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engineer

How to design electrical rooms

Electrical engineers should coordinate with mechanical engineers, architects, structural engineers, and others involved in the design of electrical rooms.

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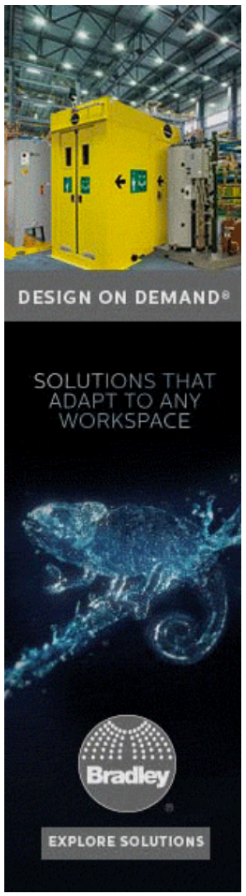


Learning objectives:

- Explain the applicable code requirements including NFPA 70: National Electrical Code.
- Evaluate the design criteria for appropriate electrical-room size to accommodate present and future needs.
- Analyze the requirements for coordinating with structural, architectural, fire protection, and HVAC requirements.

PEER REVIEWED

Electrical rooms and mechanical, electrical, and plumbing (MEP) spaces are often an afterthought when it comes to building design and planning, either relegated to locations that are left over or deemed undesirable for other planning purposes. This shortsightedness can have unfortunate consequences on the cost, operations, and flexibility of the systems for the future.

NFPA 70: National Electrical Code (NEC) dictates the minimum amount of space needed around the equipment for access, operations, safety reasons, and conduit installation. Together, with the actual equipment sizes, this defines the overall minimum dimensional requirements of the room.

There are three types of general interior electrical spaces that factor into new building design: main equipment rooms, distribution pathways, and local/branch equipment rooms. Code-required working space and dedicated space needs must be met. This article will outline important considerations for these spaces in the early stages of building design as they relate to building type, intended occupancy, size, and future expectations of both the building and the electrical systems.

Working vs. dedicated spaces

Let's first define what differentiates working and dedicated space as stated by the NEC (see Figure 1). The working space helps safeguard a clear working zone around all equipment and ensures protection for any workers or occupants within the room. This includes defining minimum width, depth, and height requirements for the working space, which varies due to voltage and the specific equipment. The higher the voltage of the equipment, the greater the depth of the working space. The width should be equal to the width of the equipment and no less than 30 in., while allowing for opening any doors or hinged panels to a full 90 deg. The height should be 6 ft 6 in. from the floor, or the height of the equipment if greater than 6 ft 6 in.

The style and construction type of the electrical equipment dictates whether only front access is required, or if rear and/or side access also is required. For each point of access to a piece of equipment, the minimum working clearances must be provided.

Dedicated space is a zone above the electrical equipment. It's reserved to provide future access to the electrical equipment, protection of the electrical equipment from foreign systems, and for installing conduit/other raceways supporting incoming and outgoing circuits. The requirement for dedicated space applies primarily to switchgear, switchboards, panelboards, and motor control centers. The space should be equal in width and depth to the equipment size and extend from the floor to a height of 6 ft above the equipment (or to a structural ceiling, whichever is lower). No equipment or systems foreign to the electrical installation are allowed in this zone by the NEC.

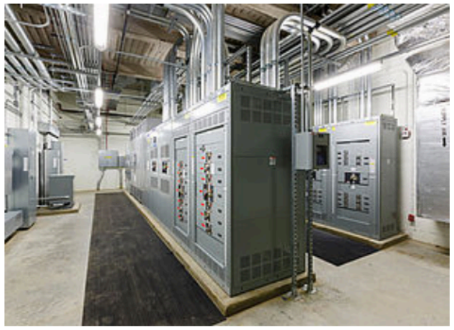
The area above the dedicated space may contain foreign systems, provided proper protection prevents damage from drips, leaks, or breaks in these systems. However, it's good practice to avoid having these systems installed in electrical rooms altogether.

While installations of equipment greater than 1,000 V generally follow the same principles, some of the specifics vary, requiring additional clearance around the equipment due to the increased hazard that these voltages impose (see Figure 2). Access to this equipment is preferably limited to only those deemed qualified to be there. For this reason, electrical equipment should be installed in rooms or spaces that are dedicated for that purpose and have controlled access.

The first room type we'll explore in this article—a main equipment room—has distinctive needs that separate it from distribution spaces or local/branch equipment rooms.

Main equipment rooms

The main electrical room, or service entrance space, should coordinate with the local electrical utility (refer to NEC Article 230, Services, for additional details pertaining to the installation of service entrance conductors and equipment). For example, main equipment rooms have requirements that dictate access to the space from the exterior for servicing, maintenance, and service feeder installation. The type of equipment installed will also further determine the room requirements. The service entrance room is typically located on an exterior wall for both code and practical reasons; it makes installation easier and minimizes the length of the service entrance conductors. Because the service conductors are usually the largest in the facility, this can have a substantial impact on cost.



Using arc-resistant switchgear will also impact space needs. This equipment will be taller and may have a larger footprint. Engineers will also need to account for the potential exhaust gases and arc flash energy by providing a pathway to expel them and relieve the pressure buildup from inside the switchgear.

If an exterior transformer is used to provide the service to a building, feeders from the transformer enter the building and transition to the main service entrance disconnect, typically a switchgear, switchboard, or panelboard. These feeders are often routed underground into the building through the exterior foundation wall via a coordinated opening. Additional coordination with the structural engineer is needed to avoid footings.

The elevation of the service entrance conduits many times do not naturally align with the equipment to which it is routed. Additional space in the form of increased height or footprint commonly is required to allow for the successful transition and termination of these conduits and conductors. Service installations that require medium-voltage equipment and/or transformers installed indoors will require additional elements including more space, higher fire ratings of the rooms (per NEC Article 450), and increased ventilation.

The location of any exterior equipment also needs to be coordinated with other architectural and landscaping elements. Minimum separation distances are often dictated by local codes/ordinances or utility requirements for proximity to screen walls, fencing, vegetation, paths of egress, or building fenestration.

Generator installations offer additional challenges when it comes to defining space needs. Noise, odor, and vibration factor into the location of this equipment within a building. The equipment should be located to minimize disturbances to building occupants and adjacent properties. Many jurisdictions have specific requirements on noise emissions, which will impact equipment placement and other components needed to meet requirements. Increasing the distance of this equipment from sensitive areas is one way of dealing with the concerns, but this comes with added feeder costs and may prove to be more costly than other options.

Sound attenuation and equipment required to meet specific emissions requirements, such as diesel oxidation catalyst, particulate filters, urea tanks, and selective catalytic reduction units, have significant cost implications and require a large amount of space to install. The U.S. Environmental Protection Agency defines the performance standards for stationary combustion engines in 40 CFR Part 60, Subpart III.

Tier 4 versus Tier 2 compliance is usually dictated by an owner's desire to use a generator for utility peak shaving or other nonemergency uses. It is crucial to have a clear understanding of current and future implications in both of these areas from the outset of a project and to discuss them thoroughly with the building owner.

The weight of a generator and the vibration experienced during its operation will have an impact on the building's structural design. Generators require a lot of ventilation for cooling and combustion needs; getting air into and out of the room is critical and will impact placement.

With regard to fuel storage, most installations require a volume of fuel that dictates an external fuel tank with interconnecting fuel lines. NFPA limits the overall capacity of diesel fuel inside buildings to 660 gal. The relationship of the exterior tank and the generator is also important to minimize pumping requirements and allow for gravity-drain return-fuel piping. This requires the fuel tank to be lower in elevation than the generator.

Direct access to the outside is preferable for maintenance and testing. All of this requires close coordination with the architectural, structural, and mechanical disciplines.

NFPA 110: Standard for Emergency and Standby Power Systems requires the emergency power supply (generators) for Level 1 installations to be installed in a separate room, separated from the rest of the building by 2-hour fire-rated construction. While NFPA 110 does allow the emergency power supply system equipment (EPSS; equipment consists of all components from the emergency power supply, or EPS, to the load terminals of the transfer switches) to be installed in the same room as the EPS, it is good practice to keep these separated to help enhance system resiliency. EPS rooms are also prone to additional dust, moisture, temperature fluctuations, and excessive noise during operation that limits the ability to have a conversation and may have a negative impact on other equipment if co-located.

For mission critical facilities (e.g., financial institutions, data centers, and airports) and other highly sensitive installations, the use of a dry-type, preaction, or another type of fire protection system that does not rely on a normally wet piping installation is highly recommended. In cold climates, this has an added advantage of preventing pipes from freezing, rupturing, and potentially flooding the EPS room.

Distribution pathways

Distribution pathways are needed for interconnecting all the electrical equipment and end-user devices, and the pathways will affect where rooms are located. Conduits can be routed above the equipment, below ground, or in the ceiling space of the floor below, though overhead conduits need space within the rooms to leave the equipment and transition to the desired route going to other parts of the building (see Figure 3). The routing of the feeders and how they enter/exit the distribution equipment must be evaluated during design and reconfirmed during the shop drawing review, as this will impact how the equipment is constructed and affect its physical size.

Below grade conduit routing needs to be coordinated with other utilities and footing/foundation elements. The restrictions that these place on the routing may impact the layout of the equipment in the room and the size of the space needed. Similarly, beams on the floor above or below the equipment may require an offset of conduit or shifting of the equipment to allow for the conduit installation to effectively occur.

Horizontal pathways can define the placement of electrical rooms, as other building elements may impede these routes and affect installation. Structural beams and large ductwork can become obstacles, especially in tandem with high ceilings. Large-volume spaces like gymnasiums and atriums require extra care as to how conduit will be routed across or around these areas, especially when the entering/exiting pathway would be lower in elevation than the ceiling.

Vertical risers are typically accommodated in either one of two ways—through shafts (pull boxes may be required depending on the height of the building and conduit layout) or stacked electrical closets. Stacked closets allow for the busway or conduits that distribute power throughout the building to be run through these spaces for a more efficient and less expensive installation. If these closets are constructed with 2-hour-rated partitions, the stacked rooms can provide the code-required circuit protection for EPSS feeders and fire alarm circuits without having to rely on more costly wiring methods.

Local/branch equipment rooms

A third space type, the local/branch equipment room, is often referred to as an electrical closet (see Figure 4). Distribution panels, branch circuit panels, and low-voltage transformers are typically located in these spaces and directly serve the end-user loads: lighting, receptacles, and small equipment. Lighting control system panels and devices (and other electrical system devices) are sometimes also located in these rooms. Given the amount of change that occurs in buildings over their lifespan, extra wall space should always be provided in these rooms for future equipment.

In multistory buildings, these spaces should be stacked. The placement of electrical closets within a building's footprint is often an item of much debate and discussion with the rest of the design team. The NEC has set restrictions on piping and ductwork routed through these rooms (i.e., dedicated spaces). Conduit needs to be routed out of the room to the floor or area served; minimizing branch circuit lengths help avoid excessive voltage drop and reduce distribution costs. These rooms should be located as close to the center of the area served, with conduits routed out in all directions.

Avoid specific adjacencies to other building elements. Often, closets are targeted for location next to mechanical shafts, but the need to get ductwork and/or piping out of these becomes challenging and conflicts with the electrical equipment's dedicated space. Similarly, locations next to stairs or elevator shafts present other challenges and limit the routing of conduits out of the electrical rooms. Locating electrical rooms next to these, especially if placed between, should be carefully evaluated to ensure there is enough space and flexibility for conduits.

Additional space needs

Outside of working- and dedicated-space needs, there are many special considerations for electrical rooms that depend on building programs as well as exterior spaces that will directly impact how the electrical systems are designed. The needs and expectations associated with an office building are very different from that of a data center or hospital with regard to the electrical distribution systems. Redundancy and resiliency are essential for mission critical-type facilities. Flooding due to natural disasters is a key element in determining equipment placement (NFPA 99: Health Care Facilities Code, Chapter 6, and NFPA 110, Chapter 7). Historically, much of the main equipment was located in basements or (partially) belowgrade levels, but now this equipment is located above the anticipated flood levels. This ensures ongoing continued operations during and after an event.

Mission critical and safety-critical (e.g., hospitals) installations require added redundancy to ensure the continuity of business operations and avoid potential loss of life or serious personal injury. Redundancy of systems requires more space, as the equipment is separated into different rooms in different parts of the building. Having panels that are part of a redundant distribution arrangement (A and B sources) located adjacent or in close proximity to each other in the same electrical room greatly minimizes the value that the intended redundancy offers. The redundant equipment should be located in separately rated spaces, with the A sources and distribution located apart from the B sources and distribution.

Additional clearance requirements include allowing for future equipment to be moved into a room or allowing for the eventual replacement of that same equipment. While code may only require 3 or 4 ft of clearance in front of a piece of equipment, the physical dimension of the equipment could be larger. Because of this, the only way to effectively remove and reinstall a replacement is to leave an area that is larger than the footprint of the equipment.

Getting equipment from the exterior of a building to its final location may not always be a concern during the initial building construction, but it will certainly be an issue during later time periods of equipment modifications, additions, or replacement. The entire pathway from the building exterior, including doorways, may need to be enlarged due to the height or width of the equipment. If the equipment is located on a floor level that is below- or abovegrade, then area wells, reinforced floors, and a pathway or removable sections of the exterior wall assembly may be required.

Buildings are expected to have a life well beyond the initial install, and yet future growth and conduit installation are rarely considered. This automatically infers change, which will likely come in the form of added equipment and conduit. Initial planning and system design should account for this by including spare breakers, additional distribution sections, and oversized-conduit rack supports.

Supporting the whole building

Appropriate lighting and illumination levels are important for occupant safety. Ventilation and cooling needs must be defined and support the heat load generated. And it's important to remember the physical protection of equipment located outside and in the open. This may entail the installation of crash-tested bollards or barriers to protect the equipment from accidental vehicle damage, for instance.

The NEC also requires that access to some equipment be limited to qualified persons only in some instances. Per the NEC, this includes only those who have the skills and knowledge related to the construction and operation of the electrical equipment, the installation, and have received safety training to recognize and avoid the hazards involved.

There is no singular method to design electrical systems, nor are two buildings ever the same. Electrical space needs differ by project and building. Electrical engineers and designers must consider many factors when making the decisions that lead to the final design. Most importantly, this includes communication and working hand-in-hand with mechanical engineers, architects, structural engineers, and others that have a hand in the design of buildings, and coordinating the electrical installation with these other disciplines.

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