Design Standards

Although several organizations are involved in establishing standards for the design, construction, and application of motor control centers, the primary standards are established by UL, NEMA, and the National Electrical Code® (NEC®). The following organizations have established standards which may be applied to motor control centers. It is beyond the scope of this course to cover every standard; however, reference will be made throughout the course to many important standards with which Siemens motor control centers comply.

UL

Underwriters Laboratories (UL) is a private company that is nationally recognized as an independent testing laboratory. UL tests products for safety and products that pass UL tests can carry a UL mark. Siemens motor control centers are designed to UL 845 standards.

NEMA

The National Electrical Manufacturers Association (NEMA) is an organization that, among other things, develops standards for electrical equipment.

NEC

The National Fire Protection Association (NFPA) is a nonprofit organization which publishes the *National Electrical Code®* (*NEC®*). The intent of the *NEC®* is to describe safe electrical practices.

ANSI

The American National Standards Institute (ANSI) is a nongovernmental organization that facilitates the development of standards by establishing a consensus among qualified groups.

IEEE

The Institute of Electrical and Electronic Engineers (IEEE) is an organization open to individual membership and provides a variety of services for its members. It also develops numerous standards for electrical and electronic equipment and practices.

IEC

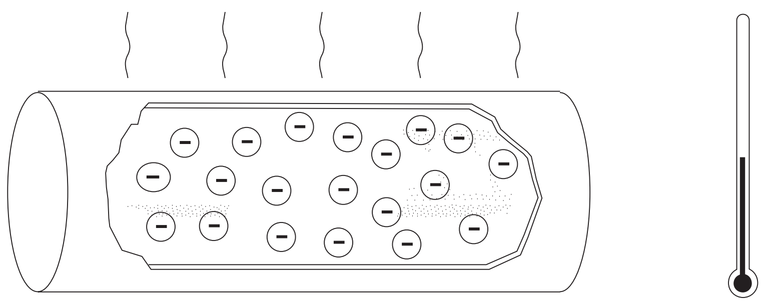
The International Electrotechnical Commission (IEC) is an organization based in Geneva, Switzerland, with over 50 member nations. IEC writes standards for electrical and electronic equipment practices.

NEC® and *National Electrical Code®* are registered trademarks of the National Fire Protection Association.

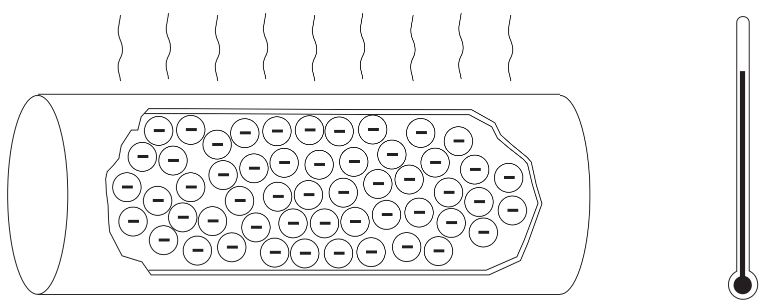
Need for Circuit Protection

Current and Temperature

Current flow in a conductor always generates heat. The greater the current flow in any one size conductor, the hotter the conductor. Excess heat is damaging to electrical components and conductor insulation. For that reason conductors have a rated, continuous current-carrying capacity or ampacity. Overcurrent protection devices, such as fuses, are used to protect conductors from excessive current flow.



Normal Current Flow



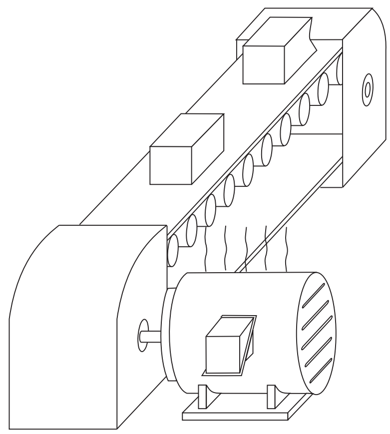
Excessive Current Flow

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).

NEC® and *National Electrical Code®* are registered trademarks of the National Fire Protection Association. Reprinted with permission from NFPA 70-2002, the *National Electrical Code®*, Copyright© 2001, National Fire Protection Association, Quincy, MA 02269.

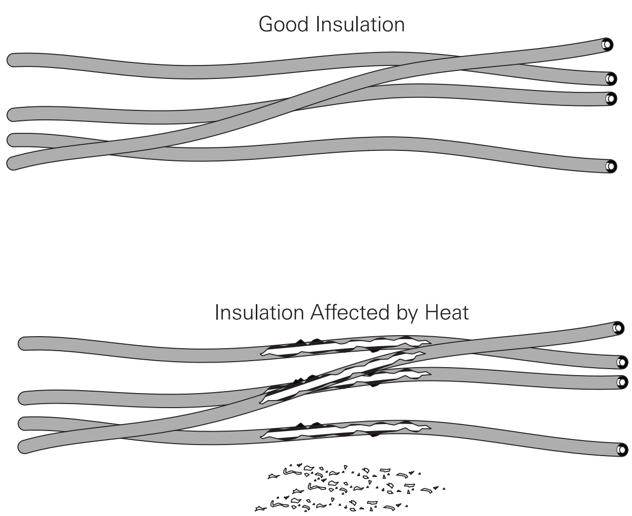
Overloads

An overload occurs when too many devices are operated on a single circuit, or a piece of electrical equipment is made to work harder than it is rated design. For example, a motor rated for 10 amperes may draw 20, 30, or more amperes in an overload condition. In the following illustration, a package has become jammed on a conveyor, causing the motor to work harder and draw more current. Because the motor is drawing more current, it heats up. Damage will occur to the motor in a short time if the problem is not corrected or if the circuit not is shut down by the overcurrent protector.



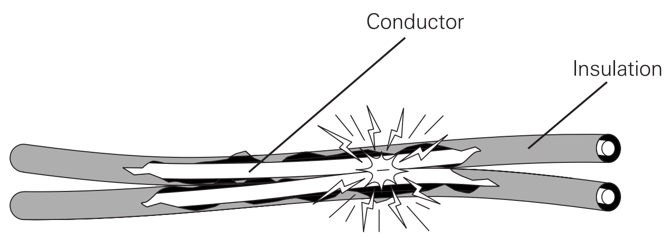
Conductor Insulation

Motors, of course, are not the only devices that require circuit protection for an overload condition. Every circuit requires some form of protection against overcurrent. Heat is one of the major causes of insulation failure of any electrical component. High levels of heat to insulated wire can cause the insulation to breakdown, melt, or flake off, exposing conductors.



Short Circuits

When two bare conductors touch, a short circuit occurs. When a short circuit occurs, resistance drops to almost zero. Short circuit current can be thousands of times higher than normal operating current.



Ohm's Law demonstrates the relationship of current, voltage, and resistance. For example, a 240 volt motor with 24 Ω (ohms) of resistance would normally draw 10 amperes of current.

$$I = \frac{E}{R}$$

$$I = \frac{240}{24}$$

$$I = 10 \text{ amperes}$$

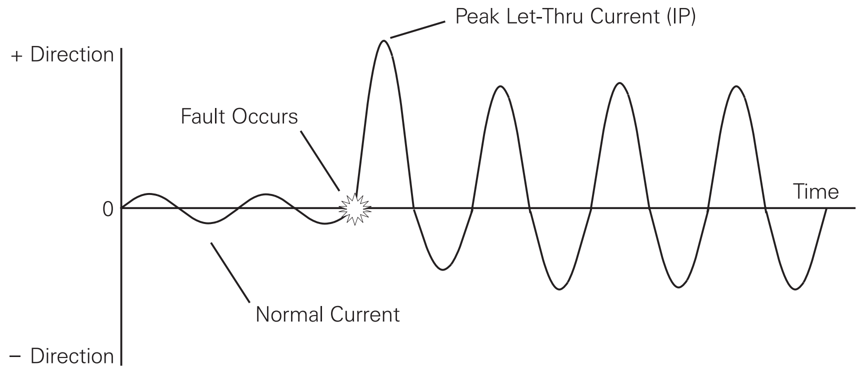
When a short circuit develops, resistance drops. If resistance drops to 24 milliohms, current will be 10,000 amperes.

$$I = \frac{240}{0.024}$$

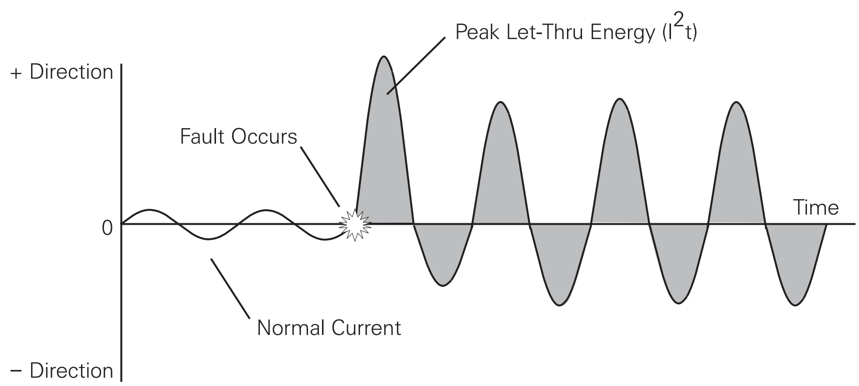
$$I = 10{,}000 \text{ amperes}$$

Short-Circuit Current on Unprotected Electrical Circuits

When a short circuit occurs, current will continue to flow in an unprotected electrical circuit. The peak short-circuit current of the first cycle is the greatest and is referred to as peak let-thru current (I_P). The force of this current can cause damage to wires, switches, and other electrical components of a circuit.

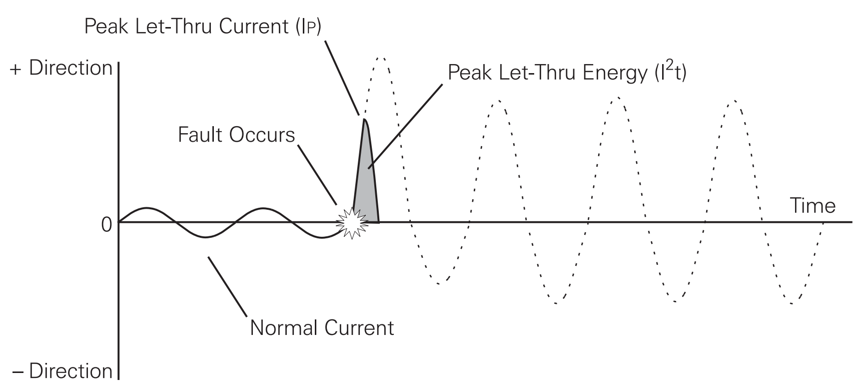


There is also energy let-thru (I^2t). This destructive thermal force is capable of melting conductors.



Short-Circuit Current on Protected Electrical Circuits

A properly used, overcurrent-protection device will open the circuit quickly, limiting peak let-thru current (I_P) and energy (I^2t).



Article 240

Circuit protection would be unnecessary if overloads and short circuits could be eliminated. Unfortunately, overloads and short circuits do occur.

Article 240 of the *NEC®* covers overcurrent protection. You are encouraged to become familiar with this material. Article 240.1 states that:

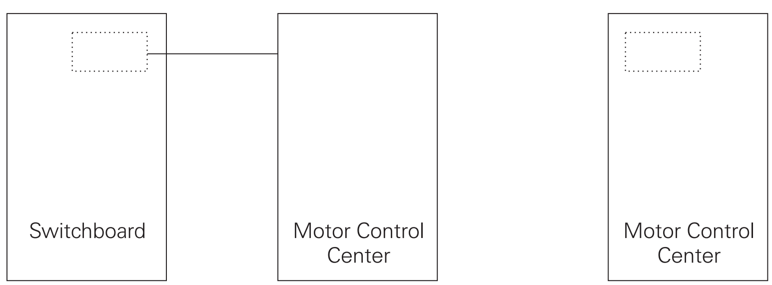
Overcurrent protection for conductors and equipment is provided to open the circuit if the current reaches a value that will cause an excessive or dangerous temperature in conductors or conductor insulation.

Article 430.94

The *National Electrical Code®* requires overcurrent protection for motor control centers. *NEC®* article 430.94 states:

Motor control centers shall be provided with overcurrent protection in accordance with Parts I, II, and IX of Article 240. The ampere rating or setting of the overcurrent protective device shall not exceed the rating of the common power bus. This protection shall be provided by (1) an overcurrent-protective device located ahead of the motor control center or (2) a main overcurrent-protective device located within the motor control center.

There are two ways Article 430.94 can be met. An overcurrent-protection device can be installed ahead of the motor control center. A switchboard, for example, located upstream of the motor control center may contain the overcurrent-protection device for the motor control center. The second way to meet this requirement is to install a main over-current protection device within the motor control center.



Overcurrent-Protection Device Ahead of MCC

Main Overcurrent-Protection Device Located in MCC

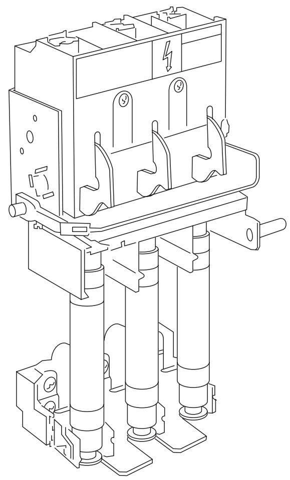
NEC® and *National Electrical Code®* are registered trademarks of the National Fire Protection Association. Reprinted with permission from NFPA 70-2002, the *National Electrical Code®*, Copyright© 2001, National Fire Protection Association, Quincy, MA 02269.

Overcurrent-Protection Devices

An overcurrent-protection device must be able to recognize the difference between an overcurrent and short circuit 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.

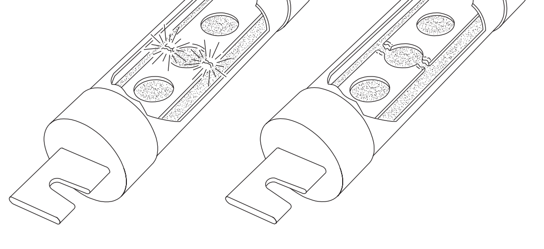
Fusible Disconnect Switch

A fusible disconnect switch is one type of device used 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

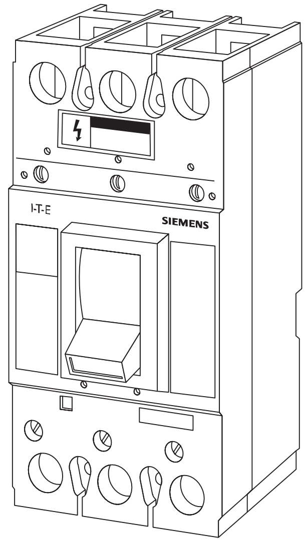
Fuses are grouped into classes based on their operating and construction characteristics. Each class has an ampere interrupting capacity (AIC) which is the amount of fault current they are capable of interrupting without destroying the fuse casing. Fuses are also rated according to the maximum continuous 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
R	250, 600	0-600	200,000	RK1 and RK5	UL 248 12
J	600	0-600	200,000		UL 248 B
L	600	601-6000	200,000		UL 248 10
CC	600	0-30	200,000		UL 248 4

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 de-energizing 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. Since it merely needs to be reset there is nothing to replace after a short circuit.



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 not exceed the conductor ampere rating. For example, if the conductor is rated for 20 amps, the circuit breaker rating should not exceed 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.

NEC® and *National Electrical Code®* are registered trademarks of the National Fire Protection Association. Reprinted with permission from NFPA 70-2002, the *National Electrical Code®*, Copyright© 2001, National Fire Protection Association, Quincy, MA 02269.

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 supply voltage. The voltage rating of a circuit breaker can be higher than the supply 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 not 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.

Review 2

1. ____________ ____________ is a private company that is nationally recognized as an independent testing laboratory.

2. The ____________ ____________ ____________ ____________ publishes the *National Electrical Code®*

3. Class R fuses have an interupting rating of ____________ amps.

4. Installing an overcurrent protective device ahead of an MCC or installing a main overcurrent protective device within an MCC are two methods of meeting *NEC®* Article ____________ .

NEMA Definition

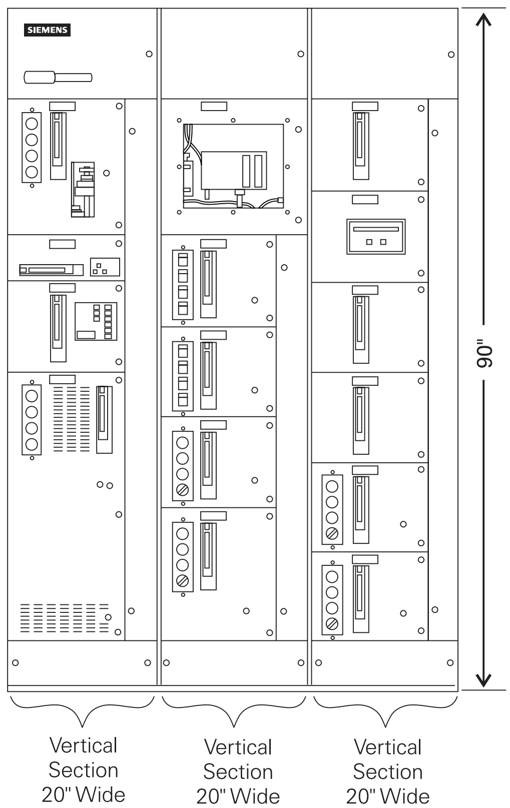
NEMA defines a motor control center in ICS-2-322 as being *a floor-mounted assembly of one or more enclosed vertical sections having a horizontal common power bus and principally containing combination motor control units. These units are mounted one above the other in the vertical sections. The sections may incorporate vertical buses connected to the common power bus, thus extending the common power supply to the individual units. Units may also connect directly to the common power bus by suitable wiring.*

According to the NEMA definition, motor control centers:

- Are floor-mounted assemblies
- Have one or more enclosed vertical sections
- Have a common horizontal power bus
- May incorporate vertical buses connected to the common bus
- Principally contain combination motor control units

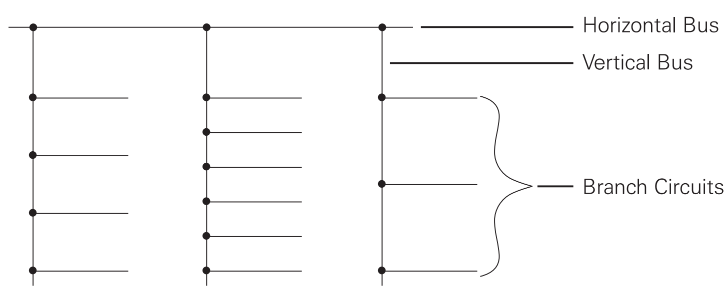
Vertical Sections

The motor control center is made up of a steel structure to contain the combination motor control units, wireways, internal wiring, and bus bars. From the NEMA definition it can be seen that a motor control center is a floor-mounted assembly made up of enclosed vertical sections. One vertical section may stand alone as a complete motor control center, or several sections may be bolted and bussed together. Vertical sections are generally 20” wide by 90” high.

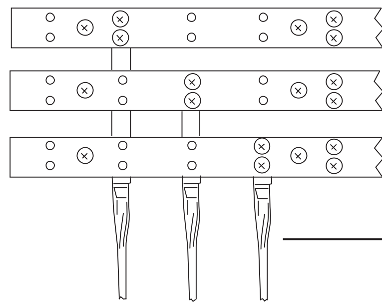


Horizontal and Vertical Bus

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.



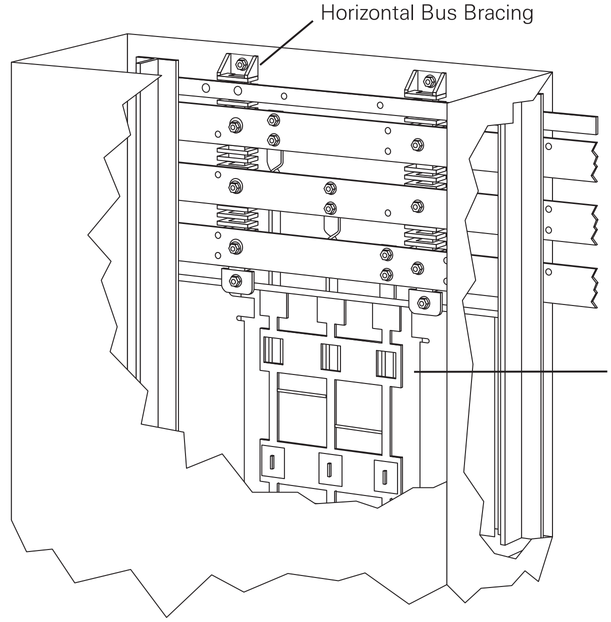
In power circuits, such as motor control centers, a bus is made of a heavy-duty metal bar. These bars provide power to each of the combination motor control units. The vertical bus is connected to a corresponding horizontal bus and is isolated from the other bus bars.



Bus Support

The *NEC®* discusses bus bars used in motor control centers in Article 430.97(A), which states that *busbars shall be protected from physical damage and be held firmly in place*.

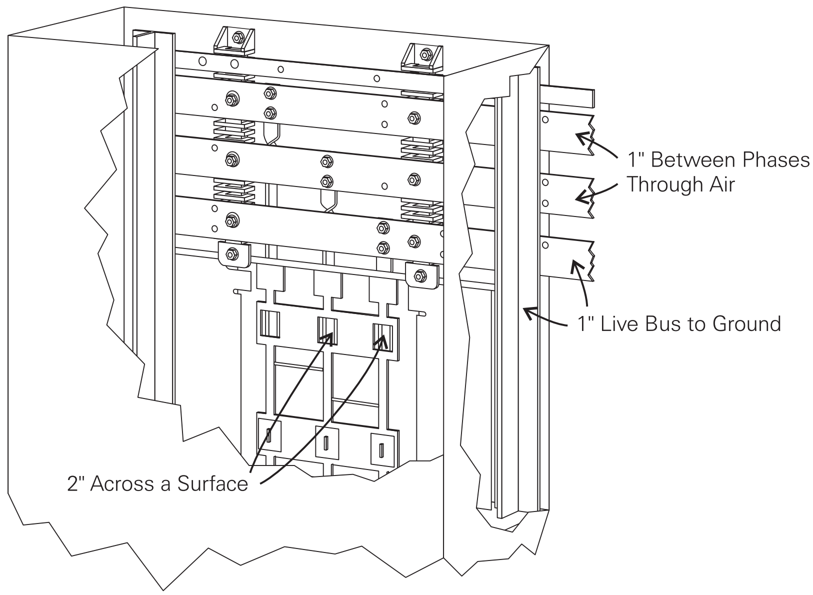
Bus bracing is very important due to the increased available fault current in today's modern power systems. In this example of a Siemens motor control center the horizontal bus is firmly bolted to molded supports. The vertical bus is either encased in a molded support or supported by bus brackets, depending on which MCC is supplied.



NEC® and *National Electrical Code®* are registered trademarks of the National Fire Protection Association. Reprinted with permission from NFPA 70-2002, the *National Electrical Code®*, Copyright© 2001, National Fire Protection Association, Quincy, MA 02269.

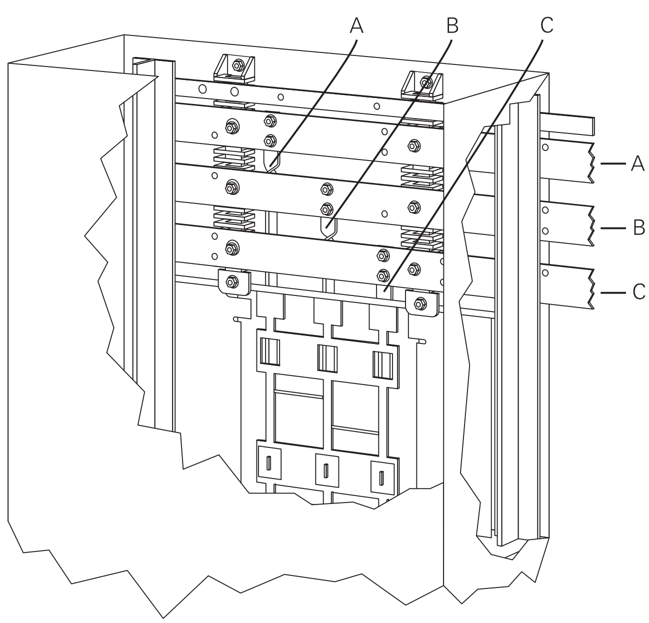
Bus Spacing

In addition, *NEC®* Table 430.97 requires 1" of clearance between a live bus and ground, 1" of clearance between phases through air, and 2" of clearance across a surface for voltages over 250 volts. These spacings are used throughout the horizontal and vertical bus in the MCC.

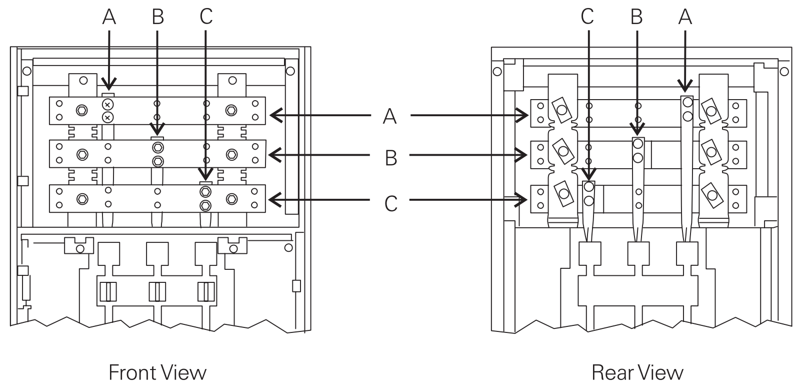


NEMA Phase Arrangement

NEMA requires bus bars to have phases in sequence so that an installer can have the same fixed phase arrangement at each termination point in any motor control center. The following diagram illustrates accepted NEMA phase arrangements. It is possible to have a non-NEMA phase sequence; however, this would have to be clearly marked.

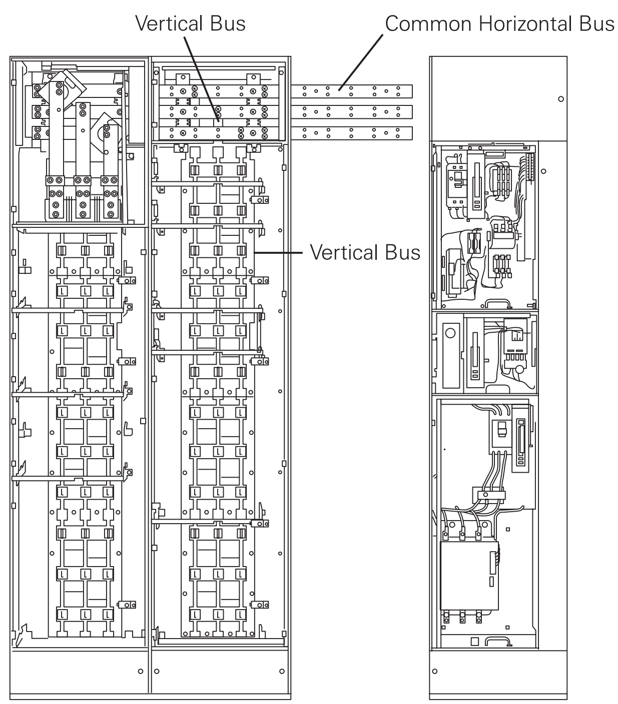


It should be noted that the NEMA phase arrangement illustrated in the previous drawing is viewed from the front. The vertical bus bars appear to be in reverse order when viewed from the rear. Some motor control centers can have devices installed on the front and rear of the motor control center.

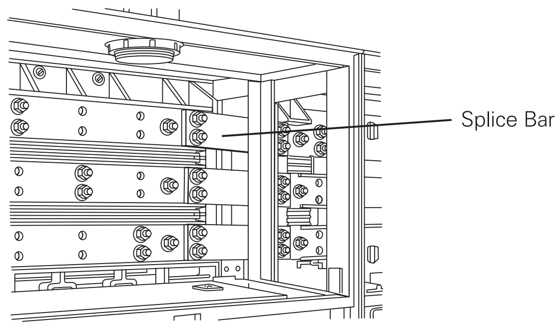


Shipping Splits

When a motor control center is made up of more than one vertical section, the sections are assembled together with a common top- and bottom-frame assembly. For shipping, this assembly can consist of a maximum of four 20” wide vertical sections (80” maximum). Several assemblies can be bolted and bussed together at the installation site to form a complete lineup. In the following illustration one vertical section has been moved to show the horizontal bus. In this case each horizontal bus bar is a single continuous piece that extends through all three sections.



When there are more than four sections or the customer specifies a split between two vertical sections a splice kit between the horizontal bus bars can be installed.



Combination Motor Control Units

Motor control centers are distinguished from other distribution devices, such as panelboards and switchboards, in that motor control centers principally contain combination motor control units. Panelboards and switchboards principally contain branch circuit-protection devices such as circuit breakers and fusible disconnects.

Underwriter's Laboratory

UL defines a motor control center similarly to NEMA. UL will allow use of branch circuit-protection units in a motor control center provided their use does not make up a major portion of the motor control center. In addition, UL 845 allows the use of associated auxiliary devices and panelboards to be part of a motor control center. Often, lighting transformers, panelboards, and load centers are incorporated in motor control centers.