Table of Contents

Introduction

Welcome to another course in the STEP 2000 series, **S**iemens **T**echnical **E**ducation **P**rogram, designed to prepare our distributors to sell Siemens Energy & Automation products more effectively. This course covers **Switchboards** and related products.

Upon completion of **Switchboards** you should be able to:

- Explain the role of switchboards in a distribution system
- Define a switchboard according to the National Electrical Code
- Explain the need for circuit protection
- Identify various components of a switchboard
- Identify various service entrance methods
- Explain the difference between hot and cold sequence in relation to current transformers
- Identify types of main and distribution devices available for Siemens switchboards
- Identify various Siemens switchboards

This knowledge will help you better understand customer applications. In addition, you will be better able to describe products to customers and determine important differences between products. You should complete **Basics of Electricity** and **Molded Case Circuit Breakers** before attempting **Switchboards**. An understanding of many of the concepts covered in these courses is required for **Switchboards**.

If you are an employee of a Siemens Energy & Automation authorized distributor, fill out the final exam tear-out card and mail in the card. We will mail you a certificate of completion if you score a passing grade. Good luck with your efforts.

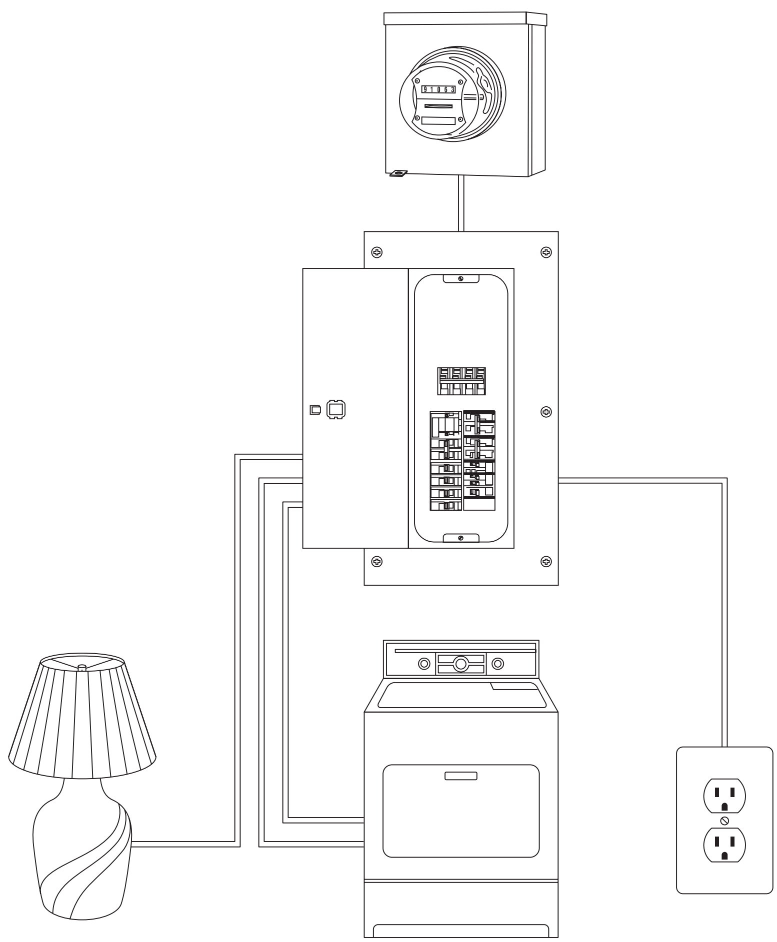
National Electrical Manufacturers Association is located at 2101 L. Street, N.W., Washington, D.C. 20037. The abbreviation “NEMA” is understood to mean National Electrical Manufacturers Association.

Distribution Systems

A distribution system is a system that distributes electrical power throughout a building. Distribution systems are used in every residential, commercial, and industrial building.

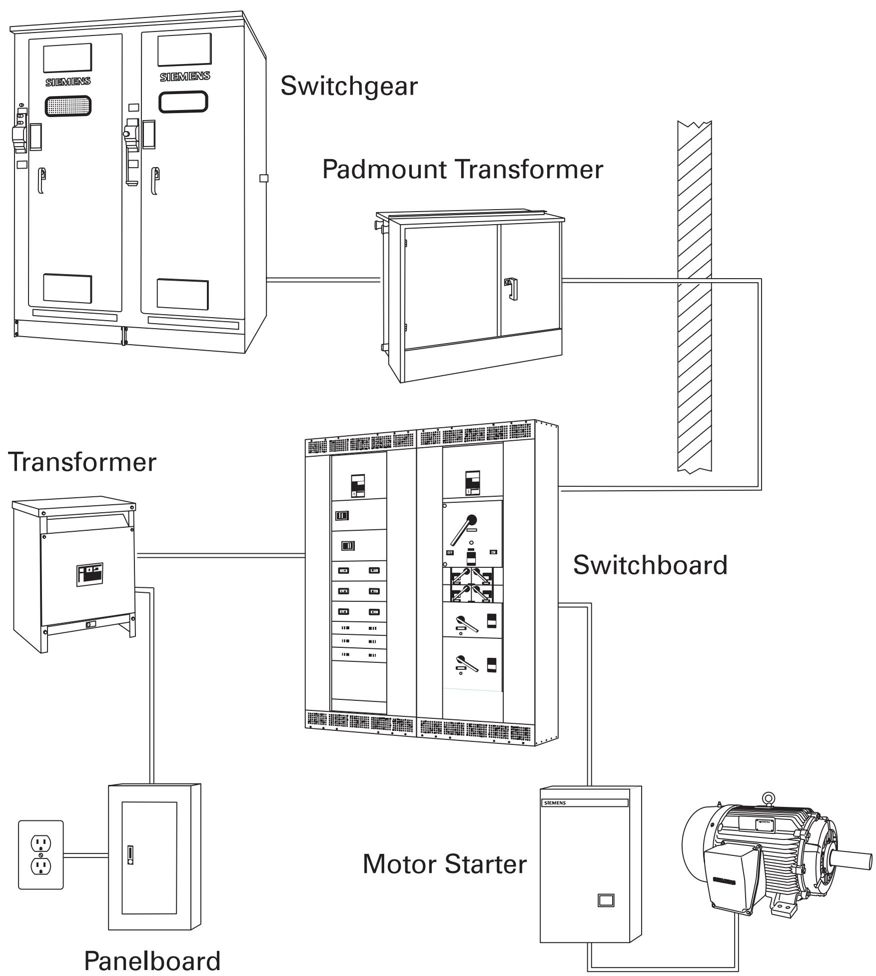
Residential distribution

Most of us are familiar with the distribution system found in the average home. Power, purchased from a utility company, enters the house through a metering device. The power is then distributed from a load center to various branch circuits for lighting, appliances, and electrical outlets.



Commercial and industrial distribution

Distribution systems used in commercial and industrial locations are more complex. An industrial distribution system consists of metering devices to measure power consumption, main and branch disconnects, protective devices, switching devices to start and stop power flow, conductors, and transformers. Power may be distributed through various switchgear and switchboards, transformers, and panelboards. Good distribution systems don't just happen. Careful engineering is required so that the distribution system safely and efficiently supplies adequate electric service and protection to both present and possible future loads.

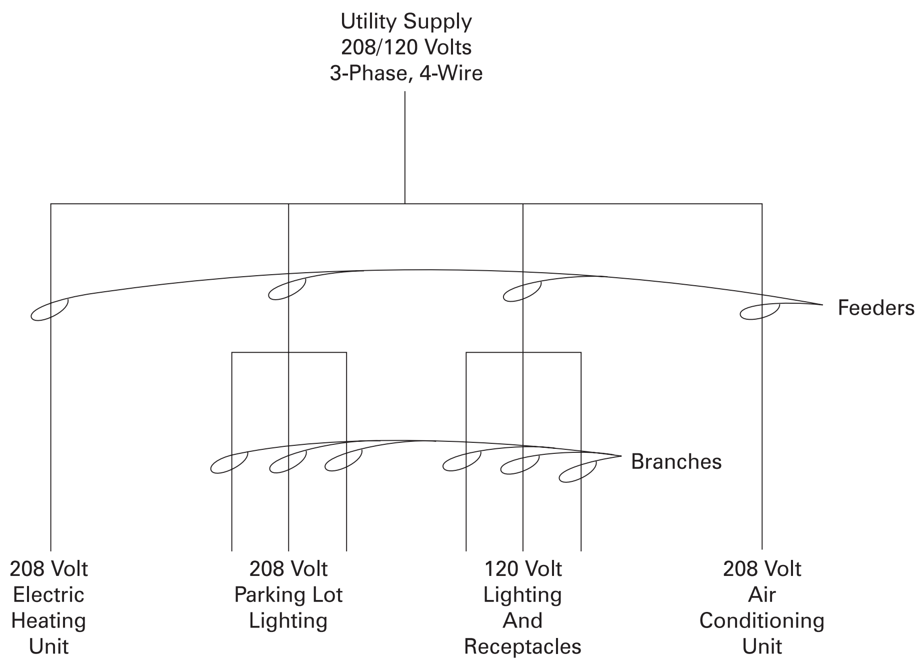


Distribution of current

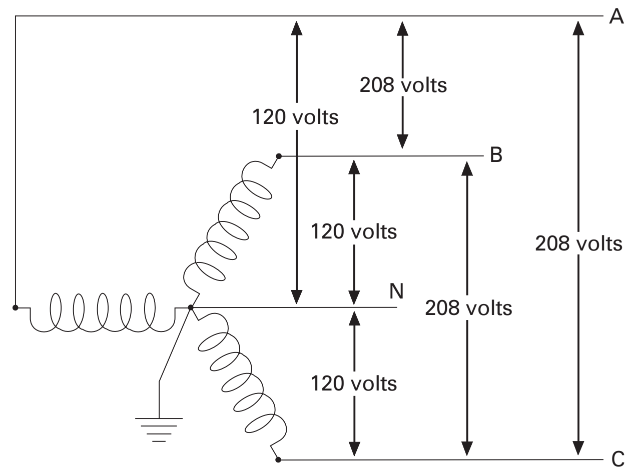
Switchboards are used in a building's electrical distribution system. A switchboard divides a large electrical current into smaller currents used to power electrical equipment. Switchboards can be found in applications ranging from small office buildings to large industrial complexes.

Small office building

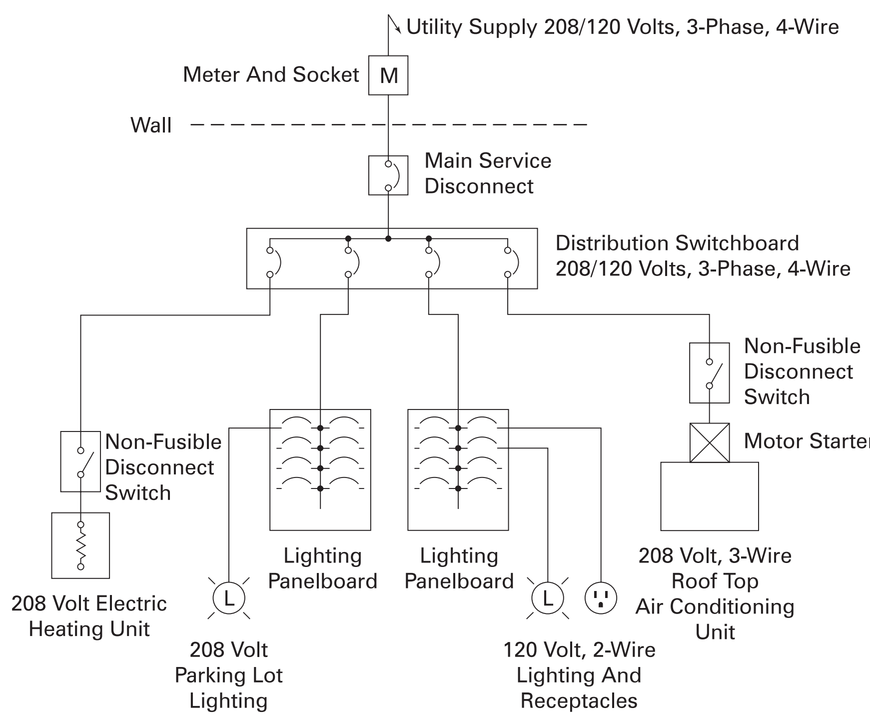
A small office building, for example, might require 120 volts for interior lighting and receptacles, and 208 volts for heating, air conditioning, and exterior lighting. In this example the utility company supplies 208/120 volt, three-phase, four-wire service. The main incoming line is divided into four feeders. The two outer feeders supply power directly to the 208 volt heating and air conditioning units. The two inner feeders are divided into a number of branch circuits. One set of branch circuits supplies power to exterior lighting (208 volts). The second set of branch circuits supplies power to interior lighting and receptacles (120 volts).



The utility company supplies power from a transformer with a wye connected secondary. The secondary winding of the transformer produces 208/120 VAC. This is referred to as three-phase, four wire (3Ø4W). Single-phase 120 VAC is available between any phase wire and neutral. Single-phase 208 VAC is available between any two phases.

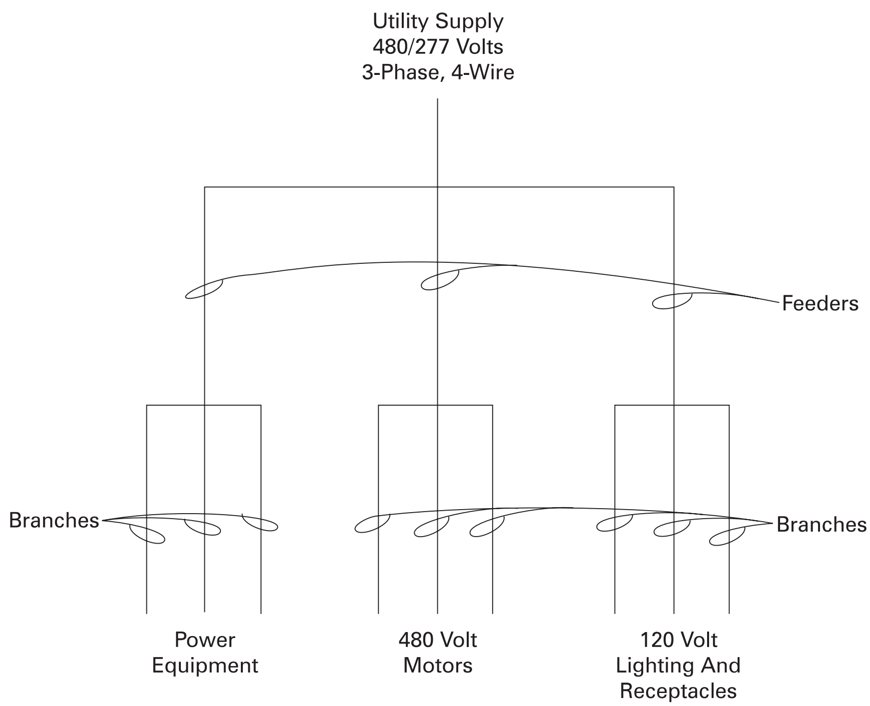


Incoming power is metered by the utility company. In this example power is supplied to the building through a main service disconnect. A switchboard divides the power into four feeders for distribution throughout the building.

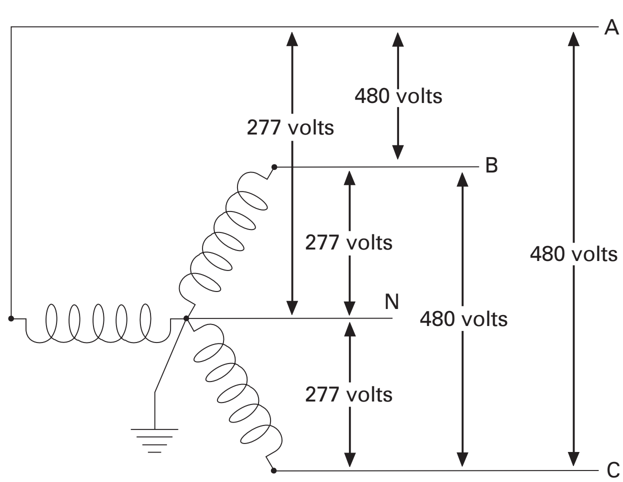


Medium industrial plant

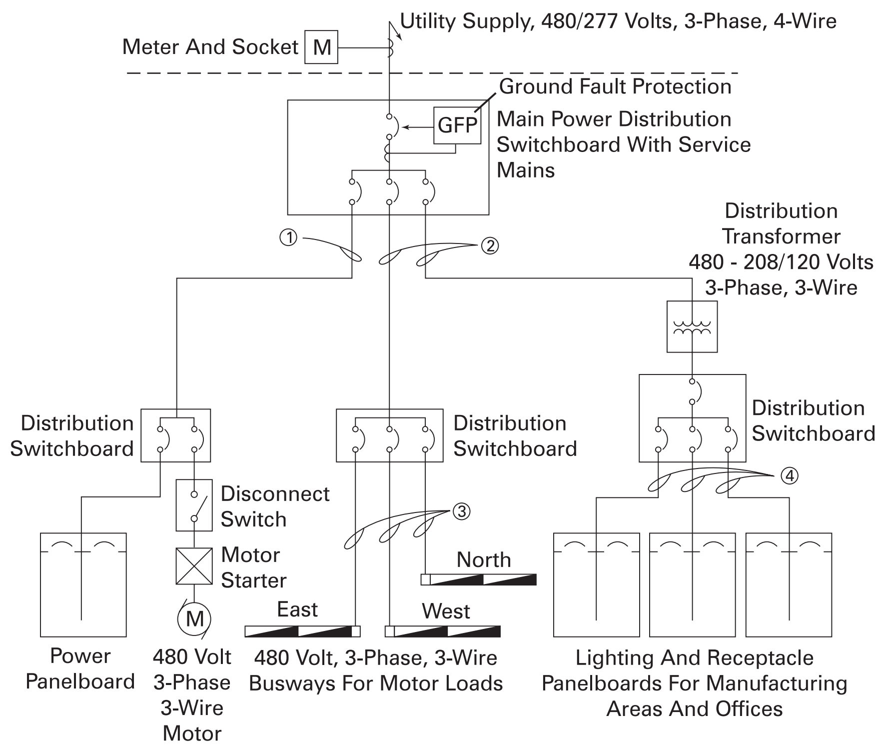
Another example of a distribution system is a medium industrial plant. In this example the incoming power is 480/277 volts, three-phase, four-wire. Three feeders are used. The first feeder is used for various types of power equipment. The second feeder supplies a group of 480 VAC motors. The third feeder is used for 120 volt lighting and receptacles.



The utility company supplies power from a transformer. The secondary winding of the transformer produces 480/277 VAC.



In this example power from the utility company is metered and enters the plant through a distribution switchboard. The switchboard serves as the main disconnecting means. The feeder on the left feeds a distribution switchboard, which in turn feeds a panelboard and a 480 volt, three-phase, three-wire motor. The middle feeder feeds another switchboard, which divides the power into three, three-phase, three-wire circuits. Each circuit feeds a busway run to 480 volt motors. The feeder on the right supplies 208/120 volt power, through a step-down transformer, to lighting and receptacle panelboards. Branch circuits from the lighting and receptacle panelboards supply power for lighting and outlets throughout the plant.



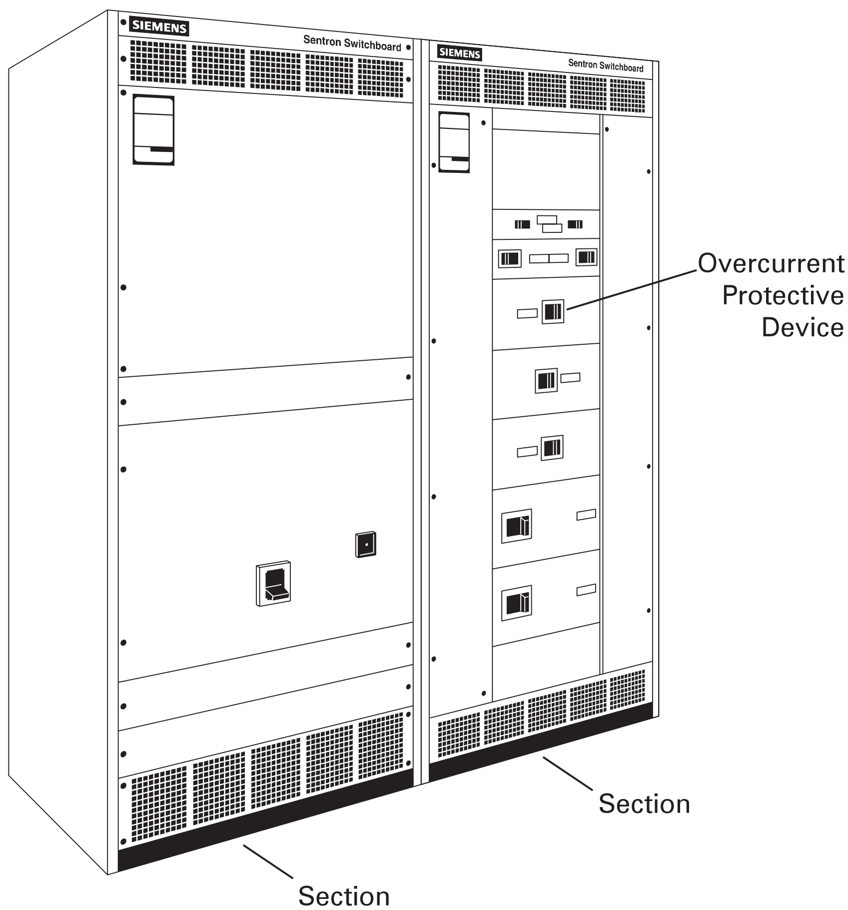
① 480/277 Volt 3-Phase, 4-Wire Feeder
② 480 Volt 3-Phase, 3-Wire Feeders
③ 480 Volt 3-Phase, 3-Wire Circuits
④ 208/120 Volt 3-Phase, 4-Wire Circuits

Switchboard Definition

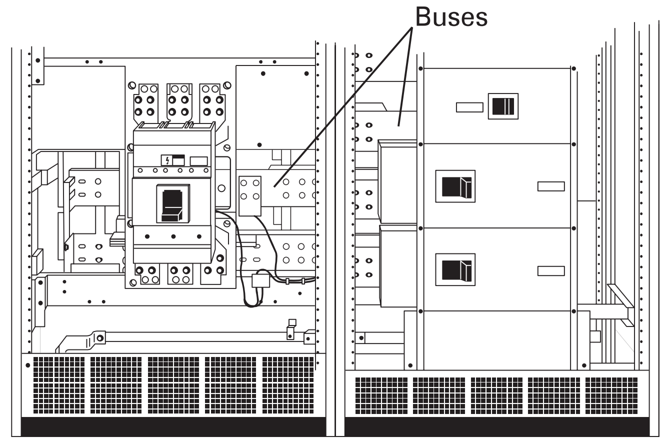
Definition

The National Electrical Code® (NEC®) defines a switchboard as *a large single panel, frame, or assembly of panels on which are mounted, on the face or back, or both, switches, overcurrent and other protective devices, buses, and usually instruments. Switchboards are generally accessible from the rear as well as from the front and are not intended to be installed in cabinets* (Article 100-definitions).

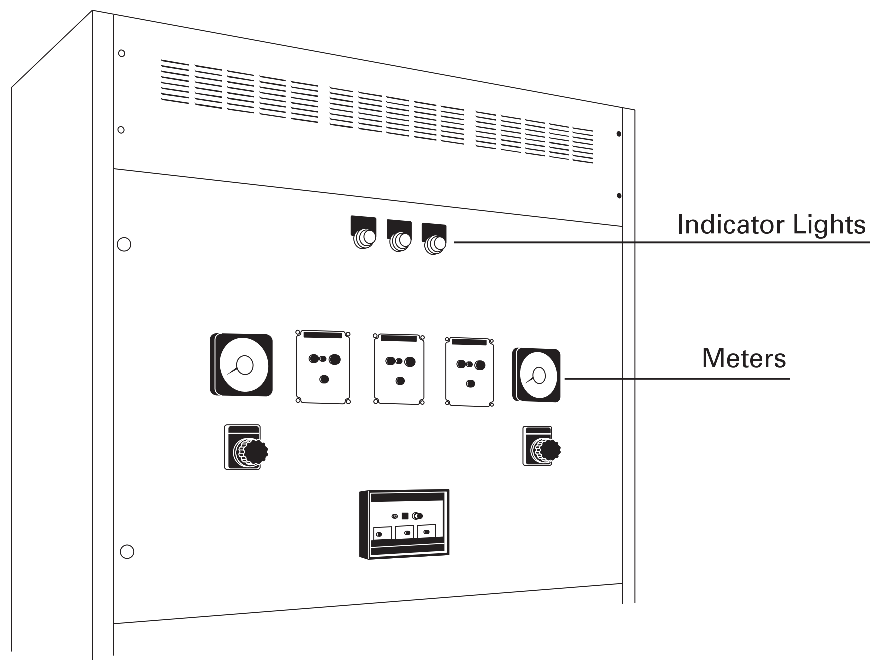
The following drawing illustrates a switchboard made up of a group of two sections. Several overcurrent protective devices (molded case circuit breakers) are mounted on the switchboard.



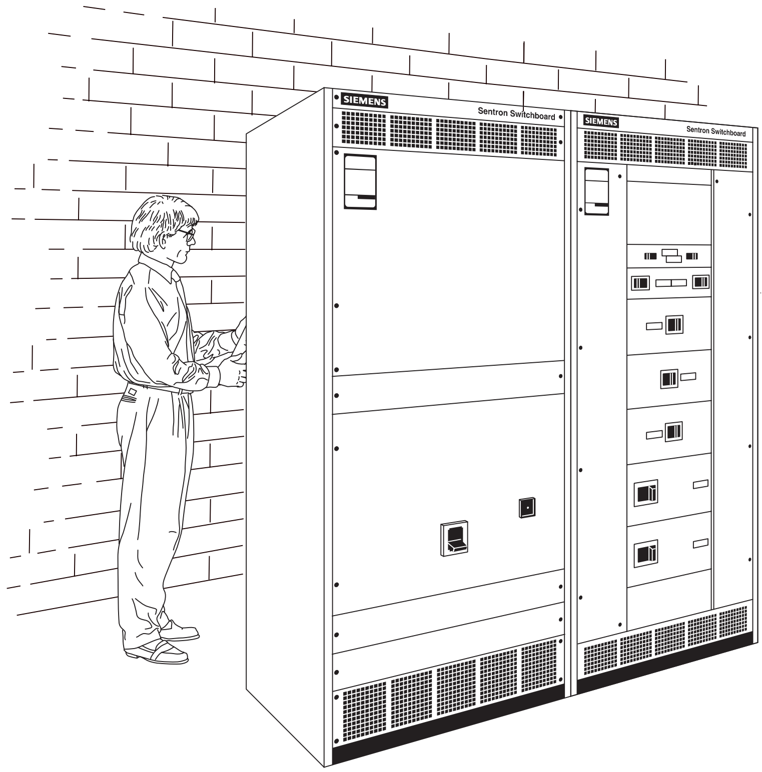
Buses are mounted inside the switchboard.



Switchboards can also have instrumentation. Indicator lights might be used to show power is applied. Meters can be used to show how much current is flowing or how much power is being consumed.



Depending on the design, switchboards may be installed next to a wall or away from the wall to permit accessibility to the rear of the switchboard.



Note: Switchboards are built according to standards set by Underwriters Laboratory (UL 891) and the National Electrical Manufacturers Association (NEMA PB2). Basic requirements for switchboards are also covered by the *National Electrical Code®* Sections 384-5 through 384-12. You are encouraged to become familiar with this material.

Review 1

1. The phase-to-neutral voltage of a wye-connected transformer with a phase-to-phase voltage of 208 volts is ___________ volts.

2. The phase-to-neutral voltage of a wye-connected transformer with a phase-to-phase voltage of 480 volts is ___________ volts.

3. Switchboards are defined in Article ___________ of the *National Electrical Code*®.

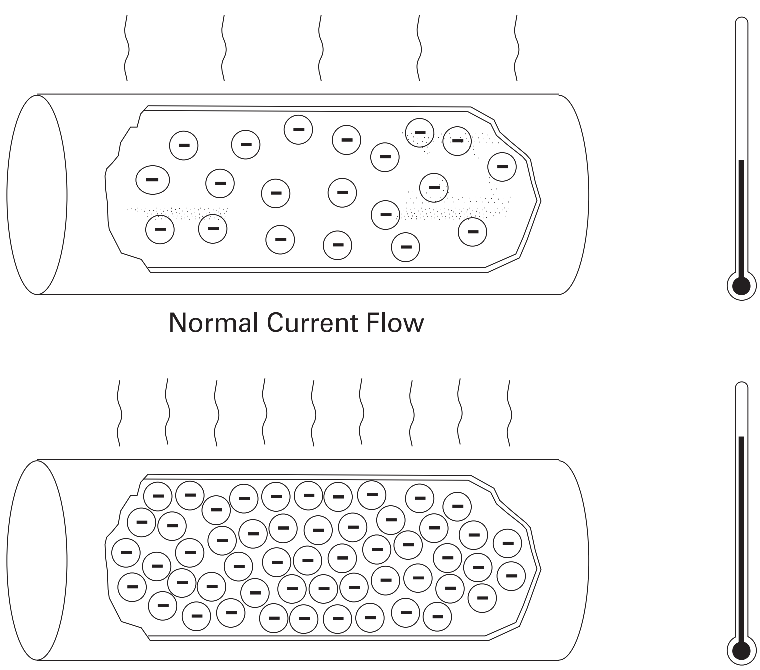
4. Switchboards are built according to standards set by ___________ and ___________ .

5. Basic requirements for switchboards are given in *NEC*® Article ___________ sections 5 through 12.

Overcurrent Protective Devices

Excessive current is referred to as overcurrent. The *National Electrical Code®* defines overcurrent as *any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault* (Article 100-definitions).

Current flow in a conductor always generates heat. The greater the current flow, the hotter the conductor. Excess heat is damaging to electrical components. For that reason, conductors have a rated continuous current carrying capacity or ampacity. Overcurrent protection devices are used to protect conductors and electrical equipment from excessive current flow. These protective devices are designed to keep the flow of current in a circuit at a safe level to prevent the circuit conductors from overheating.



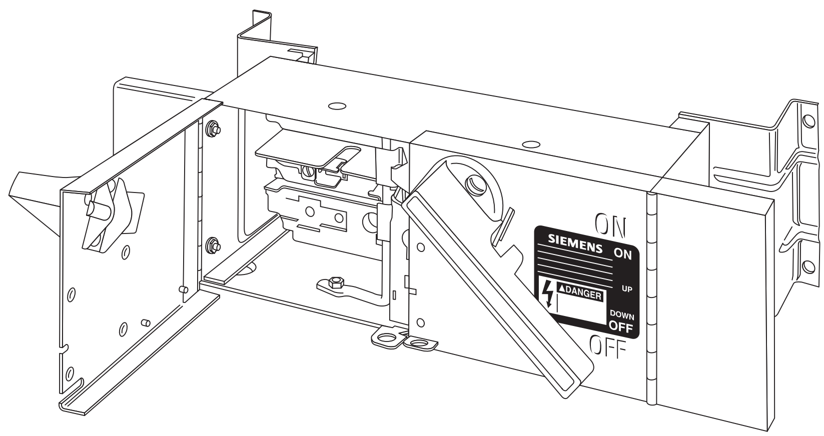
Normal Current Flow

Excessive Current Flow

Circuit protection would be unnecessary if overloads and short circuits could be eliminated. Unfortunately, overloads and short circuits do occur. To protect a circuit from these currents, a protective device must determine when a fault condition develops and automatically disconnect the electrical equipment from the voltage source. An overcurrent protection device must be able to recognize the difference between overcurrents and short circuits and respond in the proper way. Slight overcurrents can be allowed to continue for some period of time, but as the current magnitude increases, the protection device must open faster. Short circuits must be interrupted instantly.

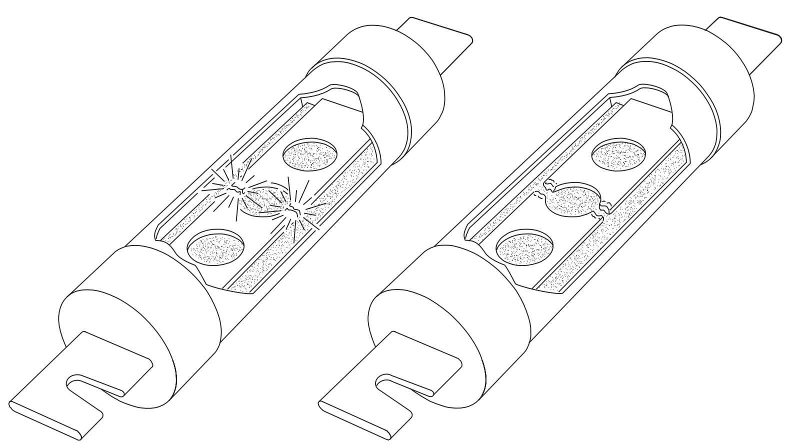
Fusible disconnect switch

A fusible disconnect switch is one type of device used in switchboards to provide overcurrent protection. Properly sized fuses located in the switch open the circuit when an overcurrent condition exists.



Fuse

A fuse is a one-shot device. The heat produced by overcurrent causes the current carrying element to melt open, disconnecting the load from the source voltage.



Nontime-delay fuses

Nontime-delay fuses provide excellent short circuit protection. When an overcurrent occurs, heat builds up rapidly in the fuse. Nontime-delay fuses usually hold 500% of their rating for approximately one-fourth second, after which the current-carrying element melts. This means that these fuses should not be used in motor circuits which often have inrush currents greater than 500%.

Time-delay fuses

Time-delay fuses provide overload and short circuit protection. Time-delay fuses usually allow five times the rated current for up to ten seconds to allow motors to start.

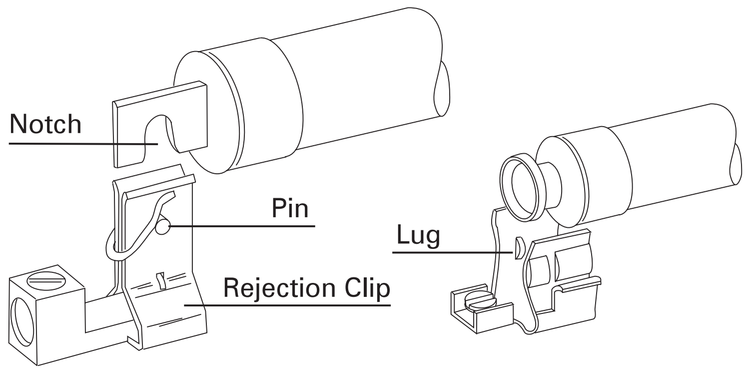
Fuse classes

Fuses are grouped into classes based on their operating and construction characteristics. Each class has an ampere interrupting capacity (AIC) which is the amount of fault current they are capable of interrupting without destroying the fuse casing. Fuses are also rated according to the maximum continuous current and maximum voltage they can handle. Underwriters Laboratories (UL) establishes and standardizes basic performance and physical specifications to develop its safety test procedures. These standards have resulted in distinct classes of low voltage fuses rated at 600 volts or less. The following chart lists the fuse class and its AIC rating.

Class	Voltage Rating	Ampere Rating	Interrupting Rating (Amps)	Sub Classes	UL Standard
G	300	0-60	100,000		UL 248 5
H	250, 600	0-600	10,000	Renewable Nonrenewable	UL 248 7
J	600	0-600	200,000		UL 248 8
K	250, 600	0-600	50,000, or 100,000, or 200,000	K1 and K5	UL 248 9
L	600	601-6000	200,000		UL 248 10
R	250, 600	0-600	200,000	RK1 and RK5	UL 248 12
T	300	0-1200	200,000		UL 248 15
T	600	0-800	200,000		UL 248 15
CC	600	0-30	200,000		UL 248 4
Plug	125	0-30	10,000	"Edison Base" and Type S	UL 198 F

Class R fuseholder

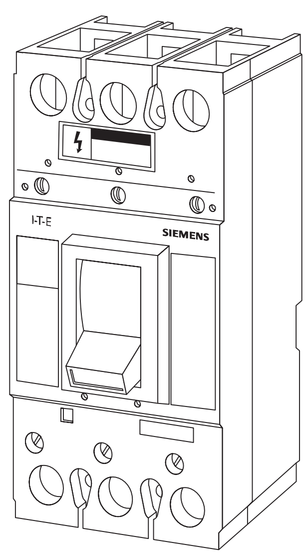
An optional Class R fuseholder can be used. The Class R rejection clip contains a pin that permits only the notched Class R fuse to be inserted. This prevents a lower rated fuse from being used.



Circuit breakers

Another device used for overcurrent protection is a circuit breaker. The *National Electrical Code*® defines a circuit breaker as *a device designed to open and close a circuit by nonautomatic means, and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating*.

Circuit breakers provide a manual means of energizing and deenergizing a circuit. In addition, circuit breakers provide automatic overcurrent protection of a circuit. A circuit breaker allows a circuit to be reactivated quickly after a short circuit or overload is cleared.



Ampere rating

Like fuses, every circuit breaker has a specific ampere, voltage, and fault current interruption rating. The ampere rating is the maximum continuous current a circuit breaker can carry without exceeding its rating. As a general rule, the circuit breaker ampere rating should match the conductor ampere rating. For example, if the conductor is rated for 20 amps, the circuit breaker should be rated for 20 amps. Siemens breakers are rated on the basis of using 60° C or 75° C conductors. This means that even if a conductor with a higher temperature rating were used, the ampacity of the conductor must be figured on its 60° C or 75° C rating.

There are some specific circumstances when the ampere rating is permitted to be greater than the current carrying capacity of the circuit. For example, motor and welder circuits can exceed conductor ampacity to allow for inrush currents and duty cycles within limits established by *NEC®*. Generally the ampere rating of a circuit breaker is selected at 125% of the continuous load current. This usually corresponds to the conductor ampacity which is also selected at 125% of continuous load current. For example, a 125 amp circuit breaker would be selected for a load of 100 amps.

Voltage rating

The voltage rating of the circuit breaker must be at least equal to the circuit voltage. The voltage rating of a circuit breaker can be higher than the circuit voltage, but never lower. For example, a 480 VAC circuit breaker could be used on a 240 VAC circuit. A 240 VAC circuit breaker could <u>not</u> be used on a 480 VAC circuit. The voltage rating is a function of the circuit breaker's ability to suppress the internal arc that occurs when the circuit breaker's contacts open.

Fault current interrupting rating

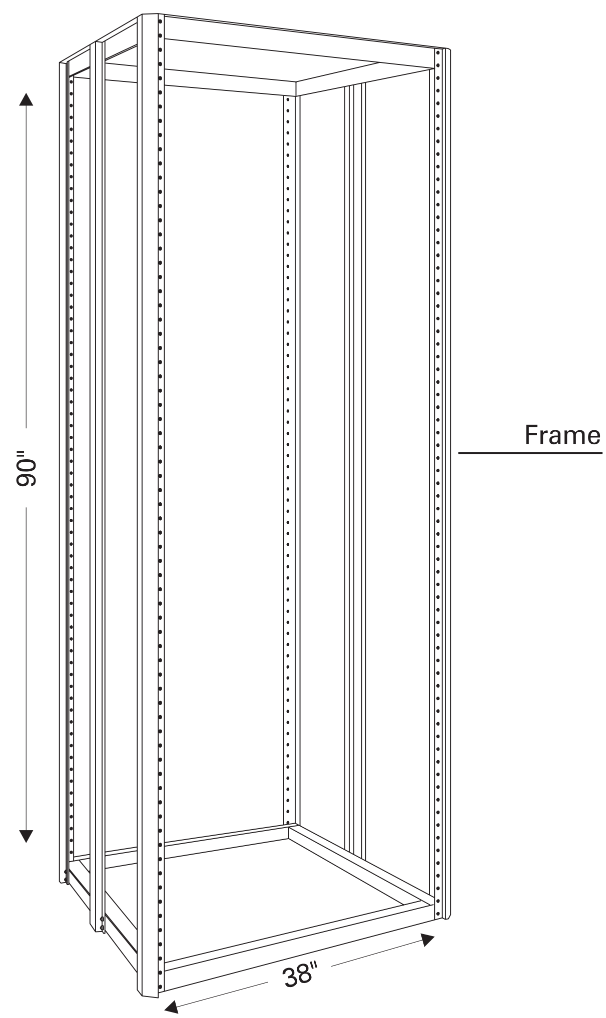
Circuit breakers are also rated according to the level of fault current they can interrupt. When applying a circuit breaker, one must be selected to sustain the largest potential short circuit current which can occur in the selected application. Siemens circuit breakers have interrupting ratings from 10,000 to 200,000 amps. To find the interrupting rating of a specific circuit breaker refer to the Speedfax catalog.

Switchboard Construction

There are several components that make up a switchboard. Switchboards consist of a frame, overcurrent protective devices, buses, instrumentation, and outer covers.

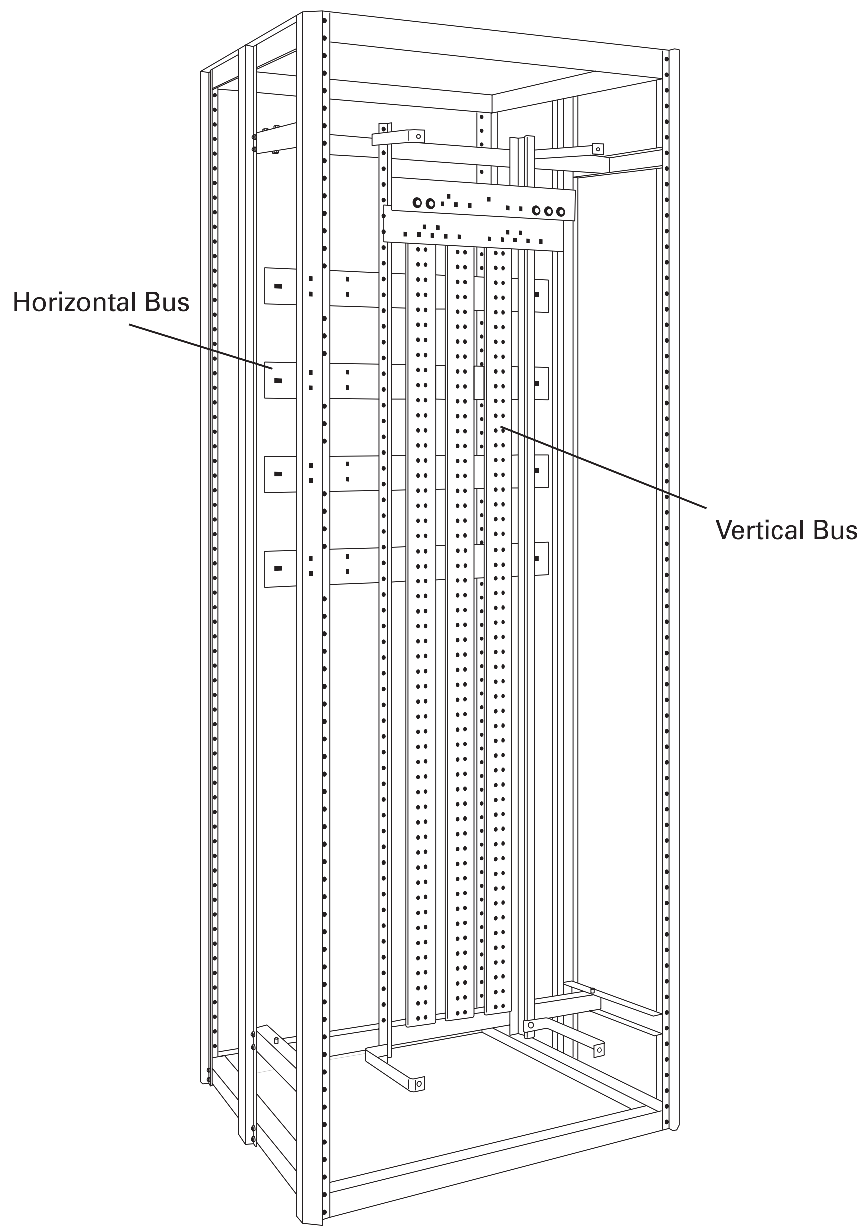
Frame

The frame of the switchboard houses and supports the other components. The standard Siemens switchboard frame is 90 inches high and 38 inches wide. Optional height of 70 inches and widths of 32 inches and 46 inches are available.

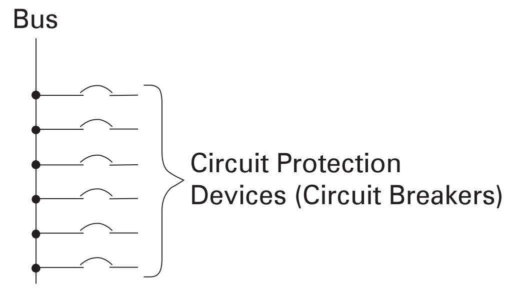


Buses

Buses are mounted within the frame. Horizontal buses are used to distribute power to each switchboard section. Vertical buses are used to distribute power via overcurrent devices to the load devices.

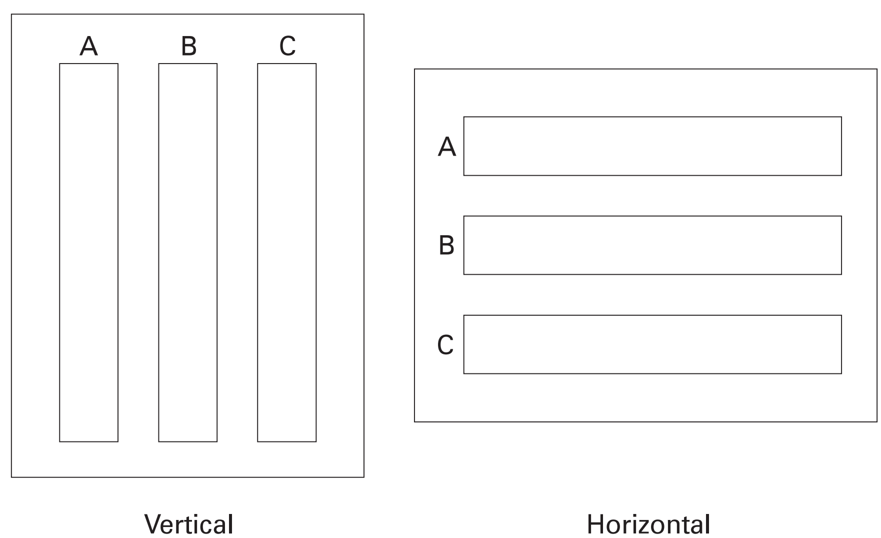


A bus is a conductor that serves as a common connection for two or more circuits. It is represented schematically by a straight line with a number of connections made to it. *NEC*® article 384-3 states that bus bars *shall be located to be free from physical damage and shall be held firmly in place*. Standard bus bars on Siemens switchboards are made of aluminum, but copper bus bars are available as an option.

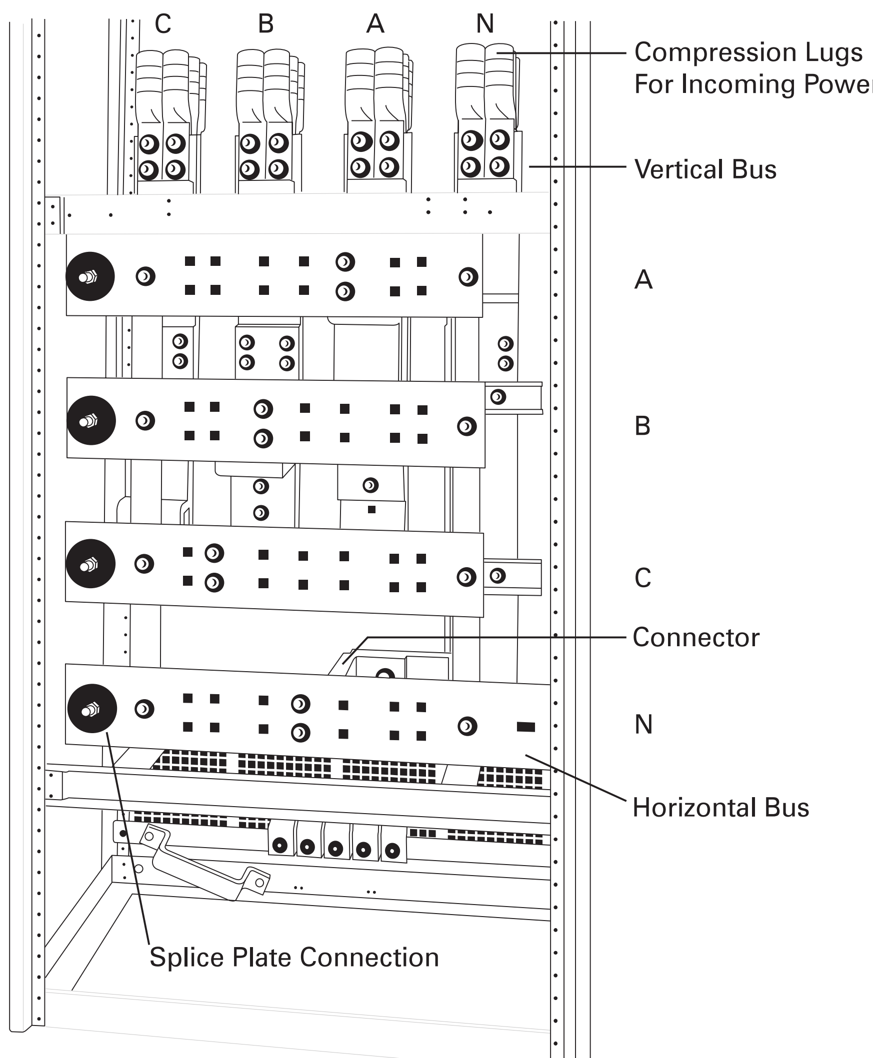


NEMA arrangement

Bus bars are required to have phases in sequence so that an installer can have the same fixed-phase arrangement in each termination point in any switchboard. This is established by NEMA (National Electrical Manufacturers Association). It is possible to have a non-NEMA phase sequence which would have to be marked on the switchboard. Unless otherwise marked, it is assumed that bus bars are arranged according to NEMA. The following diagram illustrates accepted NEMA phase arrangements.



The following rear view drawing of a switchboard illustrates vertical and horizontal bus bar connection. (The vertical phase bus bars appear to be in reverse order because they are viewed from the rear. The bus bars are in the proper NEMA order as viewed from the front.) A bus connector makes a mechanical and electrical connection between a vertical bus bar and its corresponding horizontal bus bar. In this drawing the connector can be clearly seen on the neutral bus. Compression lugs provided on this switchboard accept properly sized incoming power cables. Splice plate connections are used to join the horizontal buses of two switchboard sections.

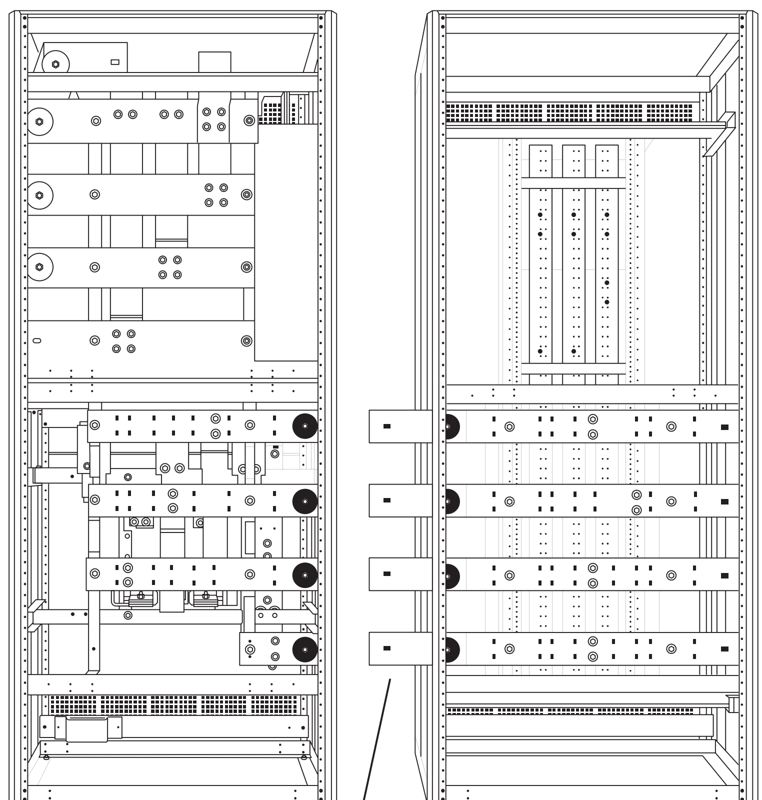


Rear View

Splice plates

Splice plates are used to join the horizontal bus bars of adjoining switchboard sections, as illustrated in the following rear view drawing. To make additional distribution sections easier to install when they are needed, the horizontal bus is extended and predrilled to accept splice plates. A new section is set flush against an existing section. The old and new sections are connected together with splice plates.

The extended horizontal bus is also referred to as through-bus. The load requirements in downstream distribution sections is generally less than in upstream service sections. The capacity of the through-bus is tapered, or reduced downstream as load falls off. The through-bus is tapered to a minimum of one-third the ampacity of the incoming service mains. Full-capacity, or non-tapered, through-bus is available as an option. The ampacity of non-tapered through-bus remains constant throughout the switchboard.

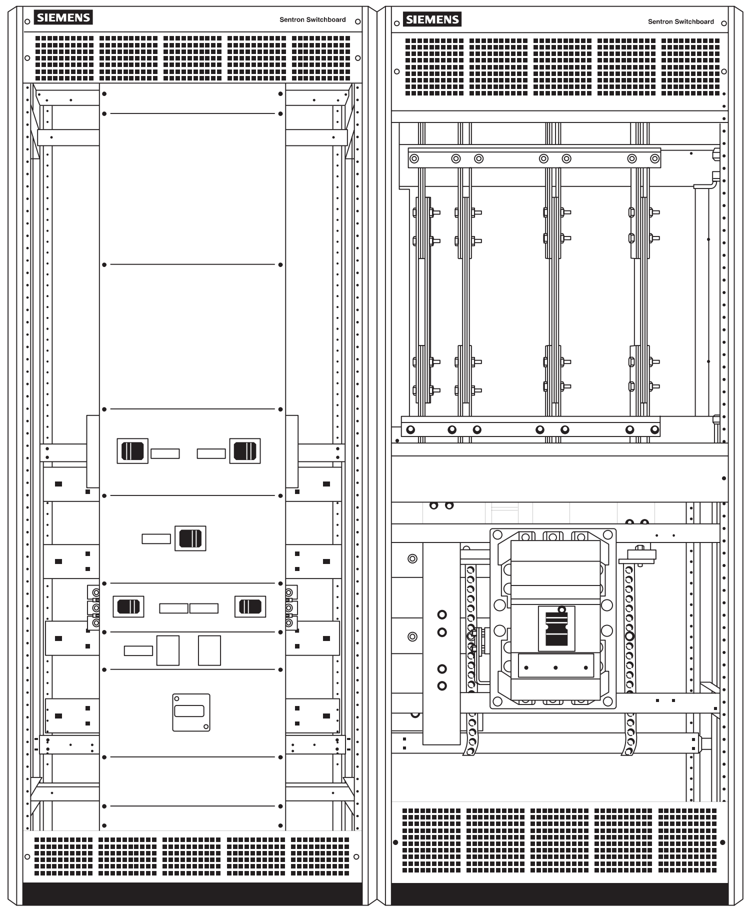


Splice Plates

Rear View

Protective devices

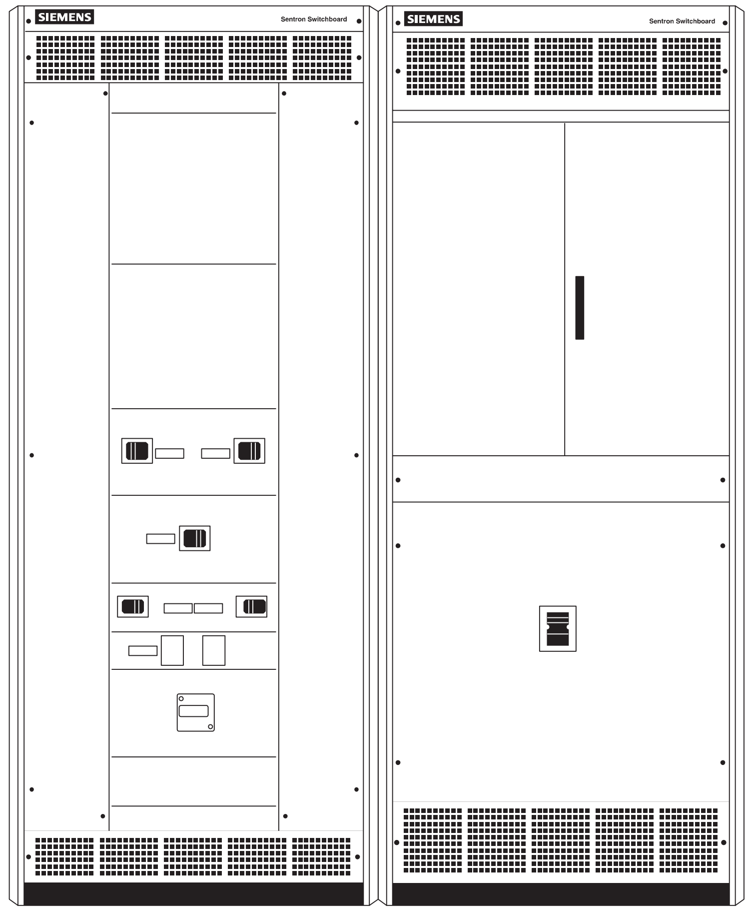
Operator components are mounted on the front side of the switchboard. This includes protective devices, such as circuit breakers and disconnect switches, which can be covered by a trim panel. These devices are mounted to the bus bars using straps connected to the line side of the devices.



Front View

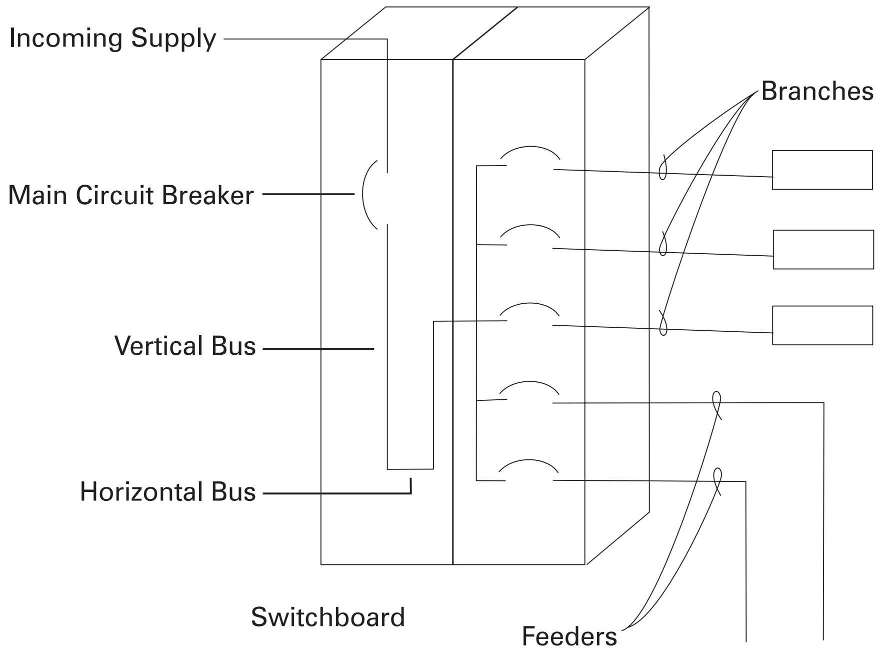
Dead front and trim

Cover panels are installed on the switchboard so that no live parts are exposed to the operator. This is referred to as dead front. The panels are also used as trim to provide a finished look to the switchboard. A product information label identifies the switchboard type, catalog number, and voltage and amperage rating.



Pictorial

Switchboards can be shown pictorially using block diagrams and/or one-line diagrams. The following pictorial illustrates a two section switchboard.



Review 2

1. The rated continuous current carrying capacity of a conductor is known as ___________ .

2. _________ - delay fuses provide overload and short circuit protection.

3. The interrupting rating of a Class R fuse is ___________ amps.

4. The height of the standard Siemens switchboard frame is ___________ inches.

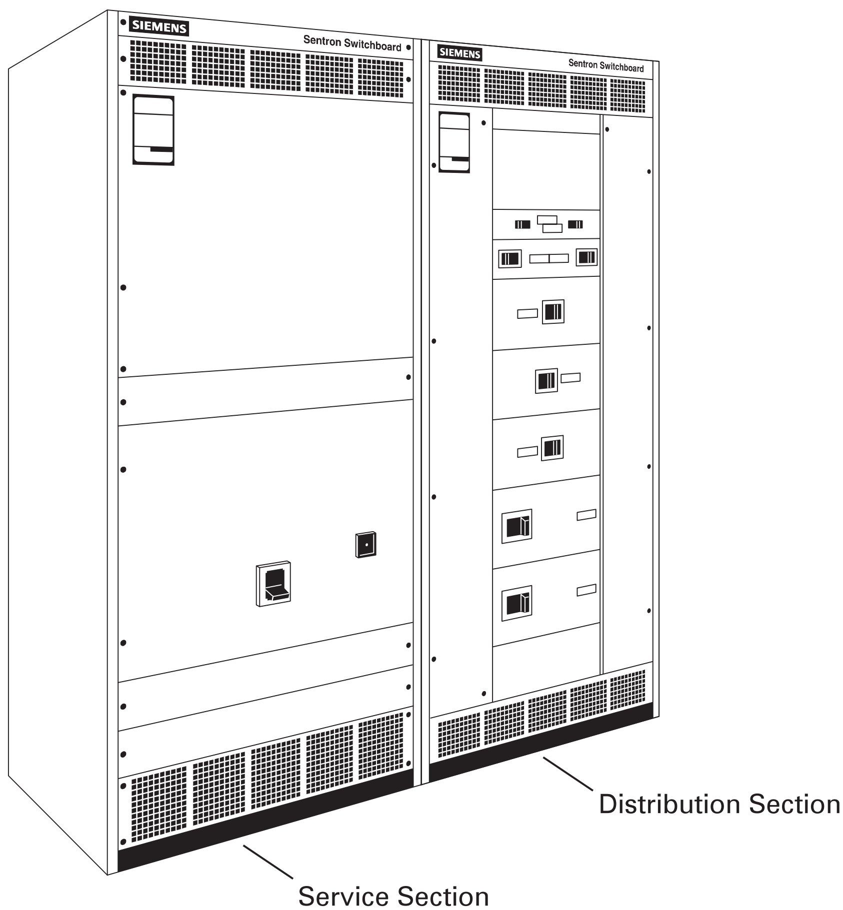
5. A ___________ is a conductor that serves as a common connection for two or more circuits.

6. ___________ plates join horizontal buses between two adjoining switchboard sections.

7. The extended horizontal bus that connects one section to another is referred to as ___________ - ___________ .

Service Section

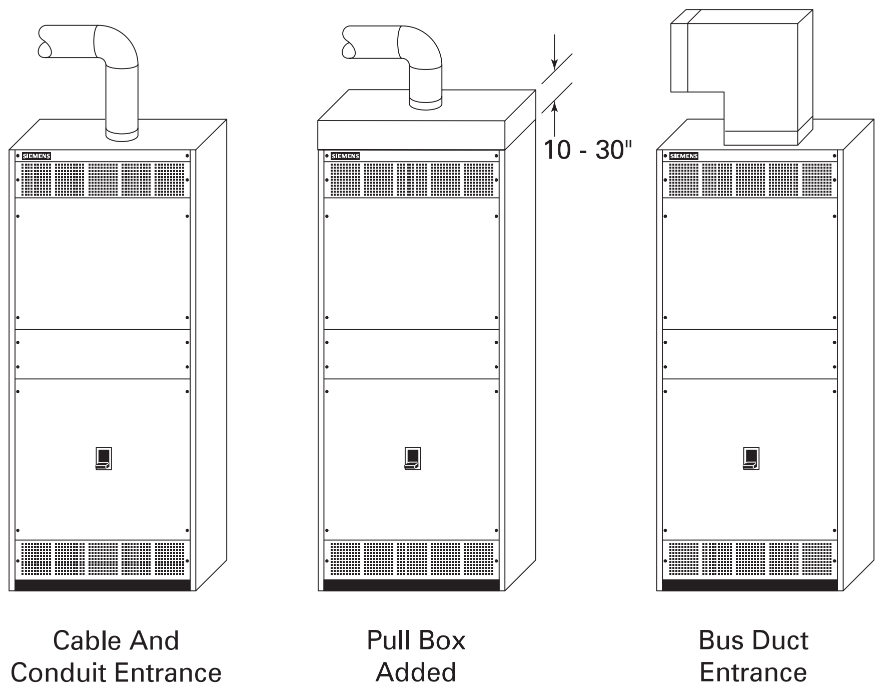
Typical switchboards consist of a service section, also referred to as the main section, and one or more distribution sections. The service section can be fed directly from the utility transformer. In addition to the main disconnect, the service section usually contains utility or customer metering provisions.



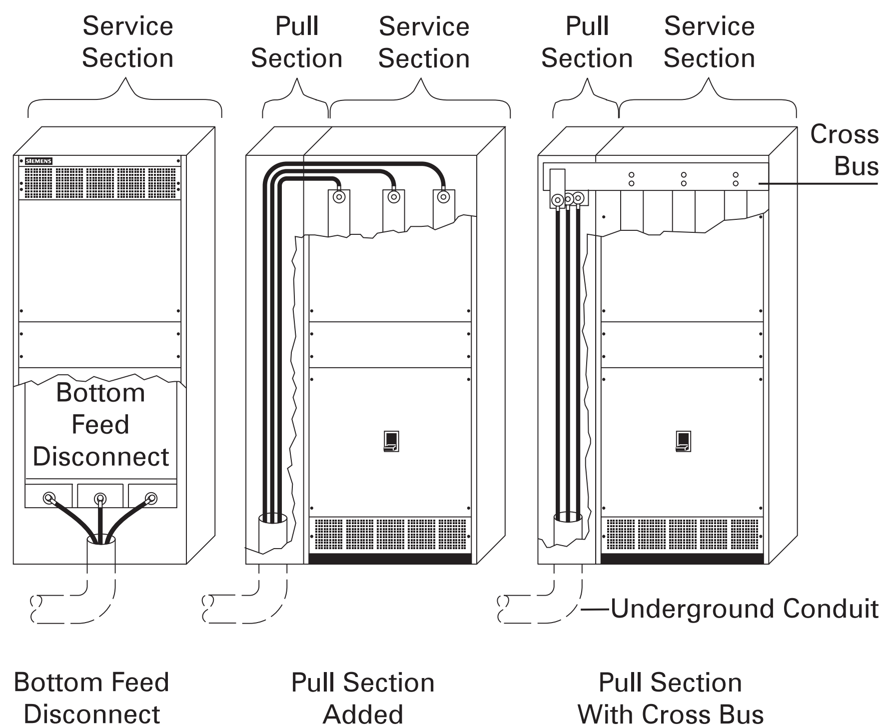
Service entrance methods

Several options are available to bring power into the switchboard service section. Cable can be brought into the switchboard from the top or the bottom.

Cable can be brought into the top of the switchboard through conduit. If the cable is a large diameter and more room is needed a pull box, available in 10” to 30” heights, can be added. A bus duct entrance can be used when metal bus is used instead of cables.



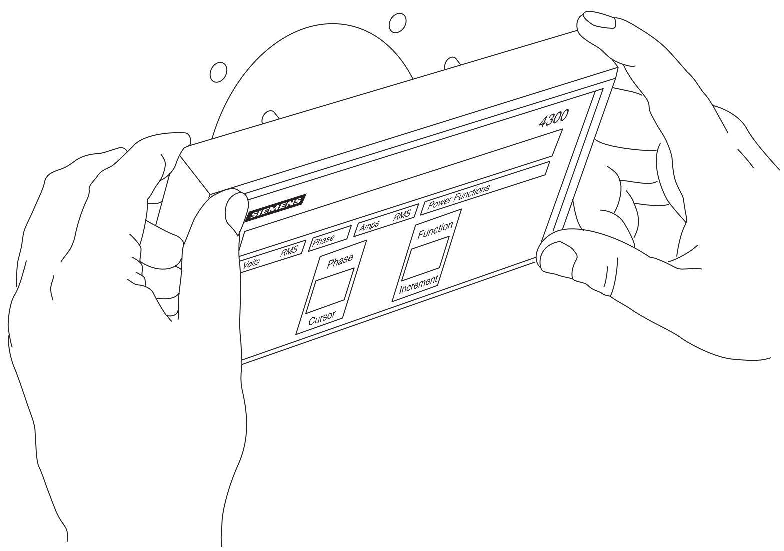
Cable may enter through a conduit to a disconnect that is fed from the bottom. A pull section can be added to the side of the service section to pass cable to the top of the switchboard. Depending on the cable bending space, cable can be connected directly to the lugs or to a cross bus. A cross bus brings the bus connections to the pull section eliminating the need to bend cables.



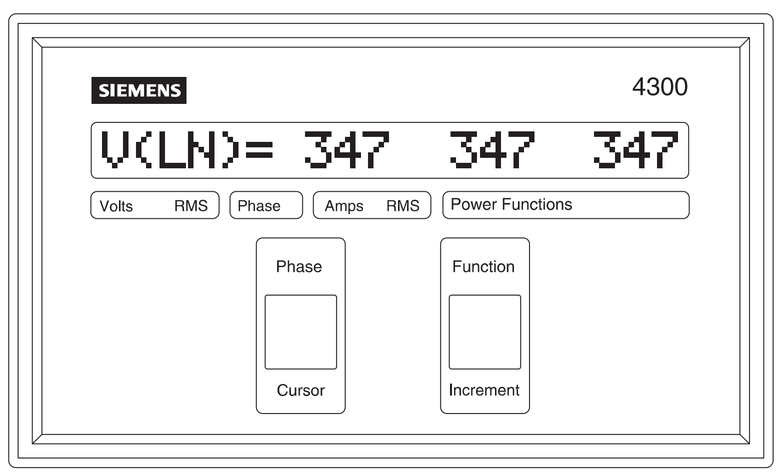
Meters can be used in the service section to measure real-time RMS values of phase currents, phase and line voltages, power usage, power factor, and peak demand.

4300 power meter

The Siemens 4300 power meter has been designed to replace standard 4” analog meters.

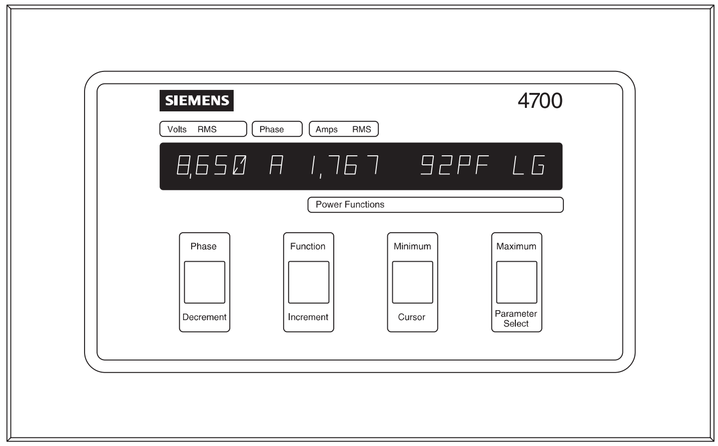


The 4300 will simultaneously show voltage, current, and power. A communication port allows connection through a RS-485 bus to remotely read real-time data with use of the Siemens ACCESS™ system.



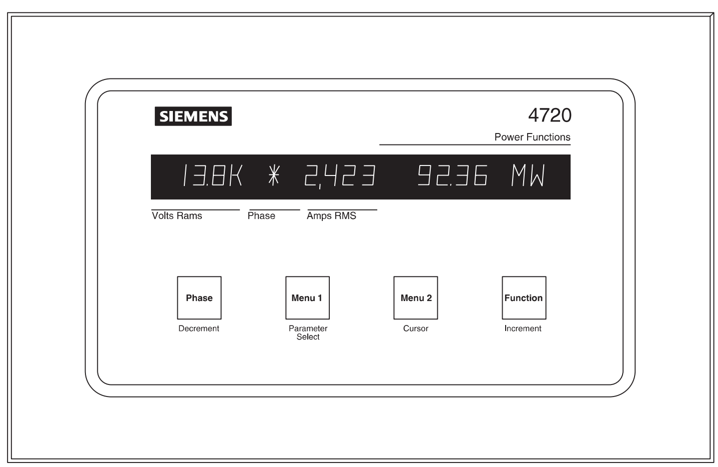
4700 power meter

The 4700 power meter is another metering device offered by Siemens. The 4700 power meter replaces up to 12 traditional analog devices with a single unit. The 4700 power meter supports an optional plug-in communication card which allows remote access to the data. A jumper on the communication card determines either RS 232C or RS-485 communications using the Siemens ACCESS system.



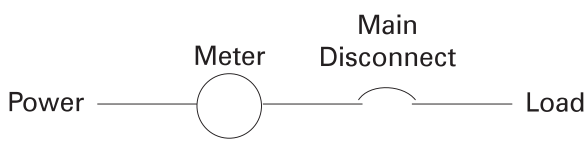
4720 power meter

The 4720 power meter can read over 300 measurements including phase currents, average phase currents, amp demand, neutral current, phase voltage, average phase voltage, average line voltage, KW, KW demand, KW hours, KVA, KVAR, KVAR hours, power factor, and frequency. The 4720 allows communication through the Siemens ACCESS system.



Hot sequence

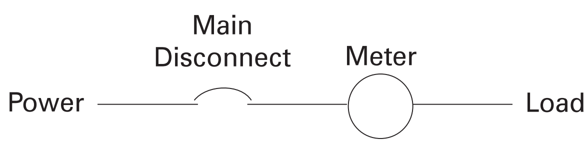
Metering can either be hot sequence or cold sequence. This refers to whether or not power is still applied to the utility meter when the main disconnect is switched off. The following drawing illustrates hot sequence. When the main disconnect is open, power is removed from the load. Power is still applied to the utility meter.



Hot Sequence

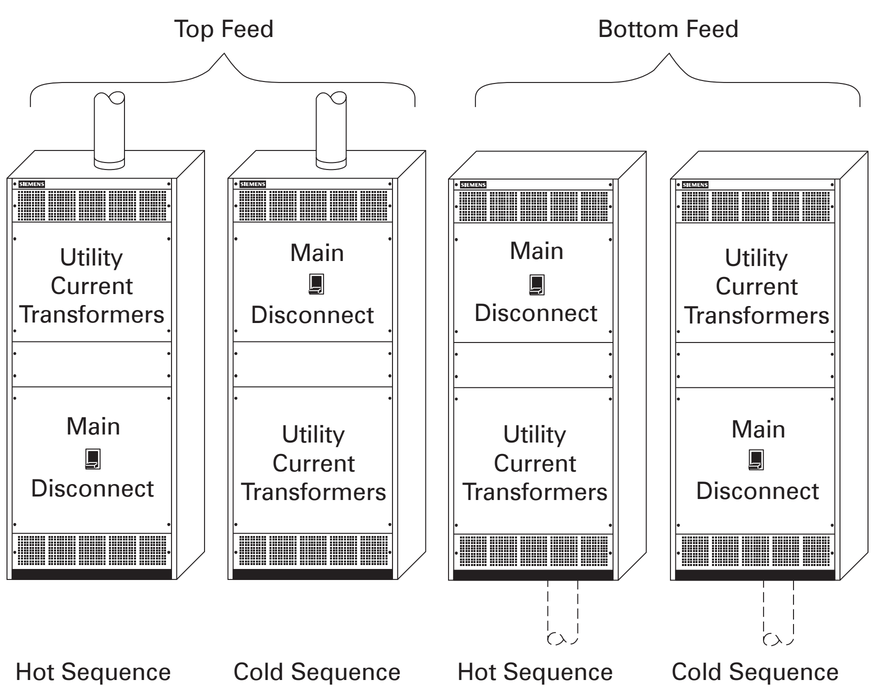
Cold sequence

The following drawing illustrates cold sequence. When the main disconnect is open, power is removed from the load and the utility meter.



Cold Sequence

Hot sequence metering on the line side of the main disconnect is normal, but cold sequence metering on the load side of the main disconnect can also be provided.

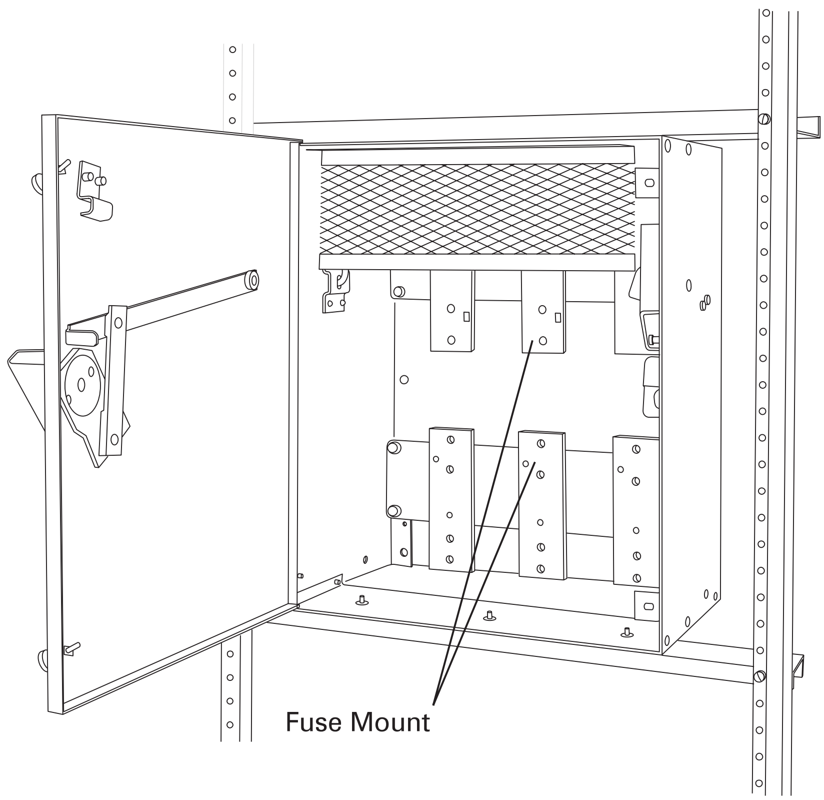


Service Section Main Disconnect Devices

The service section of Siemens switchboards will accommodate a variety of main protective devices. Selection depends on the characteristics of the electrical system and the needs of the customer.

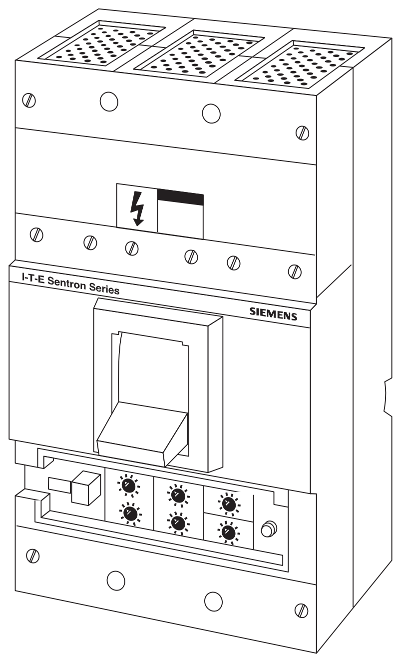
Fusible switches

One type of protective device is the Siemens Vacu-Break® fusible switch. Fusible switches are available in ampere ratings up to 1200 amps at 600 VAC.

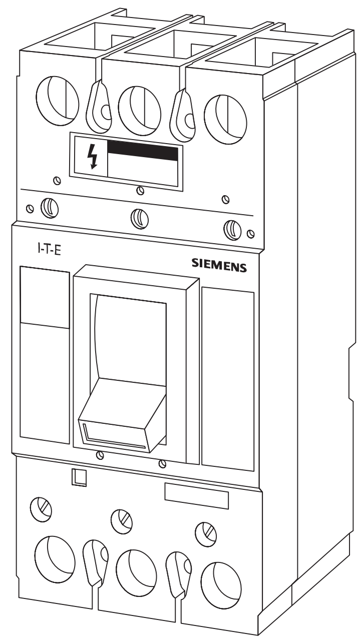


MCCBs

The Sentron™ Series molded case circuit breakers (MCCB) can also be used as main service section protective devices. Sentron Series circuit breakers are available with ampere ratings from 125 to 3200 amps, and interrupting ratings from 10,000 to 200,000 amps. The Sentron Series circuit breaker is also available with solid state protection, referred to as Sensitrip® III. Sensitrip III breakers are available with ampere ratings from 400 to 3200 amps, and interrupting ratings up to 200,000 amps. When selecting a circuit breaker, refer to the Siemens Speedfax® catalog for specific product ratings.



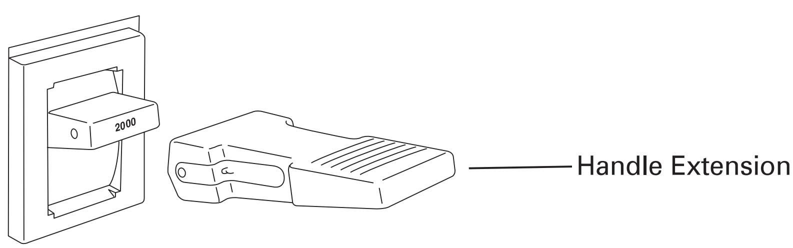
Sentron Series Sensitrip III MCCB



Sentron Series MCCB

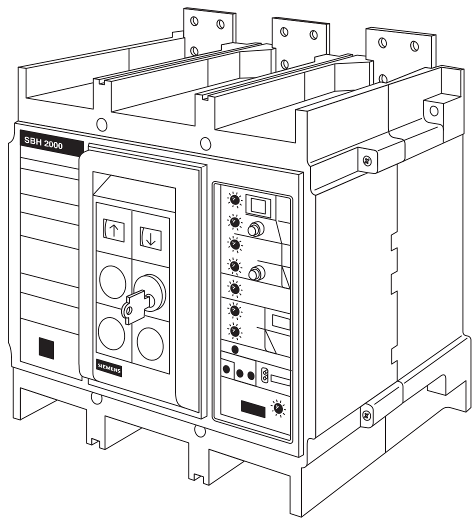
Handle extension

It can be difficult to operate some of the handles on the larger circuit breakers. A handle extension is available which allows more leverage to be applied to the circuit breaker handle. This makes opening and closing the circuit breaker easier.



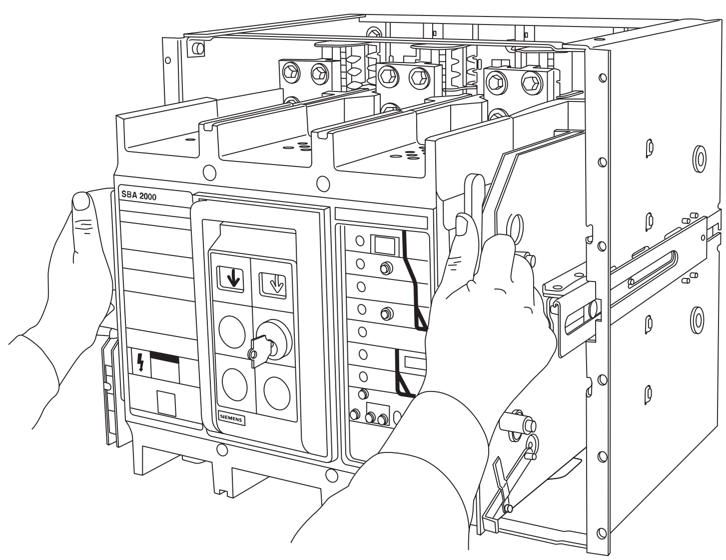
ICCBs

Insulated case circuit breakers (ICCB) can be applied in applications from 100 to 5000 amps through 600 VAC. There are four ICCB frames: 1200, 2000, 3200, and 5000 amps. Interchangeable rating plugs and a continuous current adjustment are provided with each trip unit. The frame ampere rating is determined by the current sensors in the breaker. Interrupting ratings are available in ratings up to 200,000 amps. ICCBs can be fixed mounted or drawout mounted.



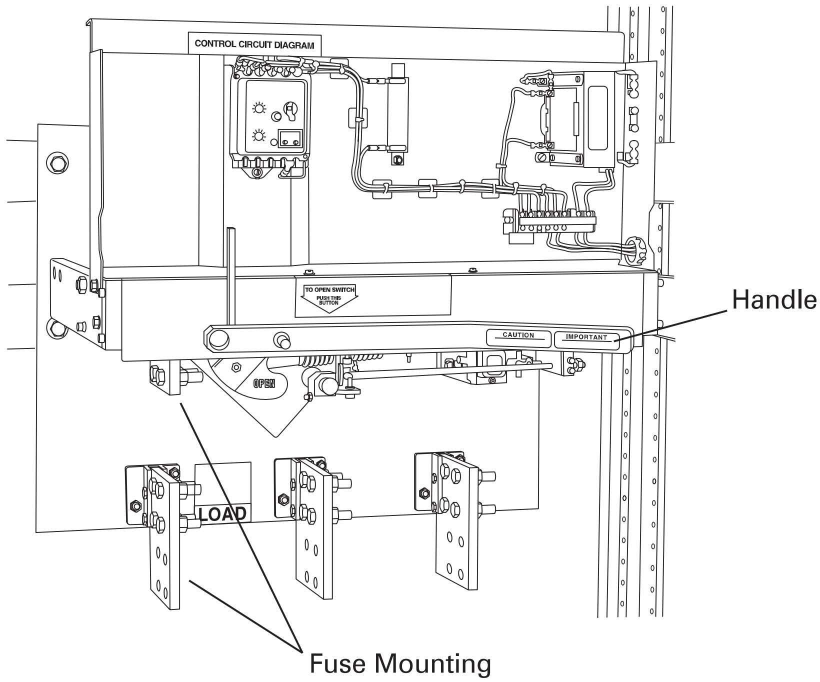
Fixed Mount

Drawout Mount



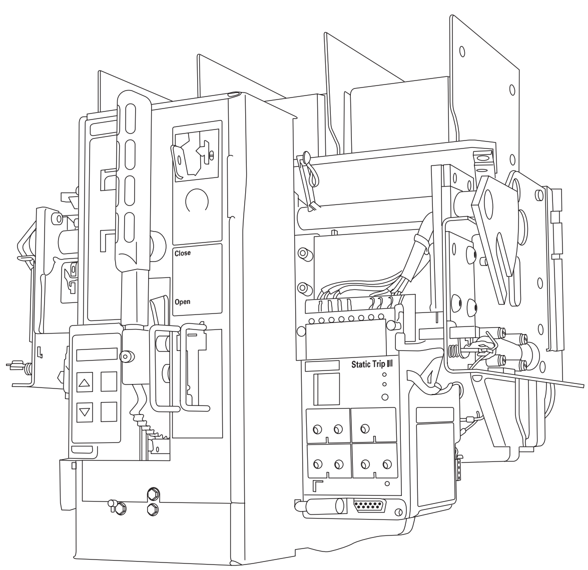
Bolted pressure switch

Bolted pressure switches can also be used as a main disconnect. Bolted pressure switches are available in 800, 1200, 1600, 2000, 2500, 3000, and 4000 amp frames. The maximum short circuit current withstandability is 200,000 amps. Bolted pressure switches are rated for 240 VAC, 480 VAC, and 600 VAC.



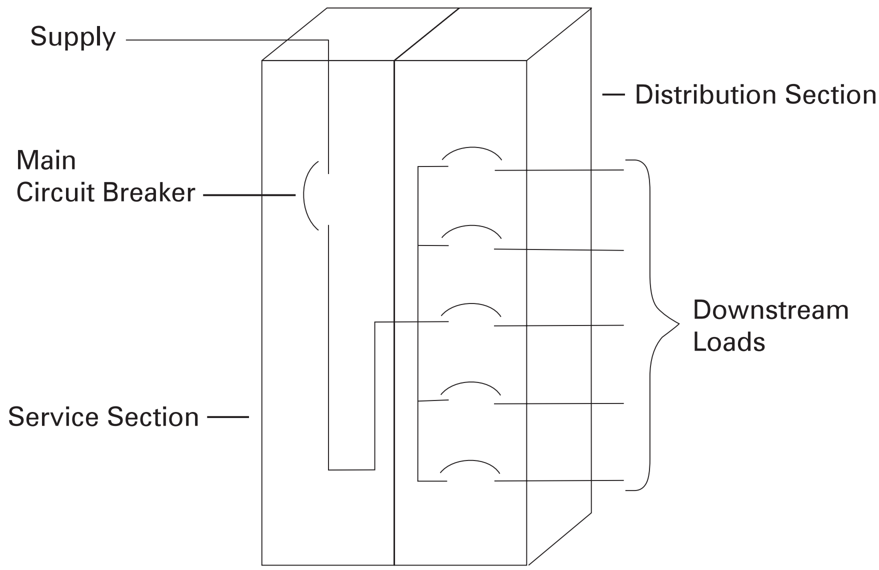
RL power circuit breakers

RL power circuit breakers can also be used in switchboards. These circuit breakers are available in 800 to 4000 amp frames at 600 VAC. RL power circuit breakers are drawout mount.



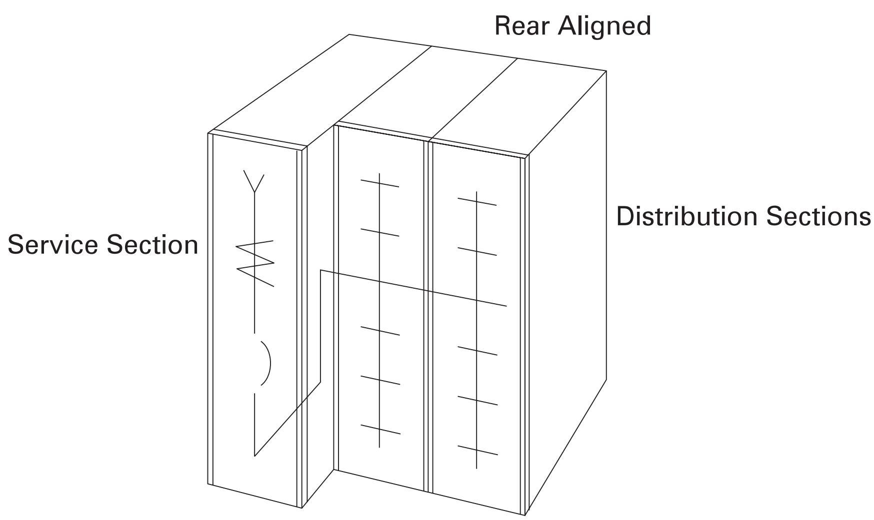
Distribution Section

The distribution section receives power from the service section and distributes it to various downstream loads.



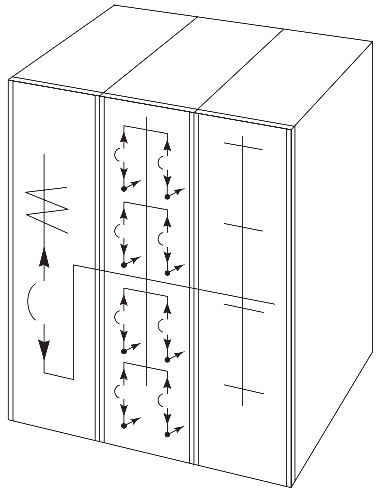
Rear alignment

Depending on the design of a specific switchboard, the service section cabinet may be deeper than the distribution section. This is due to the size of the main disconnect device and associated bus requirements. The rear of all sections align so the switchboard may be installed against a wall. This is referred to as rear alignment.



Front and rear aligned

Switchboards can also be front and rear aligned, if the depth of the service section and distribution section are the same. In some switchboards the circuit protection devices and bus may require a deeper cabinet. In other switchboards extra depth may be added as an option.



Front And Rear Aligned

Protective devices

Like the service section, the distribution section will accommodate a variety of protective devices. Selection depends on the characteristics of the electrical system. In addition, motor control starters can also be used in switchboards.

Device	Current Rating
Vacu-Break® Fusible Switches	30-1200 amps
Bolted Pressure Switches	800-4000 amps
HCP Switches	400-1200 amps
Molded Case Circuit Breakers	15-3200 amps
Insulated Case Circuit Breakers	800-5000 amps
LV Power Circuit Breakers	800-4000 amps

Review 3

1. Typical switchboards consist of a ___________ section and usually one or more ___________ section.

2. A ___________ ___________ , available in 10” to 30” heights, can be added to the top of a switchboard to allow room for large diameter cable.

3. A ___________ ___________ is added to accommodate cable entering the bottom of a switchboard and connected to the bus at the top of a switchboard.

4. The Siemens type ___________ power meter has been designed to replace standard 4” analog meters.

5. ___________ ___________ means that power is still applied to the utility meter when the main disconnect is open.

6. ___________ ___________ means that power is removed from the utility meter when the main disconnect is open.

7. Which of the following is suitable for use as a main disconnect in the service section?

   a. fusible switch
   b. molded case circuit breaker
   c. insulated case circuit breaker
   d. bolted pressure switch
   e. RL power circuit breaker
   f. all the above

8. The ___________ section receives power from the service section and distributes it to various downstream loads.

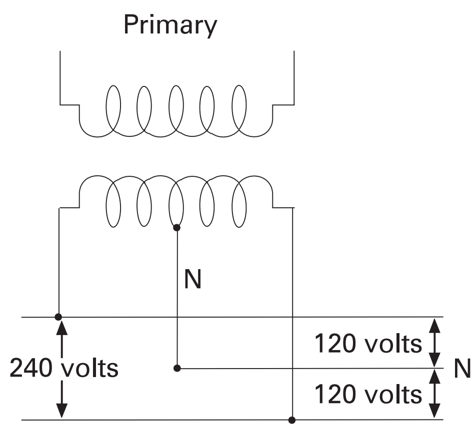
9. ___________ ___________ refers to a switchboard where the service section may be deeper than the distribution section, and the rear of all sections are aligned.

Power Supply Systems

Switchboards receive power from a variety of sources. Downstream switchboards may receive power from upstream switchboards or disconnect switches, however, power for the distribution system originates from a utility power company. Voltage from the power company is stepped down through transformers for distribution systems. The following are some examples of systems in use.

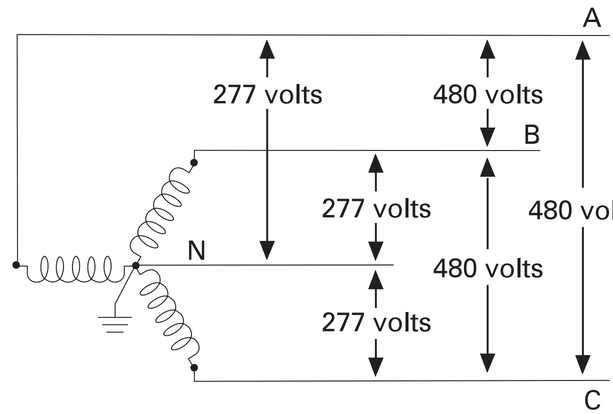
1Ø3W

The following diagram illustrates one of the most common single-phase, three-wire (1Ø3W) distribution systems in use today. There are 240 volts across the full secondary of the transformer and 120 volts between the neutral and either end of the transformer. The neutral is the third wire.



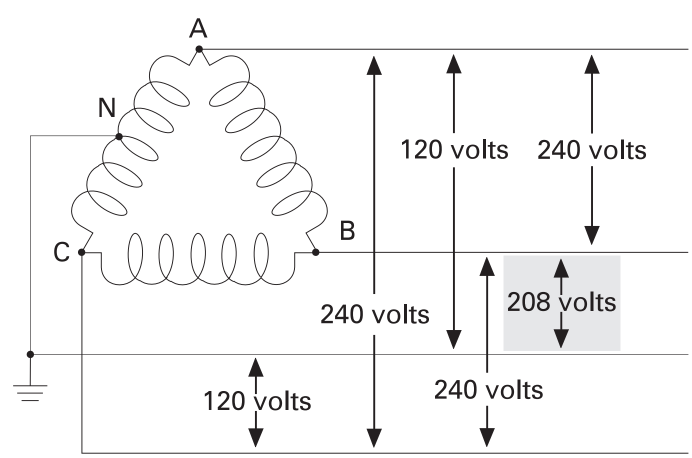
3Ø4W, wye-connected

The following illustration shows the secondary of a 480 Y/ 277 V three-phase, four-wire (3Ø4W), wye-connected transformer. The "480 Y" indicates the transformer is wye-connected and has 480 volts between any two phases. The "277 V" indicates there are 277 volts between any phase and neutral (N). Phase-to-phase voltage is 1.732 times phase-to-neutral voltage (277 x 1.732 = 480). Neutral is the fourth wire.



3Ø4W, delta-connected

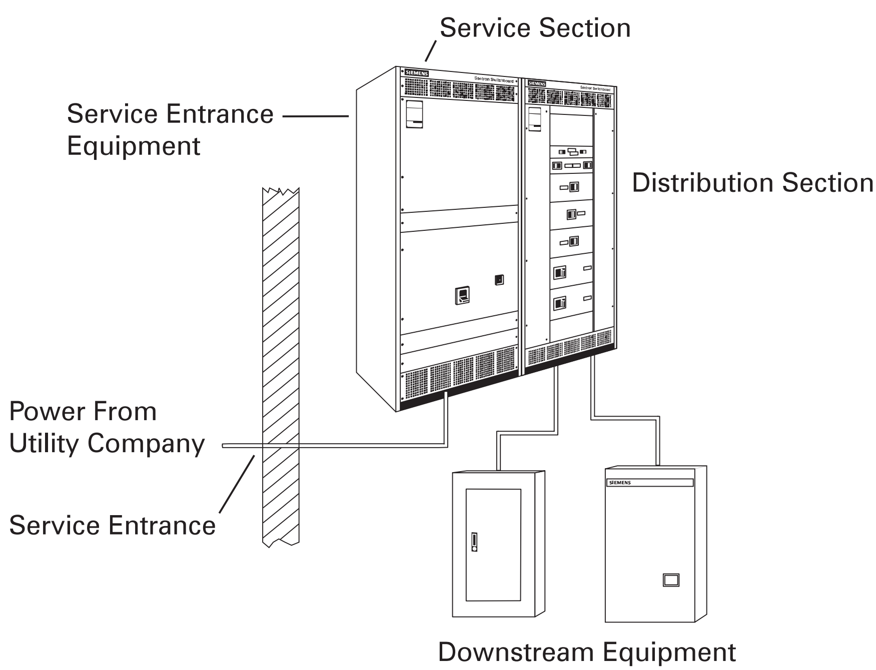
A three-phase, four-wire, delta-connected secondary works a little differently. The following illustration shows a delta-connected secondary with 240 volts phase-to-phase. The midpoint of one phase winding is grounded to provide 120 volts between phase A and neutral and 120 volts between phase C and neutral. Between phase B and neutral, however, the voltage is 208 volts. This is referred to as the high leg. The high leg can be calculated by multiplying the phase A to neutral voltage times 1.732 (120 x 1.732 = 208). Single-pole breakers should not be connected to the high leg. *NEC*® Article 215-8 requires that the high leg bus bar or conductor be permanently marked with a finish that is orange in color. This will help prevent electricians from connecting 120 volt single-phase loads to the 208 volt high leg. Four-wire, delta-connected transformers should always be wired so that the B phase to neutral is the high leg.



Service Entrance Equipment

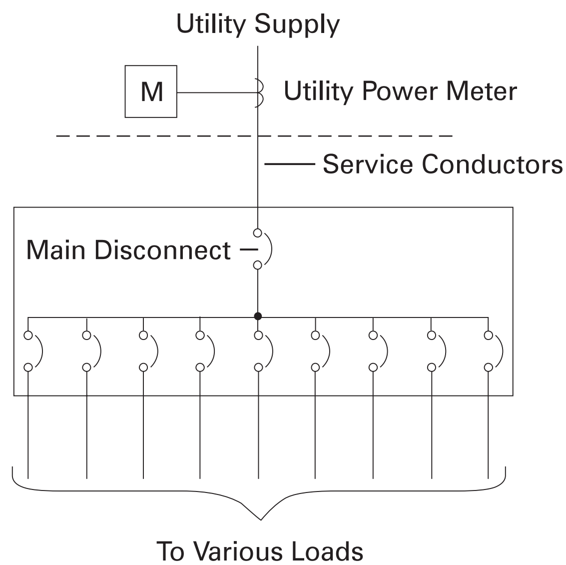
Switchboards are often used as service entrance equipment for a building. The service section of a switchboard refers to the section of a switchboard which receives incoming power. This power can be fed directly from utility power. Power can also be fed to the section from another source, such as switchboard or disconnect switch somewhere upstream.

Service entrance equipment refers to the equipment through which the power supply enters the building. The switchboard in the following drawing is considered service entrance equipment because it is where power enters the building. The incoming power supply is connected to this equipment which provides a means to control and cut off the supply. The *National Electrical Code®* discusses service entrance equipment in Article 230. Switchboards used as service entrance equipment must be approved and labeled as such. All Siemens Sentron™ Series switchboards are factory labeled as suitable for service entrance equipment when specified for service entrance.

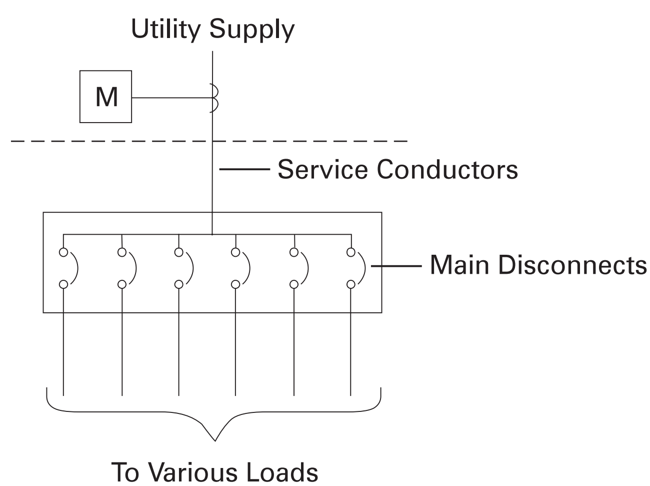


Six disconnect rule

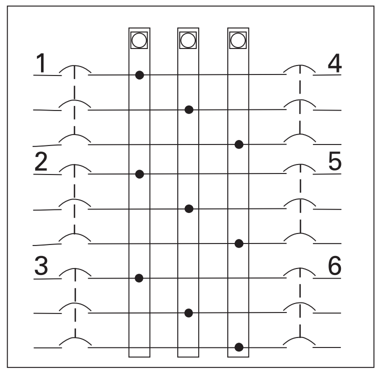
Service entrance conductors must have a readily accessible means of being disconnected from the power supply. *NEC*® Article 230-71a specifies that for each set of service entrance conductors no more than six switches or circuit breakers shall be used to disconnect and isolate the service from all other equipment. In the following example, a single main circuit breaker will disconnect power to all equipment being supplied by the service. There can be as many feeder and branch disconnect devices as needed.



In another example, a switchboard may be equipped with up to six circuit breakers to disconnect power to all equipment being supplied by the service. In any case, the circuit breaker must be clearly labeled for the load it supplies.



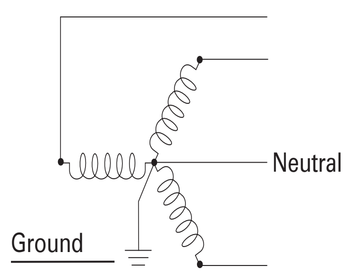
It is important to note that the “six disconnect rule” refers to the number of disconnects and not the number of poles. For example, in the illustration shown below there are 18 poles but only six circuit breakers. Three poles are mechanically linked together to form one disconnect device. In the illustrated configuration the service can be disconnected with no more than six operations of the hand. This arrangement meets the “six disconnect rule”.



Switchboard Grounding

Grounding is an important aspect of any electrical system and must be considered carefully. Article 250 of the *NEC* covers mandatory grounding requirements. The *National Electrical Code*® defines ground as *a conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth*.

The following illustration, for example, shows the neutral (N) conductor of a wye-connected transformer connected to ground.

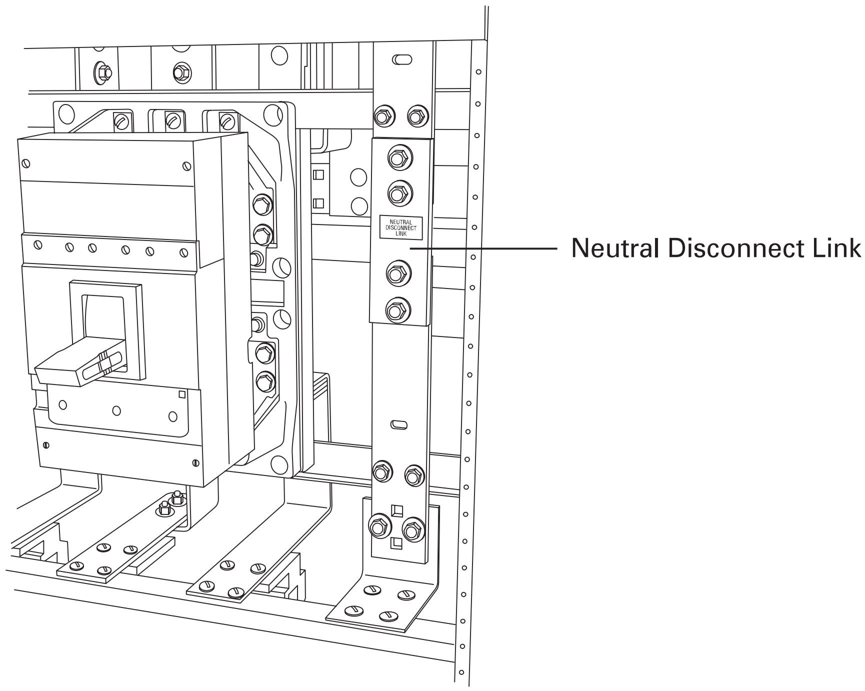


There are two objectives to the intentional grounding of electrical equipment:

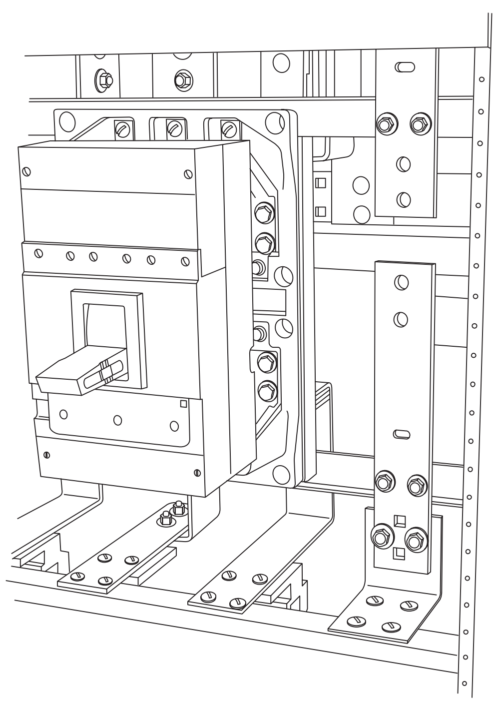
- Keep potential voltage differentials between different parts of a system at a minimum which reduces shock hazard.
- Keep impedance of the ground path to a minimum. The lower the impedance the greater the current is in the event of a fault. The greater the current the faster an overcurrent device will open.

Neutral disconnect link

If a switchboard service section is intended to be used as service entrance equipment, provision must be included to isolate the neutral bus from the grounded neutral bus. A neutral disconnect link is provided for this purpose. The following drawing shows the disconnect link in place.

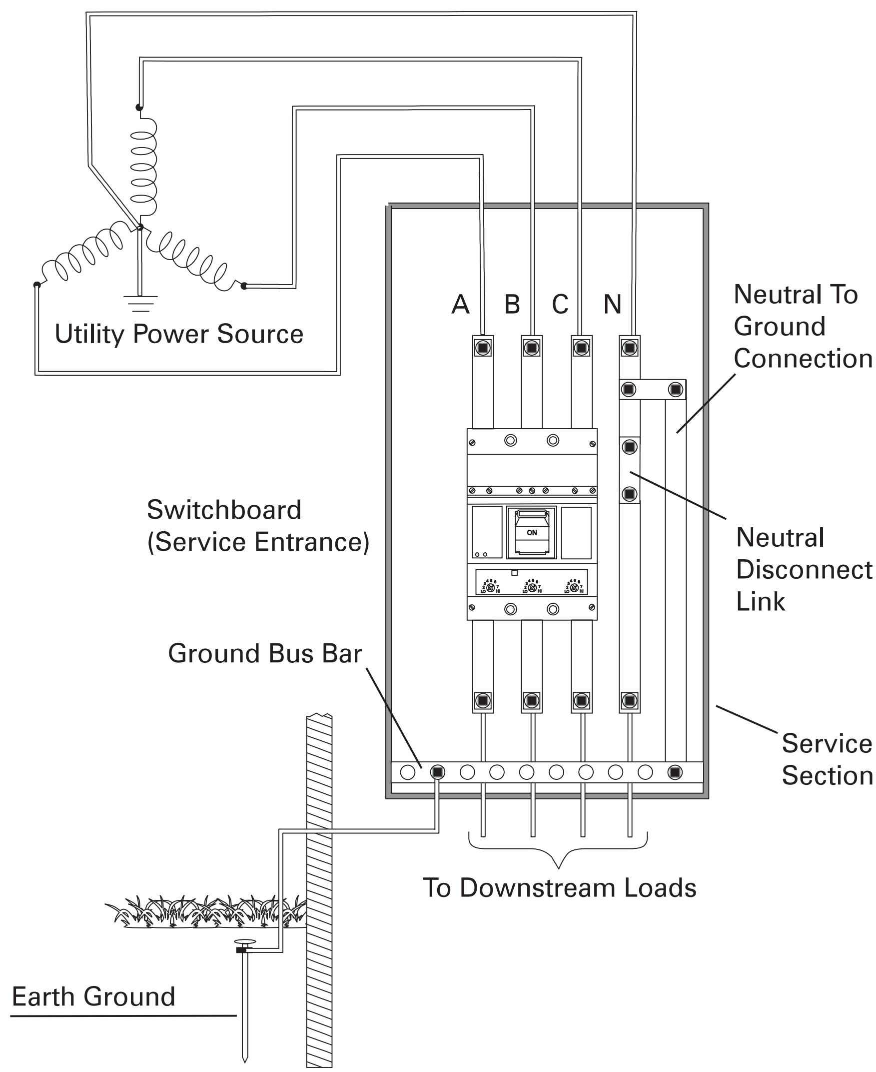


This removable link allows the branch neutral to be checked for continuity on the load side of the main disconnect. The following drawing shows the disconnect link removed.



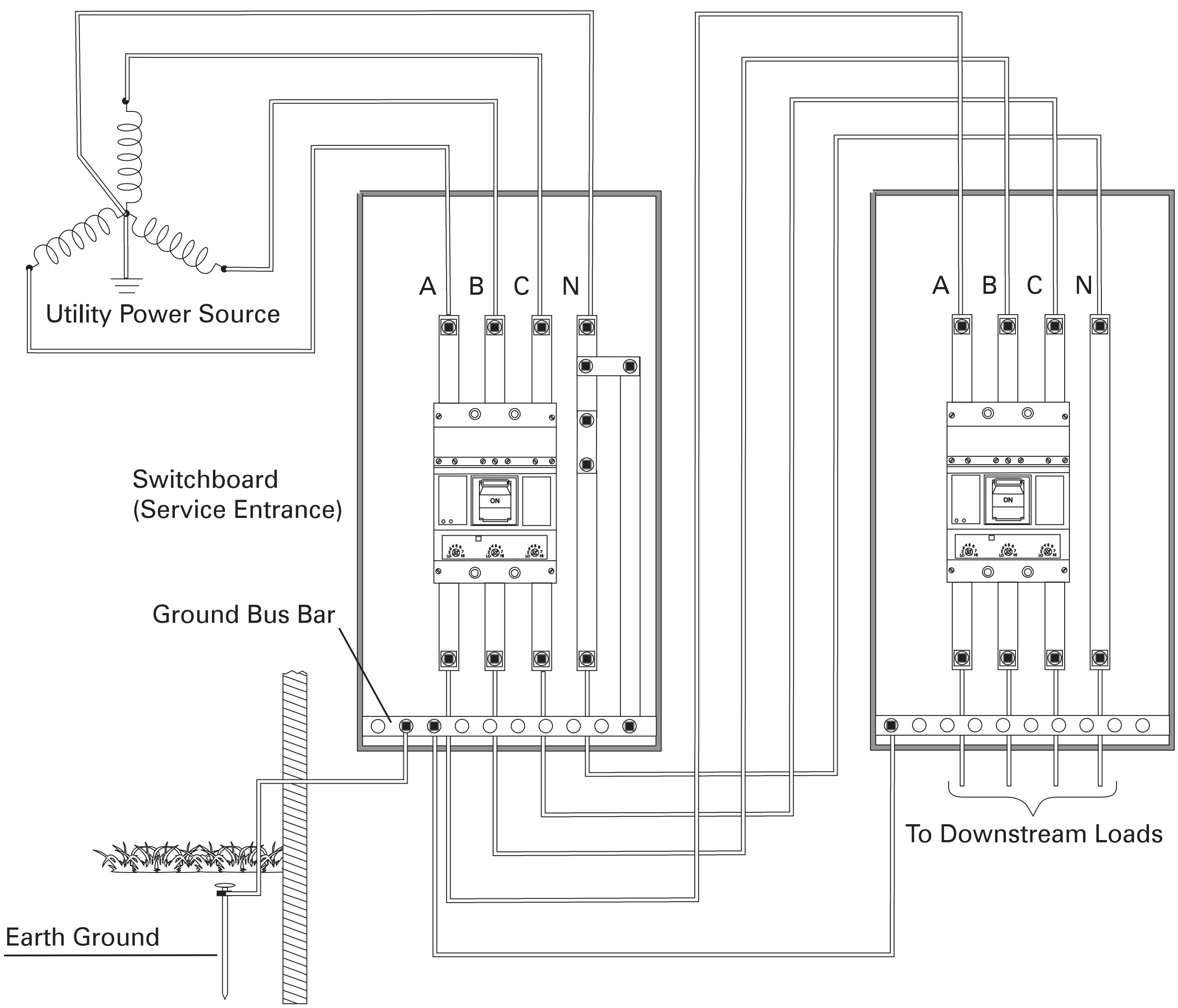
Service entrance grounding

In the following drawing a switchboard is used as service entrance equipment. Power to the service section is received from a 3Ø4W service. The neutral is always grounded in service entrance equipment. The neutral is connected to ground through a neutral to ground connection and ground bus bar. The ground bus bar is connected to the frame of the switchboard, which is connected to the system or earth ground. The neutral disconnect link is left in place to supply downstream loads. Three-phase, four-wire power is then supplied to downstream loads.



Downstream equipment

The neutral is only connected to ground at the service entrance. When downstream equipment is used the neutral is isolated in that equipment. As shown in the following illustration, the neutral is connected to earth ground through the ground bus bar of the service entrance switchboard. In this example a second switchboard is used downstream of the service entrance switchboard. The enclosure of the downstream switchboard is connected to ground through a grounding conductor back to the service equipment. The neutral is not connected to ground in the downstream switchboard. Notice also that the second (downstream) switchboard does not have a neutral disconnect link. Neutral disconnect links are not required in switchboards used as non-service entrance equipment. Similarly the second switchboard will feed additional downstream loads.



Review 4

1. If the secondary of a four-wire, wye-connected transformer is 480 volts phase-to-phase, the phase to neutral voltage is ___________ volts.

2. If the secondary of a four-wire, B phase high leg, delta connected transformer is 240 volts phase-to-phase, the phase-to-neutral voltage is

   ___________ volts A to neutral

   ___________ volts B to neutral

   ___________ volts C to neutral

3. The term service section refers to the section of a switchboard which receives incoming power. The term ___________ ___________ equipment refers to equipment through which the power supply enters the building.

4. According to *NEC*® Article 230-71a, the maximum number of circuit breakers that can be used to disconnect and isolate the service from all other equipment is ___________ .

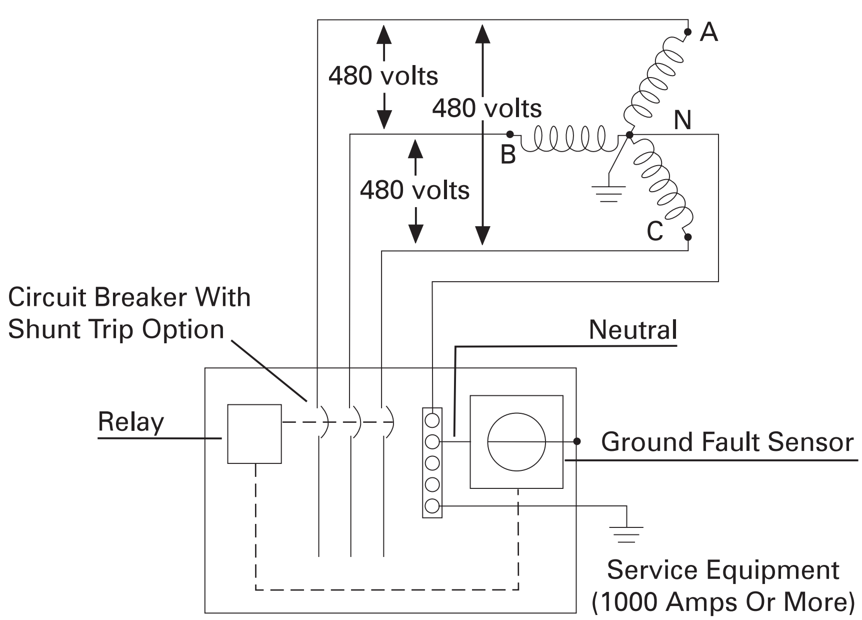
5. A neutral ___________ ___________ is supplied in switchboards used as service entrance equipment to allow the branch neutral to be checked for continuity on the load side of the main disconnect.

Ground Fault Protection

In addition to ensuring equipment is properly grounded, ground fault protection for people and equipment is also a concern. *NEC®* Article 230-95 states that *ground-fault protection of equipment shall be provided for solidly grounded wye electrical services of more than 150 volts to ground, but not exceeding 600 volts phase-to-phase for each service disconnecting means rated 1000 amperes or more.* Although ground-fault protectors are not required on service disconnects that are less than 1000 amperes, depending on the installation, they still may be desirable. Ground fault interrupters designed to provide life protection must open a circuit at 5 milliamps (± 1 milliamp). Ground fault protection for equipment must open a circuit when ground fault current reaches 30 milliamps. Health care facilities, such as hospitals, require additional ground fault protection. This is outlined in *NEC®* Article 517-17.

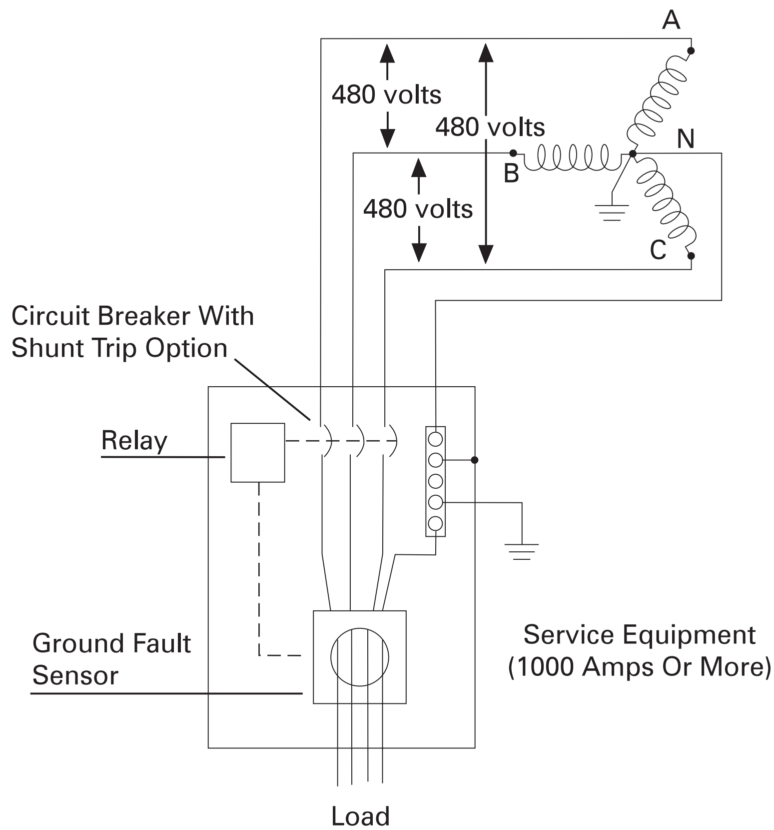
Direct method

One way a ground fault protector works is to install a sensor around one conductor, normally the neutral-to-ground strap. This is referred to as the direct method. When an unbalanced current from a line-to-ground fault occurs current will flow from ground to neutral. When the current reaches the setting of the ground-fault sensor the shunt trip opens the circuit breaker, removing the load from the line.



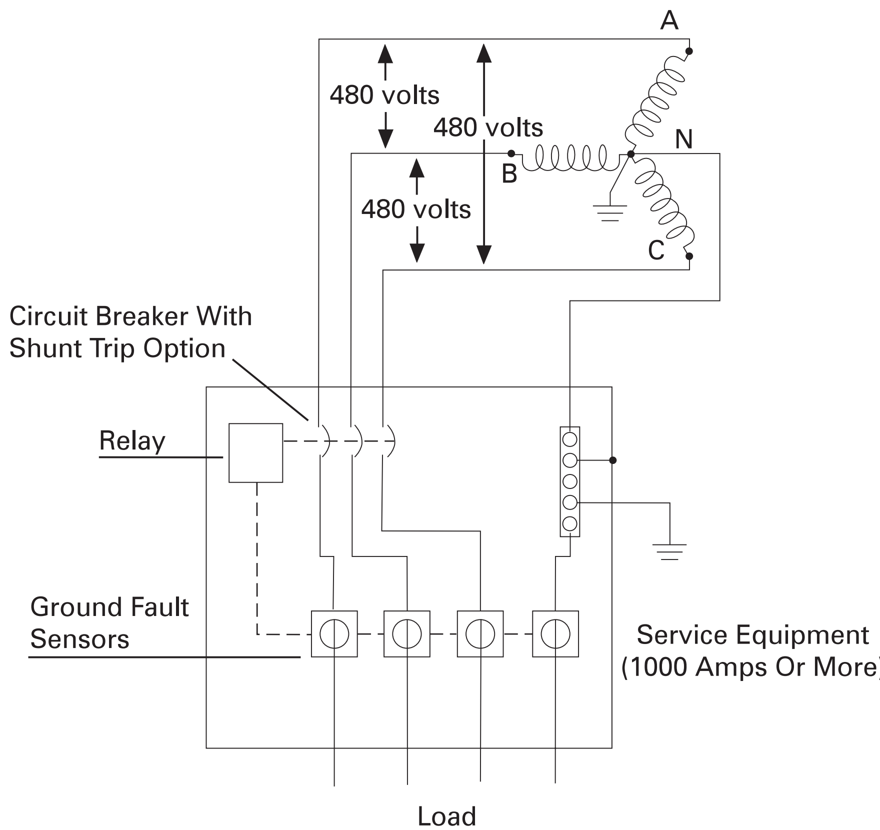
Zero sequencing method

Another way a ground fault protector works is with a sensor installed around all the circuit conductors, including the neutral on 4-wire systems. This is referred to as zero sequencing. During normal current flow the sum of all the currents detected by the sensor is zero. However, a ground fault will cause an unbalance of the currents flowing in the individual conductors. When this current reaches the setting of the ground-fault sensor the shunt trip opens the circuit breaker.



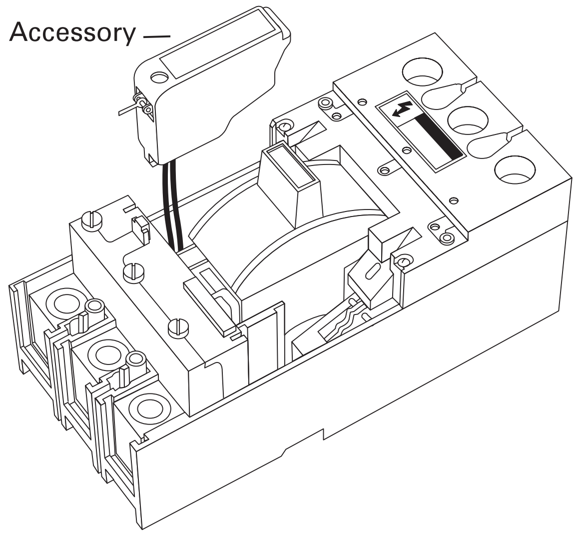
Residual method

Separate sensors monitor current on all three phases (and the neutral on a 4-wire system. If the vectorial sum of the currents on the secondary of the sensors does not equal zero the breaker will be tripped.



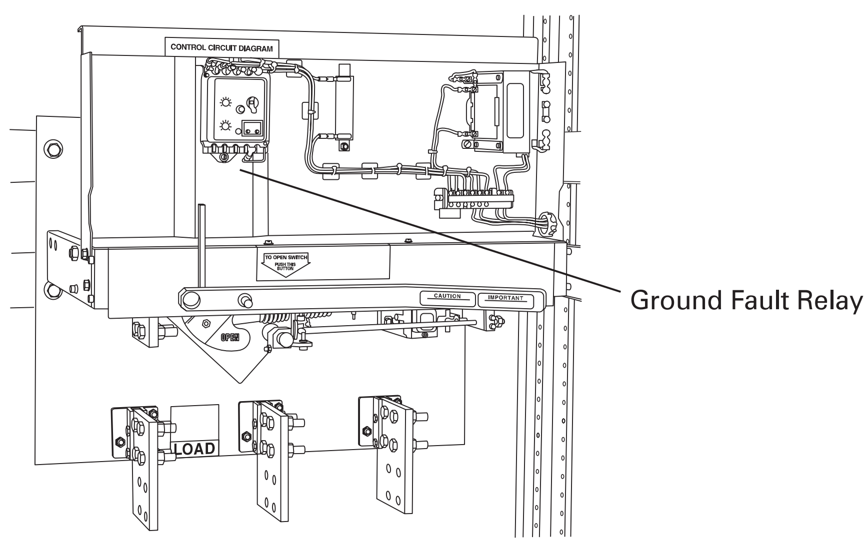
Ground fault protection devices

Ground fault protection is generally incorporated into a special type of protective device such as a molded case circuit breaker (shown below). Ground fault protection is also available in Siemens insulated case circuit breakers.



Accessory For FD - RD Frame
Molded Case Circuit Breakers

Ground fault protection can also be supplied on various disconnect switches, such as the bolted pressure switch.



Note: All main protective devices, <u>except</u> Vacu-Break® fusible switches, can be equipped with ground fault relays to comply with *NEC*® requirements.

Switchboard Ratings

When selecting switchboards and overcurrent protection devices it is extremely important to know both the maximum continuous amperes and available fault current along with several other rating terms.

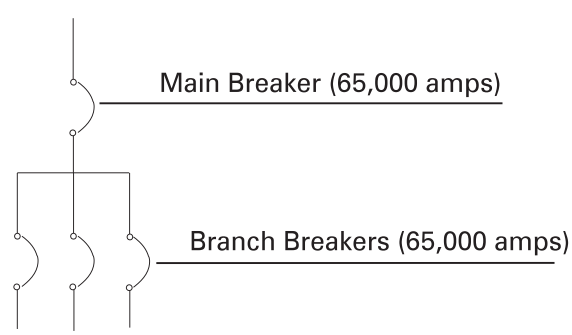
Interrupting rating

Interrupting rating refers to the current rating a protective device, such as a fuse or circuit breaker, can safely interrupt. Interrupting rating is also referred to as ampere interrupting capacity (AIC). *NEC*® article 110-9 states:

Equipment intended to break current at fault levels shall have an interrupting rating sufficient for the system voltage and the current which is available at the line terminals of the equipment. Equipment intended to break current at other than fault levels shall have an interrupting rating at nominal circuit voltage sufficient for the current that must be interrupted.

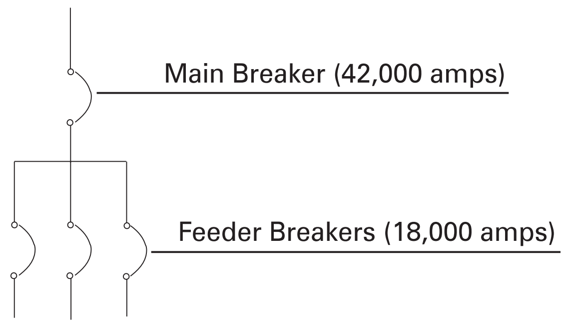
Full rating

There are two ways to meet this requirement. The full rating method is to select circuit protection devices with individual ratings equal to or greater than the available fault current. This means that, in the case of a building with 65,000 amperes of fault current available at the service entrance, every circuit protection device must be rated at 65,000 amperes interrupting capacity (AIC). Switchboards are available with short circuit withstand ratings up to 200,000 amps. However, a full-rated switchboard over 100,000 AIC can be expensive because of the necessary bus bracing.



Series-rated

A full-rated switchboard is not always required. Series-rated switchboards are UL listed and are adequate for many applications at a lower cost. The series-rated concept is that the main upstream circuit protection device must have an interrupting rating equal to or greater than the available fault current of the system, but subsequent downstream circuit protection devices connected in series can be rated at lower values. This is permitted as long as the series combinations shown have been tested and certified by UL. For example, a building with 42,000 amperes of available fault current might have the breaker at the service entrance rated at 42,000 AIC and additional downstream breakers rated at 18,000 AIC.



Series-rated breaker combinations must be tested in series in order to be UL listed. Siemens series-rated breakers are listed in the UL "Recognized Components Directory" (yellow books) Volume 1. Selected series-rated breakers are listed in the Speedfax catalog. Your Siemens sales engineer can provide more information on Siemens series-rated circuit breakers.

Keep in mind that it is the protection device mounted in the switchboard that interrupts current. Therefore, the interrupt rating applies to the protective devices.

Withstand rating

Short circuit withstand rating refers to the level of fault current a piece of equipment can withstand without sustaining damage. The standards for short circuit withstandability are set by Underwriters Laboratories (UL Standard 891). Bus structures and bracing are designed to withstand a specified amount of current for a specified amount of time. The short circuit withstand rating of a switchboard is determined by the combined withstand, interrupting, and current limiting capabilities of the bus, overcurrent protective devices in the switchboard, and any overcurrent protective devices within or ahead of the switchboard that may supply and protect it.

Ampere rating

The ampere rating refers to the current a switchboard or protective device will carry continuously without deterioration and without exceeding temperature rise limits.

Voltage rating

The voltage rating of a switchboard must be at least equal to the system voltage. The voltage rating of a switchboard can be higher than the system voltage, but never less. For example, a 480 VAC switchboard could be used on a 240 VAC system. A 240 VAC switchboard could not be used on a 480 VAC system.

Review 5

1. Ground fault protection is required for grounded wye electrical services of more than 150 volts to ground, but not exceeding 600 volts phase-to-phase when service disconnecting devices are rated at ___________ amps or more.

2. All main protective devices except ___________ - ___________ ___________ ___________ can be equipped with ground fault relays to comply with *NEC®* requirements.

3. Ground fault protection is discussed in *NEC®* Article ___________ .

4. ___________ rating refers to the level of fault current a piece of equipment can withstand without sustaining damage.

5. ___________ rating refers to the maximum current a protective device such as a fuse or circuit breaker can safely interrupt.

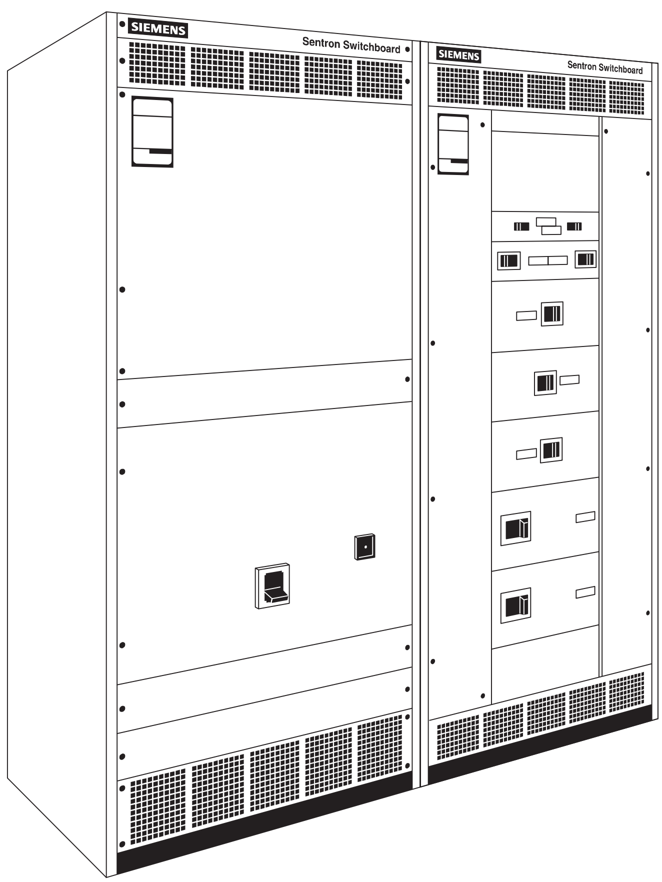
6. A switchboard is said to be ___________ - ___________ when the main upstream circuit protection device is equal to or greater than the available fault current, but subsequent downstream circuit protection devices connected in series are rated at a lower AIC.

7. ___________ ___________ refers to the current a switchboard or protective device will carry continuously without deterioration and without exceeding temperature rise limits.

SB1, SB2, and SB3 Switchboards

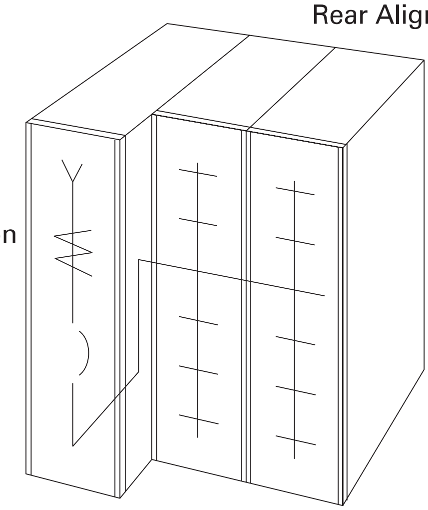
Siemens manufactures a variety of switchboards. The type of switchboard selected is determined by a variety of factors such as space, load, and environment. In addition to meeting present loads, the switchboard should be sized to accommodate reasonable future load additions. The continuous rating and through-bus can be sized on the basis of anticipated future load demand. Trip units or fuses of lower ratings can be installed to meet present load demands and changed in the future as load increases. Siemens switchboards are available in Type 1 (indoor) or Type 3R (outdoor) enclosures.

SB1, SB2, and SB3 Sentron™ switchboards can be found in a variety of industrial plants, hospitals, and commercial buildings.



SB1 switchboards

SB1 switchboards are designed to be used in an application where space is a consideration. SB1 switchboards are rear aligned. The service section can be deeper than the distribution sections. By aligning the rear the switchboard can be installed against a wall.



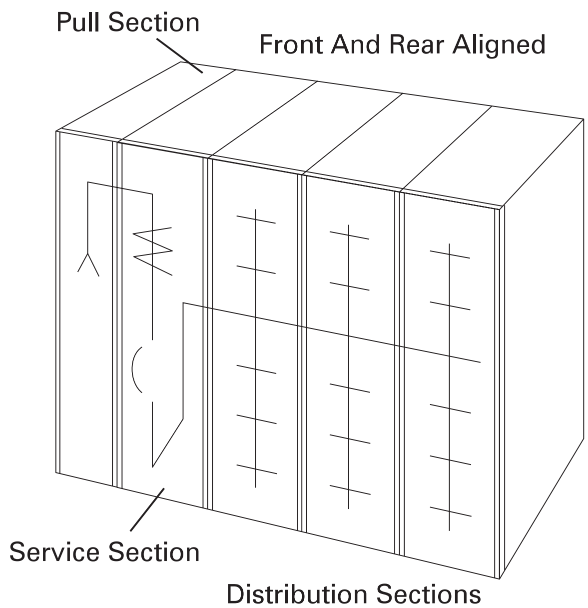
SB1 ratings and devices

The SB1 switchboard contains front-connected main protective devices and through-bus ratings up to 2000 amps at 480 VAC. SB1 switchboards are front accessible with front connected devices. Main devices, used in the service section, are available from 400 - 2000 amps. Branch devices, used in the distribution section, are available from 15 - 1200 amps.

	Molded Case Circuit Breaker	Vacu-Break Fusible Switch	Bolted Pressure Switch	HCP Fusible Switch
Main device individually mounted	400-2000 A	800-1200 A	800-2000 A	400-1200 A
Main device panel mounted	400-1200 A	400-600 A		400-1200 A
Branch device panel mounted	15-1200 A	30-600 A		400-1200 A

SB2 switchboards

The rear of SB2 switchboards align as standard. Front and rear alignment is available as an option. SB2 switchboards are front accessible and front connected. The following switchboard pictorial illustrates an SB2 that is front and rear aligned. In this example a pull section has been added to allow room to pull cable up from the bottom to connections in the top of the service section. Bottom feed without a pull section is also available. SB2 switchboards may be mounted against a wall.



SB2 ratings and devices

The SB2 contains through-bus ratings up to 4000 amps at 480 VAC. Main devices are available from 400 - 4000 amps. Branch devices are available from 15 - 1600 amps.

	Molded Case Circuit Breaker	Vacu-Break Fusible Switch	Bolted Pressure Switch	HCP Fusible Switch	Insulated Case Circuit Breaker
Main device individually mounted	400-3200 A	400-1200 A	800-4000 A	400-1200 A	800-4000 A Fixed
Main device panel mounted	400-1200 A	400-600 A		400-1200 A	
Branch device individually mounted		800-1200 A	800-1600 A	400-1200 A	
Branch device panel mounted	15-1200 A	30-600 A		400-1200 A	

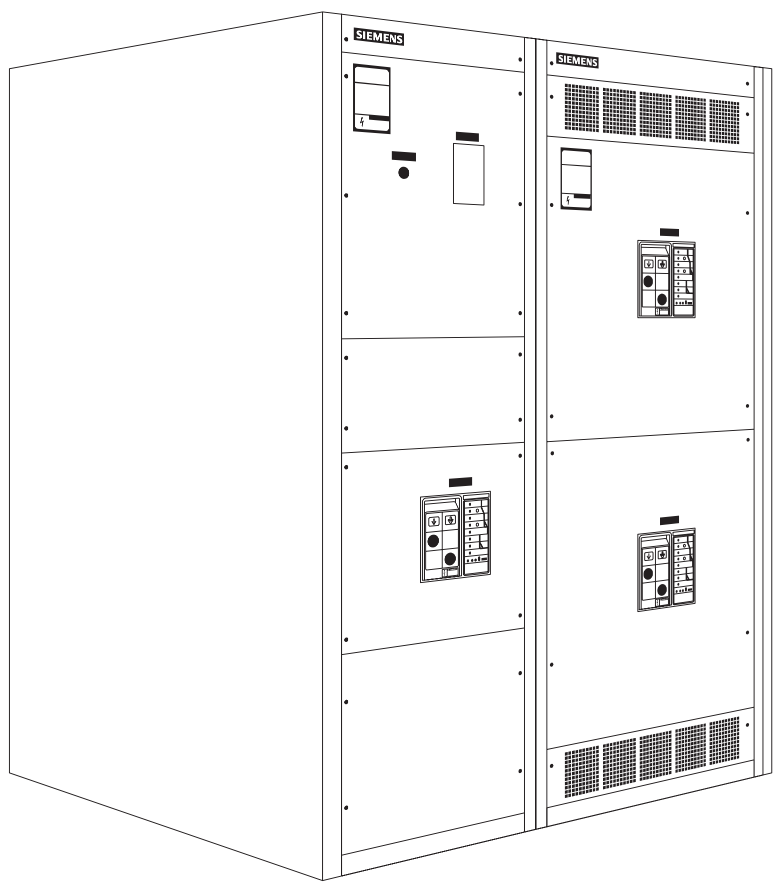
SB3 switchboards

SB3 switchboards are front and rear aligned. SB3 switchboards are designed for special configurations, such as incoming and outgoing busway connections, and automatic transfer schemes. Through-bus ratings are available up to 6000 amps. Branch devices are available from 15 - 2000 amps (custom configurations with higher ratings are available).

	Molded Case Circuit Breaker	Vacu-Break Fusible Switch	Bolted Pressure Switch	HCP Fusible Switch	Insulated Case Circuit Breaker	LV Power Circuit Breaker
Main device individually mounted	400-3200 A	400-1200 A	800-4000 A	400-1200 A	800-5000 A Fixed or Drawout	800-4000 A Drawout
Main device panel mounted	400-1200 A	400-600 A		400-1200 A		
Branch device individually mounted	400-3200 A	800-1200 A	800-4000 A	400-1200 A	800-2000 A Fixed or Drawout	
Branch device panel mounted	15-1200 A	30-600 A		400-1200 A		

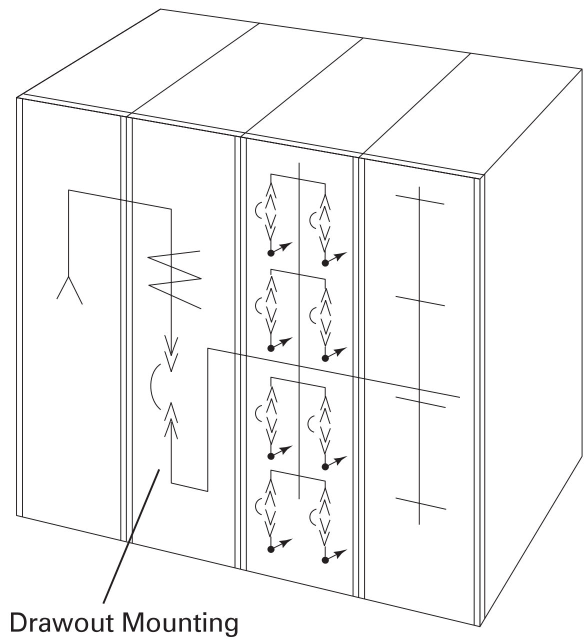
RCIII Switchboards

The branch and feeder devices in the Siemens type RCIII switchboards are individually mounted. This mounting method requires access to outgoing cable terminations from the rear. Type RCIII switchboards are rear connected and require rear access. Bus bar extensions from the feeder devices are run back to the rear of the switchboard for easy access. RCIII switchboards are front and rear aligned. The following drawing illustrates a type RCIII switchboard with Siemens insulated case circuit breakers (ICCB) in the service and distribution sections.

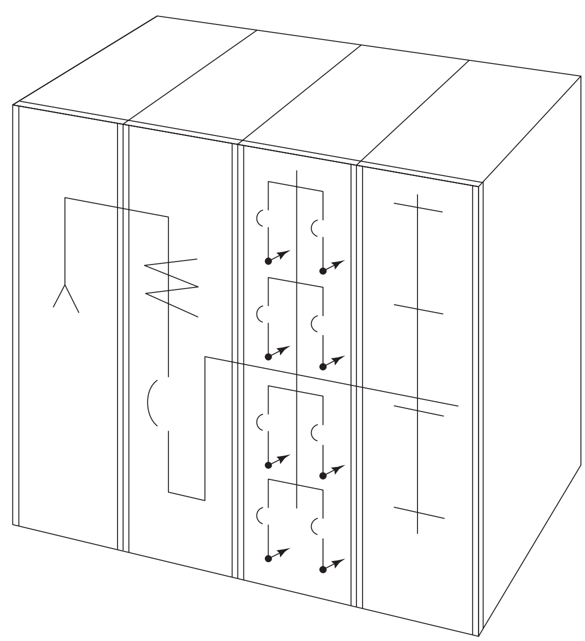


Drawout or fixed mounting

Depending on the protective device, it may be either drawout or fixed mounted. Insulated case circuit breakers (ICCB), for example, may be drawout or fixed mounted. Vacu-break® fusible switches are fixed mounted.



Drawout Mounted Devices



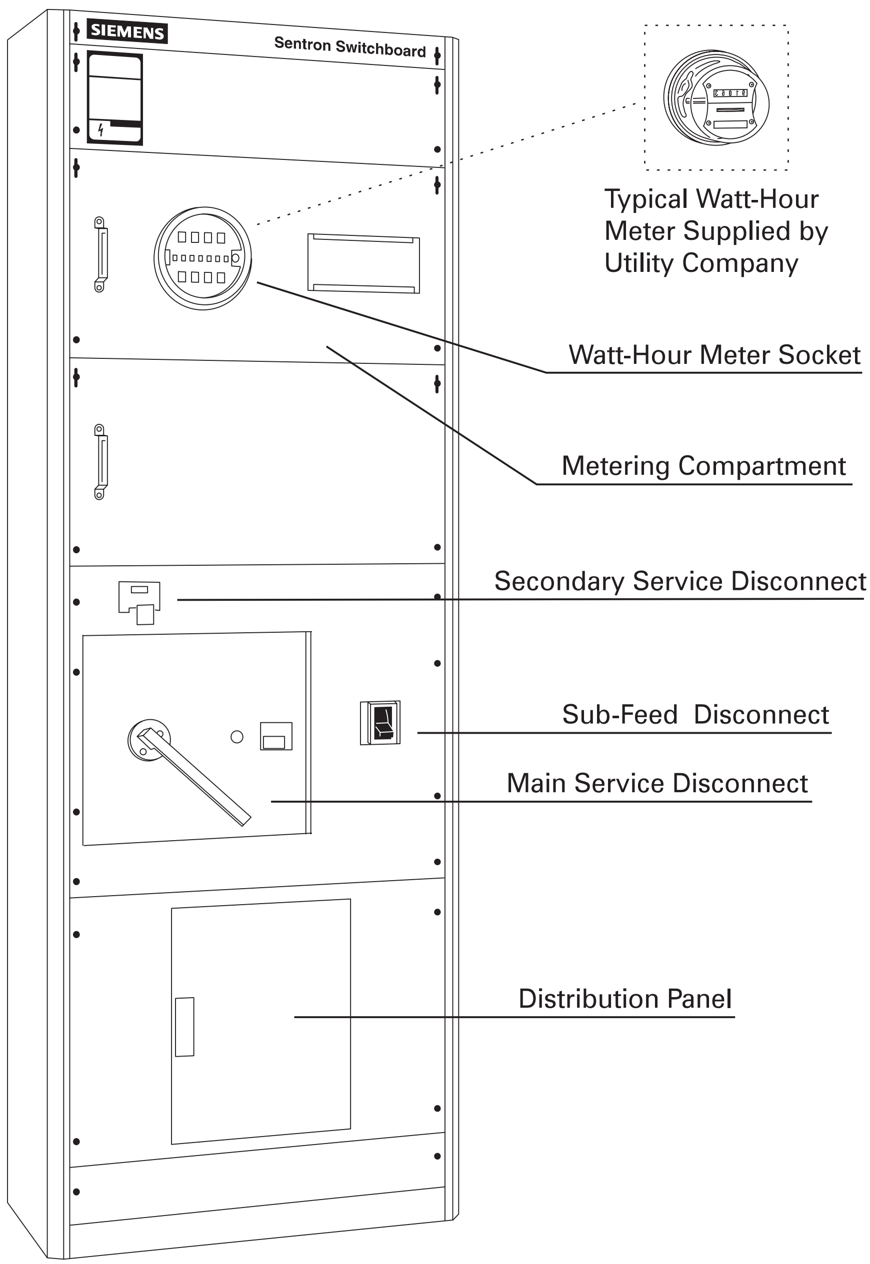
Fixed Mounted Devices

Ratings and devices

	Molded Case Circuit Breaker	Vacu-Break Fusible Switch	Bolted Pressure Switch	Insulated Case Circuit Breaker	LV Power Circuit Breaker
Main device individually mounted	400-3200 A	400-1200 A	800-4000 A	800-5000 A Fixed or Drawout	800-4000 A Drawout
Branch device individual (rear) and panel mounted	15-3200 A	30-1200 A	800-4000 A	800-4000 A Fixed or Drawout	800-4000 A Drawout

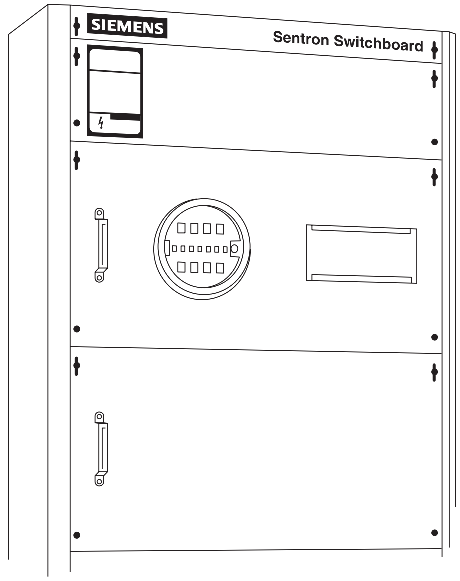
Super Blue Pennant Switchboards

The Super Blue Pennant™ switchboard is designed as a service entrance switchboard. The main service disconnect and distribution devices are contained in a single unit. The metering provisions meet EUSERC (an electrical standardization coalition) specifications. Super Blue Pennant switchboards are rated for 400, 600, or 800 amps with a circuit breaker main and 400 or 600 amps with a fusible Vacu-Break® switch main.



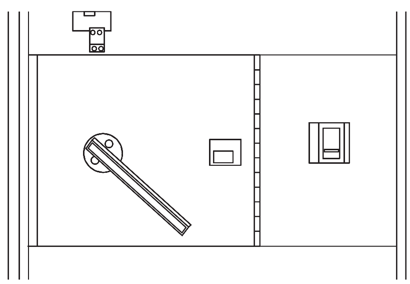
Metering compartment

The metering compartment has provisions for mounting a utility meter on the door. Super Blue Pennant uses hot sequence metering. Incoming power is connected to the main lugs.



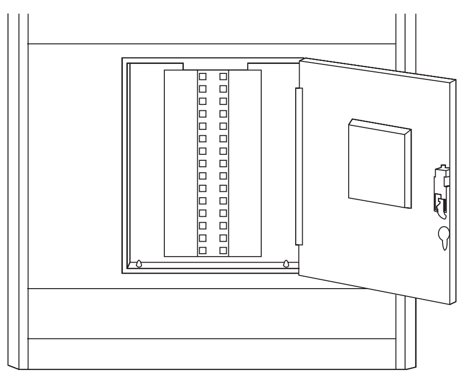
Service disconnect

The service disconnect can be a fusible Vacu-Break switch through 200,000 AIC, or a circuit breaker with a maximum rating of 65,000 AIC at 240 volts and 35,000 AIC at 480 volts.



Distribution panel

Distribution kits are optional and field adaptable with ratings of 400 - 800 amps. Up to 40 branch circuit provisions are available with an 18 branch circuit minimum.

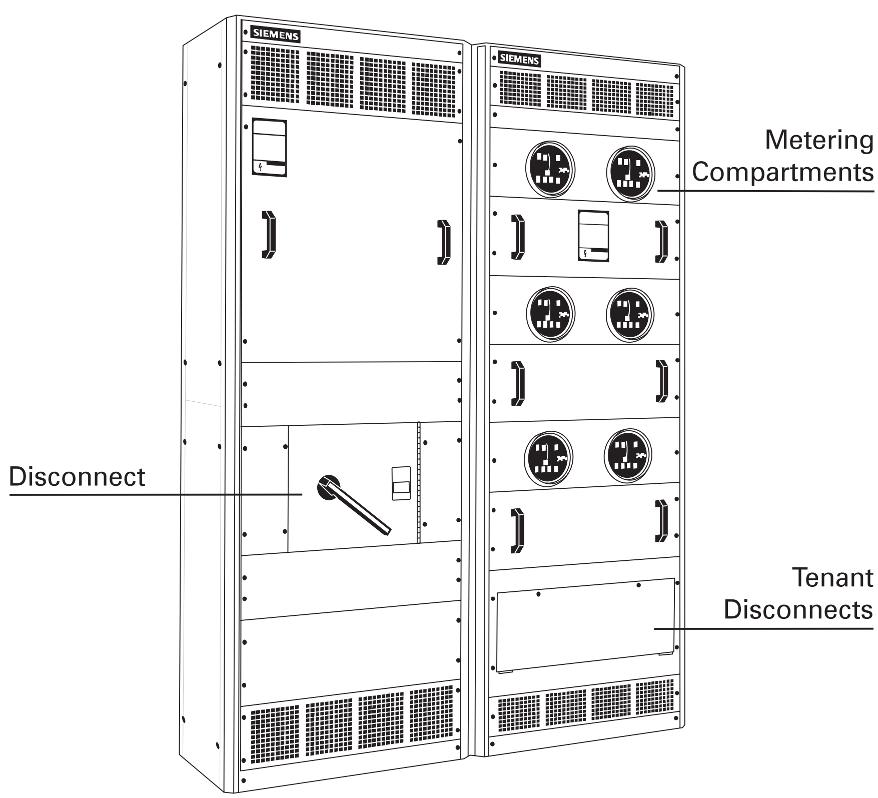


Commercial Metering Switchboards

Commercial metering switchboards are designed for commercial applications where multi-metering is required. These applications include shopping centers, office buildings, and other commercial buildings with multiple tenants.

Type SMM switchboards

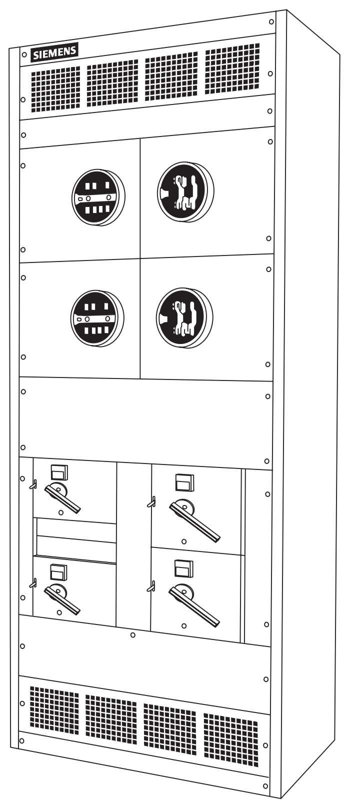
Type SMM switchboards are designed to meet west coast utility and EUSERC specifications. The switchboard main service is rated up to 4000 amps at 480 volts. Service mains can be circuit breakers (up to 2000 amps), insulated case circuit breakers (up to 3000 amps), bolted pressure switches (up to 4000 amps), or Vacu-Break®, and HCP fusible switches (up to 1200 amps). Tenant mains, rated at 100 and 200 amps, are interchangeable. Tenant mains can be circuit breakers, fusible switches, or T-fuse pullouts. The bus is braced for 65,000 amps. Higher bracing is available as an option. Metering sockets are rated for 200 amps continuous duty. The Type SMM switchboard shown below has a thru-main section.



Thru-Main Section

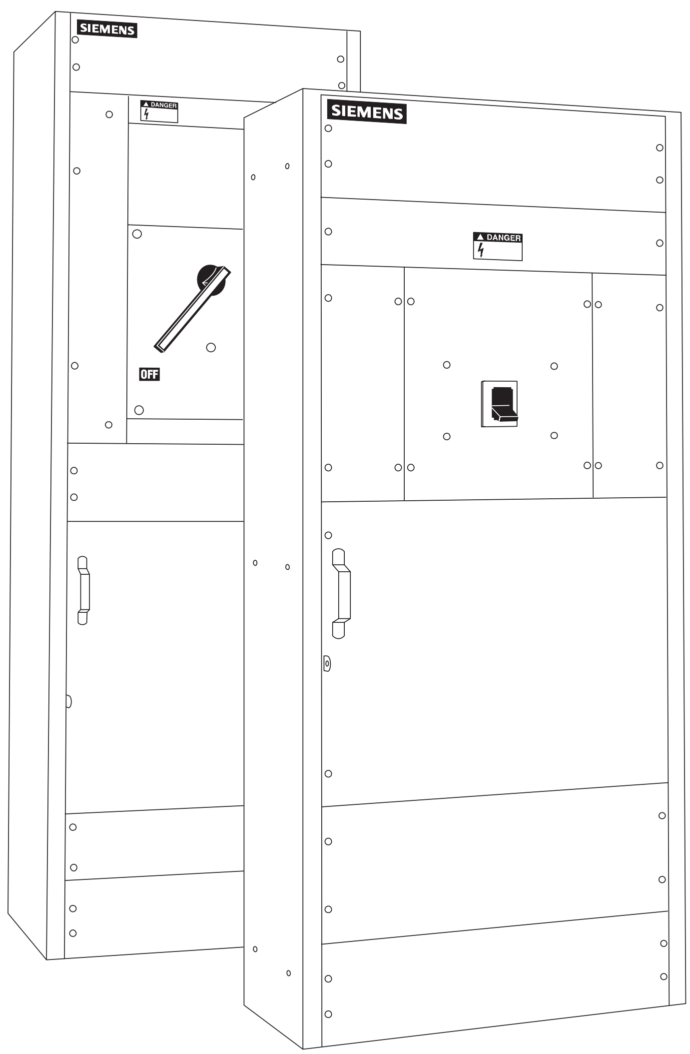
Type MMS switchboards

The MMS switchboard is similar to the SMM, however, it is not designed to meet west coast specifications. The main service is rated up to 4000 amps. Service mains can be circuit breakers (up to 2000 A), insulated case circuit breakers (up to 4000 A), bolted pressure switches (up to 4000 A), or Vacu-Break fusible switches (up to 1200 A). Tenant mains, rated at 100 and 200 amps, are interchangeable. Tenant mains can be circuit breakers, fusible switches, or T-fuse pullouts. All meter sockets are rated at 200 amps. Wiring is for 100 amps or 200 amps, depending on the tenant main device. Depending on the tenant main device, MMS switchboards are available with 2, 3, 4, or 6 sockets. The bus is braced for 50,000 amps. Higher bracing is available as an option.



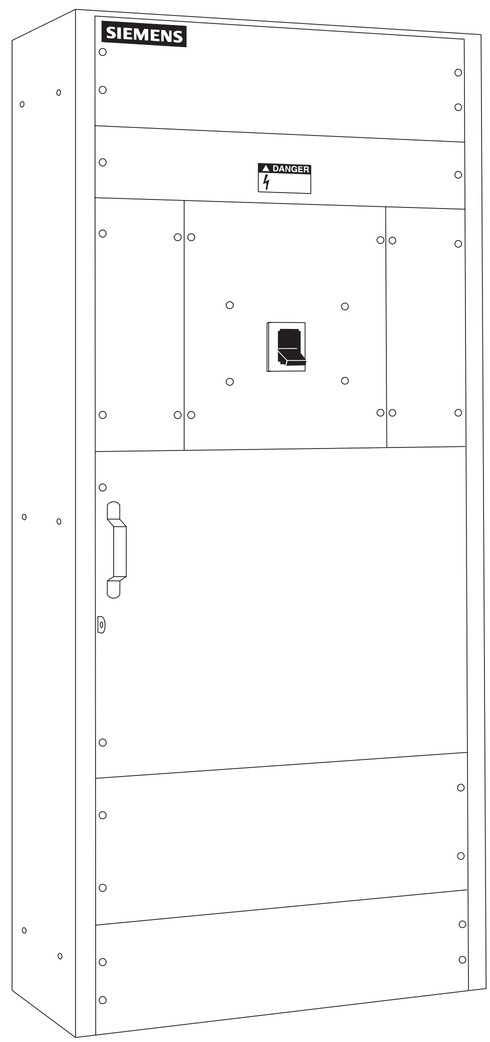
Speciality Service Entrance Switchboards

Specialty service entrance switchboards can be used in various applications. A specialty service entrance switchboard may, for example, be placed ahead of a main switchboard. The specialty switchboard serves as the disconnect for the main switchboard. Specialty service entrance switchboards are available with a single molded case circuit breaker, Vacu-Break® fusible switch, or bolted pressure switch (not shown).



BCT service cubicle

BCT service cubicles use molded case circuit breakers. They are available in current ratings from 400 - 1200 amps. BCT specialty service entrance switchboards use cold sequence metering as standard and are top fed. For hot sequence metering the unit and circuit breaker can be inverted.

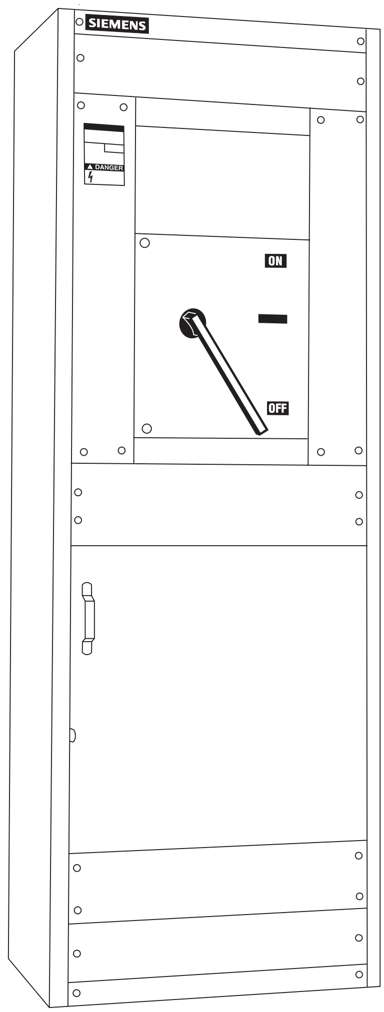


SCT service cubicle

SCT service cubicles use Vacu-Break® fusible switches. They are available with the following current ratings:

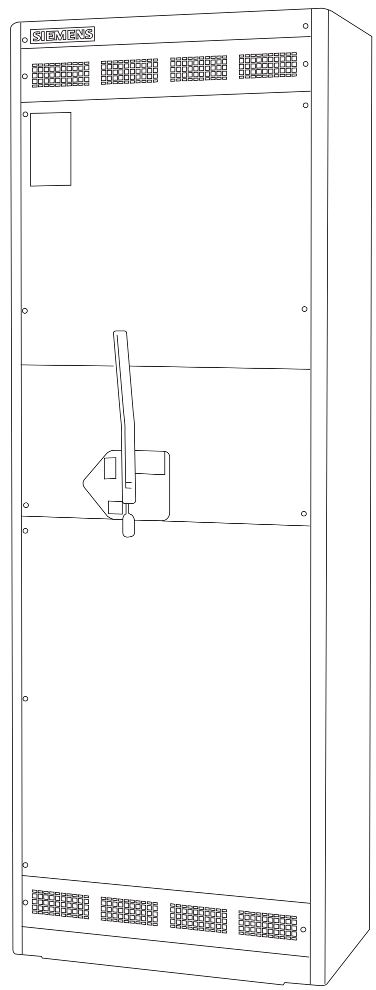
120/240, 480 Y/277 volts	400, 600, and 800 amps
208 Y/120, 240, 480, 600 volts	600 and 800 amps
208 Y/120, 240 volts	800 and 1200 amps

SCT service cubicles use cold sequence metering. Hot sequence metering is available.



Enclosed bolted

Enclosed bolted pressure switch specialty switchboards can be used when metering is not required and are available with top or bottom feed. The following drawing illustrates a top feed enclosed bolted pressure switch. Current ratings are available from 800 - 4000 amps.



Information Needed To Order Switchboards

When ordering a switchboard several questions need to be answered.

1. What are the power system specifications (voltage, phases, number of wires)?
2. What is the AIC rating (ampere interrupting capacity)?
3. Will full or series rated be required?
4. What is the NEMA Type enclosure desired?
5. How many circuits are required?
6. What types of overcurrent protective devices (MCCB, ICCB, Vacu-Break® fusible switch, bolted pressure switch) are required?
7. Does the switchboard need to be suitable for service entrance?
8. What amperage is the switchboard rated at?
9. Will the switchboard be top or bottom fed?
10. Will the switchboard be hot or cold metering?
11. What will the alignment be?
12. What type of bus material is required (temperature/ density)?
13. What special modifications are needed (serial communications, pull sections, corner sections)?

Review 6

1. SB1 switchboards are ___________ aligned.
2. The maximum main bus rating of an SB1 switchboard is ___________ amps.
3. The maximum main bus rating of an SB2 switchboard is ___________ amps.
4. The maximum main bus rating of an SB3 switchboard is ___________ amps.
5. Super Blue Pennant switchboards are rated up to ___________ amps with a circuit breaker and ___________ amps with a Vacu-Break® fusible switch.
6. Up to ___________ branch circuit provisions are available in the distribution panel of the Super Blue Pennant switchboard.
7. The type of commercial metering switchboard used on the west coast is Type ___________ .
8. The type of specialty service entrance switchboard that uses a molded case circuit breaker as a main disconnect is a Type ___________ service cubicle.
9. The type of specialty service entrance switchboard that uses a Vacu-Break fusible switch as a main disconnect is a Type ___________ service cubicle.

Review Answers

Review 1	1) 120; 2) 277; 3) 100; 4) NEMA, UL; 5) 384.
Review 2	1) ampacity; 2) Time; 3) 200,000; 4) 90; 5) bus; 6) Splice; 7) through-bus.
Review 3	1) service, distribution; 2) pull box; 3) pull section; 4) 4300; 5) Hot sequence; 6) Cold sequence; 7) f; 8) distribution; 9) Rear aligned.
Review 4	1) 277; 2) 120, 208, 120; 3) service entrance; 4) six; 5) disconnect link.
Review 5	1) 1000; 2) Vacu-Break fusible switches; 3) 230-95; 4) Withstand; 5) Interrupting; 6) series-rated; 7) Ampere rating.
Review 6	1) rear; 2) 2000; 3) 4000; 4) 6000; 5) 800, 600; 6) 40; 7) SMM; 8) BCT; 9) SCT.

Final Exam

The final exam is intended to be a learning tool. The book may be used during the exam. A tear-out answer sheet is provided. After grading the test, mail the answer sheet in for grading. A grade of 70% or better is passing. Upon successful completion of the test a certificate will be issued.

Questions

1. The requirements for switchboards are covered in *NEC*® Article ____________ .

   a. 210 b. 318
   c. 384 d. 770

2. Two causes of overcurrent are ____________ .

   a. overloads and heat
   b. overloads and short circuits
   c. short circuits and heat
   d. ground fault and heat

3. The AIC rating of a Class R fuse is ____________ amps.

   a. 10,000 b. 50,000
   c. 100,000 d. 200,000

4. The standard height of a Siemens switchboard is ____________ inches.

   a. 32 b. 38
   c. 72 d. 90

5. The correct NEMA phase sequence for a vertical bus, as viewed from the front, left to right is ____________ .

   a. A-B-C b. A-C-B
   c. C-A-B d. C-B-A

6. Two adjoining switchboard sections are connected together with ___________ .

   a. vertical bus bars b. compression lugs
   c. splice plates d. cross bus

7. A ___________ is used when cables fed from the bottom of a switchboard need to be routed to the top of the switchboard.

   a. service section b. pull section
   c. pull box d. distribution section

8. ___________ is when power is still applied to the utility meter when the service main is switched off.

   a. Hot sequence b. Cold sequence
   c. Top feed d. Bottom feed

9. A switchboard with a service section that is deeper than the distribution section would be ___________ aligned.

   a. front b. rear
   c. front and rear d. front or rear

10. On a three-phase, four-wire, wye-connected transformer with a secondary voltage of 480 volts phase-to-phase, the phase-to-neutral voltage is ___________ volts.

   a. 138 b. 240
   c. 277 d. 480

11. On a three-phase, four-wire, B phase high leg, delta connected transformerdelta-connected transformer the high leg is ___________ .

   a. A - N b. B - N
   c. C - N d. A - B

12. The maximum number of switches or circuit breakers used to disconnect and isolate the service from all other equipment on service-entrance equipment is ___________ .

   a. 1 b. 2
   c. 4 d. 6

13. The neutral conductor is ___________ grounded at the service-entrance switchboard.

a.	always	b.	never
c.	rarely	d.	often

14. All main protective devices, except ___________ , can can be equipped with ground fault relays to comply with *NEC*® requirements.

    a. Molded case circuit breakers
    b. Vacu-Break fusible switches
    c. Insulated case circuit breakers
    d. Bolted pressure switches

15. The ___________ is a removable link that isolates the neutral bus from, the grounded neutral bus.

    a. neutral disconnect link
    b. ground bus bar
    c. vertical neutral bus
    d. horizontal neutral bus

16. Article 230-95 of the *NEC*® states that *ground-fault protection of equipment shall be provided for solidly grounded wye electrical services of more than 150 volts to ground, but not exceeding 600 volts phase-to-phase for each service disconnecting means rated ___________ amperes or more*.

a.	5 milliamps	b.	10 amps
c.	1000 amps	d.	200,000 amps

17. The rating which refers to the level of short circuit fault current a piece of equipment can withstand without sustaining damage is the ___________ rating.

a.	interrupting	b.	full
c.	ampacity	d.	withstand

18. The SB2 contains through-bus ratings up to __________ amps.

a.	1200	b.	2000
c.	4000	d.	6000

19. The maximum rating for an insulated case circuit breaker used as a main device for an RCIII switchboard is __________ amps.

a.	1200	b.	2000
c.	3000	d.	5000

20. Super Blue Pennant switchboards are rated up to __________ amps with a fusible Vacu-Break switch main.

a.	600	b.	800
c.	1200	d.	2000

Notes

Notes