White Paper

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Control Panel Optimization

Five Key Elements to Consider: Space Optimization, Noise Mitigation, Environmental Protection, Security and Safety

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Introduction

Industrial automation systems are undergoing dramatic changes that require businesses to adopt new strategies to fully utilize industrial Ethernet, advanced motor controls and controller architectures to improve efficiencies, increase productivity and drive out costs. Control panel designers are struggling to address these issues and new design requirements that can arise as they work to ensure that automation systems deliver high performance and system availability in spite of the many challenges that exist. These challenges are associated with harsh environment deployments, network security liabilities, costly safety concerns, and electromagnetic interference (EMI) noise considerations in crowded, space optimized control panel systems.

For example, the increase of Ethernet nodes on the plant floor is a frequent challenge for control system designers. Greater use of Ethernet connected advanced controllers, computers and high speed motion control and power electronics can require new strategies beyond traditional panel selection and layout to avoid hazards such as electromagnetic noise or thermal risks.

The project cycle is another common challenge for designers who have limited time to complete plans and often encounter difficulty finding solutions that adequately meet numerous design requirements. Robust design is essential because the performance of a control system is only proven in the field where conditions are unpredictable and beyond what is possible to create in a laboratory environment. Problems in the field can also happen with control panel designs that are not well protected against the environmental risks, which can cause downtime or safety gaps, resulting in costly injuries. Lack of due diligence in any of these areas can cause mistakes that result in rework during panel building or problems with inspectors. Figure 1 illustrates common control panel challenges that designers can encounter.

Figure 1. Common control panel challenges facing designers today: (1) improving space utilization, (2) determining strategies for EMI noise mitigation, (3) making proper selections for environmental needs, (4) securing the control panel and (5) creating design strategies for a safe control panel.

This white paper introduces best practices and solution tools that will enable system integrators, panel designers and builders to optimize five elements common in the control panel development process and end use lifecycle. Specifically, this paper outlines the main challenges faced along with comprehensive solution approaches for both the enclosure system and the physical infrastructure internal to the panel. The five topics outlined in this paper will be covered in greater depth in a series of subsequent white papers. The intent is to provide actionable guidance, tips, and tools to streamline processes while delivering innovative solutions that reduce costs and improve overall life cycle performance.

Panduit is a world-class developer and provider of leading-edge solutions that connect, manage and automate the industrial physical infrastructure. Pentair Equipment Protection, manufacturer of the Hoffman brand of enclosure, is the leading provider of worldwide product and service solutions for enclosing, protecting and cooling electrical and electronic systems. Panduit and Pentair Equipment Protection have joined forces to holistically address the challenges of control panel design and leverage the power of two best-in-class organizations to provide control panel solutions engineered for next generation requirements.

Space Optimization

In most industries, real estate is typically one of the biggest expenses associated with running the business. Facility managers of manufacturing or process plants are forced to utilize their space in the most effective and efficient way. Therefore, they are constantly struggling to maximize the real estate in their facilities by placing as much equipment into a space as possible. As a result, the machine designers and builders are challenged to continually reduce the size and footprint of the machines they are designing and building. This, in turn, challenges the controls engineer to design and build control panels with smaller footprints or fit more into existing panels, which is a very difficult task.

The challenges associated with designing smaller control panels and enclosures include considerations for cable segregation, thermal management, cable entry, EMI, cable bend radius and space for future expansion. Safety considerations such as arc flash hazards and compliance with codes and standards must also be included in the design phase.

Panduit and Pentair have many solutions to help a controls engineer save space in the control panel. One solution is the enclosure platform, which can help maximize the space inside. For example, the highly flexible and innovative Fusion and Proline platforms from Pentair offer full three-dimensional space utilization inside the enclosure. Pentair also offers many space saving accessories and enclosure configurations such as double-hinged doors, busbar, front and rear access enclosures, and flexible cable entry.

Inside the control panel, Panduit offers innovative products such as the Corner Wiring Duct and Din Rail Wiring Duct to maximize the space. These products provide up to 40% space savings by better utilizing the area in the enclosure corners and the space between the enclosure door and the back panel. Panduit's noise mitigation products such as the Noise Shield and Shielded Wire Duct provide a 20dB reduction in noise, (which is equivalent to a maximum of six inches of distance spacing), enabling a control panel designer to route power and signal cabling closer together while providing EMI noise mitigation.

To further help you through the design process, both Panduit and Pentair have tools and services such as CAD and 3D step files. Both companies have products built into the Rockwell Automation ProposalWorks software, as well.

Noise Mitigation

Electrical noise, or Electromagnetic Interference (EMI), is an area that is increasingly identified as the root cause for system failures. EMI risks increase as a result of competing needs to add more networked components and power devices while attempting to minimize the control panel footprint to reduce panel costs. Too often, Ethernet switches are placed into existing control panel designs without any thought to the damaging effects of poor cable bend radius and exposure to EMI and potentially to radio frequency interference (RFI). These problems can disrupt communications and control functions of the entire automation system and cause the failure of industrial Ethernet installations to deliver on their promise of a robust, reliable and maintainable infrastructure (see Table 1).

Table 1. Risk to Industrial Automation Systems Due to EMI Noise

Noise Sources	Noise Victims	Business Risks
• Servo drives • VFD drives • Switching power supplies • Contact switching of inductive loads (contactor coils, solenoid valves) • ESD • Lightning	• Communications/network wiring • Analog signal wiring • High speed counting signals • Controllers • Microprocessor based devices, drives, computers, sensors • Electronic equipment • Protective devices	• Productivity Loss • Downtime • Maintenance/repair costs • Troubleshooting costs • Device replacement costs • Inability to respond to market demands

The control panel enclosure plays a significant role in controlling EMI. The enclosure is a shield in all directions or a container that controls ingress and egress of EMI to and from the control panel devices. The phenomenon by which this works is called a Faraday cage. A simple representation of how a Faraday cage works is shown in Figure 2. The ideal Faraday cage is a continuously conductive shell around the internal components. This essentially "seals" internally generated EMI in and keeps externally sourced EMI out of the enclosure.

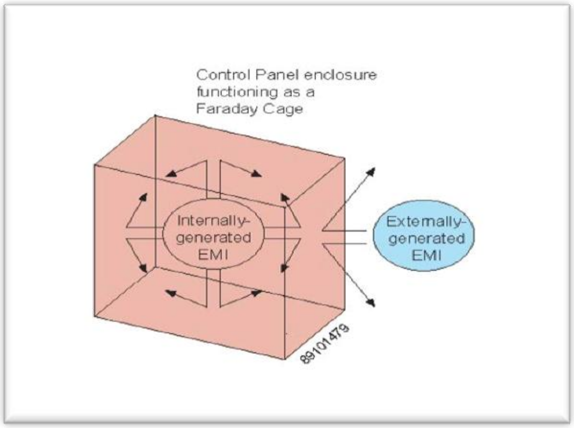

Figure 2. Effective enclosure design provides necessary user access while maximizing the Faraday cage effect when closed, controlling noise inside and outside of a control panel.

However, enclosures need to allow access to the equipment inside through doors and cable entry points. These needed access points create “leaks” in the enclosure (Faraday cage) and become pass-through points for unwanted EMI. An enclosure design with properly added EMI provisions can mitigate the “leaks” and therefore control EMI into and out of the control panel.

Another EMI consideration for the enclosure and control panel is regulatory compliance, which involves taking measures to control noise inside and outside of a panel, in order to achieve CE certification that is critical for European installations.

The most common methods used to reduce EMI inside the enclosure are to separate wiring pathways adequately and to apply more grounding products. However, additional space comes at a high price and more grounding pathways can result in ground loops and unsafe grounding pathways. The design of the grounding pathways should be considered early in the design phase. A summary of design considerations that can provide a robust grounding and bonding system and strong EMI protection include:

- Employing a central ground plane using galvanized sub-panels
- Grounding incoming circuits at a ground bar
- Grounding pathways as they exit the shielding
- Using grounding pathways with a large surface area, such as braided bonding straps
- Physically separating sensitive wiring from EMI-producing circuits
- Utilizing wire duct color to communicate noisy and clean pathways
- Using shielding barriers which keep EMI outside or inside depending on the design
- Applying filters and suppressors, especially when the source is identified

Figure 3 illustrates reference layouts specific to circuit separation for noise mitigation in control panels.

Panel ground plane extended to adjacent panels **Segregation and shielding methods to reduce EMI effects**

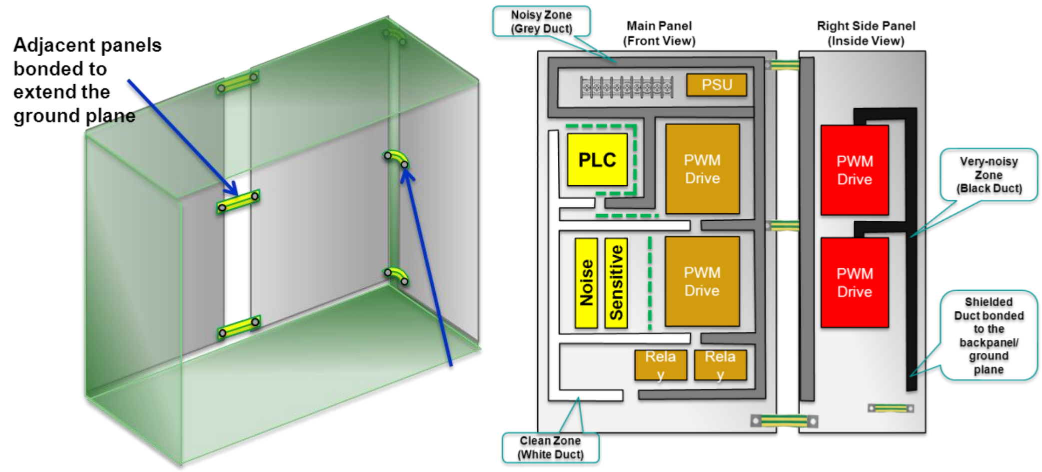

Figure 3. Reference layouts for circuit separation to mitigate noise in control panels. See Figures 10-10 and 10-11 in IEEE 1100 Emerald Book for more information.

Applying these best practice methods separately or combined can provide a low impedance path to ground, effectively reducing the susceptibility to and radiation of EMI/RFI of the control panel and assuring robust system performance.

An area of strong consideration for both space optimization and noise mitigation is when a panel is "networked." There is a compelling and growing need for data acquisition by the Enterprise to measure productivity in real time and implement systems that improve performance. Designers are witnessing an increase in network nodes and need good planning to deal with the increasing use of industrial Ethernet managed switches, networked devices and DIN rail mountable patching devices integrated as part of the controls system. Applying the space optimization and noise mitigation design techniques described above provide methods to ensure a more robust design and cost effective implementation of a networked control panel system.

Environmental Protection

The primary objective of the enclosure is to protect vital controls and the control panel infrastructure. End users rely on this protection to ensure optimal system operation. The life of electronic equipment is directly related to its operating temperature. For every 18°F (10°C) rise above normal room temperature (72-75°F), the life expectancy of electronics is reduced by 50%.[1]

When selecting an enclosure and control panel infrastructure it is important to understand all the factors relevant to the specific application. These factors include the appropriate standards, the ingress requirements, and the ambient environment including the temperature, any chemicals present, and the occurrence of EMI.

[1] Based on the Arrhenius equation, which calculates the rate of life degradation based on the rate of chemical reactions in the material due to heat. The equation states that time to failure is a function of $e^{-Ea/kT}$ where Ea = activation energy of the failure mechanism being accelerated, k = Boltzmann's constant, and T = absolute temperature.

Understanding these factors and the impact they have on the control panel infrastructure can simplify the design engineer's job and save valuable time as well as avoid costly downtime after the system is installed.

Enclosure Standards

With the complexities of a global economy, design engineers must understand the different global standards related to control enclosures. These standards include UL50, UL508A, IEC 60529, CSA, NFPA79, NEMA 250, MICE-TIA 1005/568C, UL 867, and IEC 61439. For enclosures in hazardous environments, standards such as IEC 60079 and NEC 500/505 may apply along with other regional standards such as ATEX, GOST, INMETRO, PESO, and KOSHA.

Ingress Requirements

A very important application factor is the level of ingress required. Ingress ratings specify the type and amount (if any) of a substance allowed in an enclosure under normal operating conditions. Typical substances include dust/dirt, water/liquids, and human fingers. Many of the enclosure standards outlined above define ingress protection levels.

Ambient Environment

The ambient environment is critical to selecting the enclosure and internal infrastructure components. Chemicals present in the ambient environment or used in industrial processes can dictate the enclosure's material to provide optimal corrosion protection and long life. The ambient temperature often impacts how the internal enclosure conditions are maintained. Enclosures mounted in cold climates may require heat to control condensation while those in hot, humid climates may require cooling for dehumidification and temperature control. The enclosure's location also plays a critical role in the selection criteria. For example, enclosures mounted indoors may have completely different characteristics compared to those mounted outdoors and enclosures located in direct sunlight are subject to Ultra-violet (UV) rays and high heat loads inside the enclosure.

Control Panel Security

Enclosure security focuses on the protection and security of the valued equipment and/or information contained within the enclosure. Mission critical information or components, confidential or classified information, etc., need to be protected to varying degrees depending on the storage environment. The expense of lost or stolen information or the cost of injury from unintentional access can be mitigated cost effectively with a layered approach to controlled access. For the owner of the equipment or information, it becomes a tradeoff of cost in protection versus the cost of potential loss of information or liability. The consultant or owner of the system needs to weigh and consider the following when choosing a control panel security solution.

1. The *value* of the information or equipment
2. The *risk* level of the panel environment
3. The *cost* that should be spent to protect it
4. The *function* of the equipment inside the enclosure to determine if components such as WiFi signals need to pass through the enclosure

Pentair's Hoffman enclosure solutions feature several design layers that can be employed to deter unintentional access into an enclosure, each adding some amount of cost but also adding a significant level of security, as shown in Figure 4.

Exterior Interface Mechanism

The first layer to be considered is the ***exterior interface mechanism*** that allows entry into the enclosure. There are several types of latches and locks that can be used depending on the level of desired access. The enclosures twice as likely to be tampered with are the ones with external, unprotected hinges.

Type of Material

The second layer that should be evaluated is the ***type of material*** that makes up the enclosure. Steel, aluminum, and composite materials can all be desirable, depending on the application. The thickness of material the enclosure is made of should also be considered on this level.

Internal Interface Type

After entry mechanisms and the type of material are considered, the third layer is the ***internal interface type*** that the latching or lock mechanism on the door has with the enclosure body. There are various schemes available that offer more or less connection points from the door to the body of the enclosure.

Geometry Design

The fourth layer involves the ***geometry design considerations*** that can deter the ability to pry or force entry in various ways.

Enclosure within an Enclosure

The fifth layer is an ***enclosure within an enclosure***. The designer can repeat the above layers by making another locked enclosure within the exterior enclosure. For example, a smaller locked enclosed section can be designed into the main enclosure to provide the ability to allow entry to some sections of the enclosure, but not to others, depending on the security clearance level of the personnel.

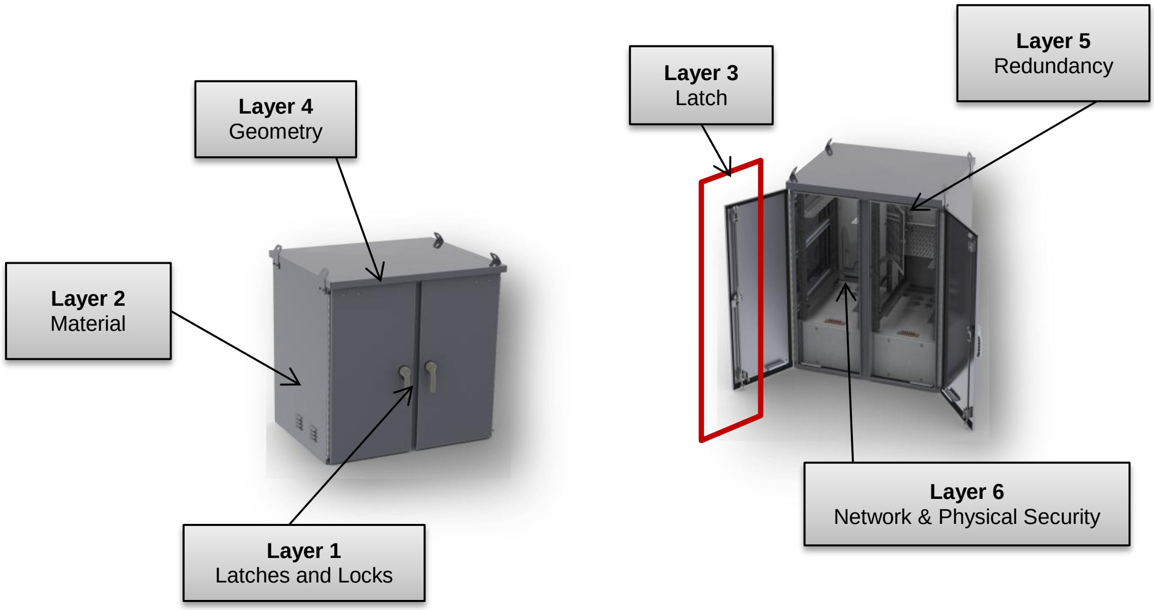

Figure 4: Six layers of security.

<u>Network Physical Security</u>

The sixth layer is an ***effective network and physical security solution*** which enhances security measures at the physical layer by deterring unauthorized network access, and offers a robust, reliable infrastructure that improves information management for better decision making (See Figure 5).

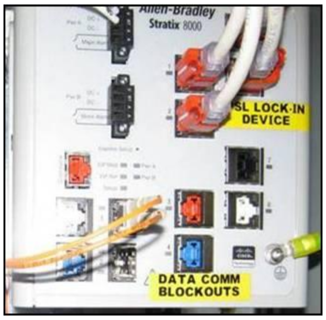

Figure 5: Network security devices in application.

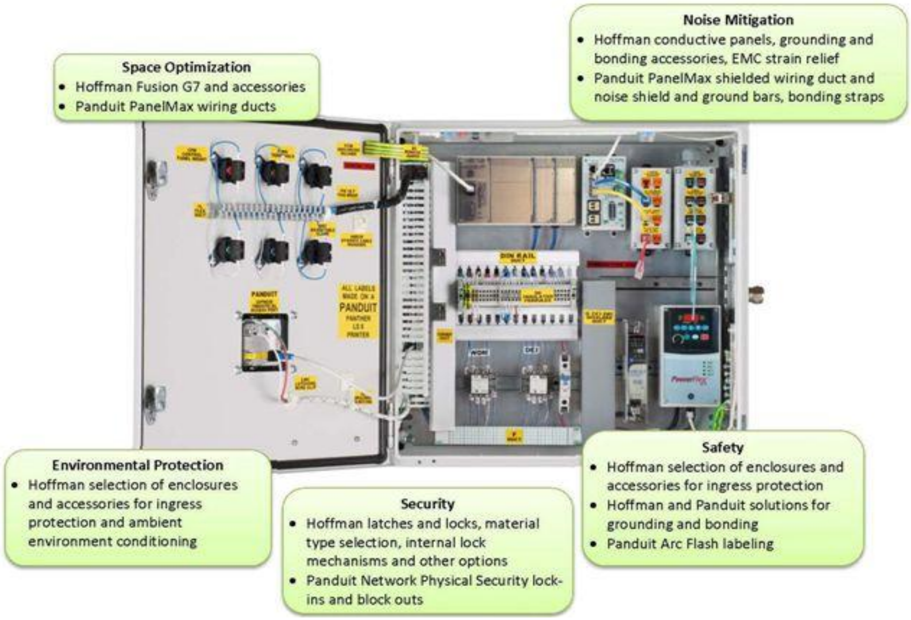

Figure 6: Hoffman/Panduit control panel featuring best practices for space optimization, noise mitigation, environmental protection, security and safety.

Technology can be a catalyst for innovation and help drive ideas into reality, but it can also be the means of potential security threats to infiltrate a system. The greater the number of people who have access to your enterprise and plant floor systems and processes, the greater the probable risks. To help protect a system from accidental or malicious events, it is necessary to take precautions. Physical security solutions that help control access to automation devices can be effective additions to other layers of security employed in contemporary control systems. Network accessories from Panduit such as block out devices and lock-in devices offer a secure solution for your network components. Block out and lock-in devices block unauthorized access and secure connections to provide additional security for data being removed (See Figure 6). This saves time and costs associated with security breaches, network downtime, repairs and hardware replacement due to theft.

Safety

As automation and control systems continue to expand and become increasingly complex and the incidents of electrical accidents grow, the need to increase safety considerations in control panel design is critical to protecting human life. To help minimize the possibility of electrical hazards, Panduit and Pentair offer control panel optimization solutions targeted at improving safety.

A growing concern in the electrical industry is the increased incidents of arc flash. An arc flash explosion is a very dangerous and often costly electrical system malfunction that occurs as a short circuit between electrified conductors. When the isolation between the conductors is breached or cannot contain the applied voltage, the air immediately surrounding the short can ionize, creating an intense energy flash of 5,000°F or more. Often, an arc flash event is triggered by operator movement or contact with the energized equipment. This is a particular threat when faults occur within an enclosure. A phase-to-ground or phase-to-phase fault that results in an explosion can cause fatal injuries, severe burns and produce considerable property damage.

A report from the State of Washington states that from September 2000 - December 2005, 350 State of Washington workers were hospitalized for serious burn injuries that occurred at work. Thirty (9%) of these injuries were due to arc flash/blast explosions. Total Workers' Compensation costs associated with these 30 claims exceeded $1.3 million, including reimbursement for almost 1,800 days of lost work time.
To protect operators, the Occupational Safety and Health Administration (OSHA) and National Fire Protection Association (NFPA) 70E standards require a "flash protection boundary." OSHA has adopted the NFPA's 70E, *Standards for Electric Safety in the Workplace*® as an acceptable means of compliance to meet this requirement and maintains that electrical work should only take place on de-energized equipment. Access to potentially energized equipment capable of generating an arc flash must be limited to qualified personnel with extensive protective clothing and equipment, including fire-resistant suits and hoods along with non-conductive wands. Figure 7 illustrates Pentair's Hoffman® Sequestr™ arc flash solution and the Panduit arc flash label which both address arc flash safety.

When designing enclosures, several industry "best practices" should be followed to increase worker safety.

- Physical safety – providing the appropriate ingress protection and offering solutions to minimize the need for people to access the inside of the enclosure; UL508, NEMA 250, IEC60529, and CSA standards define the level of unintentional human access to prevent safety issues
- Proper bonding and grounding – providing the necessary components to ensure a proper grounding path in case of a fault situation
- Labeling enclosures with incident energy – informing technicians of the incident energy inside the control panel to prescribe the correct personal protective equipment
- Wire segregation – separating low voltage wiring for high voltage cabling to minimize electrical hazards when troubleshooting live control circuits

Figure 7: Pentair's Hoffman® Sequestr™ arc flash solution (left) and the Panduit arc flash label (right).

Panduit can provide lockout/tagout and arc flash services to document, audit/review, and train personnel on proper procedures.

Conclusion

Design engineers have a tremendous amount of complexity to manage when applying control panels in today's industrial environments. Whether the application is in oil and gas, food and beverage, automotive, water treatment, or pharmaceutical, the competing design criteria make decisions about optimizing the control panel critical to the success of the project. Together, Panduit and Pentair leverage their solutions to provide the control panel optimization best practices that can benefit customers by addressing their control system needs.

More Information

This white paper is the first in a series of six papers on the topic of Control Panel Optimization. For more information on this topic, including copies of the white papers as they become available and more information on Panduit or Pentair Equipment Protection (Manufacturers of the Hoffman brand of enclosure), please visit www.Hoffman-Panduit.com.

Referenced Resources

http://www.lni.wa.gov/Safety/Research/Files/ArcFlashHazardReport.pdf

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About Pentair Equipment Protection

Pentair Equipment Protection, a Pentair global business unit, is the leading provider of worldwide product and service solutions for enclosing, protecting and cooling electrical and electronic systems. Its industry-leading brands – Hoffman®, McLean®, Schroff® - provide a broad variety of standard, modified and engineered solutions to the commercial, communications, energy, general electronics, industrial, infrastructure, medical, and security and defense markets.

About Panduit

Panduit is a world-class developer and provider of leading-edge solutions that help customers optimize the physical infrastructure through simplification, increased agility and operational efficiency. Panduit's Unified Physical Infrastructure℠ (UPI)-based solutions give enterprises the capabilities to connect, manage and automate communications, computing, power, control and security systems for a smarter, unified business foundation. Panduit provides flexible, end-to-end solutions tailored by application and industry to drive performance, operational and financial advantages. Panduit's global manufacturing, logistics, and e-commerce capabilities along with a global network of distribution partners help customers reduce supply chain risk. Strong technology relationships with industry leading systems vendors and an engaged partner ecosystem of consultants, integrators and contractors together with its global staff and unmatched service and support make Panduit a valuable and trusted partner.