Application Guide

January 20, 2020

Metal-enclosed switchgear brings simplicity, reliability, flexibility, and economy to circuit switching and fault-protection functions on medium-voltage power circuits.

Metal-enclosed switchgear, consisting of interrupter switches and power fuses, control and sensing devices, instrumentation and metering devices— all housed within rugged integral enclosures—permits tailoring of reliable, economical switching and protection packages matched to virtually any in-plant power distribution system need. Interrupter switches are specially designed to handle all load-switching duties, including full-load, transformer-magnetizing, and cable-charging currents, plus fault-closing duties. And, interrupter switches can be furnished for manual, automatic, or remote operation, extending their use over the full range of operating modes.

Power fuses provide precisely coordinated protection over the full spectrum of fault currents. A broad range of power fuses is available, permitting close fusing to achieve maximum protection and optimum coordination.

The combination of interrupter switches for switching and power fuses for protection eliminates the need for expensive circuit-breaker switchgear (metal-clad switchgear), particularly on cable-distribution systems where the rare and permanent nature of the faults makes the **Automatic Reclosing** feature of circuit breakers an unnecessary extravagance. Unlike circuit-breaker switchgear, metal-enclosed switchgear requires minimal maintenance. The interrupter switches never need adjusting, setting, or dielectric testing. Only an occasional inspection, exercising and lubrication is required. And power fuses, unlike relays, never need setting, testing, or maintenance.

In addition, metal-enclosed switchgear can be equipped to selectively protect both single-phase and three-phase loads, as opposed to circuit-breaker switchgear, which operates only on a three-phase basis. Also, in comparison to circuit-breaker switchgear, metal-enclosed switchgear is more economical, permitting protection for each load transformer, increased load segmentation to limit the extent of any power-service outage instead of protecting multiple transformers with one circuit breaker.

Metal-enclosed switchgear requires no foundation or support channels for installation; only a level pad is required. Light by comparison to circuit-breaker switchgear, metal-enclosed switchgear installs anywhere, even on balconies and rooftops. And, in outdoor installations, there is no need for additional housing or a walk-in shelter typically required with metal-clad switchgear. Metal-enclosed switchgear can be placed against a wall or back-to-back to minimize floor-space requirements.

A variety of power distribution systems are in use today, ranging from the simplest to the most complex. In designing these systems, planners generally use the four basic circuit arrangements described in this publication. Each circuit arrangement offers a level of service continuity, so the system can be matched to the criticality of the load served. In fact, the four fundamental circuit arrangements can be used in unlimited combinations to distribute power to all loads at a facility.

The extensive selection of switching and protection equipment available in metal-enclosed switchgear permits users to implement these systems easily, reliably, and economically. This publication illustrates how the four basic circuit arrangements are implemented with metal-enclosed switchgear and diagrams a few of the virtually limitless power-distribution-system designs possible. With metal-enclosed switchgear, users will be able to take advantage of its many benefits to solve their power-distribution problems and to achieve the desired reliability, flexibility, and economy.

In selecting metal-enclosed switchgear for medium-voltage power distribution systems, it is important to select components with ratings and capabilities equal to the duty and to examine the enclosure construction to make certain it matches the environmental and security requirements at the installation site. It is particularly critical to recognize the importance of metal-enclosed switchgear in maintaining continuity of power service to any facility. S&C metal-enclosed switchgear is unsurpassed in the quality and durability of its enclosure and components, reflecting more than 70 years of design and experience in this field.

To solve your power distribution problems, implement the four fundamental circuit arrangements: radial, looped-primary, common-bus primary-selective, and split-bus primary-selective with metal-enclosed switchgear.

The Radial System

This is the most widely used circuit arrangement in industrial, commercial, institutional, and high-rise installations. It is a simple system, and it is an economical one. And the simple and direct circuitry of the radial system facilitates quick location and repair of faulted circuits.

Figure 1 illustrates an extremely simple radial system. Diagrammed is a two-bay lineup of metal-enclosed switchgear, commonly identified as a service entrance, that serves the primary of a single transformer supplying a relatively small load. The transformer is switched and protected by the interrupter switch with power fuses.

A more extensive system involving multiple radial circuits serving segmented blocks of load—each switched and protected by interrupter switches with electronic power fuses or other power fuses—is illustrated in Figure 2 on page 4. Here, the service-entrance switching center uses an interrupter switch to connect the utility source to the bus serving three bays that feed radial circuits. These radial circuits demonstrate a variety of metal-enclosed switchgear that can be used to serve the loads. The utility source typically has protection at the riser pole which responds to a fault on the utility cable. This also protects for a fault on the main bus. In this case, the service entrance switching center typically does not require a main fuse. Main fuses can be provided as shown in Figure 6 on page 8 when required by the utility or when the utility cable loops to other switchgear.

Use of multi-radial circuits segmented in this way permits individual protection for each transformer. The power fuse protecting a given transformer will clear and isolate any faults associated with the transformer, allowing continuous service to the remaining loads on the system. The low cost of metal-enclosed switchgear when compared to circuit-breaker switchgear (metal-clad switchgear) is the key to the design of a system with a high degree of segmentation. The economics of circuit-breaker switchgear would normally dictate the use of fewer points of segmentation, resulting in more loads becoming affected by an outage caused by faults associated with any transformer or cable.

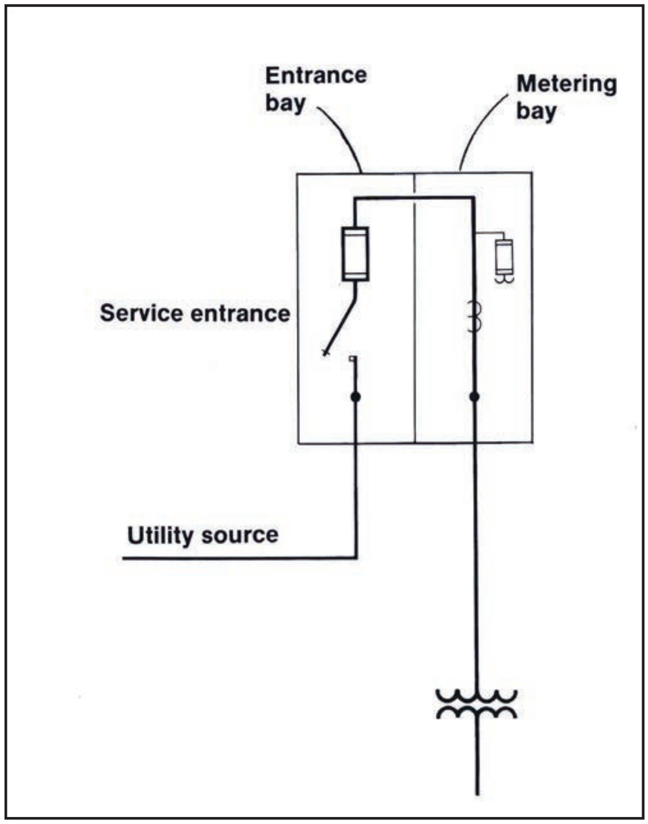

Figure 1. Metal-enclosed switchgear applied as a service entrance on a simple radial system.

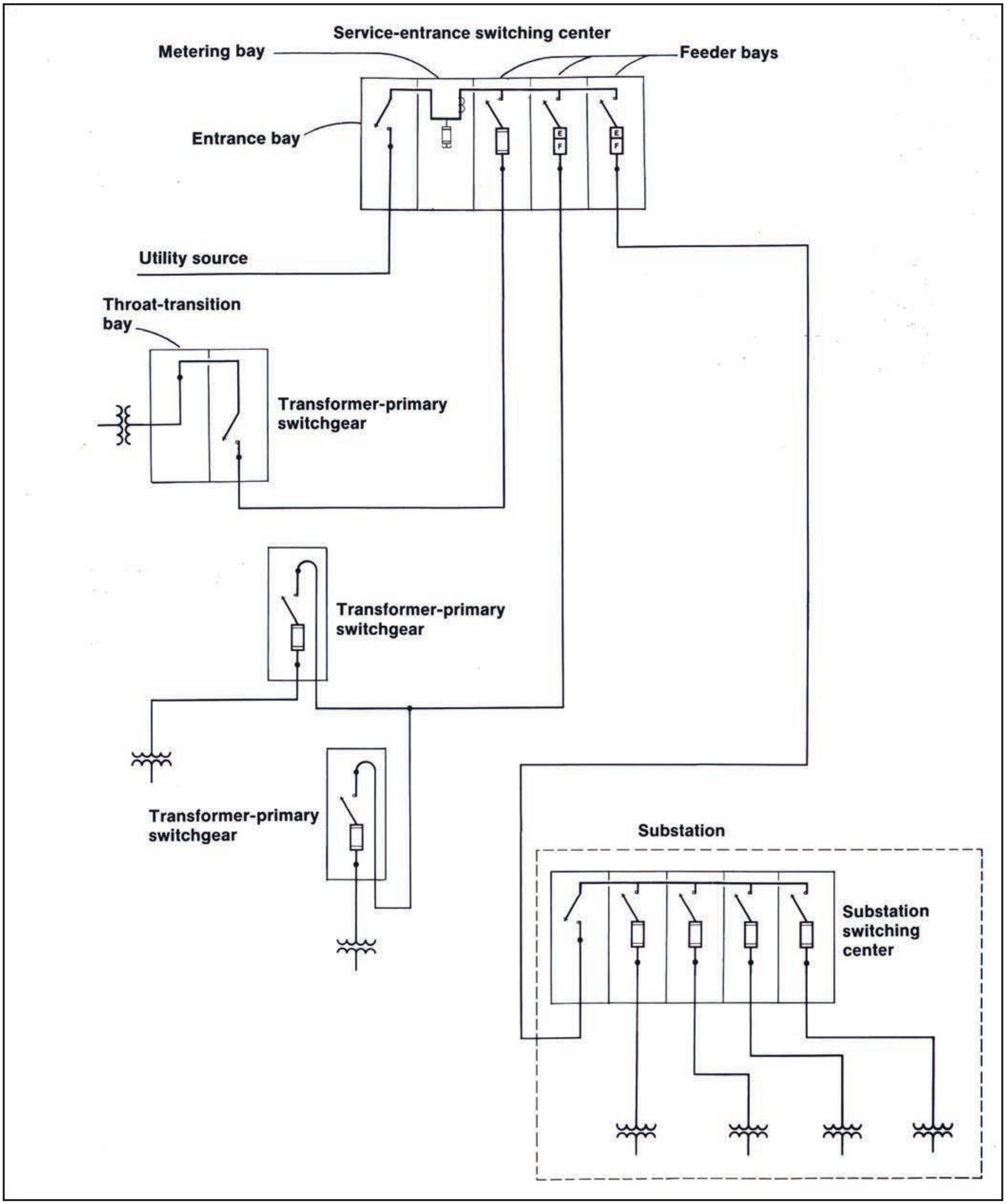

Figure 2. Multiple radial circuits are best switched and protected with metal-enclosed switchgear.

The Looped-Primary System

This system is more suitable than the multi-radial system for installations that have widely dispersed loads and require a higher level of power availability. It does not reduce the frequency of interruptions compared to a radial system, but it does permit quick restoration of service to the loads on the looped-primary feeder cable following a fault on the cable. See Figure 3. Typically, both ends of the looped primary circuit are connected to a single utility source, and provisions are made for sectionalizing the loop so power can be supplied to each load from either end of the circuit. (A loop could be made by connecting each end to a separate utility source. The application of such a loop is like that of a primary-selective system, as described on page 8.)

Figure 3 shows a small, simple loop made completely with metal-enclosed switchgear. The four-bay service entrance switching center consists of an entrance bay, a utility metering bay, and two feeder bays. Each of the feeder bays provides switching and, using electronic power fuses, protection for its associated end of the looped-primary feeder cable. The loop is sectionalized with interrupter switches located in the entrance bays at each end of the multi-bay metal-enclosed switchgear lineups, which are applied as switching centers within the loop.

Interrupter switches with power fuses in the feeder bays of these switching centers provide switching and protection for cable-connected loads, one of which is a medium-voltage motor. Under normal operating conditions, one interrupter switch near the center of the loop is open, as indicated in Figure 3. Should a fault occur on a section of the looped primary feeder cable, the electronic power fuse in the service-entrance switching-center feeder bay serving that section of the loop operates to clear the fault. Selective manual switching operations can then be performed to isolate the faulted section of cable and permit restoration of medium-voltage power to all loads.

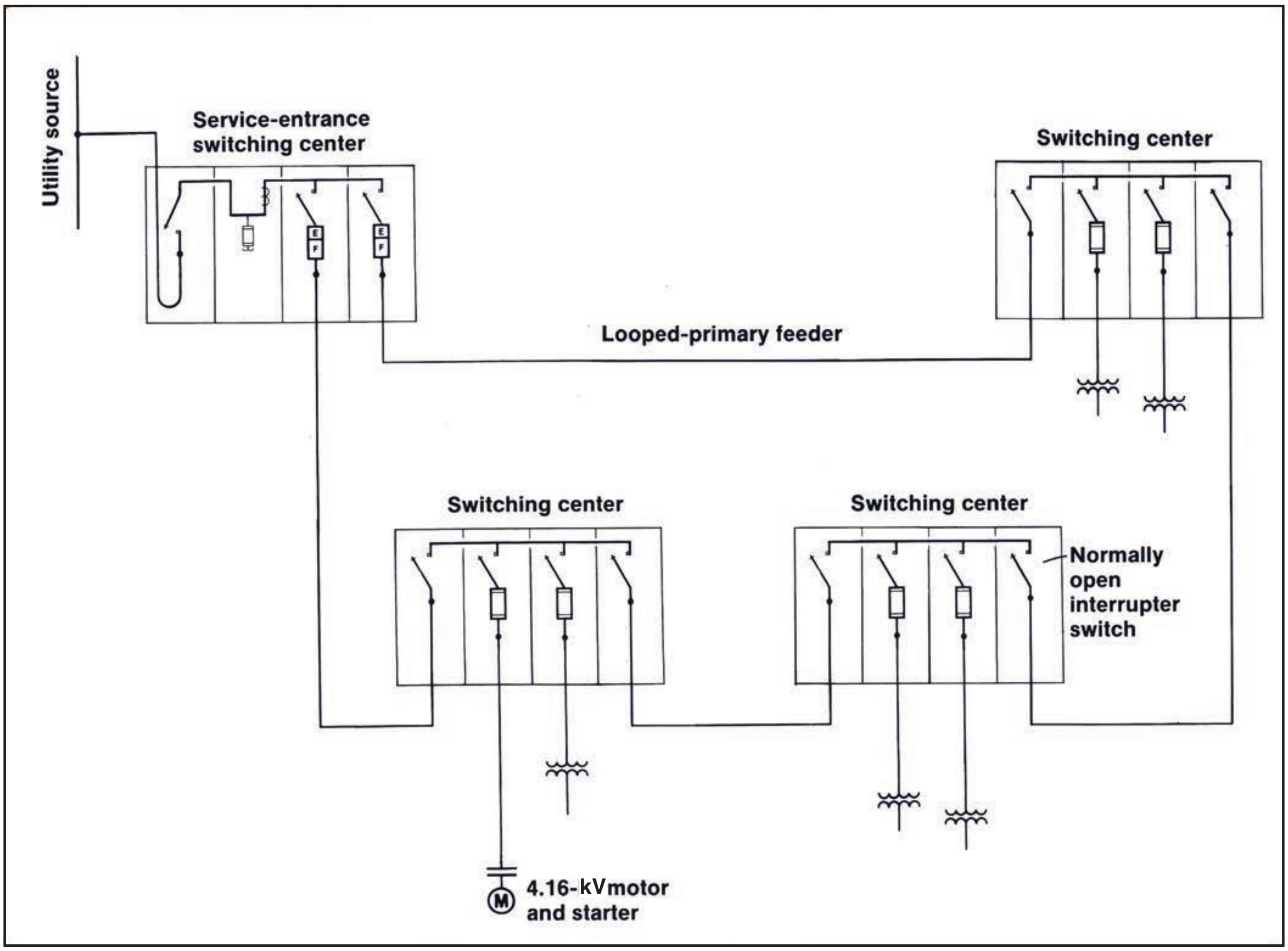

Figure 3. A simple looped-primary system implemented totally with metal-enclosed switchgear using interrupter switches and power fuses, including electronic power fuses.

In installations where load currents are high, the looped-primary system may be implemented as shown in Figure 5 on page 7. In the system depicted, the loop continuous currents exceed those that can be carried by fuses, so circuit-breaker switchgear, which has higher continuous current ratings, is used for switching and protection at the ends of the loop.

Metal-enclosed switchgear is used for all the switching centers within the loop. Interrupter switches, rated up to 1200 amperes continuous and interrupting, permit sectionalizing of the loop, and interrupter switches with power fuses, including electronic power fuses, provide for switching and protection of the loads. Although circuit breakers and complex relaying could have been used throughout the loop to expedite the restoration of service to all loads following a cable fault, the high cost would not normally be justifiable, considering the infrequency of cable faults and the relative ease of restoring service with metal-enclosed switchgear.

In addition, the use of power fuses (with their inherent fast response characteristics) instead of circuit breakers for protecting the loads permits more rapid interruption and isolation of faults on the lateral cables and transformers feeding the loads. This, in turn, allows faster relay settings to be used for the loop terminal breakers—a big advantage in that the resulting coordination greatly reduces cable fault interrupting times, minimizing short-circuit stresses on the system.

Figure 4. Metal-Enclosed Switchgear providing switching and protection to a wastewater treatment facility.

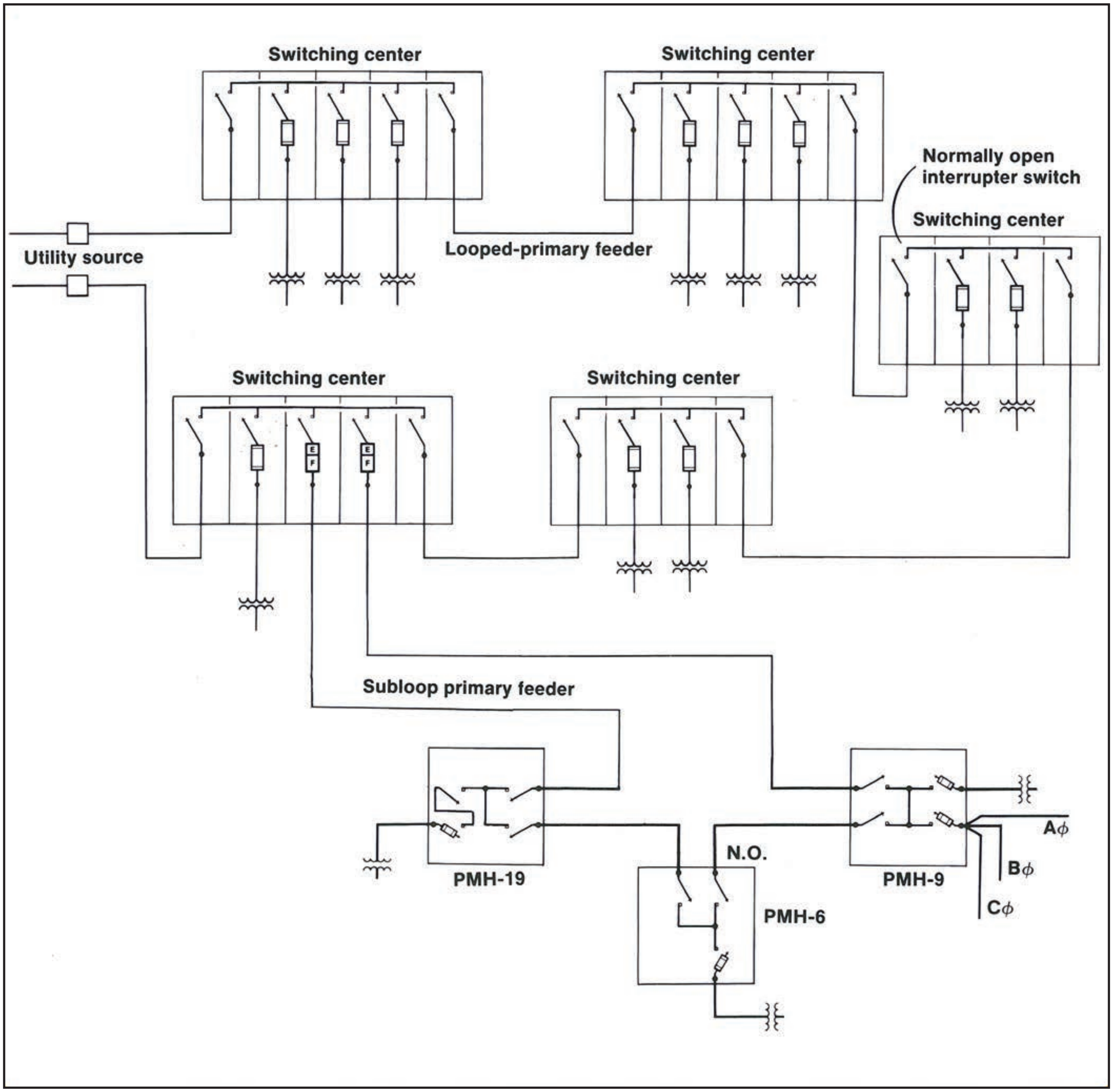

Figure 5. The ends of this looped-primary system are connected to the utility source with circuit-breaker switchgear. Metal-enclosed switchgear provides for switching and protection within the loop. A subloop is shown implemented with pad-mounted switchgear.

The Primary-Selective System

This system, unlike the two systems previously described, provides a high degree of service continuity for critical loads by minimizing interruptions resulting from utility source failure. The utility source, because of its extensive exposure to such phenomena as lightning, wind, and ice, and to equipment failure, is the most vulnerable link in the power-supply chain. As such, system planners with critical loads to serve should first provide a primary-selective system to ensure continuity of the medium-voltage supply from the utility before considering other systems that minimize interruptions caused by in-plant transformer or transformer-secondary equipment failures. The primary selective system may be implemented as either a common bus or a split-bus scheme, with manual, automatic, or remote-controlled switching.

Common-Bus Primary-Selective System

This system, shown in Figure 6, is a six-bay service entrance switching center with provisions for utility metering. A source-transfer control and switch-operator driven interrupter switches with electronic power fuses provide automatic two-way source transfer with the ability to connect either of the two utility sources to the switchgear's common bus. The electronic power fuses in the entrance bays provide protection for the switchgear's main bus and coordinate with feeder fuses. As described previously, segmenting the load into small blocks supplied by multiple radial circuits, or serving the load with looped primary circuits, will augment the service continuity and operating flexibility provided by the common-bus primary selective system.

Under normal operating conditions in switchgear with automatic two-way source transfer, one switch (for the preferred source) is closed; the other switch (for the alternate source) is open with its associated circuit available as standby. The source-transfer control monitors the condition of both power sources and initiates automatic switching when preferred-source voltage has been lost (or reduced to a predetermined level) for a period sufficient to confirm the loss is not a transient condition. The switch associated with the preferred source is automatically opened and the alternate-source switch is then automatically closed, restoring power to the load.

Two-way source transfer provides for either automatic retransfer to the preferred source when normal voltage returns for a preset time (**Automatic Return** mode) or manual retransfer to the preferred source at a convenient time (**Hold Return** mode). In the **Hold Return** mode, if the alternate source fails and if the preferred source has been restored, the switchgear will automatically retransfer to the preferred source.

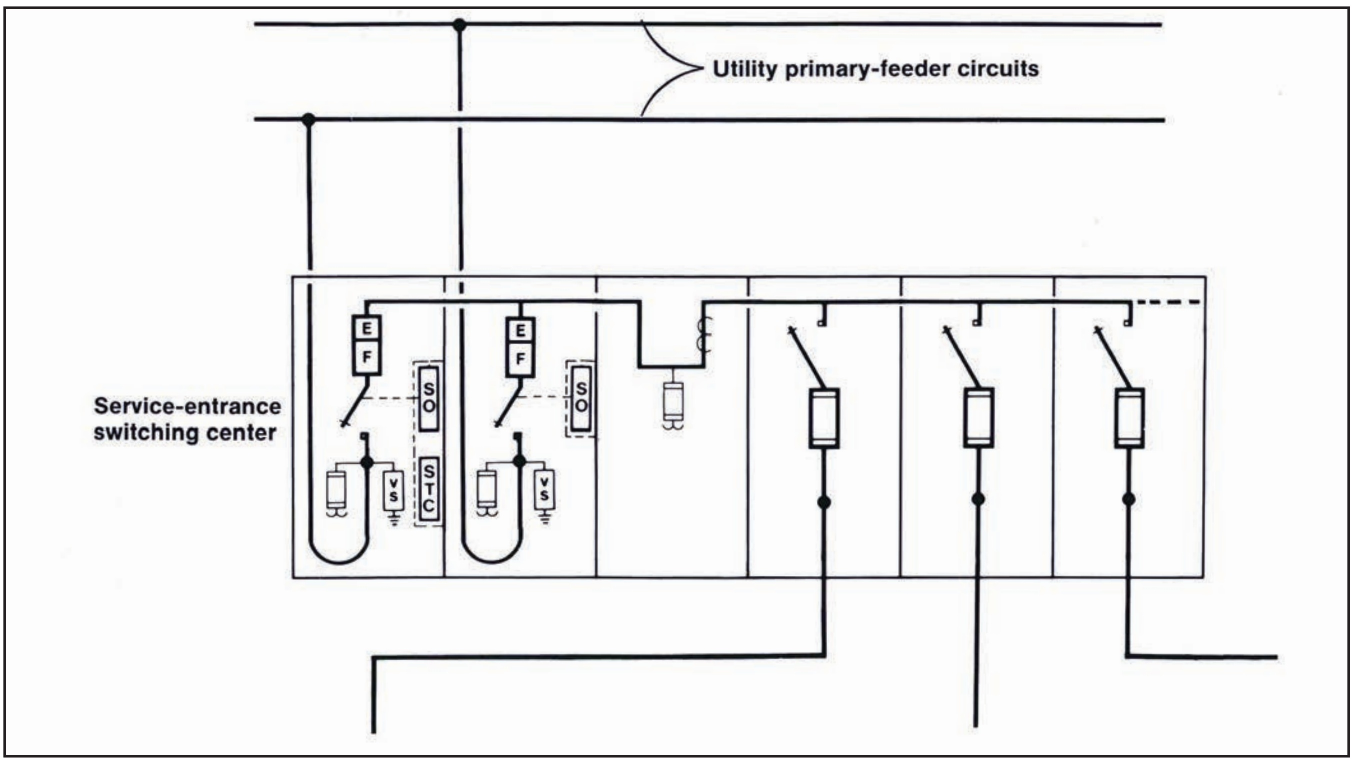

Figure 6. Metal-enclosed switchgear is available with switch operators and source-transfer controls to effect two-way source transfer in common-bus primary-selective switchgear lineups such as diagrammed above. Either of the two sources may be the preferred source. The other source then serves as the alternate source. Manually operated interrupter switches with power fuses switch and protect the load feeders.

In the **Automatic Return** mode, two-way source transfer provides for selection of either **Open Transition** or **Closed Transition** operations for retransfer to the preferred source. In the **Open Transition** operation—which prevents paralleling the power sources—the alternate source switch opens before closing the preferred-source switch; there is only a momentary interruption of service to the load. With the **Closed Transition** retransfer operation—selected when it is permissible to parallel the two sources so no interruption of service to the load occurs—the alternate-source switch opens after the preferred source switch has closed.

Common-Bus Primary-Selective With A Standby Generator

The common-bus primary-selective system can be applied to provide automatic source transfer between a utility source and a standby generator. The generator does not parallel with the utility. This approach may be taken to simplify the installation or minimize costs when a short service interruption is allowable.

The generator output breaker in Figure 7 should be a power-operated breaker. The power-operated breaker has a motor operator to charge the operating mechanism. The breaker will close when the generator is ready to accept load and open when it is not carrying load or to clear a cable fault. Generator controls should be located in the generator.

Under normal operating conditions in switchgear with automatic two-way source transfer, one switch (for the utility source) is closed; the other switch (for the standby generator) is open and the generator is not running. The source-transfer control monitors the condition of the utility power source and closes a dry contact to signal the generator control as soon as utility source voltage has been lost or reduced to a predetermined level. The generator control provides a time delay for a period of time sufficient to confirm the loss is not a transient condition. If the utility source has not returned before the end of that period, the generator control starts the generator. When the standby generator is available to accept load, the transfer control initiates automatic switching. The switch associated with the utility is automatically opened and the alternate-source switch is then automatically closed, restoring power to the load.

Two-way source transfer provides for either automatic retransfer to the preferred source when normal voltage returns for a preset time (**Automatic Return** mode). The transfer control should be programmed for open transition (break before make) so the generator will not be paralleled with the utility because the generator does not sync with the utility. Enable the Transition Dwell Timer to protect motors from being connected to another source that may not be in sync. Set this timer so the bus is de-energized long enough to cause motors to drop off line. This time is often called dead bus time and is the time between opening one switch and closing the other switch. Dry contacts signal the generator control that the load has been transferred back to the utility. The generator control can then begin the cool-down cycle.

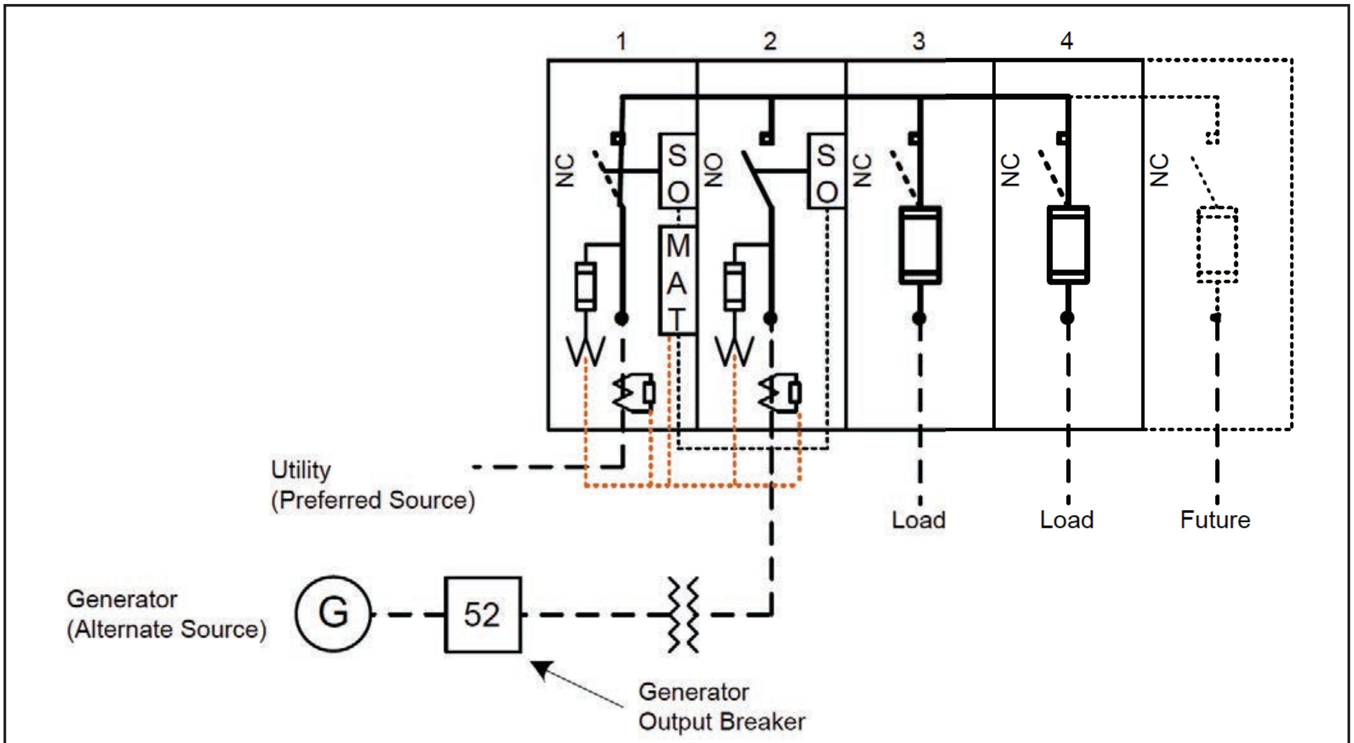

Figure 7. Metal-enclosed switchgear for automatic source transfer from a utility source to a standby generator.

The standby system may consist of multiple generators with paralleling switchgear at low-voltage as shown in Figure 8.

The tie breaker in Figure 7 on page 9 should be a power-operated breaker. The power-operated breaker has a motor operator to charge the operating mechanism. The breaker will close when the generator is ready to accept load and open when it is not carrying load or to clear a cable fault. Generator controls should be located in the paralleling switchgear.

Split-Bus Primary-Selective System

In the basic split-bus primary-selective system, the switchgear bus is divided into two sections by a bus-tie switch, as illustrated in Figure 9 on page 11. The diagram depicts a nine-bay metal-enclosed switchgear lineup, with automatic operation of the two source-interrupter switches and the bus-tie switch provided by switch operators and a source transfer control. Again, segmenting the load with multiple radial circuits or serving it with looped-primary circuits complements service continuity and operating flexibility.

In the switchgear lineup diagrammed in Figure 9 on page 11, each section of the split bus serves two feeder bays that provide switching and protection for the loads. A secondary selective system (described on page 11) provides an added measure of service continuity to the especially critical loads connected to the two transformers.

Switchgear of this configuration normally operates with the two source-interrupter switches closed and the bus-tie switch open so each bus section receives power from its associated, separate source. Typically, each source cable is sized for normal operating conditions—and is loaded to rated capacity—because under emergency conditions most installations have some loads that can be shed, making it unnecessary for either source to carry the switchgear's total load over an extended period. The switchgear provides the same high degree of service continuity as the common-bus primary-selective switchgear described on page 8. Moreover, by simultaneously using both sources, it can supply larger concentrated loads, thereby often obviating the need for multiple switching centers.

In addition, the serving utility benefits from a more evenly loaded system that precludes the need for idle substation and feeder capacity. That, in turn, reduces the likelihood of intolerable system disturbances occurring when a source transfer involving the entire load occurs.

Each source, in effect, is the preferred source for its section of the bus and the alternate source for the other section of the bus. Upon loss of voltage from one source, the interrupter switch associated with that source opens and the bus-tie switch closes so all the load is served from the remaining source. Retransfer to the normal circuit configuration—bus-tie switch open and both source interrupter switches closed—may be performed on restoration of normal voltage with the same selection of programming modes as described for the common-bus primary-selective system.

Even greater operating flexibility—and an unusually high degree of service continuity—may be achieved by sectionalizing the switchgear bus into more than two sections with multiple bus-tie switches and using additional sources of power (each source supplying one of the bus sections). Extension of the split-bus primary-selective system in this way permits the design of very sophisticated primary-selective switching schemes.

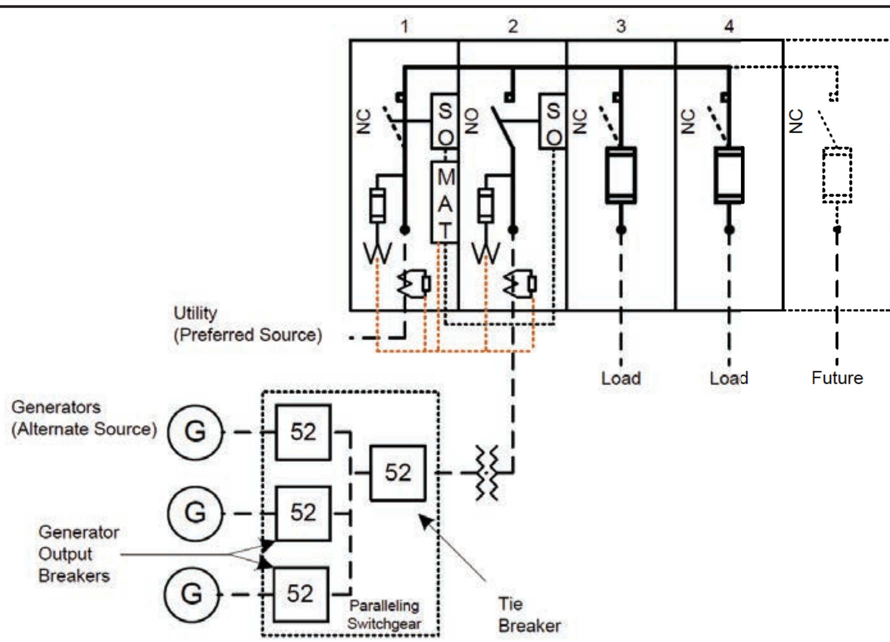

Figure 8. Metal-enclosed switchgear for automatic source transfer from a utility source to a bank of standby generators with paralleling switchgear.

Other Considerations for Primary-Selective Systems

Unbalance Detection

This feature, which may be incorporated into source transfer controls to protect three-phase loads from voltage unbalance, initiates automatic transfer in response to any source-side open-phase condition at the same system voltage as the metal-enclosed switchgear—whether caused by utility-line burn-down, broken conductors, single-pole switching, equipment malfunctions, or single-phasing resulting from blown source-side fuses. Such a feature, to be effective, must detect the open-phase condition, even if backfeed results in normal-magnitude voltage appearing on the opened phases. One method that has proved successful develops and monitors the phasor sum of the line-to-ground voltages of each source and can, therefore, detect three-phase voltage unbalance, which exists under virtually all open-phase conditions.

Overcurrent Lockout

This feature may be included in source-transfer controls to prevent a transfer operation that would close a source switch or bus-tie switch into a fault, thereby avoiding utility system disturbances. To implement this scheme, three-phase current sensing is required in the metal-enclosed switchgear. When this sensing scheme detects an overcurrent caused by a fault that is cleared by the source-side protective device, the prolonged loss of voltage causes the associated source interrupter switch to open.

At the same time, a **Lockout** mode is set up in the source transfer control so the alternate-source switch operator (a bus-tie switch operator in the case of two-way source transfer with a bus-tie switch) will not automatically close its switch into the fault. (When the overcurrent is caused by a fault cleared by feeder fuses, there is no prolonged loss of voltage, so the source-transfer control does not initiate any switching operations.)

Can other circuit arrangements improve further upon service continuity?

Primary-selective systems of the types just described generally can be designed to provide the desired degree of protection against source failure—the most common cause of service disruption in a medium-voltage power system. To further improve service continuity for extremely critical loads, consideration is sometimes also given to the addition of Secondary Selective systems or Secondary Network systems to provide protection against transformer failure.

The Secondary-Selective System

This system consists of circuits joined on the secondary sides of transformers by normally open tie breakers. A critical load divided into two parts and served by two transformers connected to the primary distribution system is illustrated in Figure 9. Should a transformer failure occur, the load served by that transformer is automatically transferred to the secondary of the other transformer. This system clearly requires considerable additional expense and is usually not justifiable unless the criticality of the load requires more reliability than can be achieved with the primary-selective system alone.

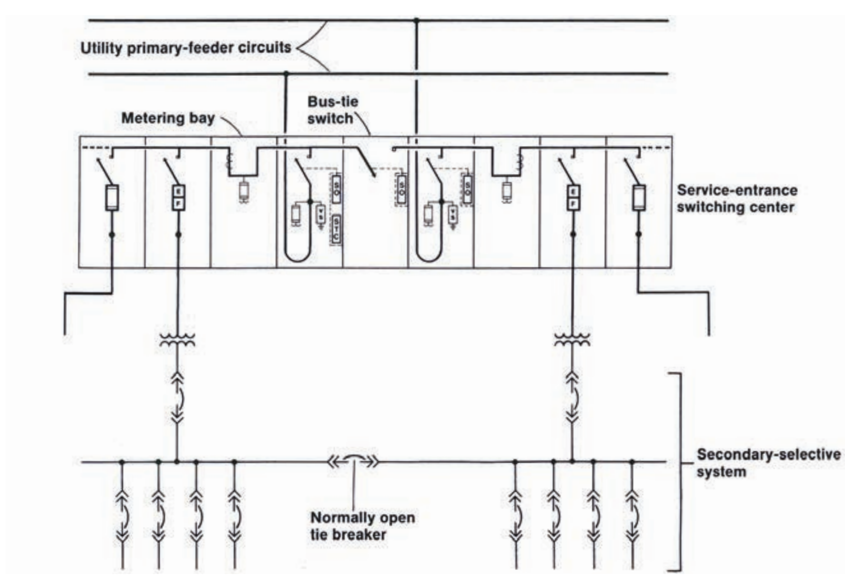

Figure 9. Split-bus primary-selective metal-enclosed switchgear, in addition to providing a high degree of service continuity, permits supplying large loads with one switching center through full utilization of both utility sources. Under normal operating conditions, each bus section receives power from its associated, separate source. The bus-tie switch and the two source interrupter switches are driven by switch operators that both open and close the switches, either automatically or manually, depending upon the operating mode selected. The source-transfer control monitors source voltages and switch operation, keeping power interruption to a minimum. Load feeders are switched and protected by manually operated interrupter switches with power fuses.

The Secondary-Network System

This system is sometimes used for concentrated critical loads. However, the very substantial added cost for network protectors and special oversized transformers makes this system economically prohibitive for most applications. Moreover, protection from faults in the network secondary bus depends on such faults burning clear and self-extinguishing, without de-energizing the system. Consideration must be given to the hazards if such faults do not burn clear—a problem that is eliminated with radial or primary-selective systems that have been properly fused.

The Resistance-Grounded System

This is a special type of system that can use any of the basic circuit arrangements and is often used on medium-voltage industrial power systems to reduce equipment damage caused by ground faults and from transient overvoltages caused by restriking ground faults. Shown in Figure 10 is a low-resistance-grounded system with the neutral grounding resistor—connected between the secondary neutral of the source-side transformer and ground—selected to limit single-phase-to-ground fault currents to less than 800 amperes. The resistor does not limit the fault current between phases, only fault current to ground.

High-speed automatic switching of resistance-limited ground faults is made possible on each feeder circuit of the switching center with interrupter switches power-operated by switch operators. On each feeder circuit, a window-type current transformer (CT) provides sensing for a latching-type ground-overcurrent relay, and a timer provides coordination with overcurrent-blocking relays. Sensing for these blocking relays is provided by other window-type CTs in the entrance bay. The combination of a ground-overcurrent relay with a timer and the blocking relays ensures the feeder switch operates only on single-phase-to-ground faults; the fuses clear all other faults before the interrupter switch opens.

In the system diagrammed in Figure 10, consider a phase-to-ground fault occurring at the point indicated. Such faults are sensed by the CT on the affected feeder circuit, and the associated overcurrent relay and timer are then actuated. The fault current is limited by the resistance and, when the timer times out, the switch is tripped open. Operating time with high-speed switches is typically 10 cycles—a 6-cycle delay for the timer plus a 4-cycle operating time for the switch. Blocking relays in the entrance bay are set so the magnitude of the current sensed by the associated CTs on single-phase-to-ground faults is not sufficient to actuate the blocking relays.

For multi-phase faults involving ground, the fault current is sensed by all the CTs and will exceed the setting of the blocking relays. The blocking contacts are actuated instantly, blocking control power to the timer. However, the relay associated with the CT on the faulted circuit is also actuated. After the fuse clears the fault, the blocking relays drop out. Then, because a latching relay is used in conjunction with the CT in the feeder bays, the timer is energized. After the timer times out, the switch is tripped open, isolating the faulted circuit.

Note: This application can be used when the neutral-grounding resister is connected to the transformer feeding the switchgear as shown in Figure 10. It can't be used when the neutral-grounding resister is connected to a downstream transformer.

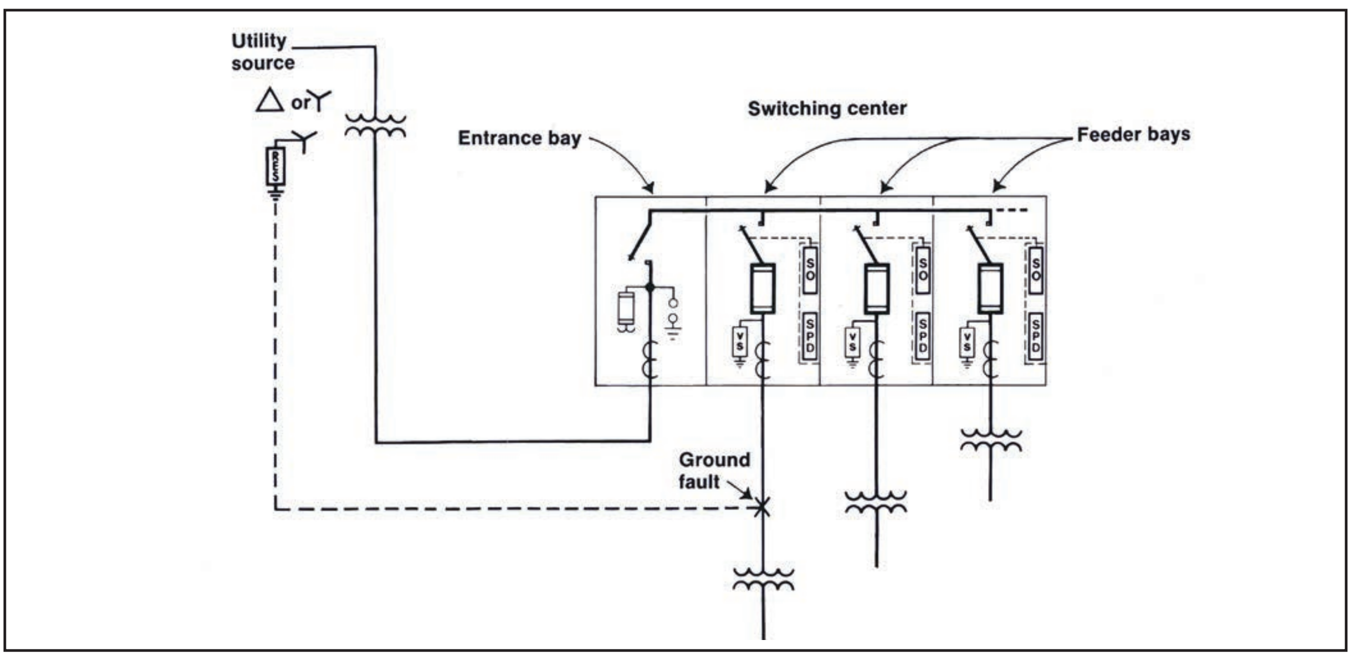

Figure 10. Resistance-grounded system has resistor connected between secondary neutral or source transformer and ground.

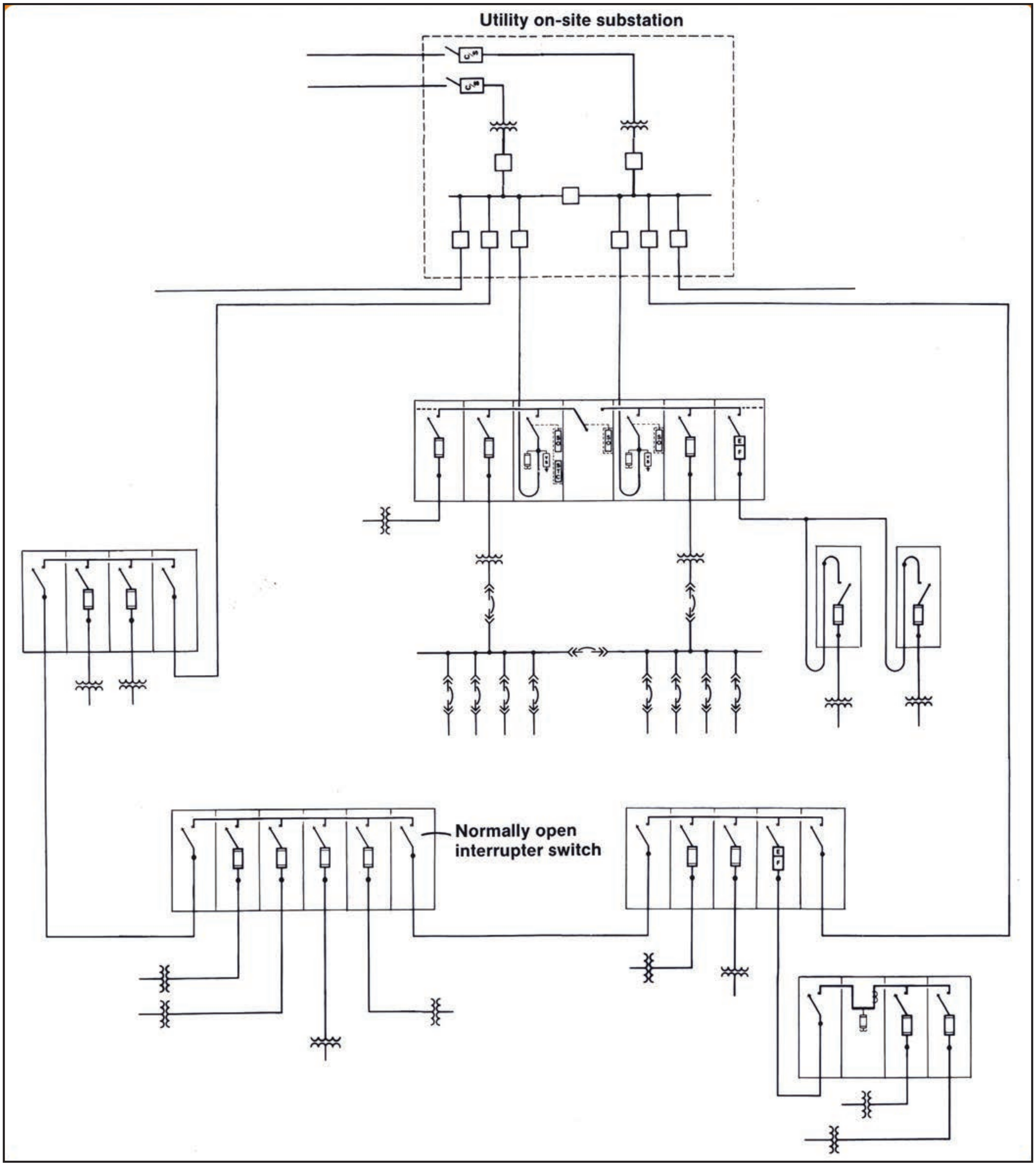

Figure 11. To serve widely dispersed loads in a large plant, the four fundamental circuit arrangements are often combined in a complex distribution system. Illustrated here is an in-plant medium-voltage power distribution system that uses a split-bus primary-selective circuit, a looped-primary circuit, and radial circuits. To ensure maximum service continuity for extremely critical loads, a secondary selective system has been added to two of the transformers served by the switching center of the split-bus primary-selective circuit.

Power fuses provide protection for your transformers and feeder cables... with load capabilities and fault ratings to suit almost any application.

Power fuses used in metal-enclosed switchgear should provide full-fault-spectrum protection for individual midsize to large power transformers and for feeder circuits serving multiple loads. S&C Power Fuses offer such protection and many other benefits as well. When protecting individual transformers with S&C Power Fuses, full-fault-spectrum protection means the fuse will detect and even interrupt all faults, regardless of whether:

- They are large, medium, or small (even down to minimum melting or tripping current)
- They are on the primary or secondary side
- They are with line-to-line or line-to-ground voltage across the fuse
- The transformer is adjacent to the switchgear or cable-connected to it from a remote location
- Transformer-winding connections are all the same type

S&C Power Fuses can handle the full range of transient recovery voltages associated with these conditions. Also, they allow fusing closer to the transformer full-load current than is possible with ordinary current-limiting fuses, providing the maximum degree of protection against secondary faults. S&C Power Fuses thus furnish protection against faults in the secondary buswork ahead of the secondary-side protective devices and, furthermore, supply backup protection in the event of incorrect functioning of the secondary-side protective devices, even in the lower ranges of the faults, where the current may be as low as 230% of the transformer full-load rating.

S&C's Fault Fiter® Electronic Power Fuses and SM Power Fuses have surge capacities more than adequate to withstand transformer magnetizing current inrush, as well as the combined transient inrush of magnetizing and load currents following a momentary interruption of source voltage—a performance characteristic not generally found in other makes of fuses.

When protecting feeders serving multiple loads, S&C Power Fuses provide source-side continuity should feeder cable faults occur. And they develop a positive internal gap of high dielectric strength after circuit interruption, thus precluding destructive re-ignitions when exposed to full system voltage—such as is experienced with current-limiting fuses after clearing under low recovery-voltage conditions. A wide selection of ampere ratings and speeds of S&C Power Fuses and a variety of types and TCC curve parameters of S&C Fault Fiter Electronic Power Fuses permit precise coordination with protective relays and other fuses in both the load-side and the source-side circuits. Comprehensive fuse-application data are available from the fusing specialist at the nearest S&C Sales Office.

To help in initial planning, Table 1 on page 16 shows the maximum short-circuit ratings of S&C Metal-Enclosed Switchgear (fuse-interrupting ratings equal or exceed these values) and the maximum three-phase loading (in kVA) that may be carried per fused feeder bay, between 2.4 and 34.5 kV. Two loading levels are given: one is the maximum continuous load in terms of total connected transformer kVA, and the other indicates the peak loading that can be accommodated during emergency conditions. S&C Power Fuses will:

- Withstand magnetizing inrush currents associated with the total connected transformer kVA listed
- Carry load currents associated with the kVA values listed as Permissible Peak Load values
- Withstand the combined transient inrush of magnetizing and load currents associated with energizing transformers loaded to the values listed under the Permissible Peak Load values following a momentary interruption of source voltage

The switchgear short-circuit ratings and loading capabilities shown in Table 1 on page 16 are based on the S&C Power Fuse that offers the maximum loading and interrupting values at the given system voltage.

The nearest S&C Sales Office will assist customers in selecting the most economical power fuse for a particular application, and help customers choose the specific fuse rating and response characteristics that will provide the maximum protection and optimal coordination.

Single-phase protection for the load (specify for grounded systems if required)

Open-phase detection relays are provided for power-operated feeder bays (outgoing) to protect three-phase loads from open-phase conditions occurring on downstream circuits energized at the same voltage as the metal-enclosed switchgear. This condition is usually caused by blown feeder bay fuses. It also can be caused by source-side open-phase conditions occurring on upstream circuits energized at the same voltage level as the metal-enclosed switchgear such as blown fuses or single-phase protective devices at the riser pole, utility-line burndown, broken conductors, single-phase switching and equipment malfunctions. The relay trips the associated switch operator for a loss of one or two phases but not for a loss of all three phases.

Note: This relay uses voltage sensors or voltage transformers connected phase-to-ground to detect open-phase conditions.

Single-phase protection for the load (specify for grounded or ungrounded systems if required)

Specialty current-detection relays are provided for power-operated feeder bays (outgoing) to protect three-phase loads from single-phasing conditions occurring on downstream circuits energized at the same voltage as the metal-enclosed switchgear. This condition is usually caused when feeder bay fuses operate to clear a downstream fault. It also can be caused by operation of a source-side protective device for a fault. The relay detects current to a downstream fault followed by an absence of current in one or two phases to determine the loss of one or two phases. When that happens, the overcurrent relay will trip the associated switch operator after the downstream fault has been cleared. The relay does not trip the associated switch operator for a loss of all three phases.

Note: The relay uses current sensors to monitor phase current and to detect open-phase conditions.

Normal service conditions

Switchgear and components are intended to be used in accordance with their rated characteristics and the normal (usual) service conditions listed below.

- The ambient air temperature does not exceed 40°C (104°F) or fall below minus 30°C (minus 22°F).
- Altitude at the site does not exceed 1000 m (3280 ft) above sea level.

Special service conditions (specify if required)

The user's requirements should be specified when the switchgear will be applied under conditions different from those shown in normal service conditions.

Construction features

Dust-resistant construction (specify if required)

Dust-resistant construction helps protect the switchgear when there is a high concentration of airborne dust at a site. Provide foam gasket:

- Between bays at the top and front and rear edges
- For any flat panels such as indoor roof or removable plate to extend the main or ground bus

Provide neoprene gasket:

- Completely around the opening of doors and hinged panels
- Along the top and sides of main bus openings
- For any items mounted on the exterior of the bay including door handles, viewing panes and manual switch operating handles

All vents have externally removeable glass-fiber filters.

Drip-resistant feature for indoor switchgear (specify if required)

Drip-resistant construction to help protect indoor switchgear when there is a possibility that liquid may drip on indoor switchgear. Provide foam gasket:

- Between bays at the top and front and rear edges
- For any flat panels such as indoor roof or removable plate to extend the main or ground bus

Provide neoprene gasket:

- At the top of doors and hinged panels
- Along the top and sides of main bus openings
- For any items mounted on the exterior of the bay including door handles, viewing panes and manual switch operating handles

Enclosure categories

Switchgear assemblies are installed in a variety of locations. Some are accessible by the general public and some are not. The enclosure of the switchgear assembly provides a degree of protection for internal energized parts and a degree of protection for authorized personnel against unintended contact with live parts. Enclosures are categorized by IEEE as Category A, B, or C.

Category A enclosures

Category A enclosures are intended to provide a degree of protection against contact with live parts within enclosed equipment in ground-level installations where the general public has access to the switchgear because it is not enclosed in a locked area.

Category B enclosures

Category B enclosures are intended for use in installations not accessible to the general public and primarily provide a degree of protection to personnel against unintended contact with live parts within the equipment. This category should be in a locked area accessible only to authorized personnel.

Category C enclosures

Category C enclosures are for designs that have exposed live parts, such as roof bushings, and should be in a locked area accessible only to authorized personnel.

Hazardous locations

Metal-Enclosed switchgear is not suitable for application in areas classified by the National Electrical Code as a hazardous location.

Table 1. S&C Metal-Enclosed Switchgear—Maximum 60-Hertz① Short-Circuit Ratings and Three-Phase Load Capability②

System Voltage, kV			2.4	4.16 2.4/4.16Y	4.8	7.2	4.8/ 8.32Y	12	7.2/ 12.47Y	13.2 7.62/ 13.2Y	13.8	14.4	16.5
Switchgear Ratings	Voltage, kV	Nominal	4.16		4.8	13.8							
		Max	4.8		5.5	17.0							
		BIL	60		60	95							
	Main Bus, Continuous Amperes		600, 1200, or 2000		600, 1200, or 2000	600, 1200, or 2000							
	Short-Circuit, and Two-Time Duty-Cycle Fault-Closing, as applicable ④ ⑥	Amperes, RMS, Sym.⑤	37 500	(40 000)	(40 000)	25 000 (34 600)	25 000 (34 600)	(40 000)	(40 000)	(40 000)	(40 000)	(40 000)	(40 000)
		MVA, 3-Phase Sym. at Nom. System Voltage	155	(290)	(330)	310 (430)	360 (500)	(830)	(860)	(915)	(960)	(1000)	(1140)
Max 3-Phase Load per Fused Feeder③	Continuous Load, kVA		3000	(8600)	(10 000)	9000 (5000)	10 400 (5800)	(24 900)	(25 900)	(27 400)	(28 000)	(29 900)	(34 200)
	Permissible Peak Load, kVA		3300	(11 600)	(13 400)	9900 (5500)	11 400 (6300)	(33 300)	(34 600)	(36 600)	(38 300)	(40 000)	(45 800)

① For 50-Hertz ratings, consult the nearest S&C Sales Office.

② For each column that contains two sets of values, the set of values in parentheses provides a higher short-circuit rating but a lower continuous load capability than the set of values not in parentheses.

③ Three-phase load capabilities are based on an ambient temperature of 30°C (86°F) inside the switchgear enclosure. Furthermore, **Permissible Peak Load** values are based on the Y-hour daily emergency peak-load capabilities for the applicable power fuse. For three-phase load capabilities based on ambient temperatures greater than 30°C (86°F) or for **Permissible Peak Load** values based on daily emergency peak-loads longer than a half-hour, consult the nearest S&C Sales Office.

④ The duty-cycle fault-closing ratings listed in parentheses are one-time ratings. The associated two-time duty-cycle fault-closing ratings are 25,000 amperes symmetrical, 40,000 amperes asymmetrical, except for switchgear rated 25 kV nominal where the two-time duty-cycle fault-closing ratings are 20,000 amperes symmetrical, 32,000 amperes asymmetrical.

⑤ The short-circuit interrupting ratings and the duty-cycle fault-closing ratings expressed in amperes RMS asymmetrical are 1.6 times the symmetrical ratings listed. An exception applies to the 40,000 amperes symmetrical ratings where the corresponding asymmetrical value is 61,000 amperes.

⑥ Fault-closing ratings not available for 46-kV switchgear.

● For 150-kV BIL applications, consult the nearest S&C Sales Office.

Table 1. S&C Metal-Enclosed Switchgear—Maximum 60-Hertz① Short-Circuit Ratings and Three-Phase Load Capability②—continued

System Voltage, kV			16.5	23	14.4/ 24.9Y	27.6	27.6	34.5 20/ 34.5Y	46
Switchgear Ratings	Voltage, kV	Nominal	25				34.5		44
		Max	29				38		48.3
		BIL	125 or 150●				150 or 200		250 or 350
	Main Bus, Continuous Amperes		600, 1200, or 2000				600, 1200, or 2000		600 or 1200
	Short-Circuit, and Two-Time Duty-Cycle Fault-Closing, as applicable ④ ⑥	Amperes, RMS, Sym.⑤	20 000	(40 000)	(40 000)	(40 000)	17 500	17 500	20 000
		MVA, 3-Phase Sym. at Nom. System Voltage	570	(1590)	(1720)	(1910)	835	1050	1520
Max 3-Phase Load per Fused Feeder③	Continuous Load, kVA		11 400	(47 700)	(51 700)	(57 300)	14 300	17 900	22 800
	Permissible Peak Load, kVA		12 000	(63 700)	(69 000)	(76 500)	17 900	22 400	27 400

The footnotes above this table apply to this section.