The New Dynamic of High Performance Buildings: Advanced Electrical Design Principles in Practice

Executive Summary

As the high performance building (HPB) movement has evolved and matured, so have the design disciplines that are essential to delivering building operations and functionality. This evolution is not only occurring within each design area – such as mechanical, electrical or security – but also across all trades with increasing interaction and interdependency.

The electrical system, and the physical infrastructure that enables it, is a central component in the design and operation of a high performance building. This complex system is rapidly changing in response to technology and marketplace developments.

A new set of principles is emerging that should serve as the basis for electrical system design when striving to optimize a building's performance on multiple fronts.

The key principles are:

1. Employ life cycle planning
2. Focus on the occupant
3. Enable device connectivity
4. Embrace IT and open systems
5. Harvest system data

This paper reviews the basis for these principles and examines their application in high performance building projects ranging from healthcare to commercial office buildings to educational institutions. In each case, applying the five principles within an integrative design process known as "whole building design" contributes significantly to achieving the high performance vision. In some cases it enables unanticipated benefits that go well beyond the design phase, extending throughout the project lifespan.

The High Performance Building Movement

The last few decades witnessed a steady evolution of thought and practice in building design and construction. The high performance building movement began in the 1970s as concerns began to emerge about workplace productivity and grew in the 1980s and 90s as energy efficiency and other sustainability issues gained currency in the design community. The movement accelerated in the 21st century and continues to expand.

While defining a concept as encompassing as a high performance building is challenging, the federal government articulated a clear vision in the Energy Independence and Security Act (EISA) of 2007. According to that legislation, a high performance building is one that "integrates and optimizes on a life cycle basis all major high performance attributes, including energy conservation, environment, safety, security, durability, accessibility, cost-benefit, productivity, sustainability, functionality, and operational considerations."[1]

The bar for what constitutes "high performance" continues to rise as many significant social, economic and environmental trends place new demands and raise expectations of the buildings where people live and work.

The Importance of Whole Building Design

To achieve the vision of high performance and to meet the expanding needs within the built environment, a holistic approach to building design and construction must be employed. This approach is known as "whole building design,"[2] and it consists of two major components:

- Integrated design approach
- Integrated team process

At its heart, the integrated design approach embraces all stakeholders in the building process as early as possible to join in ongoing collaboration, rather than the conventional approach of relying on specialists with focused expertise working in isolation from one another.

The second component of whole building design focuses on the project team dynamic, in which the design team and all affected stakeholders collaborate throughout the design process. By drawing upon the expertise of the entire community, the project gains the benefit of multi-faceted perspectives not only in the design phase, but also in other phases of the building life cycle, such as construction and operations. Hence, a project team includes not only design professionals such as architects and engineers, but also building owners, facility management professionals, stakeholders from the immediate community impacted by the project, as well as specialists in specific building systems, and materials and product vendors.

[1] "Energy Independence and Security Act of 2007," (U.S. Government: GPO) Title IV - Energy Savings in Buildings and Industry, Section 401, Definitions

[2] Don Prowler, FAIA, revised and updated by Stephanie Vierra, Assoc. AIA, LEED AP BD+C, "Whole Building Design" (National Institute of Building Sciences: Whole Building Design Guide, March 22, 2012)

Once involved in the project team, vendors may be expected to play a more proactive role in meeting the design intent. For example, they might provide Building Information Modeling (BIM) objects, replacing construction drawings with project-specific shop drawings and supporting new approaches to implementing the vision while working within the construction restraints of time, space and cost.

This trend is becoming particularly evident in the realm of electrical system design, as these systems are highly configurable and are often prefabricated off site.

The Role of the Electrical System in the Building

The electrical system is:

- Composed of a wide range of low and high voltage devices, wiring, cabling and connectors that deliver electrical power, including wireless power for inductive charging, safely and reliably.
- The source of tens of thousands of the data points that inform and shape building performance.
- A key enabler to achieving the potential of demand response.

New technology means that today's electrical system is increasingly sophisticated. It is essential to the delivery of vital building services, including lighting, communications, alarm and life safety systems, heating, ventilation and cooling, as well as all forms of equipment and is connected to a burgeoning number of Internet of Things (IoT) devices supplying big data.

- Breakthrough energy technologies, including refinements in renewable generation technologies combined with advances in energy storage technologies, are creating new opportunities for flexibility in the electricity infrastructure, from the long-distance transmission grid to the local distribution grid, past the utility meter and into the individual occupant spaces of today's built environments.
- Transformative building technologies, such as LED lighting and wireless communication devices, are enabling control over individual comfort and productivity not possible even five years ago.
- Digital communications, ubiquitous Internet access and cloud-based data storage make data analysis, and action based on those analytics, possible from virtually any location.

Advances in electrical system design are enabling a profound transformation in building performance. Realizing these benefits requires recognition that new principles are needed to guide the design process.

Five Electrical Design Principles Have Emerged to Capture Performance Opportunities

1. Employ Life Cycle Planning

As a project team approaches the electrical systems design, keeping the building life cycle squarely in mind provides the greatest opportunity to realize the most robust vision for high performance. **This requires a deep understanding of the client's needs, the intended mission of the building and its many spaces, and an intuitive appreciation for how the built environment will be used across its own lifespan.**

Parkland Hospital, the largest public hospital in the U.S., is employing life cycle planning as an integral part of its new hospital construction. Scheduled to open in the spring of 2015, the renovated Parkland Hospital will provide state-of-the-art healthcare in a facility expected to achieve LEED Silver certification.

New Parkland Hospital Achieves Sustainability on a Grand Scale

The statistics are staggering:

- 2.1 million square feet
- 865 private adult beds
- 58 labor delivery rooms
- 120 emergency exam rooms
- 10 trauma rooms
- 27 surgery suites

- **575 miles of conduit**
- **More than 32,000 light fixtures**
- **More than 42,000 data outlets**
- **Nearly 900 cameras**
- **45 elevators**
- **More than 1,500 miles of copper data cabling**

Image Source: Parkland Hospital

To achieve its ambitious vision for high performance, the Parkland project team employed modeling as a vital part of its life cycle planning. While many HPB projects utilize BIM, the Parkland team moved beyond computerized modeling and constructed extensive full-scale mockups to test design concepts, usability and make product and vendor selections.

MC Dean, the design-assist and systems integration firm responsible for the new Parkland Hospital electrical system, pioneered the Pre-installation Testing and Check Out (PITCO) process for networked systems and used the mockup process to support pre-fabrication.

Pre-fabrication, which includes configuring and testing controls off site, addresses many construction concerns and ensures consistent work quality that cannot be matched in the field. It also reduces assembly time and labor costs, both the materials and work force come together in a controlled environment, while also minimizing construction site waste.

PITCO also brings the owner into the process to approve the usability and performance of intelligent devices before they are deployed in the field. MC Dean uses this process for Security, Video, Fire Alarm and Lighting Control Systems. The owner's representative evaluates the full system performance in a lab environment prior to field deployment, minimizing the costs and impact to the schedule caused by field changes.

To facilitate the electrical systems design at Parkland, 10,000 square-feet of patient care and surgical areas were modeled. One design nuance identified during this phase was the need to calibrate the controls to work efficiently with every light source. Because LED fixture drivers respond differently to standard low voltage control signaling, control of light and energy usage can fluctuate up to 20% if using an uncalibrated control system. By commissioning the controls for each fixture type to ensure linear performance, centralized commands will accurately deliver the desired light conditions and energy savings. This is important during both normal and emergency operations, as the ability to accurately reduce the lighting load during a power outage minimizes the need for capital spending on generators and other emergency infrastructure.

In addition, the modular assembly and pre-testing of the lighting control system allows the lighting to be scheduled off after hours, providing substantial energy cost savings during the construction cycle and once the facility is operational.

"I can't think of any reason why you wouldn't want to do it," observes Jerry Nickerson, Senior Vice President of Engineering and Controls for Parkland Hospital. "Mockups like this offer the opportunity to fine tune a range of operational functions that will reap benefits throughout the entire lifespan of the hospital."

2. Focus on the Occupant

Traditionally not a major factor in electrical infrastructure design in conventional buildings, the needs of building occupants have become an essential consideration in high performance building design.

Understanding how different occupants use different spaces in a building can help the design team make more informed decisions earlier in the process, saving resources from the construction phase through the operations phase of the building life cycle.

In the healthcare sector, for instance, the emergence of patient-centered care and the importance of published quality systems such as the Hospital Consumer Assessment of Healthcare Providers & Systems (HCAHPS) scores are major drivers in healthcare facility design. An understanding of these considerations is vital in achieving a high performance hospital or healthcare facility.

Embracing the mockup process to anticipate problems can prove invaluable. During the Parkland mockup, vendors observed that caregiver evaluators were uncomfortable using touch screens at workstations or in patient rooms.

“Some staff expressed their reluctance to use touch screens,” commented Pete Horton, VP Market Development for WattStopper. “In many cases they didn’t object to the technology, but they preferred more simplicity in their work environment. Rather than having to spend 30 seconds concentrating on how to use the interface, they wanted the ability to activate lighting immediately so they could focus on the patient.” This led the team to develop engraved switch buttons that clearly identified programmed light levels at-a-glance for caregivers and patients alike. Switch buttons were also color-coded so any user could immediately and intuitively distinguish ordinary lighting (white) from emergency lighting (red).

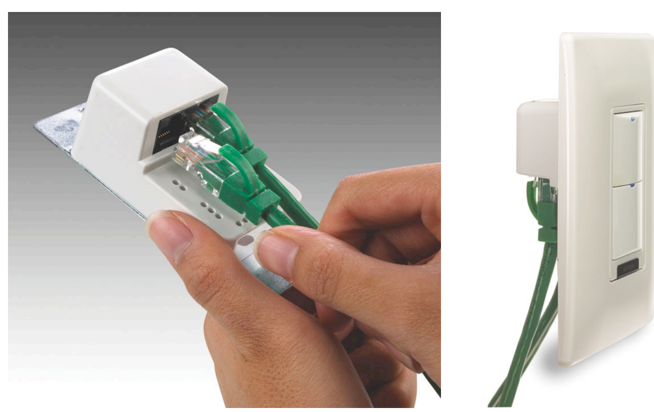
Evaluators at Parkland Hospital recommended engraved switch buttons for simple, intuitive lighting control rather than touch screens

Image Source: Legrand

3. Enable Device Connectivity

In order to capture data from building systems, **the HPB must connect a wide variety of devices across the built environment including edge devices such as lighting fixtures, sensors, switches and receptacles.** If the distributed devices include intrinsic intelligence, they will be capable of withstanding external or network failures, including server, Ethernet or Internet failure.

Connectivity can be established via wired or wireless networks. Both have advantages and disadvantages, so project teams should assess the particular needs of the project. Often, a combination of wired and wireless proves to be the optimal solution. Wired connectivity for interior spaces often reduces the initial investment for control devices, while wireless solutions for connecting remote buildings can be the most practical and least resource-intensive.



Distributed edge devices, including switches, are connected via standard category cabling

Image Source: Legrand

New energy code requirements are also are driving additional monitoring and control of electrical products and systems. ASHRAE 90.1-2010 and -2013 require automatic shut-off of designated plug receptacles in many commercial areas.

Devices and Data

The 2.5 million square foot Parkland Hospital project includes:

- 63,000 lighting control devices, monitored every 15 minutes
- 2.2 Billion data points accumulated per year
- 1 trended data point per 35 square feet
- 1 data point available for configuration and monitoring per 5 square feet

The new Liberty Mutual Headquarters building in Boston, Massachusetts, recently complied with these requirements by installing over 700 receptacle controllers connected to both lighting occupancy sensors and building management system (BMS). This digital control network solution automatically turns off controlled receptacles when the space is vacant and reports energy use per square foot to the BMS. Liberty Mutual selected open protocol systems communicating via BACnet protocol over the IP network to efficiently and cost-effectively manage energy use without the need for a second IP network and provide visibility into ongoing operations. Robust IP networks are critical for handling the big data generated by modern lighting control systems.

4. Embrace IT and Open Systems

In a high performance building, electrical and IT and cloud infrastructures are rapidly converging. The use of open source protocols ensures that electrical systems can more effectively integrate with other building systems, rather than operate in individual silos.

The key advantage to convergence is the ability to aggregate, evaluate and deliver actionable information to facility managers anywhere and in any format. This enables organizations to manage building data from disparate systems across multiple locations using shared applications in a hosted environment. This architecture delivers additional benefits including reducing capital expenditure on IT infrastructure and support, while increasing scalability to address new organizational challenges such as sustainability, predictive maintenance and asset management.[3]

Increasingly, electrical manufacturers are supporting IP protocols, taking advantage of the IT infrastructure and software to compete with traditional electrical components.

[3] Greg Turner, "BAS-IT Convergence, Now and Into the Cloud" (automatedbuildings.com, April 2010)

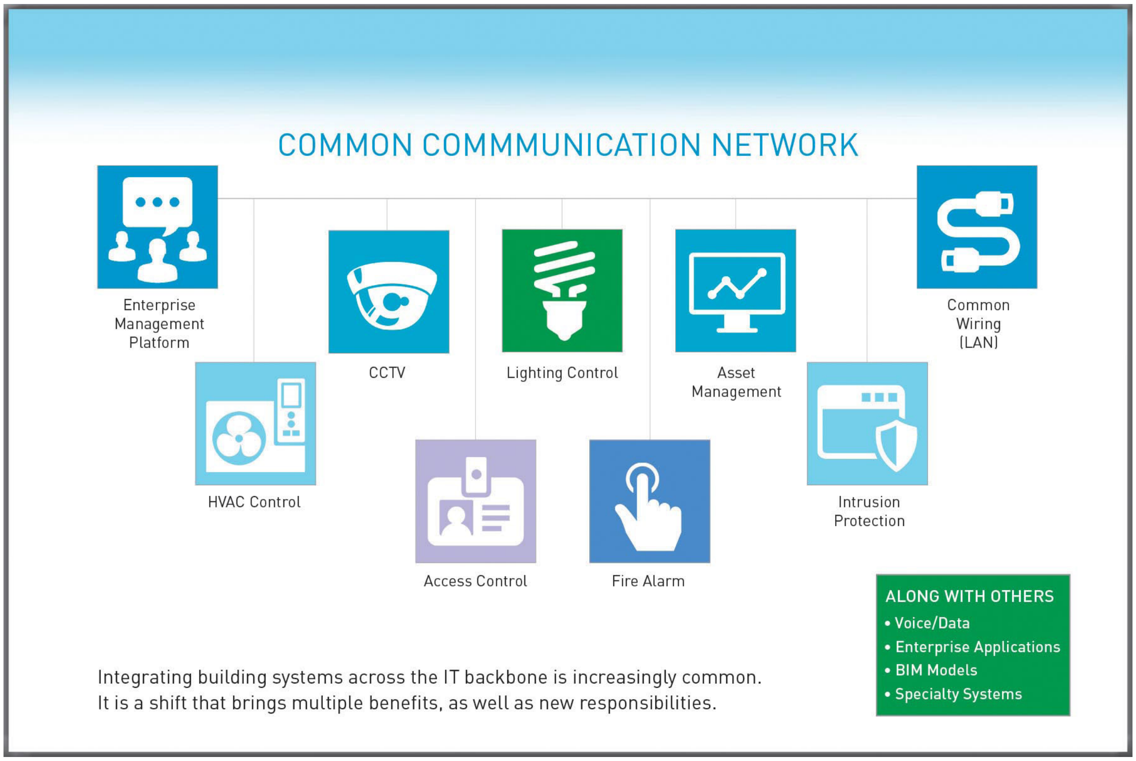


Image Source: Legrand

The ability to utilize existing IT frameworks is also enabling real-time monitoring and reporting of energy performance data.

Two Canadian high performance building projects in Ontario illustrate the benefits such system integration can provide. At Fanshawe College and University of Western Ontario (UWO), the project teams – consisting of systems integrators, electrical and mechanical engineers, and product vendors – collaborated to integrate lighting controls and building controls using the existing IT infrastructures and open-source BACnet protocols. As a result, the projects were able to harvest data from hundreds of lighting control occupancy sensors via the BAS system, and use that data to optimize operation of the HVAC equipment.[4]

[4] "Effective Integration Dramatically Improves Building Performance" (WattStopper, 2014)

5. Harvest System Data

With the electrical and IT infrastructure in place, and when equipped with the appropriate analytical tools, facility and property managers can monitor a wide range of performance indicators. These can include trending and reporting of a building's energy performance, but these data can also inform managers about many other important facets of building operations:

- Energy and water consumption
- Indoor environmental quality
- Equipment performance
- Space utilization
- External building security conditions
- Predictive maintenance capabilities

Actionable energy information across many different space types needs to be normalized and categorized. For the Liberty Mutual facility, both the lighting and plug load power is measured in watts per square foot (W/ft^2). This provides an instantaneous measurement of how different spaces are performing at the present time. Energy consumption (watt-hours) is also recorded every 15 minutes for each space. With that data, the facility manager can graph energy (watt-hours) per square foot by space type over time, with an option to compare against similar or different space types.

At the Adobe headquarters in San Jose, California, a highly sophisticated system provides an ongoing stream of real-time data, including energy use and occupancy by building, floor, and individual clusters of desks known as "neighborhoods." In addition to providing actionable information about how electrical energy is being used, the system also tracks when spaces are used via occupancy sensors distributed throughout the spaces. As data about space utilization accrues, the system highlights possible improvements in layout and scheduling.[5]

Data visualization tools continue to evolve. Early and current generation dashboards have relied on tree- or map-based interfaces, which serve up data in context with a linear project framework or a floor plan view. While helpful, these interfaces also demonstrate limitations, particularly in the flexible, rapidly changing work environments of today's high performance buildings. Tree-based interfaces can be confusing to scale. Floor plan views require intensive customized graphical coding that can be rendered obsolete upon the next tenant's improvements or workplace reconfiguration.

Emerging visualization tools emphasize intuitive data "tiles" that can be grouped functionally, geographically, or in other meaningful arrangements depending on the specific application. This format has been successfully utilized in other data-intensive settings, such as the financial industry where stock and commodity market information must stream continuously to enable real-time interpretation and action.

[5] Defining Performance" (High Performing Buildings, Fall 2012) 8

Traditional energy management dashboards often present data in charts or on building floor plans.

Image Source: Legrand

Newer visualization tools provide data "tiles" that can be arranged in the manner most meaningful to the energy manager.

Image Source: Legrand

Conclusion

The evolution of high performance building design continues to evolve with each new generation of building sustainability codes; the many policy drivers aimed at addressing myriad social, economic and environmental challenges; and the transformative market technologies that allow a convergence of building system capabilities.

These forces are shaping advances in electrical infrastructure design and installation.

- Collaborating in new ways across HPB project teams by focusing on the entire life cycle of a project, rather than simply the design or operational phases, can bring greater value across all phases.
- Maintaining a central focus on occupant needs not only results in greater occupant satisfaction and productivity but may also bring unanticipated benefits in design or construction cost savings.
- Embracing closer partnerships with IT and leveraging open source protocols and platforms can provide best-of-breed solutions more quickly.
- Ensuring device connectivity throughout the electrical infrastructure enables the harvesting of actionable energy and space usage data that can then be analyzed to optimize a host of operational conditions, including energy and water consumption, indoor environmental quality, equipment performance, space utilization, and external building security conditions.
- Flexible, network-based solutions also facilitate the addition of new functionality in the future, ensuring that the HPB will support the needs of the owners and occupants in years to come.
- Next steps for many building designers will include integrating key card access with systems including lighting and HVAC, both for occupant comfort but also to improve building security – a mission-critical aspect of building performance.

These many benefits illustrate just some of the reasons that building owners are reaping greater returns on investments in high performance buildings than ever before, enjoying reduced operating costs and higher building valuation. As the expectation for constant connectivity to more systems and data increases, costs for networked solutions will continue to drop. This strengthens the case for integrated systems and design – and underscores the important role of electrical system design as a factor in achieving building performance objectives.

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