ASHE Monograph

Evaluating Electrical Distribution Equipment to Determine Replacement Needs

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Evaluating Electrical Distribution Equipment to Determine Replacement Needs

Over time, a health care facility undergoes numerous changes, such as modifications to medical services, equipment replacement, and aesthetic upgrades. Many of these modifications, especially small or minor projects, are completed in a vacuum—disconnected from the designs, code requirements, and related systems already in place. The typical reason for this is that assessing the building and its engineering systems in their entirety is neither in the budget nor in the immediate scope of work for the project. As a result, those involved in an upgrade or remodeling project rely on the belief (or hope) that the current facilities are capable of handling modified loads and added infrastructure.

Unfortunately, one ramification of this piecemeal approach is the loss of a modern, code-compliant, and logical electrical distribution system. What remains is a maze of dissimilar equipment and distribution methodologies, stressed equipment, and aging infrastructure in dire need of attention. In fact, a common sight during an electrical infrastructure assessment are remnants of past remodeling projects, with different manufacturers' products, various ratings, and designs that may once have complied with code requirements but have not been upgraded as codes have changed.

Assessing Existing Electrical Infrastructure

The electrical infrastructure is an essential part of a building, yet a facility's dependence on electrical power and its distribution system is typically taken for granted. The expectation is that power will always be available and reliable. A well-known urban legend concerns a floor buffer running on the seventh floor taking out the main breaker in the switchboard. That tall tale is not too far from reality, however, especially when a facility has an aging electrical infrastructure.

Typically, a facility's electrical infrastructure is not evaluated until a power loss or failure occurs. A failure could be as simple as a warning, such as a branch circuit breaker tripping, or as catastrophic as an explosion that destroys equipment and injures personnel. The single point of failure can be anywhere in the system. Therefore, routine checks and periodic maintenance on existing infrastructure are imperative.

A complete assessment of a facility electrical system reveals inconsistencies, noncompliance with current codes and standard-of-care recommendations, and other limitations that could prevent equipment from functioning properly and safely in a code-compliant manner.

A Team Approach

Evaluation of a facility's electrical distribution is most successful when performed by a team assembled specifically to address all aspects of the existing infrastructure and the proposed upgrade or installation.

The team must include at least one member of the owner's facility department, as these staff members live with the equipment daily and can share insights and information about performance and maintenance. A manufacturer's representative can help decipher the characteristics of old equipment that has lost identifying markings and provide insight on the technical limitations of specific equipment. Physical evaluation of the equipment is a task well suited to an electrician or electrical contractor member of the team, who will often have a checklist to use for the testing process. Electrical engineers will assess existing conditions and identify code compliance issues using information gathered by the rest of the team. The team's assessment should include recommendations for modifications to existing equipment as well as any new equipment that is needed.

The ultimate goal of an electrical distribution assessment is twofold: (1) to make sure upgrades can work with existing infrastructure and (2) to move toward a reliable infrastructure that is easy and less costly to maintain and minimizes electrical mishaps that endanger lives and damage property.

Testing and Exercising Distribution Equipment

Many health care facilities do a good job of physically evaluating (testing and exercising) their equipment and maintaining accurate logs of electrical events. However, even when a facility department closely monitors the status and functioning of older equipment, additional physical evaluation is still needed to gain a full picture of the status of the equipment.

Typically, when a building constructed in the 1950s is remodeled, it receives new light fixtures, medical equipment, and computers, all supported by the building's original and aging electrical distribution equipment. This works if the electrical distribution equipment is tested and exercised as outlined in ANSI/NETA (American National Standards Institute/InterNational Electrical Testing Association) MTS-2011: *Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems*, National Fire Protection Association (NFPA) codes, and the manufacturer's recommendations, potentially extending the life of the equipment. Exercised and well-maintained equipment should last longer than equipment that receives attention only in the event of a failure.

Although there is no standard for the useful service life of distribution equipment, the general consensus in the industry is that it lasts approximately 30 years. The American Hospital Association publishes *Estimated Useful Lives of Depreciable Hospital Assets*, a guide that lists the expected life cycle of various equipment and other assets. For example, the document suggests the estimated useful life is 15 years for electrical switchgear, 30 years for transformers, and 20 years for generators. These estimates are significantly less lenient than those generally accepted in the industry. Factors that affect equipment life include installation, maintenance, testing, and ambient or environmental conditions. The types of loads downstream of the equipment can also have an impact on the useful life expectancy of a system. All of these factors could either extend the life of the equipment or cause a failure earlier than anticipated.

ANSI/NETA MTS-2011 is an excellent resource for information on equipment testing. This document presents uniform testing procedures as well as standardized criteria for field tests and inspections to validate equipment reliability.

Even though many health care facilities have electricians on staff, the recommendation is for a third-party electrical contractor, electrical distribution equipment manufacturer, or testing firm to perform the selected tests. Many large firms that specialize in this type of testing have established and follow their own protocols and associated check sheets for equipment evaluations. These protocols are based on the ANSI/NETA standards. Employing a third party to test the equipment can help streamline the physical evaluation process.

A caveat is in order here: Testing is not always recommended. Depending on the age and state of the distribution equipment, certain tests could introduce more problems than can be offset by the information gained about the equipment's longevity. If maintenance, testing, and exercising have not been routinely performed, it may be physically impossible to reenergize a piece of equipment de-energized during testing because the overcurrent device can no longer hold in a closed position. In addition, aging equipment may have breakers that are permanently welded closed. Testing that requires these breakers to open may cause additional unexpected damage to the gear and risk the safety of the person conducting the test. For equipment that falls into this category, a contingency plan that enables quick reaction to an incident must be in place.

Before creating and implementing a testing and inspection schedule, facility personnel should physically scrutinize the equipment to be tested for the safety of the electrician doing the work, the equipment itself, and the building. When deemed safe, testing reveals either a passing or failing grade and gives specific directions for improvement.

Even if regularly tested and maintained, however, aging equipment in many old facilities may need to be replaced. This is because spare or replacement parts are likely to be unavailable when needed or the equipment may be difficult to repair quickly (or at all), causing an electrical failure. Remember, not planning ahead for possibilities will lead to an electrical emergency at some point.

Code Compliance Considerations

Since the initial publication of NFPA 70: *National Electrical Code*® (*NEC*) in 1897, many modifications have been made to the electrical equipment criteria and associated installation requirements. With each new edition of the *NEC*, new safety changes are incorporated. These changes come from the recommendations of manufacturers, electricians, and designers in conjunction with field observations and research on improving equipment reliability and safety. The 2011 edition of the *NEC* includes even more safety standards and design compliance criteria than were adopted 20 years ago. Specifically, many significant changes concern existing electrical installations. Classes on NFPA codes can keep facility engineers updated on the newest safety criteria.

A number of code compliance issues consistently come up when existing distribution systems in health care facilities are evaluated:

Separation of Systems

According to Section 700.10 (B) and Article 517 Part III of the *NEC*, emergency loads must be kept entirely independent of other wiring and equipment. Article 517, as it is currently enforced, was introduced in the 1971 edition of the *NEC*. Before that, the accepted practice was to commingle the emergency system with other branches of power. Today, in facilities where essential electrical systems are 150kVA or less, loads may be combined but they must be separated from the normal power source unless they meet the criteria of the *NEC* exceptions. Many older hospitals still have "E" power and have not completely separated their system to meet current code requirements.

The intent of this separation requirement is to assure emergency systems can maintain power in the event of a utility outage or fault by another branch of power. There are many interpretations of how this requirement should be implemented for both new construction and remodeling or upgrade projects. Thus, it is always prudent to discuss the installation and design intent with the authority having jurisdiction (AHJ) before proceeding with any system modification.

Selective Coordination

Electrical system coordination has been required by the *National Electrical Code* for many years. Section 240-12 of the 1975 edition mandates electrical system coordination in industrial locations to minimize hazards to personnel and equipment. This section changed in the 1987 edition, widening its scope beyond industrial applications.

Selective coordination was introduced for elevators in Article 620 of the 1993 edition and for health care facilities in Article 517 of the 2005 edition. The 2005 code cycle instituted Article 517.26, which deferred to the requirements stated in Article 700—all overcurrent devices in the essential electrical system must be selectively coordinated. Specifically, the 2005 edition defined selective coordination as "localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the choice of overcurrent protective devices and their ratings or setting." The requirement for selective coordination is even more stringent in the *NEC*'s recent editions.

Section 700.27 of the 2011 edition of the *NEC* requires selective coordination of all supply-side overcurrent protective devices in the emergency system. The purpose of this coordination is to assure that each overcurrent device trips in sequential order.

The application of this requirement and how it is enforced vary from jurisdiction to jurisdiction. Some jurisdictions have interpreted or extended this *NEC* requirement to include portions of the normal electrical system as well. Jurisdictions may also enforce different standards for the point in time after origination of a fault when selective coordination begins. Some jurisdictions insist that selective coordination begins at inception of the fault, while others permit using delays of 0.01 or 0.1 second. Many engineering tools and much equipment performance documentation use the 0.01-second standard.

Section 6.4.2.1.2 of NFPA 99-2012: *Health Care Facilities Code* clarifies for the first time that selective coordination is required for the period a fault's duration extends beyond 0.1 second. In some jurisdictions, however, electrical inspectors do not recognize the requirements of NFPA 99. Often, the level enforced for new construction is down to 0.01 second. This level is chosen on the basis of documentation available for breaker and fuse characteristics, which start at 0.01 second. The bottom line is it is prudent to confirm the level and method of coordination required with the AHJ prior to implementing a design.

It is good engineering practice, although not code mandated, to also coordinate the extent of the normal branch systems that are not associated with the essential electrical systems with a goal of selective coordination at 0.1 second. Given that NFPA code requirements are sometimes inconsistent and that an electrical distribution system often includes a combination of newer and older equipment, a less stringent variance for selective coordination of existing devices can be discussed with the AHJ. If a variance is requested and granted, it is important to have a written document that lays out expectations and agreed-upon parameters to avoid future code compliance issues.

Ground Fault Protection

Sections 215.10 and 230.95 of the *NEC* call for ground fault protection when the rating of the disconnecting means (mains) is greater than 1,000A on a 480V system. Article 517, which focuses on health care facilities, includes additional requirements. For example, Section 517.17 requires an additional level of ground fault protection in all next-level feeder-disconnecting means downstream of the main breakers. The purpose of having two levels of ground fault protection is to allow the feeder breaker to open on a fault condition so that only the feeder loads (instead of the entire switchboard) are de-energized. Section 700.26 of the *NEC* indicates that ground fault protection should not be installed on the load side of the essential electrical system (the emergency switchboard), but Section 700.6 (D) states that ground fault indication should be provided. Since an emergency system is a facility's last opportunity to maintain power in an emergency, shutting down the emergency distribution system for a ground fault situation is inappropriate and could cause more damage.

Fault Current Rating

The fault current rating of a piece of equipment is based on the highest electrical current a piece of equipment can withstand in the event of a short-circuit condition. Calculating the fault current rating entails identifying the available fault current, which originates from the utility and the generators. If the available fault current exceeds the equipment's rating, a catastrophic failure could occur.

Often, older facilities have never had a fault current study performed to determine the available fault current at each piece of equipment. Instead, the default AIC (available interrupting current) ratings have been used. But even when a fault current study was performed on the original installation, a system can become unsafe due to remodeling/expansion projects that add additional electrical equipment without updating or maintaining an accurate fault current study.

Determining the available fault, considering the utility contribution, and evaluating the system for the generator contribution are crucial to assure safe operation. The actual available fault currents of each source and known loads, including motor contributions, should be used in this analysis instead of assumed default values. In addition, equipment ratings should be reevaluated when changes are made to the system.

Arc Flash Hazard

Arc flash rating is based on a specific piece of equipment's ability under a fault condition to cause an explosion, or an arc fault. The rating defines the equipment's ability to deliver energy. Section 110.16 of the *NEC* requires each piece of equipment to be marked with the arc flash hazard category.

Arc flash hazard categories correlate to the personal protective equipment (PPE) gear an electrical worker is required to wear to be safe when working on or around energized equipment. An arc flash rating of more than 40 cal/cm2 is categorized as "dangerous," and no PPE gear is available to safely work on live equipment. NFPA 70E: *Standard for Electrical Safety in the Workplace*® provides additional details on PPE and related requirements. If energized equipment must be worked on, it is recommended that the affected personnel fully understand and implement these safety standards.

Although the arc flash hazard level of electrical equipment is not a specific code requirement, it is a determining factor in the decision to replace existing equipment. Often, the electrical system of a hospital must remain energized during maintenance procedures, and the lower the arc flash hazard of the equipment the safer the personnel who must work on that equipment. Similar to a selective coordination study, an arc flash hazard study can be completed on existing equipment. Findings from such studies can be useful for electrical engineers conducting an infrastructure survey.

Space Provisions for Existing Equipment

Storage is always a challenge in an aging building, and miscellaneous items often find their way into the "extra space" inside electrical rooms. Provisions such as those listed below should be taken into consideration when evaluating environments where electrical equipment is located:

Dedicated Equipment Space

A dedicated equipment space must be allocated for equipment rated 600V, nominal or less. Section 110.26 (E) of the *NEC* delineates requirements for this space and specifies that it must be free of "foreign systems" (i.e., piping, ducts, or other equipment foreign to the electrical installation).

Working Space

Working space is required around all equipment. Table 110.26 (A)(1) in the *NEC* specifies the following clearances for equipment rated 151-600V, nominal voltage to ground:

- A minimum clear distance of 4 feet for a 480V piece of equipment with exposed live parts on both sides of the working space
- A distance of 3 feet 6 inches for equipment with live parts on one side and grounded parts on the other side of the working space
- A distance of 3 feet when there are live parts on one side and no live or grounded parts on the other side

As a building ages and remodeling occurs, new equipment is often added to already cramped electrical spaces—a fact that impedes compliance with code-mandated clearances.

Required Egress

Section 110.26(C)(2) of the *NEC* stipulates that two exits—one at each end of the working space—must be provided for equipment rated 1,200A and greater. If two exits are not feasible, a single exit is acceptable, but the working space must be doubled. All exits are required to be continuous and unobstructed. Egress doors must swing in the path of egress, and door-opening hardware must allow for immediate exit. This "panic hardware" enables an injured worker to quickly leave the room without fumbling with the doorknob, handle, or latch.

Maintenance Considerations

When the installers have left and an electrical project has been completed, the facility personnel are left to operate and maintain the altered system, preferably with O & M (operations and maintenance) manuals for the new equipment in hand. At this point, the facility department should have a record of the old equipment that has been retained and the new equipment that has been added. If the complete electrical infrastructure has not been replaced, the inevitable result is that some inconsistencies of equipment and design methodology remain in the distribution system.

Following are some aspects of an electrical distribution system that includes both old and new equipment to consider when planning an equipment replacement strategy and its associated maintenance plan:

Equipment from Multiple Manufacturers

When equipment from multiple manufacturers is part of an electrical system, a great number of spare pieces and parts must be stocked. Because storage space for electrical equipment is often small or non-existent in a facility, attention must be paid to finding a place for these items. In addition, maintenance personnel must be trained on each piece of equipment to assure that all equipment is tested, maintained, and used correctly.

Obsolete Equipment

Some old pieces of equipment will have been made by manufacturers that are no longer in business and therefore cannot supply replacement or spare parts if needed. In general, parts (if they can be found) are reconditioned pieces from the original product line, which means they present the same age problems as the obsolete equipment from which they were taken. Workarounds can always be employed to address emergency situations related to obsolete equipment, but this is a short-term fix and not recommended as a long-term solution for a health care facility.

Mystery Equipment

Mystery equipment falls into the same category as old equipment in the distribution system. These pieces have lost the distinguishing marks that noted their manufacturer and electrical characteristics. As a result, determining how long they will last or when they need to be replaced becomes a guessing game. The goal of a replacement strategy is to remove all mystery equipment from the distribution system.

Multiple Design Methodologies

Sometimes, it is acceptable to have electrical infrastructure that is based on multiple design methodologies if this is because new methodologies are being introduced as a step toward moving an entire facility to a new electrical distribution design. If the new design simplifies the infrastructure while adhering to all applicable codes and requirements, the inconsistencies will eventually be phased out as the rest of the facility is upgraded. Without a master plan that applies throughout the facility, however, different design methodologies will cause confusion for those who perform maintenance, locate source equipment, and troubleshoot problems.

Inconsistencies in Equipment Nomenclature

Variations in equipment nomenclature, such as multiple designations for voltage and branch of power, can be confusing. Not only does this present a maintenance challenge, but it also creates a risk for the facility when the voltage or branch of power associated with a piece of equipment is unclear. In addition, it makes the task of providing appropriate sources of power for new loads difficult for future electrical designers.

Strategies for Upgrading an Electrical Distribution System

A common misconception is that an aging electrical infrastructure has irreversible physical deficiencies and does not meet current codes and therefore must be replaced. However, upgrading an entire electrical distribution system is often not feasible or is financially unrealistic, and the truth is that a facility has other options for correcting the deficiencies of aging equipment. The first step in identifying these options is evaluating the existing electrical distribution equipment to identify the code compliance and potential points of failure of each part of the system.

A phased implementation plan is often the most acceptable approach to upgrading an electrical distribution system. The plan should state the desired outcome of the upgrade and the steps to achieve that end goal. Each phase should have a timeline to fully convey the design intent and keep everyone involved on track. Phased implementation of an electrical system upgrade is a prudent strategy, as facilities generally have other construction projects that can be coordinated with upgrade activities.

Each approach to upgrading an electrical system has financial, safety, and risk ramifications as well as potential legal consequences if an electrical incident occurs after only a portion of a needed upgrade has been implemented. While all of these factors are important, safety must take priority in evaluating the options. Safety will also be a deciding factor for the AHJ (electrical inspector) who must approve the option selected by the facility.

Modifying an existing electrical distribution system requires input not only from the assembled project team, but also from the AHJ. It is the AHJ's responsibility to approve a proposed design to assure the resulting installation is safe and complies with current codes. As mentioned earlier, an assessment of the existing electrical infrastructure at a facility often uncovers numerous conditions that do not comply with the current *National Electrical Code*. As a result, the AHJ may have to consider grandfathering in existing conditions for a new design to be approved. The AHJ will determine when it is acceptable to retain existing conditions and when an upgrade to current codes is required to maintain the safety of the facility. The extent of the effort required will depend on how substantial a proposed electrical infrastructure upgrade is.

Ultimately, proper planning, preparation, and maintenance will prevent most electrical distribution system problems.

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