Basics in low voltage distribution equipment

Mark Rumpel
Product line manager
Eaton

Executive summary

Depending on their unique needs, multi-family, commercial and industrial sites typically rely upon either low or medium voltage service entrance equipment to control or cut off the electrical supply of their buildings from a single point. Low voltage distribution equipment typically operates at less than 600 volts; in contrast, medium voltage equipment affords a wider range of 600 to 38,000 volts.

This paper provides a basic overview of the definitions, components, applications and other details associated with low voltage distribution equipment. It covers electrical panelboards, switchboards and switchgear operating at 600 volts alternating current (AC) or direct current (DC) or below. The information is intended to help readers understand the purpose of electrical distribution systems and associated equipment and increase their technical knowledge about it.

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Basics of electricity generation

In the U.S., as elsewhere, electricity has historically been generated from precious natural resources including coal, oil or natural gas. Nuclear energy and hydropower innovations advanced electrical generation capabilities at the end of the 20th century. Today, alternative and renewable fuels such as geothermal energy, wind power, biomass and solar energy are gradually becoming more readily available; these sources are popular both for their higher efficiency and long-term sustainability.

Once harvested, natural resources and mechanical energy sources must first be converted into electrical energy to make it transmissible and usable. Power plants complete this function using steam turbines.

Water is heated in a massive boiler to produce steam, which is used to turn a series of blades mounted on a shaft turbine. The force of the steam rotates a shaft connected to a generator. The spinning turbine shafts turn electromagnets surrounded by heavy coils of copper wire inside generators. This creates a magnetic field, which causes the electrons in the copper wire to move from atom to atom, thereby creating electricity.

After the turbines have generated electricity, voltage must be increased to transport it as power. This is accomplished by passing the electricity through a series of step-up transformers for routing onto a network of high voltage transmission lines. Electrical power then travels very efficiently and safely over long distances along these lines.

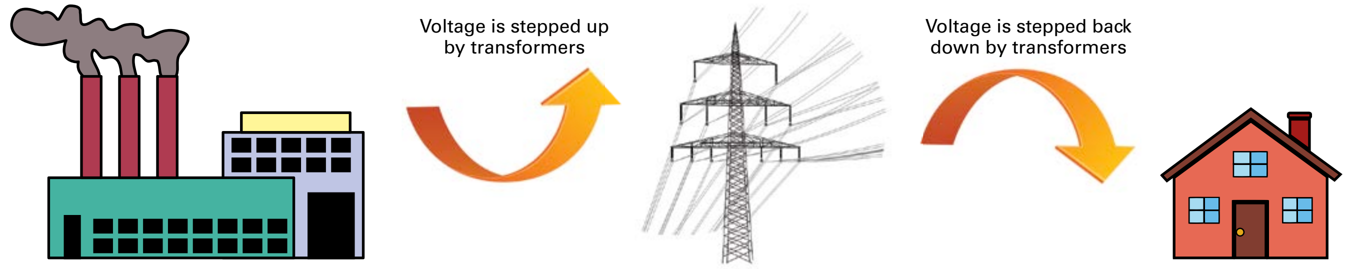

Figure 1. Understanding energy production and electrical distribution: from generation to transmission to consumption.

Electrical distribution systems further facilitate the economic and safe delivery of adequate electrical power to all the electrical equipment used in a home, commercial building, or industrial facility. The transmitted power arrives first at an electric distribution substation, where it is passed through a series of step-down transformers that again lower the voltage to more usable levels. Finally, the usable electricity enters the building at a single point known as the service entrance. Power enters through a main device (circuit breaker or fusible switch) located within an electrical assembly referred to as the service entrance electrical distribution equipment.

Panelboards, switchboards and switchgear can all be used as service entrance electrical distribution equipment or at a point downstream, in which case it is known simply as power distribution equipment. Each option offers unique uses and benefits to the multi-tenant home, commercial facility or industrial site, so it is helpful to consider each in greater detail.

Panelboards

A panelboard is a component of an electrical distribution system that divides an electrical power feed into branch circuits while providing a protective fuse or circuit breaker for each circuit in a common enclosure. In essence, panelboards are used to protect against electrical overloads and short circuits while distributing electricity throughout a building or facility.

The main components of a panelboard typically include the enclosure, interior, circuit protection devices, labels, deadfront and trim, and filler plates.

Figure 2. Homeowners should be familiar with the basic components of panelboards.

More commonly referred to as the "box" or "can," the enclosure provides the housing in which all the other panelboard components reside. Enclosures are made of galvanized or painted steel to provide protection for personnel and internal equipment. Removable end panels allow for simple conduit installation where installers can easily locate and cut holes as needed.

Inside the enclosure, overcurrent protection devices, busbars and other components are mounted on support rails. This interior assembly is commonly called a chassis. Circuit breakers are commonly used as circuit protection devices and are connected to the busbars by bus connector fingers.

A busbar is a conductor used as a connection point for multiple circuits. Busbars are mounted to insulators on the interior rails, which are then mounted to studs inside the box. A neutral bar is also chassis- or gutter-mounted next to the interior, providing the termination point for the neutral wires from the incoming service and the load circuits.

Panelboards should always be well labeled. Labels provide regarding the unit's voltage rating, ampacity, interrupting rating, manufacturing date, panel vintage and renewal parts. This information is critical to ensuring the safety of people and equipment.

Enclosures feature a front cover piece known as the panelboard's deadfront and trim. This component covers the front surface of the panelboard and provides a hinged access door that allows access to the circuit breakers while preventing contact with the energized interior components. Filler plates cover any unused pole spaces not occupied by a circuit breaker.

The National Electrical Manufacturers Association (NEMA®) has established guidelines for electrical equipment enclosures. A NEMA Type 1 enclosure is the standard for indoor panelboard enclosures.

Panelboards can be installed using one of two common approaches. When flush mounted, the panelboard is placed in a recessed area between the wall studs. When surface mounted, the panelboard projects out from the wall.

Flush mounting saves space and is generally more aesthetically attractive, while surface mounting is ideal for buildings with concrete, block or steel walls, and columns. Generally, flush mounting is commonly used for commercial, office, school and other public buildings. Industrial buildings, electrical closets and basements typically feature surface-mounted installations.

Panelboards are often categorized by their general application, whether they are used for lighting and appliances or used for power. Lighting and appliance panelboards contain overcurrent protection and a means to disconnect lighting, appliances, receptacles and other small load circuits. All other panelboards are used for power and may also feed other panels, motors and transformers in the building's or site's overall power distribution systems.

Power panelboards are generally used in industrial facilities and new or retrofit commercial construction applications where the electrical distribution needs are more complex and require system-level solutions. These panelboards offer broad system application capability for service entrance requirements or general power circuit distribution. For example, multi-tenant use facilities commonly employ power panelboards for electrical distribution. Increasingly, power panelboards are specifically designed to meet applications where changes and additions must be fast, convenient and easy.

Today's innovative power panelboards enable facilities to achieve reliable power performance at optimal energy-efficiency levels within the smallest footprint possible. The primary benefits of power panelboards are their ability to accommodate wider ranges of volts AC while housing more breakers in less space. Both circuit breakers and fusible switches can be included on a single, bolt-on chassis design. A variety of special power panelboard features enable facility managers to coordinate power distribution selectively, meter and monitor power usage closely and remotely, and ensure personnel safety with arc flash and fault protection options.

Switchboards

For larger scale buildings or sites, a large single panel, frame, or assembly of panels can be used for mounting the overcurrent switches and protective devices, buses and other equipment. These floor-mounted, freestanding solutions are known as switchboards. Switchboards are most often accessible from the front, mounted on the floor and close to the wall.

Switchboards function the same as panelboards (and often simply feed other panelboards), but on a larger scale and at the low voltage of 600 Vac or less. They are used to divide large blocks of electrical current into smaller blocks used by electrical devices. This division is helpful for distributing power to loads; disconnecting loads for safer maintenance; and protecting conductors and equipment against excess current due to overloads, short circuits and ground faults.

The primary components of a switchboard include the frame, bus, overcurrent protective devices, instrumentation, enclosures and exterior covers. The switchboard frame is a metal skeleton that houses all the other components. Within this frame, the bus is mounted. It distributes power from the incoming cables to the branch circuit devices. A horizontal bus distributes power to each switchboard section. The standard orientation for a horizontal bus is A-B-C from top to bottom. In contrast, a vertical bus distributes power to the circuit protection devices and is normally oriented either left to right or front to back.

Overcurrent protective devices are mounted to the vertical busbars from the front of the unit. Four common types are power circuit breakers, molded case circuit breakers, fusible switches and bolted pressure switches. Other protective devices used in the switchboard interior may include meters, surge protective devices (SPDs), utility compartments, transfer switches, transformers and other equipment.

The switchboard interior may also house specialized instrumentation. Meters can be used in the incoming section to measure current, voltage, power usage, peak demands and other important power characteristics. Instrumentation can be especially helpful in monitoring and managing power usage to ensure the highest efficiency possible.

Standard enclosures for switchboards include NEMA Type 1 for indoor and NEMA Type 3R for outdoor uses. After equipment installation, the frame is enclosed with exterior cover panels. Like the deadfront of a panelboard, these covers allow access to the protective devices while sealing off the bus and wiring from accidental contact.

There are four main structure types common to all switchboards, but all switchboards do not use all of these structure types:

- The main structure contains the main disconnects or main lugs. It often contains surge protection, utility and/or customer metering equipment.
- The pull structure is a blank enclosure containing empty space through which cabling can be pulled. It is commonly used with service entrance switchboards where the utility feed comes through the floor. Service can be fed from the top without any exposed conductors.
- A distribution structure divides and sends power to branch circuit protection devices and then to branch circuits to power downstream loads. Power moves from the incoming structure to the distribution structure via cross bus.
- Last but not least, the Integrated Facility System (IFS) switchboard structure includes panelboards, dry-type transformers, transfer switches and blank back pans for field mounting other equipment. The IFS is helpful when panelboards and dry-type transformers are used in the same room as switchboards as it can reduce the need for linear wall space and area required for equipment. A key benefit of the IFS is that it significantly reduces the installation and wiring time and the number of pieces of equipment to be handled.

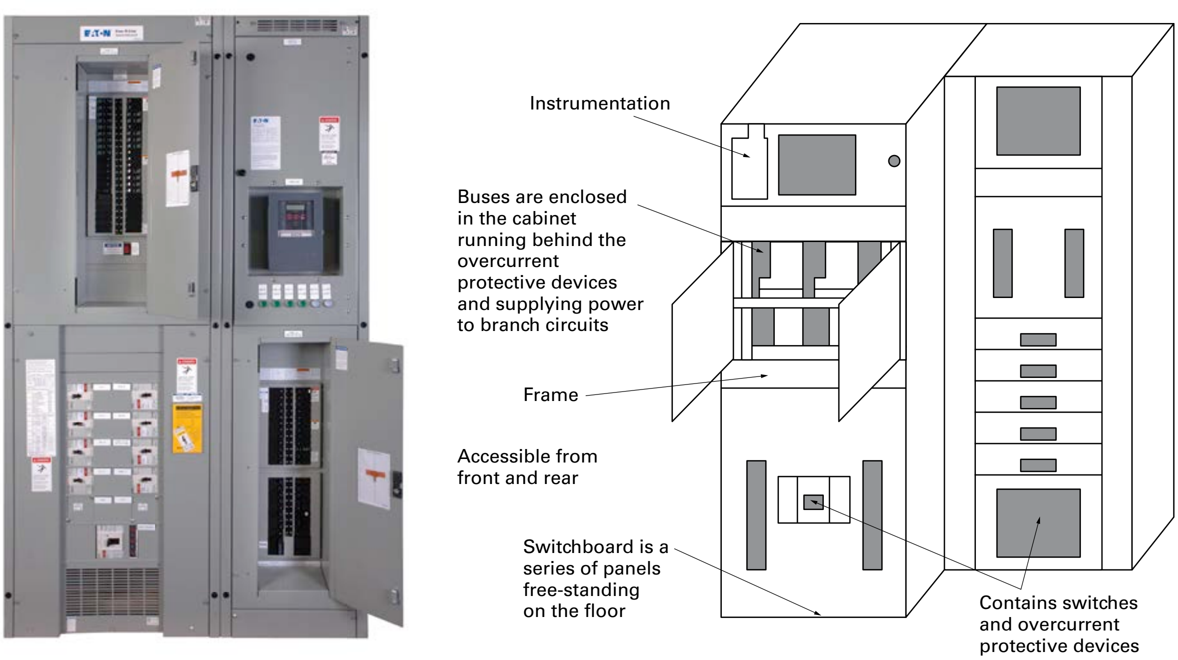

Figure 3. The switchboard enclosure houses a number of critical components.

Figure 4. Integrated Facility System (IFS) structures are easy to install and cost-effective because of their simplified wiring.

Low voltage switchgear

In some cases, more highly functional low voltage distribution equipment is needed to best protect, control and monitor critical power electrical distribution systems safely and efficiently. In these instances, low voltage switchgear is often the optimal solution.

Low voltage switchgear provides centralized control and protection of low voltage power equipment and circuits in industrial, commercial and utility installations involving transformers, generators, motors and power feeder circuits.

Unlike the other options reviewed, switchgear uniquely withstands short circuit currents for an extended period of time (30 electrical cycles). This time allows the downstream protective device closest to the fault to open and clear it; accordingly, these capabilities are referred to as short time or withstand ratings. Molded case circuit breakers in switchboard assemblies do not offer these ratings.

Low voltage switchgear features the following components: low voltage drawout power circuit breakers, circuit breaker compartments, primary and secondary power connections, secondary control compartments, structures, busbars (main and section) and customer termination areas.

Low voltage drawout power circuit breakers automatically protect an electrical circuit from damage due to overload or short circuit. The term drawout refers to the ability of these circuit breakers to connect to the primary and secondary power connections without nuts, bolts, connector kits or other mechanical means.

Figure 5. Drawout circuit breakers are easy to install and help reduce material expenses.

A bus is mounted in the frame to distribute power from incoming power cables to the branch circuit devices. Horizontal circuit breaker compartments distribute power to each switchboard section. Vertical circuit breaker compartments distribute power to the circuit protection devices in a single structure.

The power connections are categorized as primary or secondary power. The main electrical distribution system power that is being brought to the assembly and feeding out to the connected loads is known as the primary power. These connections are made by extending busbars into the breaker compartment for connection to the main system power components of the drawout power circuit breaker.

Secondary power includes the circuits used to provide power to control and monitoring equipment for electrically operated devices such as solid-state trip units, shunt trips, pilot lights, meters and control switches.

Accessed at the front of the switchgear in each structure, separate compartments are used to segregate and protect low voltage control and monitoring cables from other areas of the switchgear assembly. These secondary control compartments may contain isolated terminal blocks dedicated to specific circuit breaker compartments and other control devices. Secondary control compartments make it possible to connect devices in various control compartments to others via dedicated control circuit wireways.

The freestanding steel enclosure in which all the main switchgear components are housed is known as the structure. It contains all the power circuit breaker compartments, the primary and secondary power connections, and the secondary control compartments.

In the middle of the structure are the busbars, which are made of silver or tin-plated copper. The main busbars distribute power horizontally within the switchgear assembly from structure to structure. In each section of the structure, vertical section busbars connect to the horizontal main bus. This vertical structure bus delivers power to the power circuit breakers so the electricity can be fed out to the individual load devices.

Customer termination areas are typically located at the rear of the structure. These areas are reserved for incoming service entry power and outgoing power cable or busway connections. Each outgoing load connection terminates here for exit from the assembly to the connected equipment. For additional safety, the area is well isolated from the circuit breakers by grounded metal barriers.

Switchgear is generally installed at the highest level of the power system. Cables or conduits can be used to feed power from the switchgear into other switchboards for a systematic or segmented approach. In this way, the switchgear eliminates damage from catastrophic power outages to the maximum extent possible.

Switchgear is a robust option, but it’s larger and more expensive than other low voltage distribution equipment. Always consider whether the benefits of switchgear in terms of reliability, safety, maintainability and ease of use will be worth the added investment.

Generally, switchgear should be considered whenever the highest degree of power reliability is desired. It is especially appropriate for critical power applications—those that are so important to a user's enterprise that they cannot sustain a loss of power without incurring harmful loss of revenue, production, or human safety. Example application areas that are ideal for low voltage switchgear include hospitals, petrochemical plants, airports, water treatment facilities, data centers, major governmental facilities, defense support facilities, financial institutions and large office buildings.

In applications where near continuous uptime is a high priority, an emergency power source—such as a generator or a backup utility feed—is often used when the normal power source is unavailable. In these scenarios, a transfer switch is responsible for quickly and safely transitioning all electrical power consumed by the circuit, equipment, or systems connected to the transfer switch output between those normal and emergency power sources.

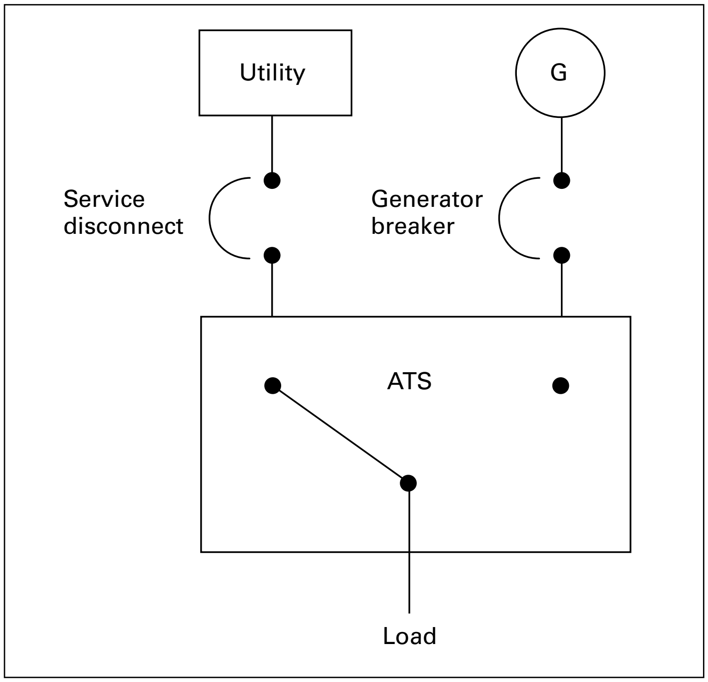

Figure 6. Basic elements of a transfer switch.

Transfer switches can transition loads between normal and emergency power sources in two basic ways: open or closed. An open transition transfer switch breaks its connection to one power source before making a connection to the other. Open-delayed switches build in a short pause prior to the switch to prevent higher than normal electrical current (also known as "inrush current") from developing. Open-in-phase switches automate this process with greater intelligence and precision.

In closed transition solutions, the transfer switch makes a connection to the new power source before breaking its connection to the old one. As there is no gap between disconnection and connection, downstream loads receive continuous power throughout the transfer process.

The switching mechanism is the part of a transfer switch that is physically responsible for carrying the rated electrical current and shifting the connection from one power source to another. Low voltage switching mechanism technology comes in two basic varieties, commonly referred to as "contactor type" and "circuit breaker type." Circuit breaker switching mechanisms can be further divided into two sub-types: molded case and power case. The specific functions performed by a given load and the importance of those functions to safety or security play an important role in determining which kind of transition is required, and therefore, which kind of transfer switch is best suited for the job.

Busway solutions

If time or space is limited, busway solutions can be used in place of cable or conduit to distribute electrical power. This efficient alternative includes three core elements: copper or aluminum conductors (known as busbars) that carry electrical current; metal enclosures that house the busbars; and insulation—via either air or epoxy designs—to prevent faults by separating the busbars.

Figure 7. (Diagram core elements): Busway solutions consist of insulated conductors contained within a housing; available in a variety of configurations, busway is an especially agile option, offering both modularity and scalability in design.

For power distribution needs that are likely to be reconfigured frequently, or evolve and expand over time, busway is an ideal solution. New bus plugs can simply be added to existing busway at any time without major infrastructure expenses or other disruptions. Busway's modular design allows for pieces to be added easily to an existing run, which brings scalable expansion not present in cable/conduit alternatives. These features make busway an especially good fit for applications in data centers, hospitals, industrial and manufacturing facilities, and some commercial and residential structures as well.

Two basic styles of busway are feeder or plug-in solutions. Feeder busway is especially agile and configurable in any way imagined. Plug-in busway can support one or more bus plugs (points of power connection) at fixed positions, but is only available in straight lengths. Some product families include bus plugs that offer breaker, fusible switch, contactor and starter options for every requirement, as well as multiple surge protection and metering alternatives.

Busway is available for indoor or outdoor use in a wide variety of current ratings. To protect sensitive electrical equipment, look for busway products that feature high fault current ratings. To assure system safety, look for busway products certified by Underwriters Laboratories (UL®), the Canadian Standards Association (CSA®), or the International Electrotechnical Commission (IEC).

Although busway is not ideal for all applications, it does offer a number of benefits that have recently increased its popularity. It is inexpensive, easy to install, highly compact, adaptable, scalable and even sustainable. A greener option, busway can support a site's ENERGY STAR® or Leadership in Energy and Efficient Design (LEED®) certification efforts.

Conclusion

A wide variety of low voltage power distribution equipment is available on the market today to meet the varying needs of specific homes, commercial buildings and industrial facilities. By gaining greater familiarity with the basic similarities and differences between panelboards, switchboards, low voltage switchgear and busway options, consumers can make more educated choices about the many products and services available in the electrical control, distribution, and power quality categories. High-quality vendors are innovative and knowledgeable about the increasing array of product options, but also capable of providing tailored guidance on how best to meet consumers' specific needs.

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1000 Eaton Boulevard
Cleveland, OH 44122
United States
Eaton.com

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