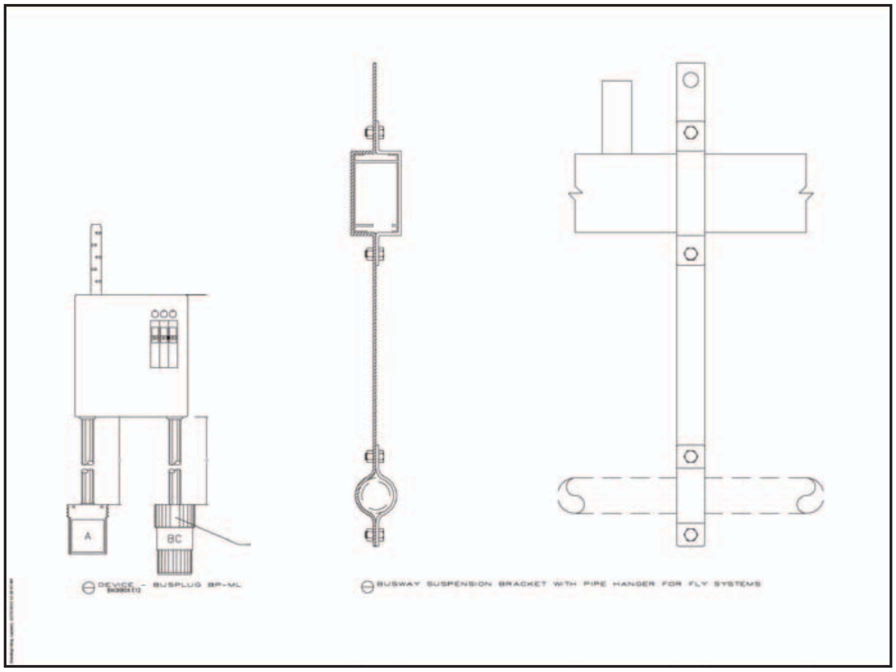
Since LED luminaires are self-dimming, they can share circuits without giving up individual control. With fewer required circuits, installations within new facilities or large renovations can experience significant savings in the area of electrical distribution. It's possible to see a reduction in infrastructure to 20% of the conventional distribution (when measured by weight). Under a revised power distribution model, a designer may incorporate a small system of switched circuits and three-phase power distribution via powered busways, with the busways replacing the more typical connector strips.

There are other advantages to powered busways, including moveable outlets that are individually protected with 15 A or 20 A, 120 V or 208 V breakers. Busways are fed with three-pole breakers at 100 A, 200 A, or even 400 A. It is helpful to think of them as elongated panelboards with readily interchangeable breakers. These busways have been available for decades and are in use in retail, hotel, and data-center environments. For the performance environment, busways are switched with remote-controlled multipole contactors.

LED technology has made optimized control a very important requirement.

For smaller power densities, switched 20 A circuits may be distributed via DMX-controlled relays or through recently launched smaller-footprint devices such as motorized breaker panels. These are more familiar to licensed electrical contractors and offer cost savings over relays in dimmer racks or adjacent to panelboards. While these measures make sense for large renovations or new installations, those converting to LED technology within an existing infrastructure are simply replacing 15% of their dimmers with relay modules.

Many technicians see advantages through better capabilities for monitoring and control of the electrical architecture feeding their lighting installations. Monitoring facilitates load balancing between circuits and provides improved performance by allowing users to identify short circuits, burnouts, and power malfunctions and rapidly take the appropriate action. Interest in current monitoring also creates a new



Busway details

demand for remote monitoring capabilities. With some circuit breaker systems now equipped with built-in web servers, theatre technicians can access their lighting installations directly from devices such as smartphones and tablets. Through an IP connection, technicians gain instant remote access to electrical information such as breaker on/off, tripped status, and current draw in addition to alarm features to alert them of any anomalies automatically. In larger theatre installations, auto messaging via text or email greatly facilitates situational awareness and can allow a technician to reset a circuit remotely during performances. For organizations wanting to burnish their sustainability credentials, current monitoring allows them to be aware of their power consumption.

As Katie Oman noted in her excellent article, "Stage Lighting and the Environment: Results from a Year-Long Study" in the Fall 2013 issue of *Protocol*, system designers should be aware that except in high duty-cycle environments, they cannot recuperate their investment from energy savings alone. However, once you take into account expendables and labor, the numbers become more favorable—with the slam-dunk happening in new construction or major renovation. In cases where users require more flexibility in their electrical infrastructure and reduced maintenance and are interested in future-proofing a newly constructed space, the best choice is LEDs, busway power distribution, robust control distribution, and at-luminaire dimming for conventional luminaires.

System design considerations

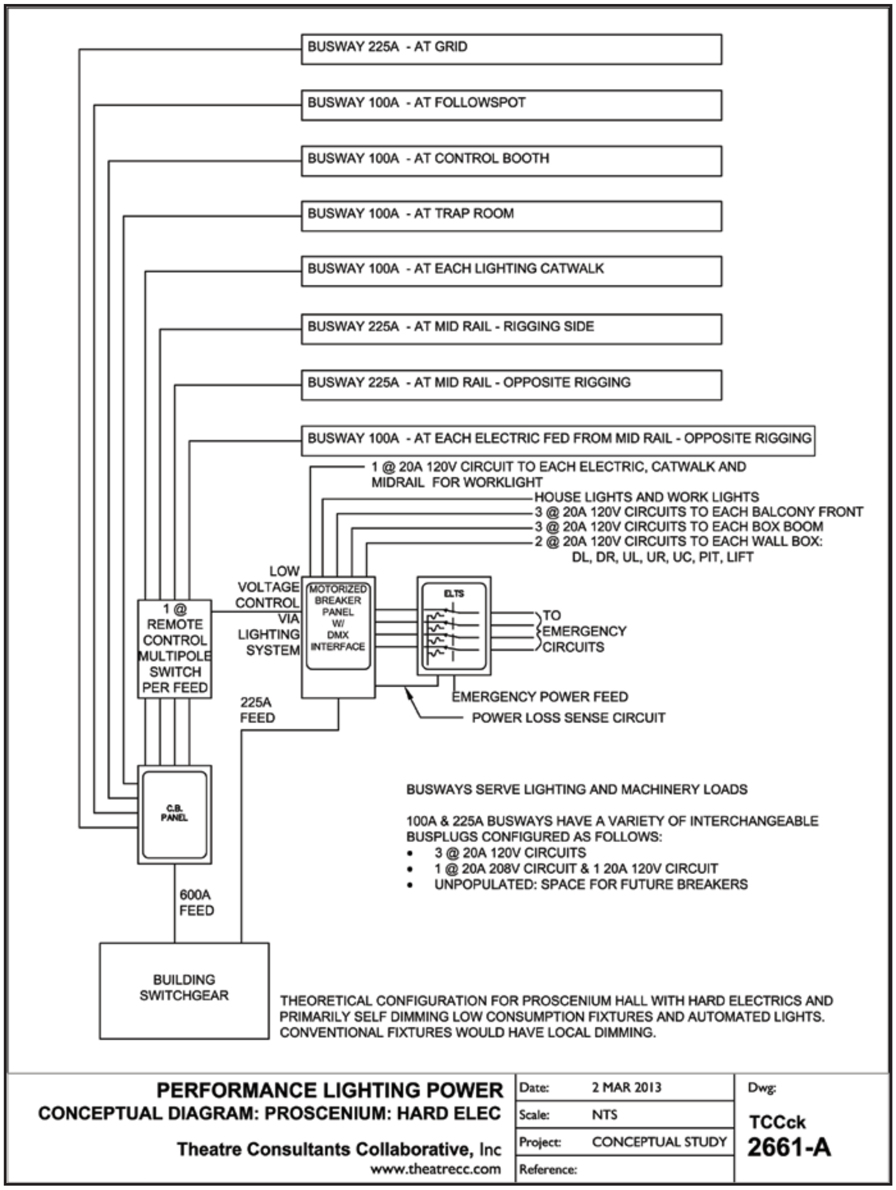
A primary electrical design concern for venues with LED luminaires is the in-rush of current that happens when they are energized, caused by luminaires with switching power supplies. When an LED luminaire is initially energized, a significant amount of current is drawn to charge the capacitors. Depending on the type of luminaire and the power supply design, this can reach up to 150% of the rated draw, resulting in a very brief bump in current called "in-rush." Using three-phase contactors—one per three-phase busway—designers can sequence the lighting rig on, allowing the current bump to remain within the design capacity of the lighting system. Circuits powered from the switched panelboard can be used to operate the work lights, eliminating the need to energize the entire rig in order to turn the work lights on.

LED technology has made optimized control a very important requirement. LED luminaires typically require between three and 15 (or more) channels per luminaire, while moving lights can require even more. LED walls or other large-production imaging applications can add dozens of DMX universes. While different luminaires have varying control requirements, a sound rule of thumb is to plan for one universe per typical major lighting position such as a catwalk or electric. It is prudent to include an open Ethernet jack at each electric for future expansion and to employ high-bandwidth Ethernet protocols such as streaming ACN for primary control distribution.

Looking ahead

Questions and challenges associated with fully migrating to LED technology within the theatre space remain—especially in halls hosting multiple touring productions. For instance, how can these spaces cross-walk show files from shows that have been cued for specific luminaires (e.g., halogen or LED) to differing luminaires within the space?

Spectral distribution for LED-based luminaires is improving but imperfect even for the best luminaires, which gives many lighting designers pause. LEDs with good spectral distribution still require a significant investment, driving many to purchase luminaires with poor spectral distribution. This can tarnish the reputation of better-performing luminaires and create more discomfort for the lighting design community, further slowing adoption. Also, the variations in spectral distribution of white-light LEDs, from LED luminaire to LED luminaire, can cause the



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resulting color of a gelled light to deviate from that of a halogen luminaire and be inconsistent between LED luminaires. Another issue is the question of how newer luminaires can be merged into the inventory of older LED-based luminaires. One answer may be calibration that sits in the luminaire. There is no consensus solution for the issue at this time.

Beyond traditional DMX512 and ACN control networks, a popular discussion is the question of whether theatre lighting will embrace the new AVB Ethernet protocol now emerging in the audio/visual industry. Unlike ACN, AVB is being adopted by some powerful manufacturers in a much larger market. This will result in more hardware being available to support this technology than is the case with ACN. AVB sends data at high speeds over an infrastructure very similar to ACN with inherent time-critical delivery protocols just as robust, if not more. Fortunately, both employ the same physical infrastructure with the possible exception of the Ethernet switches.

In conclusion

When designing LED lighting systems and implementing three-phase power distribution, system designers are creating phenomenal amounts of flexibility. This is an inherently future-proofing decision since infrastructures will be able to adapt to changes easily, and the design does not preclude the use of conventional luminaires. In the control system, a high-bandwidth Ethernet implementation adds further flexibility to a lighting system, allowing it to carry many universes of DMX.

As global demand for dimmers continues to slow, resulting in less production and a global phase-out of tungsten-based lamps across industries, it's highly possible that LED will soon take over as the dominant theatre and performance space lighting technology. Like any rapidly spreading innovation, it is impossible to predict whether LED will be the end-all solution or how long the transition will take. But we can say with confidence that conventional halogen lamps will be displaced by another more efficient technology, and the entertainment industry needs to be ready. ■

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