

1.0 GENERAL

1.1 The metal-enclosed switchgear shall conform to the following specification.

1.2 Drawings

- (a) The metal-enclosed switchgear assembly shall be in accordance with the plans and drawings.
- (b) The manufacturer shall furnish, with each metal-enclosed switchgear assembly, a set of drawings complete with a bill of material. The drawings shall include typical front and open side views for each module as well as typical components, their positions, and available space for cable termination; an anchor bolt plan with dimensions; a single-line diagram; and appropriate wiring diagrams.
- (c) The manufacturer shall furnish a comprehensive instruction manual covering installation of the switchgear assembly and operation of the various components.

1.3 The metal-enclosed switchgear assembly shall consist of one or more (indoor, outdoor) self-supporting bays containing interrupter switches along with power fuses and/or electronic fuses, with the necessary accessory components, all completely factory-assembled and operationally checked.

1.4 Ratings

- (a) The distribution system shall be grounded, resistance-grounded with _____ amperes ground-fault current, or delta.
- (b) The ratings for the integrated switchgear assembly shall be as designated below (*select values from Table 1 on page 2*):

Nominal Voltage, kV _____

Maximum Voltage, kV _____

BIL Voltage, kV _____

Main Bus Continuous Current, Amperes. _____

Short-Circuit

Amperes, RMS, Symmetrical _____

MVA, Three-Phase Symmetrical, at Rated Nominal Voltage. . . _____

Two-Time Duty-Cycle Fault-Closing, Amperes, RMS, Asymmetrical _____

The momentary and duty-cycle fault-closing ratings of switches, the momentary rating of the bus, and the interrupting ratings of fuses shall equal or exceed the short-circuit ratings of the metal-enclosed switchgear.



Custom Metal-Enclosed Switchgear

TABLE 1. SELECTION OF RATINGS^①

Nominal Voltage, kV		4.16	4.16	4.16	4.16	4.16	4.16
Maximum Voltage, kV		4.8	4.8	4.8	4.8	4.8	4.8
BIL Voltage, kV		60	60	60	60	60	60
Main Bus Continuous Current, Amperes		600	1200●	600	600	1200●	600
Short-Circuit	Amperes, RMS, Symmetrical	17 200	17 200	25 000	37 500	37 500	40 000
	MVA, Three-Phase Symmetrical, at Rated Nominal Voltage	125	125	180	270	270	290
Two-Time Duty-Cycle Fault-Closing, Amperes, RMS, Asymmetrical		27 500	27 500	40 000	60 000	60 000■	61 000■

Nominal Voltage, kV		13.8	13.8	13.8	13.8	13.8	13.8
Maximum Voltage, kV		17.0	17.0	17.0	17.0	15.0	15.0
BIL Voltage, kV		95	95	95	95	95	95
Main Bus Continuous Current, Amperes		600	1200●	600	1200●	1200●	600
Short-Circuit	Amperes, RMS, Symmetrical	14 000 (or 12 500)▲	14 000 (or 12 500)▲	25 000	25 000	34 000	40 000
	MVA, Three-Phase Symmetrical, at Rated Nominal Voltage	335 (or 300)▲	335 (or 300)▲	600	600	815	960
Two-Time Duty-Cycle Fault-Closing, Amperes, RMS, Asymmetrical		22 400 (or 20 000)▲	22 400 (or 20 000)▲	40 000	40 000	54 000■	61 000■

Nominal Voltage, kV		25	25	25	25	25	34.5	34.5	34.5
Maximum Voltage, kV		27	27	29	29	29	38	38	38
BIL Voltage, kV		125◆	125	125	125	150	150▼	150▼	150
Main Bus Continuous Current, Amperes		600□	600□	600□	600□	600	600	600	1200△
Short-Circuit	Amperes, RMS, Symmetrical	12 500 (or 9400◆)▲	20 000	20 000	25 000	17 500	8450 (or 6250▼)▲	17 500	17 500
	MVA, Three-Phase Symmetrical, at Rated Nominal Voltage	540 (or 405◆)▲	860	860	1080	760	500 (or 375▼)▲	1000	1000
Two-Time Duty-Cycle Fault-Closing, Amperes, RMS, Asymmetrical		20 000 (or 15 000◆)▲	32 000	32 000	40 000■	28 000	13 500 (or 10 000▼)▲	28 000	28 000

① Ratings are 60 hertz only.

● Also available with 2000-ampere main bus.

■ One-time duty-cycle fault-closing rating.

▲ Alternate rating shown in parentheses is also available.

◆ Also available with 150 kV BIL, in which case the switch interrupting rating increases to 600 amperes.

▼Also available with 200 kV BIL.

□ Switch interrupting rating is 400 amperes, except when 150 kV BIL is specified, in which case switch interrupting rating increases to 600 amperes.

△ Switch interrupting rating is 900 amperes.

1.5 Certification of Ratings

- (a) The manufacturer of the metal-enclosed switchgear shall be completely and solely responsible for the performance of the basic switch and fuse components as well as the complete integrated assembly as rated.
- (b) The manufacturer shall furnish, upon request, certification of ratings of the basic switch and fuse components and/or the integrated metal-enclosed switchgear assembly consisting of the switch and fuse components in combination with the enclosure(s).
- (c) The integrated switchgear assembly shall have a BIL rating established by test on switchgear of the type and kind to be furnished under this specification. Certified test abstracts establishing such ratings shall be furnished upon request.

1.6 Compliance with Standards and Codes

The metal-enclosed switchgear shall conform to or exceed the applicable requirements of the following standards and codes:

- (a) IEEE C37.20.3, Standard for Metal-Enclosed Interrupter Switchgear (*for switchgear installed in the United States*) or CSA C22.2 No. 31-14 (*for switchgear installed in Canada*)
- (b) The applicable portions of:
 - (01) Article 490 in the National Electric Code, including Article 490-21(e), which specifies that the interrupter switches in combination with power fuses shall safely withstand the effects of closing, carrying, and interrupting all possible currents up to the assigned maximum short-circuit rating (*for switchgear installed in the United States*)
 - (02) Sections 36 and 75 of the Canadian Electrical Code or the applicable portions of the Ontario Electrical Safety Code (*for switchgear installed in Canada*).
- (c) For standard 4.16-kV and 13.8-kV bays with 600-ampere or 1200-ampere main bus and Mini-Rupter® Switches or 1200-ampere Alduti-Rupter® Switches only: The switchgear manufacturer shall furnish equipment that is listed by Underwriters Laboratories Inc.

The following optional features should be specified as required:

- (d) For 4.16-kV and 13.8-kV bays with 600-ampere or 1200-ampere main bus and Mini-Rupter Switches or 1200-ampere Alduti-Rupter Switches only: The switchgear manufacturer shall provide enclosures that have been proven by Underwriters Laboratories Inc. to be in compliance with the Category A enclosure test requirements in accordance with conformance standard IEEE C37.20.3. Category A enclosures are intended to provide a degree of protection against contact with enclosed equipment in ground level installations subject to deliberate unauthorized acts by members of the unsupervised general public. Category A enclosures require the addition of padlockable covers for windows and accessories such as ammeters, voltmeters, kilowatt-hour meters, etc. (*only for switchgear installed in the United States*).
- (e) Metal-enclosed switchgear shall be certified to have passed the test requirements of the Electrical and Electronic Manufacturers Association of Canada, "Procedure for Testing the Resistance of Metalclad Switchgear Under Conditions of Arcing

Due to an Internal Fault,” G14-1, 1987. The gear shall meet the test requirements for Accessibility Type B: Switchgear with arc-resistant construction at the front, back, and sides.

Note: Features (d) and (e) cannot be specified together. Underwriters Laboratories Inc. does not have a category for arc-resistant switchgear.

2.0 CONSTRUCTION

2.1 To ensure a completely coordinated design, the metal-enclosed switchgear shall be constructed in accordance with the minimum construction specifications of the fuse and/or switch manufacturer to provide adequate electrical clearances and adequate space for fuse handling.

2.2 Enclosure Construction

- (a) In establishing the requirements for the enclosure design, consideration shall be given to all relevant factors, such as controlled access; tamper-resistance; corrosion-resistance; protection from ingress of rodents, insects, and weeds; and the possibility of arcing faults within the enclosure.
- (b) The enclosure of each bay shall be of unitized monocoque construction to maximize strength, minimize weight, and inhibit corrosion.
- (c) The material for all external sides of the enclosure and the roof shall be 11-gauge hot-rolled and pickled and oiled steel sheet.
- (d) Each bay containing high-voltage components shall be a complete unit in itself, with full side sheets, resulting in double-wall construction between bays. To guard against unauthorized or inadvertent entry, side and rear sheets and the top shall not be externally bolted.
- (e) The base (select the appropriate option below):
 - (01) Shall be a continuous steel channel of a thicker gauge material than used for the enclosure and shall extend completely around all four sides of each bay (*for switchgear installed in the United States*)
 - (02) Shall consist of continuous 90-degree flanges, turned inward and welded at the corners, for bolting to a concrete pad (*for switchgear installed in Canada*)
- (f) Access to the interior of the enclosure shall be from the front only, allowing placement of the metal-enclosed switchgear assembly tightly against a wall or back to back, to minimize floor-space requirements. If requested, rear access to the interior of the enclosure shall be provided.
- (g) To guard against unauthorized or inadvertent entry, there shall be no access to high voltage through side or rear sheets of the metal-enclosed switchgear assembly and no access to high voltage by means of externally removable panels.
- (h) To guard against corrosion, all hardware (including door fittings, fasteners, etc.), all operating-mechanism parts, and other parts subject to abrasive action from mechanical motion shall be of either nonferrous materials or galvanized or zinc-nickel-plated materials. Cadmium-plated ferrous parts shall not be used.
- (i) Externally accessible hardware shall not be used for support of high-voltage components or switch-operating mechanisms within the switchgear.

2.3 Door Construction

- (a) Doors shall be constructed of 11-gauge hot-rolled and pickled and oiled steel sheet.
- (b) Doors shall have 90-degree flanges and shall overlap with the door openings. For strength and rigidity and to minimize exposure, the door flanges shall be welded at the corners and shall be formed (at the top and both sides as a minimum) with a double bend so the sheared-edge flanges at the top and both sides fold back parallel to the inside of the door. The double bend shall not be required on arc-resistant switchgear.
- (c) Doors more than 40 inches (1016 mm) in height shall have a minimum of three concealed galvanized steel or non-ferrous hinges with stainless steel hinge pins. Doors 40 inches in height or less shall have a minimum of two such hinges.
- (d) Each door shall be equipped with a door handle. The door handle shall be padlockable and, on outdoor gear, shall incorporate a hood to protect the padlock shackle from tampering.
- (e) In consideration of controlled access, tamper-resistance, and arcing faults, each door more than 40 inches (1016 mm) in height shall have a minimum of three concealed, interlocking, high-strength latches. Doors 40 inches in height or less shall have a minimum of two such latches.
- (f) Doors providing access to interrupter switches or interrupter switches with power fuses shall be provided with a wide-view window constructed of an impact-resistant material to facilitate checking of switch position without opening the door.
- (g) Doors providing access to solid-material power fuses or fused voltage transformers shall have provisions to store spare fuse units or refill units. Doors providing access to electronic power fuses shall have provisions to store spare interrupting modules, if possible.
- (h) All doors providing access to high-voltage components shall be provided with a sturdy, self-latching door holder, which shall be zinc-nickel plated and chromate dipped.

2.4 Access Control

Access control shall be provided as follows:

- (a) Doors providing access to interrupter switches with fuses shall be mechanically or key interlocked to guard against both:
 - (01) Opening the door if the interrupter switch on the source side of the fuse is closed
 - (02) Closing the interrupter switch if the door is open
- (b) Doors providing access to interrupter switches only that are operated by stored-energy type switch operators shall be mechanically or key interlocked to guard against operating the interrupter switch if the door is open.
- (c) Doors and hinged-bolted panels providing access to high-voltage components (*select the appropriate option*):
 - (01) Shall be provided with flush-mounted key-operated snaplocks and shall have provisions for padlocking (*for switchgear installed in the United States*)

(01) Shall have provisions for padlocking (*for switchgear installed in Canada*)

2.5 Internal Protective Screens

- (a) In addition to the enclosure door, each bay or compartment containing high-voltage components shall be provided with an internal bolted-closed protective screen to guard against inadvertent entry to these components when the enclosure door is open.
- (b) Each bay containing a control-power transformer capable of 5 kVA or greater output shall be provided with an bolted-closed internal protective screen to guard against inadvertent contact with the primary fuse when the enclosure door is open. In such cases, the screen shall also be interlocked to ensure the secondary load has been disconnected prior to removal of these fuses.

2.6 Insulators

The interrupter-switch and fuse-mounting insulators, main-bus support insulators, insulated operating shafts, and (if applicable) push rods shall be of a cycloaliphatic epoxy resin system with characteristics and restrictions as follows:

- (a) Operating experience of at least 25 years under similar conditions
- (b) Adequate leakage distance established by test per IEC Publication 507, "Artificial Pollution Test on High Voltage Insulators to be Used on AC Systems," First Edition, 1975
- (c) Adequate strength for short-circuit stress established by test
- (d) Conformance with applicable ANSI or Canadian standards
- (e) Homogeneity of the cycloaliphatic epoxy resin throughout each insulator to provide maximum resistance to power arcs (Ablation caused by high temperatures from power arcs shall continuously expose more material of the same composition and properties so no change in mechanical or electrical characteristics takes place because of arc-induced ablation. Furthermore, any surface damage to insulators during installation or maintenance of switchgear shall expose material of the same composition and properties so that insulators with minor surface damage need not be replaced.)

The following optional feature should be specified as required:

- (f) Isolating through-bushings for the (*select one*: 4.16-kV, 13.8-kV) switchgear assembly shall be provided between (bay _____ and bay _____, etc.; all bays) to guard against the propagation of a fault from one bay into the adjacent bay. The isolating through-bushings shall have features and capabilities as follows:
 - (01) The bushings shall be of a nontracking, self-scouring, nonweathering cycloaliphatic epoxy resin. Such bushings shall be the only dielectric insulating material between the energized bus conductor and the ground plane. A single semiconducting material is permissible as an interface between the energized conductors and bushings. Isolating systems that incorporate multiple insulating materials in series shall not be acceptable, thus avoiding generation of corona that can break down the weakest insulation material.
 - (02) The bushings shall be designed for adequate BIL. Certified tests shall be provided upon request.
 - (03) The bushings shall provide a minimum of 12½ inches (317.5 mm) of leakage distance between the energized bus conductor and the ground plane.

- (04) To avoid thermally induced stresses that are likely to cause interface separation and failure, the bus conductor shall not be molded or cemented into the bushing.
- (05) Openings between the bushings and bus conductors shall be closed with a semiconducting grommet. To avoid multiple insulating materials in series, insulating materials such as fiberglass or porcelain shall not be used for such purpose.
- (06) Bushing bus conductors and main bus conductors shall be designed for direct connection and shall not require laminated or flexible bus connections.
- (07) The manufacturer of the switchgear assembly shall furnish, upon request, certified tests that establish the capability of the isolating through-bushing, bus conductor, and connections to meet the short-circuit rating of the switchgear assembly. Certified tests shall be furnished, upon request, that establish the capability of the bus connections to meet applicable temperature-rise requirements.
- (08) To minimize space requirements, the overall length of the bushing shall be a maximum of 9½ inches (241.3 mm) from end to end.
- (09) To avoid mechanical stresses that are likely to cause interface separation and failure, the isolating through-bushing shall include a flange at the ground-plane interface that shall be a formed homogeneous section of the bushing and not a separate part of dissimilar material that is molded or cemented to the bushing.
- (10) Bushings shall be secured to the ground plane by clamps that overlap the bushing flanges and press the flanges securely against the ground plane to seal the openings and restrict the propagation of ionized gases between bays.
- (11) For outdoor or drip-proof applications, a drain channel shall be installed above the isolating through-bushings as a backup for the bay-to-bay gasketing so any moisture entering between bays will not fall on the bushing or the bus.

2.7 Bus

High-Voltage Main Bus

- (a) Bus and interconnections shall consist of aluminum bar of a minimum 56% IACS conductivity.
- (b) Bus supports, bus, and interconnections shall withstand the stresses associated with short-circuit currents up through the maximum rating of the switchgear.
- (c) Before installation of the bus, all electrical contact surfaces shall first be prepared by machine-abrading to remove any aluminum-oxide film. Immediately after this operation, the electrical contact surfaces shall be coated with a uniform coating of an oxide inhibitor and sealant.
- (d) Bolted aluminum-to-aluminum connections shall be made with 1/2—13 galvanized-steel bolts, with two Belleville spring washers per bolt, one under the bolt head and one under the nut. These bolts shall be tightened to 50 foot-pounds torque.
- (e) The bus to which cable will be terminated shall be equipped with grounding provisions. Grounding provisions shall also be provided on the ground bus in such bays.

- (f) Bus rated 1200 amperes and to which cable will be terminated shall be equipped with provisions for two cables per phase.

The following optional feature should be specified as required:

- (g) Bus and interconnections shall consist of copper bar CA110, square edge, hard temper per ASTM B187. *Select the appropriate option:*
 - (01) Bolted copper-to-copper connections shall have silvered interfaces and shall be made with ½-13 stainless-steel bolts, with two brass flat washers per bolt, one under the bolt head and one under the nut, and with a stainless steel split lockwasher between the flatwasher and the nut. These bolts shall be tightened to 35 foot-pounds torque (*for switchgear installed in the United States*).
 - (01) Bolted copper-to-copper connections shall have tin-plated interfaces and shall be made with ½-13 stainless-steel bolts, with two brass flat washers per bolt, one under the bolt head and one under the nut, and with a stainless steel split lockwasher between the flatwasher and the nut. These bolts shall be tightened to 35 foot-pounds torque (*for switchgear installed in Canada*).

2.7.1 Ground Bus

- (a) Ground bus with a short-circuit rating equal to that of the integrated assembly (or a ground connection, in the case of single-bay switchgear) shall be provided, maintaining electrical continuity throughout the metal-enclosed switchgear.
- (b) Ground bus shall consist of aluminum bar of a minimum 56% IACS conductivity.
- (c) In each bay, the ground bus (or connector) shall be bolted to a nickel-plated steel bracket, which shall be welded in place.
- (d) Nickel-plated steel brackets (at least one per bay) shall have a short-time current-carrying capability consistent with the short-circuit rating of the metal-enclosed switchgear.
- (e) Bolted connections shall be as specified for the main bus, except only one Belleville spring washer shall be required per bolt for attachment of ground bus to the nickel-plated steel bracket.
- (f) For multi-bay metal-enclosed switchgear assemblies, two ground cable connectors accommodating No. 2 through 500 kc mil conductors shall be provided for connection of ground bus to station ground.

The following optional feature should be specified as required:

- (g) The ground bus shall consist of copper bar CA110, square edge, hard temper per ASTM B187. Bolted copper-to-copper connections shall have silvered interfaces and shall be made with ½-13 stainless steel bolts, with two brass flat washers per bolt, one under the bolt head and one under the nut, and with a stainless steel split lockwasher between the flat washer and the nut.

2.8 Low-Voltage Components

- (a) All low-voltage components, switch operators (except those integrally mounted in the switchgear stile), source-transfer controls, meters, instruments, and relays shall be located in grounded, metal-enclosed compartments separate from high voltage to provide isolation and shall be arranged to allow complete accessibility for operation without exposure to high voltage.

- (b) Space heaters, where used, shall have a grounded, perforated, galvanized steel guard.
- (c) To provide isolation from high voltage, low-voltage wiring, except for short lengths such as at terminal blocks or at secondaries of sensing devices, shall be in grounded conduit, cable trays, or raceways.

2.9 Cable-Termination Space

To facilitate cable pulling and installation of cable terminators, provisions shall be made for:

- (a) Full front access for positioning and removal of cable-pulling sheaves
- (b) Free access without interference from nonremovable structural members or from mechanical linkages between the interrupter-switch blades and operating mechanism

3.0 FINISH AND FEATURES

3.1 Indoor Switchgear

3.1.1 Indoor Finish

- (a) The enclosure finish shall conform to or exceed the applicable requirements of ANSI C57.12.28.
- (b) During fabrication, the areas of structural parts that may later become inaccessible, such as folded edges and overlapping members, shall be given an iron-oxide zinc-chromate anticorrosion primer to ensure all surfaces are protected.
- (c) Full coverage at joints and blind areas shall be achieved by processing enclosures independently of components such as doors and roofs before assembly into the unitized structures.
- (d) To remove oils and dirt, to form a chemically and anodically neutral conversion coating to improve the finish-to-metal bond, and to retard underfilm propagation of corrosion, all surfaces shall undergo a thorough pretreatment process comprised of a fully automated system of cleaning, rinsing, phosphatizing, sealing, drying, and cooling before any protective coatings are applied. By using an automated pretreatment process, the enclosure shall receive a highly consistent thorough treatment, eliminating fluctuations in contact time, temperature, pressure/flow, and chemical concentrations.
- (e) After pretreatment, protective coatings shall be applied to help resist corrosion and protect the steel enclosure. To establish the capability to resist corrosion and protect the enclosure, representative test specimens coated by the enclosure manufacturer's finishing system shall satisfactorily pass the following tests:
 - (01) Crosshatch adhesion testing per ASTM D 3359 Method B, with no loss of paint
 - (02) Humidity Test: 1000 hours of testing per ASTM D 4585, with no blistering as evaluated per ASTM D 714
 - (03) Impact Test: 80-inch-pound impact, followed by adhesion testing per ASTM D 2794, no red rust visible in the impact area of the panel after the panel exposed to 24 hours of salt spray per ASTM B117
 - (04) Ultraviolet accelerated-weathering test (QUV): 500 hours of ultraviolet-accelerated weathering testing per ASTM D4587, using the FS 40 bulb, 4 hr. UV at

60°C (140°F), and 4 hr. condensation at 50°C (122°F). Loss of gloss shall not exceed 50% per ASTM D523. No cracking as evaluated per ASTM D 661 or checking per ASTM D660 under unaided visual inspection

- (05) Simulated corrosive atmospheric breakdown (SCAB) test: Follow IEEE test procedure and evaluate per ASTM 1654 Table 1 (Maximum average of 3 mm (1/8 in.) loss adhesion from scribe after 15 cycles. No blisters per ASTM D 714.)
- (06) Abrasion Resistance test: 3000 cycles of abrasion testing per ASTM 4060 (Abraded panel must exhibit no rust after salt spray exposure for 24 hours.)
- (07) Gravelometer test: The coating panel to be tested is per ASTM D 3170, and expose the test panel 24 hours in salt spray per ASTM B117. A minimum rating of 4 B per SAE J400
- (08) 4000 hours of salt-spray testing per S&C internal testing requirements for harsh-climate durability

Certified test abstracts substantiating the above capabilities shall be furnished upon request.

- (09) After the enclosures are completely assembled and the components (switches, fuses, bus, etc.) are installed, the finish shall be inspected for scuffs and scratches. Blemishes shall be touched up to restore the protective integrity of the finish.
- (10) Touch-up materials—with complete instructions—shall be included with each shipment of metal-enclosed switchgear for touch-up in the field.
- (11) The finish shall be ANSI 70 Gray. Additional colors are available on request.

3.1.2 Indoor Features

- (a) Ventilation openings shall be provided at the top and bottom on the front and rear of each bay and shall include an inside baffle with louvered openings. Ventilation openings on the front of arc-resistant switchgear shall be provided at the top only.
- (b) Lifting eyes shall be removable.
- (c) Covered windows for infrared imaging of critical joints and components. (*Window placement specified by user.*)

3.2 Outdoor Switchgear

3.2.1 Outdoor Finish

- (a) The enclosure finish shall conform to or exceed the applicable requirements of ANSI C57.12.28-2014.
- (b) During fabrication, the areas of structural parts that may later become inaccessible, such as folded edges and overlapping members, shall be given an iron-oxide zinc-chromate anticorrosion primer to ensure all surfaces are protected.
- (c) Full coverage at joints and blind areas shall be achieved by processing enclosures independently of components such as doors and roofs before assembly into the unitized structures.
- (d) To remove oils and dirt, to form a chemically and anodically neutral conversion coating to improve the finish-to-metal bond, and to retard underfilm propagation

of corrosion, all surfaces shall undergo a thorough pretreatment process comprised of a fully automated system of cleaning, rinsing, phosphatizing, sealing, drying, and cooling before any protective coatings are applied. By utilizing an automated pretreatment process, the enclosure shall receive a highly consistent thorough treatment, eliminating fluctuations in contact time, temperature, pressure/flow and chemical concentrations.

- (e) After pretreatment, protective coatings shall be applied to help resist corrosion and protect the steel enclosure. To establish the capability to resist corrosion and protect the enclosure, representative test specimens coated by the enclosure manufacturer's finishing system shall satisfactorily pass the following tests:
 - (01) Crosshatch-adhesion testing per ASTM D 3359 Method B, with no loss of paint
 - (02) Humidity test: 1000 hours of humidity testing per ASTM D 4585, with no blistering as evaluated per ASTM D 714 and softening as evaluated per ASTM D3363
 - (03) Impact test: 80-inch-pound impact, followed by adhesion testing per ASTM D 2794, no red rust visible in the impact area of the panel after the panel exposed to 24 hours of salt spray per ASTM B117
 - (04) Ultraviolet accelerated-weathering test (QUV): 500 hours of ultraviolet-accelerated weathering testing per ASTM D4587, utilizing the FS 40 bulb, 4 hr. UV at 60°C (140°F) and 4 hr. condensation at 50°C (122°F) (Loss of gloss shall not exceed 50% per ASTM D523. No cracking as evaluated per ASTM D 661 or checking per ASTM D660 under unaided visual inspection.)
 - (05) Simulated corrosive atmospheric breakdown (SCAB) test: follow IEEE test procedure and evaluate per ASTM 1654 Table 1 (Maximum average of 3 mm (1/8 in.) loss adhesion from scribe after 15 cycles. No blisters per ASTM D 714.)
 - (06) Abrasion Resistance test: 3000 cycles of abrasion testing per ASTM 4060 (Abraded panel must exhibit no rust after salt spray exposure for 24 hours.)
 - (07) Gravelometer test: the coating panel to be test as per ASTM D 3170 and expose the test panel 24 hours in salt spray per ASTM B117. A minimum rating of 4 B per SAE J400
 - (08) 4000 hours of salt-spray testing per S&C internal testing requirements for harsh-climate durability.

Certified test abstracts substantiating the above capabilities shall be furnished upon request.

- (f) A heavy coat of insulating "no-drip" compound shall be applied to the inside surface of the roof structure to prevent condensation of moisture.
- (g) After the enclosures are completely assembled and the components (switches, fuses, bus, etc.) are installed, the finish shall be inspected for scuffs and scratches. Blemishes shall be touched up to restore the protective integrity of the finish.
- (h) Touch-up materials—with complete instructions—shall be included with each shipment of metal-enclosed switchgear for touch-up in the field.
- (i) The finish shall be ANSI 70 gray. Additional colors can be made available upon request.

3.2.2 Outdoor Features

(a) Enclosure Ventilation

(01) Ventilation openings shall be provided at the top and bottom on the front and rear of each bay. Ventilation openings on the front of arc-resistant switchgear shall be provided at the top only.

(02) Vents shall be rain-resistant and corrosion-resistant.

(03) Each vent shall have an inside screen and baffle to exclude insects and to protect against insertion of foreign objects.

The following optional feature should be specified as required:

(04) In consideration of exceptionally high concentrations of airborne dust, externally accessible glass-fiber filters shall be provided.

The following optional features should be specified as required:

(05) Infrared windows for imaging of terminal pads and terminations.

(b) Lifting eyes shall be removable. Sockets for lifting eyes shall be blind-tapped.

(c) Gasketing and Sealing

(01) Door openings and openings for hinged bolted panels (and bolted panels providing access to low-voltage components) shall have resilient compression gasketing to prevent water from entering the enclosure.

(02) Gasket seals shall be provided at the top and side edges of adjoining bays to prevent water entry between the double walls.

(03) The top and both sides of bus openings between bays shall be covered with channel gaskets as an additional protection against entrance of water, or external labyrinthine metal rain shields shall be provided over enclosure roof flanges between adjacent bays.

(04) Roofs shall be weather-sealed in place with a suitable sealant.

(d) Space Heaters

(01) Space heaters with sheaths of high-temperature chrome steel shall be provided to maintain air circulation inside the enclosure.

(02) There shall be a space heater in each bay.

(03) Space heaters shall be wired.

The following optional features should be specified as required:

(04) A low-voltage circuit breaker shall be provided in the strip heater circuit.

(05) Infrared windows for imaging of terminal pads and terminations. (*Window placement specified by user.*)

4.0 BASIC COMPONENTS (*Select applicable component specifications from those that follow.*)

4.1 Interrupter Switches

(a) Interrupter switches shall have a one-time or two-time duty-cycle fault-closing rating equal to or exceeding the short-circuit rating of the switchgear. These ratings define the ability to close the interrupter switch either alone (unfused) or in combination with the appropriate fuse, once or twice (as applicable) against a three-phase fault with asymmetrical current in at least one phase equal to the

rated value, with the switch remaining operable and able to carry and interrupt rated current. Tests substantiating these ratings shall be performed at maximum voltage. Certified test abstracts establishing such ratings shall be furnished upon request.

- (b) Interrupter switches intended for manual operation shall be operated by means of an externally operable, nonremovable handle. The handle shall have provisions for padlocking in both the Open and Closed positions. Interrupter switches intended for power operation shall be operated by means of a switch operator expressly designed to be compatible with the interrupter switch.
- (c) Interrupter switches shall use a quick-make quick-break mechanism installed by the switch manufacturer. The mechanism shall swiftly and positively open and close the interrupter switch independent of the switch-handle or switch-operator-operating speed.
 - (01) For manually operated interrupter switches and for interrupter switches operated by direct-motor-drive switch operators, the quick-make quick-break mechanism shall be integrally mounted to the switch frame.
 - (02) For interrupter switches operated by stored-energy switch operators, the quick-make quick-break mechanism shall be an integral part of the switch operator.
- (d) Interrupter switches shall be completely assembled and adjusted by the switch manufacturer on a single rigid mounting frame. The frame shall be of welded steel construction so the frame intercepts the leakage path that parallels the open gap of the interrupter switch to positively isolate the load circuit when the interrupter switch is in the Open position.
- (e) Interrupter switches shall be provided with a single blade per phase for circuit closing, including fault closing, continuous current carrying, and circuit interrupting. Spring-loaded auxiliary blades shall not be permitted.
- (f) Circuit interruption shall be accomplished by use of an interrupter, which is positively and inherently sequenced with the blade position. Circuit interruption shall take place completely within the interrupter, with no external arc or flame. Any exhaust shall be vented in a controlled manner through a labyrinthine muffler or a deionizing vent.
- (g) Interrupter switches shall have a readily visible open gap when in the Open position to allow positive verification of switch position.
- (h) Terminals on interrupter switches to which cable will be terminated shall be equipped with grounding provisions. Grounding provisions shall also be provided on the ground bus in such bays.
- (i) Terminals on interrupter switches rated 1200 amperes and, for entrance-bay applications only, terminals on interrupter switches used in conjunction with fuses rated 600 amperes or greater, shall be equipped with provisions for two cables per phase.

4.2 Grounding Switch

4.2.1 Grounding switches shall meet the requirements of:

- (01) IEEE C37.20.4 (*for switchgear installed in the United States*)
- (02) CSA C22.2 No. 193-M1983 (*for switchgear installed in Canada*)

- 4.2.2 Grounding switches shall have a peak current withstand rating equal to or exceeding the peak current withstand rating of the switchgear.
- 4.2.3 In feeder (outgoing) bays, grounding switches shall be interlocked so the associated interrupter switch must be open before the grounding switch can be closed. *(select if appropriate)*
- 4.2.4 In entrance bays, the grounding switch may be interlocked so an upstream device must be open before the grounding switch can be closed if required by the utility or owner. *(select if appropriate)*
- 4.3 Fuses
 - 4.3.1 Solid-Material Power Fuses
 - (a) Solid-material power fuses shall utilize refill-unit-and-holder or fuse-unit-and-end-fitting construction. The refill unit or fuse unit shall be readily replaceable.
 - (b) For switchgear rated up through 270 MVA at 4.16 kV, 600 MVA at 13.8 kV, 860 MVA at 25 kV, and 1000 MVA at 34.5 kV, mountings for solid-material power fuses shall be disconnect style. Non-disconnect style mountings for power fuses shall be used only where higher ratings are required.
 - (c) Fusible elements shall be nonaging and nondamageable, so it is unnecessary to replace unblown companion fuses following a fuse operation.
 - (d) Fusible elements for refill units or fuse units, rated 10 amperes or larger, shall be helically coiled to avoid mechanical damage caused by stresses from current surges.
 - (e) Fusible elements that carry continuous current shall be supported in air to help prevent damage from current surges.
 - (f) Refill units and fuse units shall have a single fusible element to eliminate the possibility of unequal current sharing in parallel current paths.
 - (g) Solid-material power fuses shall have melting time-current characteristics (TCCs) that are permanently accurate with a maximum total tolerance of 10% in terms of current. TCC curves shall be available that permit coordination with protective relays, automatic circuit reclosers, and other fuses.
 - (h) Solid-material power fuses shall be capable of detecting and interrupting all faults, whether large, medium, or small (down to minimum melting current); under all realistic conditions of circuitry; and with line-to-line or line-to-ground voltage across the power fuses. And they shall be capable of handling the full range of transient recovery voltage severity associated with these faults.
 - (i) All arcing accompanying solid-material power fuse operation shall be contained within the fuse, and any arc products and gases evolved during fuse operation shall be vented through exhaust control devices that shall effectively control fuse exhaust.
 - (j) Solid-material power fuses shall be equipped with a BLOWN FUSE indicator that shall provide visible evidence of fuse operation while installed in the fuse mounting.
 - (k) Solid-material power fuses in feeder bays shall be equipped with grounding provisions on the load side of each fuse and on the enclosure ground bus.

4.3.2 Electronic Power Fuses

- (a) Electronic power fuses shall use an expendable interrupting module and a reusable control module.
 - (01) The interrupting module shall consist of a main-current section and a fault-interrupting section. These sections shall be arranged coaxially and contained within the same housing.
 - (02) The main-current section shall carry current under normal operating conditions.
 - (03) The fault-interrupting section shall operate only under fault conditions. It shall not carry enough current continuously to determine the TCC minimum operating curve shape.
 - (04) The fusible-element section shall not be subject to damage caused by current surges.
 - (05) All arcing accompanying operation of the electronic power fuse shall be contained within the interrupting module and fuse operation shall be silent, without any exhaust.
 - (06) The control module shall continuously monitor the line current through an electronic sensing circuit.
 - (07) The electronic components shall be located within a cylindrical cast aluminum housing that shall serve as a path for continuous current and as a shield to protect the electronic components against interference from external electric fields.
 - (08) To prevent damage to the control-module circuits by surges (such as because of lightning or inrush currents), the control module shall be free of external control wiring and connections to ground, and shall incorporate a device that acts as a buffer to isolate the electronic components at a level of current well below their surge-withstand capability.
 - (09) The control module shall be factory-sealed to ensure a dry, contaminant-free environment for the electronic components.
 - (10) The control module shall be self-powered with the capability to supply power for operating the sensing logic circuits and to actuate the interrupting module when a fault occurs.
 - (11) The control module shall include one or more integrally mounted current transformers to provide both the sensing signal and the control power.
 - (12) The current transformer used to provide control power shall be designed to act as a buffer against surges in the line by saturating at a level of current well below the surge-withstand capability of the electronic components.
 - (13) No leads (including coaxial leads) between the current transformers and the electronic components shall be exposed.
- (b) To make the integrity of the electrical connection between the interrupting and control modules independent of the mechanical force with which the modules are joined, the connection shall be through a louvered ring-type sliding contact.
- (c) Electronic power fuses in feeder bays shall be equipped with grounding provisions on the load side of each fuse and on the enclosure ground bus.

- (d) Electronic power fuses shall be equipped with a BLOWN FUSE indicator that shall provide visible evidence of fuse operation while installed in the fuse mounting. Fuse mountings shall be disconnect style.
- (e) It shall not be necessary to replace unblown companion interrupting modules following operation of an electronic power fuse.
- (f) Electronic power fuses shall have TCCs that are permanently accurate. TCC curves shall be available that permit coordination with a variety of source-side and load-side protective devices (e.g., protective relays, automatic circuit reclosers, other power fuses, etc.).

4.3.3 Current-limiting power fuses

- (a) Provide current-limiting power fuses in accordance with IEEE C37.40, IEEE C37.41, IEEE C37.46, and IEEE C37.47.

4.4 Circuit breakers

4.4.1 Drawout circuit breakers

- (a) Drawout circuit breakers shall comply with IEEE C37.04, IEEE C37.06, IEEE C37.09, and meet the requirements of IEEE C37.20.3.
- (b) Acceptable manufactures include: (*specify manufacturer*)

4.4.2 Stationary Circuit Breakers

- (a) Stationary circuit breakers shall comply with IEEE C37.04, IEEE C37.06, IEEE C37.09, and meet the requirements of IEEE C37.20.3.
- (b) Acceptable manufactures include: (*specify manufacturer*)

4.5 Switch Operators (*Select applicable switch operators from the three types that follow.*)

4.5.1 The following requirements apply to switch operators that incorporate an integral quick-make quick-break mechanism for solenoid trip-open and solenoid trip-closed operation with motor recharge—for use with interrupter switches rated 4.16 kV and 13.8 kV nominal, 600 amperes load interrupting and 25 kV nominal, 400 amperes load interrupting (600 amperes continuous):

- (a) Switch operators shall be of the stored-energy type. They shall be equipped with an integral quick-make quick-break mechanism installed by the switch operator manufacturer. The mechanism shall store sufficient mechanical energy to either open or close the interrupter switch. The mechanism shall swiftly and positively open and close the associated interrupter switch independent of the speed of the charging motor or manual handle.
- (b) Switch operators shall be equipped with a tripping solenoid to release the stored energy to open or close the associated interrupter switch in response to a control signal. Total operating time for opening or closing shall not exceed 4 cycles from the time the solenoid is energized.
- (c) Switch operators shall be equipped with a charging motor that shall charge the quick-make quick-break mechanism within 1½ seconds after each switch operation.
- (d) Switch operators shall be equipped with a torque limiter to absorb deceleration forces when travel limits are reached during charging to allow the motor to positively and completely charge the quick-make quick-break mechanism without transmitting excessive torque to the mechanism.

- (e) Pushbuttons shall be provided to permit local electrical trip-open and trip-closed operation. Local electrical operation shall be prevented when the source-transfer control is in the automatic mode.
- (f) Switch operators shall be provided with a manual charging access port and a removable manual-charging handle to allow manual charging of the quick-make quick-break mechanism in the absence of control power. While the manual charging access port is open, the motor-charging circuit shall be disconnected to prevent inadvertent electrical charging of the quick-make quick-break mechanism.
- (g) Switch operators shall be equipped to permit local mechanical trip-open and trip-closed operation in the event control power is lost.
- (h) Switch operators shall be located within a grounded, metal-enclosed low-voltage compartment in the switchgear stile and shall be mounted on a drawout carriage. The metal-enclosed compartment shall provide isolation from high voltage to help protect operating personnel. The drawout carriage shall permit decoupling of the switch operator from the associated interrupter switch for testing and exercising of the switch operator without opening or closing the interrupter switch and without exposure to high voltage. When the switch operator is decoupled, the associated interrupter switch shall be locked open or closed, depending upon switch position at the time of decoupling. It shall not be possible to recouple the switch operator to the interrupter switch unless the switch operator is in the same position (Open or Closed) as the interrupter switch.
- (i) Switch operators shall be equipped with targets to show whether the quick-make quick-break mechanism is charged or discharged; whether the switch operator is in the Switch Open or Switch Closed position; whether the associated interrupter switch is in the Open or Closed position; and whether the switch operator is in the Coupled or Decoupled position.
- (j) Switch operators shall be equipped with an operation counter.
- (k) Switch operators shall be provided with a hinged padlockable steel cover or door to protect the switch operators and to guard against tampering. The cover or door shall be equipped with windows (unless Category A enclosures are required) to allow observation of the switch operator targets. Gasketing shall be installed between the cover or door and the mounting surfaces.

The following optional features should be specified as required:

- (l) Switch operators shall be equipped with an extra 4-PDT auxiliary switch coupled to the switch operator.
 - (m) Switch operators shall be equipped with an extra 6-PDT auxiliary switch coupled to the interrupter switch.
 - (n) A receptacle shall be provided for attachment of a remote-control station to allow electrical Trip Open and Trip Closed operation from an adjacent area.
- 4.5.2 The following requirements apply to switch operators that incorporate an integral quick-make quick-break mechanism for solenoid Trip Open operation with manual recharge—for use with interrupter switches rated 4.16 kV and 13.8 kV nominal, 600 amperes load interrupting and 25 kV nominal, 400 amperes load interrupting (600 amperes continuous):
- (a) Switch operators shall be of the stored-energy type. They shall be equipped with an integral quick-make quick-break mechanism installed by the switch operator

manufacturer. The mechanism shall swiftly and positively open and close the associated interrupter switch independent of the speed of the manual charging handle. For opening operation only, the mechanism shall store sufficient mechanical energy to open the associated interrupter switch.

- (b) Switch operators shall be equipped with a tripping solenoid to release the stored energy and open the associated interrupter switch in response to a control signal. Total operating time for opening shall not exceed 4 cycles from the time the opening solenoid is energized.
- (c) Switch operators shall be provided with a removable manual-operating handle to allow closing of the associated interrupter switch following each opening operation and to allow charging of the quick-make quick-break mechanism for each opening operation. Following a closing operation, the manual charging handle shall not be removable from the switch operator until after the quick-make quick-break mechanism has been charged for the next opening operation to guard against operating personnel leaving the switch operator in the discharged condition.
- (d) Switch operators shall be non-drawout and shall be integrally mounted in the switchgear stile. No internal access to a high-voltage compartment shall be required to operate the switch operator.
- (e) Switch operators shall be equipped with a manual trip lever to allow mechanical manual Trip Open operation.
- (f) Switch operators shall be equipped with targets to indicate whether the associated interrupter switch is in the Open or Closed position.
- (g) Switch operators shall be provided with a hinged padlockable steel cover or door to protect the switch operator and to guard against tampering. The cover or door shall be equipped with a window (unless Category A enclosures are required) to allow observation of the switch operator targets. Gasketing shall be installed between the cover or door and the mounting surfaces.

The following optional features should be specified as required:

- (h) Switch operators shall be equipped with an extra 6-PDT auxiliary switch coupled to the interrupter switch.
- (i) Switch operators shall be equipped with an auxiliary tripping relay for remote supervisory operation.

4.5.3 The following requirements apply to switch operators that provide direct motor drive—for use with interrupter switches having an integral quick-make quick-break mechanism and having switch blades with opening cams and rated 4.16 kV and 13.8 kV nominal, 600 and 1200 amperes load interrupting; 25 kV nominal, 600 amperes load interrupting; and 34.5 kV nominal, 600 amperes load interrupting or 900 amperes load interrupting (1200 amperes continuous):

- (a) Switch operators shall be chain-coupled to the associated interrupter-switch operating shaft and shall open and close the interrupter switch by charging the quick-make quick-break mechanism integrally mounted on the interrupter-switch frame.
- (b) Switch operators shall be equipped with a torque limiter to absorb deceleration forces when travel limits are reached and to allow the switch operator to positively

drive the associated interrupter switch fully open or fully closed without transmitting excessive torque to the interrupter-switch operating shaft.

- (c) Switch operators shall have a total operating time for opening or closing the associated interrupter switch that does not exceed 1-1/2 seconds from the time the motor is energized.
- (d) Push buttons shall be provided to permit local electrical Trip Open and Trip Closed operation. Local electrical operation shall be prevented when the source-transfer control is in Automatic mode.
- (e) Switch operators shall be provided with a manual-operating shaft and a removable manual-operating handle to allow manual operation of the associated interrupter switch in the absence of control power. When the manual-operating handle and shaft are engaged, the motor control circuit shall be disconnected to prevent energization of the switch operator motor during manual operation.
- (f) Switch operators shall be mounted in a grounded, metal-enclosed low-voltage compartment in the switchgear stile. The metal-enclosed compartment shall provide isolation from high voltage.
- (g) Switch operators shall be equipped with a Decoupling feature to permit testing and exercising of the switch operator without opening or closing the associated interrupter switch and without exposure to high voltage. It shall not be possible to recouple the switch operator to the interrupter switch unless the switch operator is in the same position as the interrupter switch.
- (h) Switch operators shall be equipped with targets to indicate whether the associated interrupter switch is in the Open or Closed position, and whether the switch operator is in the Coupled or Decoupled position.
- (i) Switch operators shall be equipped with an Operation counter.
- (j) Switch operators shall be provided with a hinged padlockable steel cover or door to protect the switch operators and to guard against tampering. The cover or door shall be equipped with windows (unless Category A enclosures are required) to allow observation of the switch operator targets. Gasketing shall be provided between the cover or door and the mounting surfaces.

The following optional features should be specified as required:

- (k) Switch operators shall be equipped with an extra 4-PDT auxiliary switch coupled to the switch operator.
- (l) Switch operators shall be equipped with an extra 6-PDT auxiliary switch coupled to the interrupter switch.
- (m) A receptacle shall be provided for attachment of a remote-control station to allow electrical Trip Open and Trip Closed operation from an adjacent area.

4.6 Source-Transfer Controls

4.6.1 Operating Description *(Select one of the two operating descriptions.)*

4.6.1.1 Common-Bus Primary-Selective System

- (a) Transfer on Loss and Return of Source Voltage
 - (01) The source-transfer control shall use the common-bus primary-selective system. The normal condition shall be with one source interrupter switch

(for the preferred source, as field-programmed) closed to energize the high-voltage bus, and with the other source interrupter switch (for the alternate source) open with its associated circuit available as a standby.

- (02) The control shall monitor the conditions of both power sources and initiate automatic switching when the preferred-source voltage has been lost (or reduced to a predetermined level) for a period of time sufficient to confirm that the loss is not transient. The automatic switching shall open the preferred-source interrupter switch and then close the alternate-source interrupter switch to restore power to the high-voltage bus.
 - (03) When normal voltage returns to the preferred source for a preset time, the control shall initiate retransfer to the preferred source if in the Automatic Return mode, or await manual retransfer if in the Hold Return mode. In the Hold Return mode, if the alternate source fails and if the preferred source has been restored, the control shall initiate automatic retransfer to the preferred source.
 - (04) In the Automatic Return mode, the control shall provide either open transition (nonparalleling) or closed transition (paralleling) on retransfer as field-programmed.
- (b) Transfer on Unbalance Condition
- (01) A field-programmable Unbalance Detection feature shall initiate automatic switching on detection of source-side open-phase conditions at the same voltage level as the metal-enclosed switchgear, whether caused by utility-line burndown, broken conductors, single-phase switching, equipment malfunctions, or single-phasing resulting from blown source-side fuses. The control shall continuously develop and monitor the negative-sequence voltage to detect any unbalance present as a result of an Open Phase condition. Automatic switching shall occur when the system unbalance exceeds a predetermined unbalance-detect voltage for a period of time sufficient to confirm that the condition is not transient.
 - (02) When normal phase voltages return to the preferred source, the control shall initiate retransfer to the preferred source as described in 4.6.1.1(a) (03) and (04).

4.6.1.2 Split-Bus Primary-Selective System

- (a) Transfer on Loss and Return of Source Voltage
- (01) The source-transfer control shall use the split-bus primary-selective system. The normal condition shall be with the two source interrupter switches closed and with the bus-tie interrupter switch open so each section of high-voltage bus is energized by its associated, separate source.

The control shall monitor the conditions of both power sources and shall initiate automatic switching when voltage has been lost (or reduced to a predetermined level) on either source for a period of time sufficient to confirm that the loss is not transient. The automatic switching shall open the interrupter switch associated with the affected source and then close the bus-tie interrupter switch to restore power to the affected section of the high-voltage bus.
 - (02) When normal voltage returns to the affected source for a preset time,

the control shall initiate retransfer to the original configuration if in the Automatic Return mode, or await manual retransfer if in the Hold Return mode. In the Hold Return mode, if the source in use fails and if voltage to the other source has been restored, the control shall initiate automatic retransfer to the restored source.

- (03) In the Automatic Return mode, the control shall provide either open transition (nonparalleling) or closed transition (paralleling) on retransfer as field-programmed.

(b) Transfer on Unbalance Condition

- (01) A field-programmable Unbalance Detection feature shall initiate automatic switching on detection of source-side open-phase conditions at the same voltage level as the metal-enclosed switchgear, whether caused by utility-line burndown, broken conductors, single-phase switching, equipment malfunctions, or single-phasing resulting from blown source-side fuses. The control shall continuously develop and monitor the negative-sequence voltage to detect any unbalance present as a result of an Open Phase condition. Automatic switching shall occur when the system unbalance exceeds a predetermined unbalance-detect voltage for a period of time sufficient to confirm that the condition is not transient.
- (02) When normal phase voltages return to the preferred source, the control shall initiate retransfer to the preferred source.

4.6.2 Control Features

- (a) The operating characteristics of the source-transfer control and its voltage-, current-, and time-related operating parameters shall be field-programmable and entered into the control by means of a keypad. To simplify entry of this information, a menu arrangement shall be used including keys dedicated to the operating characteristics and to each of the operating parameters. Entry of an access code shall be necessary before any operating characteristic or operating parameter can be changed.
- (b) All operating characteristics and operating parameters shall be available for review on a liquid-crystal display with backlighting.
- (c) Light-emitting diode lamps shall be furnished for indicating the presence of acceptable voltage on each high-voltage source.
- (d) A light-emitting diode lamp shall be furnished for indicating that all switch operators are coupled to their respective interrupter switches and in the correct positions, the control is in Automatic mode, all doors providing access to interrupter switches powered by stored-energy switch operators are closed and latched, and all control circuitry is properly connected for automatic transfer. The display specified in 4.6.2 (b), when not being used to show menu information, shall show messages explaining why this lamp is not lighted.
- (e) A selector switch shall be furnished for choosing Manual or Automatic operating mode. In Manual mode, local electrical trip-open and trip-closed operation by means of pushbuttons shall be enabled while automatic switching shall be inhibited.
- (f) Test keys shall be furnished for simulating loss of voltage on each of the two sources as well as for checking the functioning of the lamps, display, and keypad.

- (g) The control shall automatically record system status and source-transfer control status every time a control operation occurs for use in analyzing system events. All such operations shall be indicated by the illumination of a light-emitting diode lamp and shall be available for display by means of a dedicated event key.
- (h) The present source voltage and current inputs and the present status of discrete inputs to and outputs from the control shall be available for display by means of a dedicated examine key.
- (i) The control shall have the capability to automatically calibrate to a known voltage on each source. This capability shall be keypad-selectable.

The following optional features should be specified as required:

- (j) An Overcurrent Lockout feature shall be provided to prevent an automatic transfer operation that would close a source interrupter switch into a fault. The feature shall include a light-emitting diode lamp for indicating when a Lockout condition has occurred, a reset key for manually resetting the Lockout condition, and three current sensors for each source. Provisions shall be furnished for manually resetting the Overcurrent Lockout feature from a remote location. Test keys shall be provided for simulating an Overcurrent condition on each source.

Note: When the entrance bays do not have main fuses, the source-transfer control uses the current sensing and voltage sensing on the source side of the main switch to determine lockout is required. When the entrance bays have main fuses, additional voltage sensing is required on the main bus to detect the operation of a main fuse so the transfer control will go into Lockout mode if the utility line successfully recloses.

- (k) Remote-indication provisions shall be provided to permit remote monitoring of the presence or absence of preferred- and alternate-source voltage; the operating mode of the source-transfer control (i.e., Automatic or Manual); and the status of the indicating lamp furnished in 4.6.2 (d), the indicating lamp furnished in 4.6.2(g), and (where applicable) overcurrent lockout.
- (l) A test panel shall be provided to permit the use of an external, adjustable three-phase source to verify, through independent measurement, the response of the control to Loss of Source, Phase Unbalance, and (where applicable) Overcurrent-Lockout conditions.
- (m) Supervisory control provisions shall be provided to permit switch operation from a remote location.
- (n) A communications card shall be provided to permit local loading to a user-furnished personal computer of system events recorded by the source-transfer control; operating characteristics and voltage-, current-, and time-related operating parameters programmed in the control; discrete inputs and outputs from the control; and messages explaining why the indicating lamp furnished in 4.6.2(d) is not lighted. The communications card shall also permit local downloading of the user's standard operating parameters from the personal computer to the control.

4.6.3 Construction Features

- (a) The source-transfer control shall use an advanced microprocessor and other solid-state electronic components to provide the superior reliability and serviceability required for use in power equipment. All components shall be soldered on printed-circuit boards to minimize the number of interconnections for increased reliability.

- (b) All interconnecting-cable connector pins and receptacle contacts shall be gold-over-nickel plated to minimize contact pressure.
- (c) The surge withstand capability of the control shall be verified by subjecting the device to both the ANSI/IEEE Surge Withstand Capability Test (ANSI Standard C37.90.1) and to:
 - (01) ANSI Standard C62.41 Category B Power Line Surge (*for switchgear installed in the United States*)
 - (02) CSA C233.1 (*for switchgear installed in Canada*)
- (d) To identify and eliminate components that might be prone to early failure, the control shall be subjected to a dielectric test, a functional check, and a 48-hour screening test followed by a second functional check. For the screening test, the control shall be energized at rated control voltage while subjected to 48 hours of temperature cycling repeatedly between -40°C (-40°F) and 65°C (149°F).
- (e) The control shall be located in a grounded, metal-enclosed low-voltage compartment in the switchgear stile and shall be mounted on a drawout carriage. The metal-enclosed compartment shall provide isolation from high voltage.
- (f) For source-transfer control connections not soldered directly to the printed-circuit board, all interconnecting-cable connector pins and receptacle contacts shall be gold-over-nickel plated to minimize contact resistance.
- (g) Source-transfer controls shall be provided with a hinged padlockable steel cover or door to protect the control and to guard against tampering. The cover or door shall be equipped with a window (unless Category A enclosures are required) to allow observation of the status indicator on the control. Gasketing shall be installed between the cover or door and the mounting surfaces.

4.7 Single-Phasing Protection

- 4.7.1 Open-Phase Detection on Grounded Systems with Electronic Phasor Summing—Power-Operated Feeders
 - (a) Open-phase detectors shall be provided for power-operated feeders to protect three-phase loads from load-side Open Phase conditions (such as single-phasing resulting from blown feeder fuses) occurring on downstream circuits energized at the same voltage as the metal-enclosed switchgear. Also, open-phase detectors shall protect three-phase loads from source-side Open Phase conditions (such as those caused by utility-line burndown, broken conductors, single-phase switching, equipment malfunctions, or single-phasing resulting from blown source-side fuses) occurring on upstream circuits energized at the same voltage level as the metal-enclosed switchgear.
 - (b) Open-phase detectors shall use proven solid-state electronic construction to continuously monitor the phasor sum of the three-phase feeder's line-to-ground voltages to determine the degree of unbalance. The open-phase detector shall be able to detect all Open Phase conditions and shall not be defeated by backfeed.
 - (c) Open-phase detectors shall not be affected by circuit load levels and shall not require close coordination with the feeder fuses.
 - (d) Open-phase detectors shall provide for field adjustment of the voltage-unbalance level necessary to initiate a switching operation.

- (e) Open-phase detectors shall be equipped with a field-adjustable 5- to 30-second timer, providing a time delay after detection of an Open Phase condition or voltage unbalance to eliminate response to transient disturbances and allow coordination with source-side protective devices.
 - (f) Open-phase detectors shall be located in a grounded, metal-enclosed low-voltage compartment in the switchgear stile. The metal-enclosed compartment shall provide isolation from high voltage and shall permit ready access to the open-phase detector for testing and adjustment.
 - (g) The surge withstand capability of open-phase detectors shall be verified by subjecting each device to both the ANSI/IEEE Surge Withstand Capability Test (ANSI Standard C37.90.1) and to:
 - (01) ANSI Standard C62.41 Category B Power Line Surge (*for switchgear installed in the United States*)
 - (02) CSA C233.1 (*for switchgear installed in Canada*)
 - (h) All electronic components shall be mounted on a single printed-circuit board to minimize the number of interconnections for increased reliability.
 - (i) To identify and eliminate components that might be prone to early failure, all open-phase detectors shall be subjected to a dielectric test, a functional check, and a 48-hour screening test followed by a second functional test. For the screening test, the open-phase detector shall be energized at rated control voltage while subjected to 48 hours of temperature cycling repeatedly between -40°C (-40°F) and 65°C (149°F).
 - (j) Open-phase detectors shall be equipped with a TRIP indicator and a RESET push button. The indicator target shall appear when a Trip operation has occurred and shall continue to be visible until manually reset.
- 4.7.2 Single-Phasing Protection on Ungrounded and Grounded Systems with a Specialty Current Detection Relay—Power-Operated Feeders
- (a) Specialty relays shall be provided for power-operated feeders to protect three-phase loads from Single Phasing conditions. The specialty relay shall trip the associated switch operator after a downstream fault has been cleared by the feeder fuse(s) or the source-side protective device.
 - (b) Specialty relays shall employ proven solid-state electronic components and shall continuously monitor the current in each phase of the feeder circuit. Specialty relays shall be capable of distinguishing between transformer inrush current and fault current and produce a trip signal only on fault currents.
 - (c) Specialty relays shall:
 - (01) Use closed-gap current sensors to sense the current in each phase of the feeder circuit.
 - (02) Include a TRIP indicator that displays a red target when the relay has operated. A pushbutton shall be provided to reset the TRIP indicator.
 - (03) Provide for field adjustment of the trip-level detector setting over the range 400 to 2400 amperes. This setting shall determine the level of phase current above which the relay is to respond.
 - (04) Include a PICKUP indicator lamp that illuminates when an overcurrent that

exceeds the trip-level setting has been detected. The lamp shall extinguish after the relay has operated and shall have a Push to Test feature.

- (05) Include a field-adjustable delay timer for selecting the duration between detection of an overcurrent and initiation of a tripping operation as a means to confirm whether the overcurrent is momentary or permanent. The timer range shall be from 1 to 35 seconds.
- (06) Use, on detection of an overcurrent, a two-millisecond time delay before starting the field-adjustable 1- to 35-second tripping circuit timer to eliminate response to transient disturbances.
- (07) Include a field-selectable Inrush Restraint feature that shall inhibit relay response to overcurrents occurring during initial energization or during reclosing of a source-side protective device. The Inrush Restraint feature shall delay, for one second, the starting of the two-millisecond time relay.
- (08) Include an elapsed-time indicator lamp that illuminates when the delay timer times out. The lamp shall extinguish after the relay has operated and shall have a Push to Test feature.
- (09) Reset if normal load current of 3.5 amperes or greater returns on all three phases before the delay timer times out.
- (10) Include test jacks to simulate proper functioning of the three-phase over-current relay in response to transformer inrush currents and fault currents and to permit verification of the pickup and trip levels as well as the trip-current timer setting. (These test jacks shall also permit verification of the proper functioning of the current sensors.)
- (11) Use a blocking circuit to prevent tripping of the switch operator while the overcurrent exceeds 600 amperes.
- (12) Mount in a grounded, metal-enclosed low-voltage compartment in the switch-gear stile. (The metal-enclosed compartment shall provide complete isolation from high voltage.)
- (d) The surge-withstand capability of all overcurrent relays shall be verified by subjecting each device to both the ANSI/IEEE Surge Withstand Capability Test (ANSI Standard C37.90.1) and to :
 - (01) ANSI Standard C62.41 Category B Power Line Surge (*for switchgear installed in the United States*)
 - (02) CSA C233.1 (*for switchgear installed in Canada*)
- (e) Specialty relays shall use printed-circuit-board construction.
- (f) To ensure the high quality and reliability of the electronic components, all specialty relays shall be subjected to a dielectric test, a functional check, and a 48-hour screening test followed by a second functional test. For the screening test, the specialty relay shall be energized at rated control voltage while subjected to 48 hours of temperature cycling repeatedly between -40°C (-40°F) and 65°C (149°F).

4.8 Voltage-Sensing Devices

- (a) Voltage-sensing devices for use with open-phase detectors shall be capacitively coupled voltage sensors on three phases. Voltage-sensing devices for use with source-transfer controls shall be capacitively coupled voltage sensors on two

phases and a voltage transformer for sensing and control power on the third phase.●

- (b) To maximize usable cable-training space within the switchgear assembly, the voltage sensors shall directly replace apparatus insulators at the hinge end of fuses or the lower terminal of interrupter switches. Separate mounting shall be permitted for special applications.
- (c) Voltage sensors shall be constant-current-output devices that do not require primary fuses.
- (d) The output voltage of the voltage sensors shall be directly proportional to line-to-ground voltage and shall have relay accuracy over an ambient temperature range of -40°C (-40°F) and 71°C (160°F).
- (e) The output of the voltage sensors shall be connected to a secondary burden that does not require adjustment to compensate for a difference between system line-to-ground voltage and the sensor's rated nominal line-to-ground voltage.
- (f) Test jacks and adjustment screws shall be provided, allowing measurement and adjustment of the voltage-sensor signal inputs.
- (g) Each voltage sensor shall be equipped with a secondary-side protective device to prevent damage to the voltage sensor in the event that the secondary circuit is inadvertently opened or the burden is removed.

5.0 METERING BAY (*select if applicable*)

5.1 Utility metering bay (*select if applicable*)

- (a) Provide (*select one: 2 or 3*) voltage transformers connected (*select one: phase-to-phase or phase-to-ground*) in accordance with utility requirements.
- (b) Provide (*select one: 2 or 3*) current transformers in accordance with utility requirements.
- (c) Provide meter(s) in accordance with utility specifications
- (d) Provide design of the metering bay in accordance with utility specifications.

5.2 Power user metering bay (*select if applicable*)

- (a) (1) Provide (*select one: 2 or 3*) voltage transformers connected (*select one: phase-to-phase or phase-to-ground*) in accordance with owner's requirements.
- (b) (2) Provide meter(s) in accordance with owner's specifications
- (c) (3) Provide (*select one: 2 or 3*) current transformers in accordance with owner's specifications.

6.0 LABELING

6.1 Hazard-Alerting Signs

- (a) All external doors and hinged bolted panels providing access to high voltage shall be provided with "Caution—High Voltage—Keep Out" signs.
- (b) All internal protective screens providing access to high voltage shall be provided with "Danger—High Voltage—Keep Out—Qualified Persons Only" signs.
- (c) All internal protective screens providing access to interrupter switches shall be provided with warning signs indicating that "Switch Blades May Be Energized in Any Position."

● For switchgear rated 34.5 kV nominal, three voltage transformers or potential devices shall be used.

- (d) All internal protective screens providing access to fuses shall be provided with warning signs indicating that “Fuses May Be Energized in Any Position.”

6.2 Ratings Nameplates and Labeling

- (a) The integrated switchgear assembly shall be provided with an external nameplate indicating the manufacturer’s drawing number and the following: voltage ratings (kV, nominal; kV, maximum; kV, BIL); main bus continuous current rating (amperes); short-circuit ratings (amperes, RMS, symmetrical and MVA, three-phase symmetrical, at rated nominal voltage); and the momentary and fault-closing ratings (amperes, RMS, asymmetrical). If the assembly is UL listed, the external nameplate shall include the UL classification markings, comprised of “UL” in a circle; the word “Listed;” the assigned control number; and the product identity. If the assembly is CSA listed, the external nameplate shall include the CSA certification markings consisting of a stylized “C” with the letters “SA” inside.
- (b) Each individual bay shall bear a nameplate indicating the ratings of the interrupter switch (amperes, continuous and interrupting); the maximum rating of the fuse (amperes); and the catalog number of the fuse units, refill units, or interrupting modules and control modules. If the individual bay is UL listed, this nameplate shall include the UL classification markings, comprised of “UL” in a circle; the word “Listed;” the assigned control number; and the product identity. In addition, the enclosure category shall be specified. If the assembly is CSA listed, the external nameplate shall include the CSA certification markings consisting of a stylized “C” with the letters “SA” inside.

The following optional features should be specified as required:

- (c) A weather-resistant one-line representation of the contents of each bay or “mimic bus” shall be applied to the exterior of the bay doors.

7.0 ACCESSORIES (*Specify as required.*)

- 7.1 Fuse units, refill units, voltage-transformer fuses, interrupting modules, and control modules shall be provided, as required, for original installation and for spares.
- 7.2 A fuse handling tool and universal pole as recommended by the fuse manufacturer shall be provided.
- 7.3 A total of _____ set(s) of three grounding jumpers [8 feet (244 cm) or 10 feet (305 cm)] in length shall be provided, complete with a storage bag for each set.
- 7.4 A voltage tester with audio-visual signal capability shall be provided, complete with batteries, shotgun clamp-stick adapter, and storage case.
- 7.5 A shotgun clamp stick [6 feet-5½-inches (197 cm) or 8 feet-5½-inches (258 cm)] in length shall be provided, complete with canvas storage bag.
- 7.6 A portable remote-control station with 50-foot (1524-cm) cord shall be provided for power-operated switchgear, to permit Open/Close operations of power-operated switches from an adjacent location.
- 7.7 A test accessory shall be provided for power-operated switchgear to permit preliminary checkout of the source-transfer system using a separate single-phase control source before medium voltage is connected to the switchgear.

8.0 ANALYTICAL SERVICES

The following analytical services should be specified as required:

8.1 Short-Circuit Analysis

- (a) The manufacturer shall provide a short-circuit analysis to determine the currents flowing in the electrical system under faulted conditions. Because expansion of an electrical system can result in increased available short-circuit current, the momentary and interrupting ratings of new and existing equipment on the system shall be checked to determine whether the equipment can withstand the short-circuit energy. Fault contributions from utility sources, motors, and generators shall be taken into consideration. If applicable, results of the analysis shall be used to coordinate overcurrent protective devices and prepare an arc-flash hazard analysis of the system.
- (b) Data used in the short-circuit analysis shall be presented in tabular format and shall include the following information:
 - (01) Equipment identifications
 - (02) Equipment ratings
 - (03) Protective devices
 - (04) Operating voltages
 - (05) Calculated short-circuit currents
 - (06) X/R ratios
- (c) A single-line diagram model of the system shall be prepared and shall include the following information:
 - (01) Identification of each bus
 - (02) Voltage at each bus
 - (03) Maximum available fault current, in kA symmetrical, on the utility source side of the incoming feeder or first upstream device
 - (04) Data for each transformer
 - (i) Three-phase kVA rating
 - (ii) Percent impedance
 - (iii) Temperature rise, 65 °C and 55/65 °C (149°F and 131/149°F)
 - (iv) Primary voltage
 - (v) Primary connection
 - (vi) Secondary voltage
 - (vii) Secondary connection
 - (viii) X/R ratio
 - (ix) Tap settings and available settings
- (d) The manufacturer shall use commercially available PC-based computer software such as Power System Analysis Framework (PSAF – Fault) from CYME International, CYMDIST, and/or SKM Power Tools® for Windows with the PTW Dapper

Module to calculate three-phase, phase-to-phase, and phase-to-ground fault currents at relevant locations in the electrical system, in accordance with ANSI Standards C37.010, C37.5, and C37.13. If applicable, an ANSI closing-and-latching duty analysis shall also be performed to calculate the maximum currents following fault inception.

8.2 Overcurrent Protective Device Coordination Analysis

- (a) The manufacturer shall provide an overcurrent protective device coordination analysis to verify electrical equipment is protected against damage from short-circuit currents. Analysis results shall be used to select appropriately rated protective devices and settings that minimize the impact of short-circuits in the electrical system by isolating faults as quickly as possible while maintaining power to the rest of the system.
- (b) As applicable, the analysis shall take into account pre-load and ambient-temperature adjustments to fuse minimum-melting curves, transformer magnetizing-inrush current, full-load current, hot-load and cold-load pick-up, coordination time intervals for series-connected protective devices, and the type of reclosers and their reclosing sequences.
Locked-rotor motor starting curves and thermal and mechanical damage curves shall be plotted with the protective-device TCC curves, as applicable.
- (c) Differing per-unit fault currents on the primary and secondary sides of transformers (attributable to winding connections) shall be taken into consideration in determining the required ratings or settings of the protective devices.
- (d) The time separation between series-connected protective devices, including the upstream (source-side) device and largest downstream (load-side) device, shall be graphically illustrated on log-log paper of standard size. The time-current characteristics of each protective device shall be plotted such that all upstream devices shall be clearly depicted on one sheet.
- (e) The manufacturer shall furnish coordination curves indicating the required ratings or settings of protective devices to demonstrate, to the extent possible, selective coordination. The following information shall be presented on each coordination curve, as applicable:
 - (01) Device identifications
 - (02) Voltage and current ratios
 - (03) Transformer through-fault withstand duration curves
 - (04) Minimum-melting, adjusted, and total-clearing fuse curves
 - (05) Cable damage curves
 - (06) Transformer inrush points
 - (07) Maximum available fault current, in kA symmetrical, on the utility source side of the incoming feeder or first upstream device
 - (08) Single-line diagram of the feeder branch under study
 - (09) A table summarizing the ratings or settings of the protective devices, including:
 - (i) Device identification

- (ii) Relay current-transformer ratios, and tap, time-dial, and instantaneous-pickup settings
 - (iii) Circuit-breaker sensor ratings; long-time, short-time, and instantaneous settings; and time bands
 - (iv) Fuse type and rating
 - (v) Ground fault pickup and time delay
- (f) The manufacturer shall use commercially available PC-based computer software such as CYMTCC from CYME International and/or SKM Captor to create the TCC curves for all protective devices on each feeder.
- (g) As applicable, a technical evaluation shall be prepared for areas of the electrical system with inadequate overcurrent protective device coordination, with recommendations for improving coordination.

8.3 Arc-Flash Hazard Analysis

- (a) The manufacturer shall provide an arc-flash hazard analysis to verify electrical equipment on the system is “electrically safe” for personnel to work on while energized. An arc flash is a flashover of electric current in air from one phase conductor to another phase conductor, or from one phase conductor to ground that can heat the air to 5,000°F (2,760°C). It can vaporize metal and cause severe burns to unprotected workers from direct heat exposure and ignition of improper clothing. And the arc blast resulting from release of the concentrated radiant energy can damage hearing and knock down personnel, causing trauma injuries.
- (b) The arc-flash hazard analysis shall include the following:
 - (01) Identification of equipment locations where an arc-flash hazard analysis is required
 - (02) Collection of pertinent data at each equipment location, including:
 - (i) Transformer kVA ratings, including voltage, current, percent impedance, winding ratio, and X/R ratio, plus wiring connections
 - (ii) Protective device ratings, including current, TCCs, settings, and time delays
 - (iii) Switchgear data, including conductor phase spacing, type of grounding, and appropriate working distances
 - (03) Preparation of a single-line diagram model of the system
 - (04) Preparation of a short-circuit study to determine the three-phase bolted fault current at each location
 - (05) Preparation of arc-flash calculations in accordance with NFPA 70E and IEEE 1584, including:
 - (i) Calculation of arc current in accordance with applicable guidelines
 - (ii) Determination of protective device total-clearing times based upon the TCCs
 - (iii) Calculation of arc-flash incident energy level based on the protective device total-clearing times and appropriate working distance
 - (06) Determination of appropriate personal protective equipment in accordance with risk levels defined in NFPA 70E

- (07) Calculation of the arc-flash protection boundary distance
- (08) Documentation of the results of the analysis, including:
 - (iv) Preparation of a written report
 - (v) Preparation of single-line diagrams
 - (vi) Preparation of arc-flash hazard labels to be affixed to the equipment
- (09) The manufacturer shall use commercially available PC-based computer software such as the arc-flash module in SKM Power Tools® for Windows to calculate the incident energy category levels, in accordance with IEEE 1584

8.4 Analytical Service Site Visits

- (a) The manufacturer shall perform a site walk-down to gather:
 - (01) Transformer ratings, including voltage, current, power, percent impedance, winding ratio, and X/R ratio, plus wiring connections
 - (02) Protective device ratings, including current, time-current characteristics, settings, and time delays
 - (03) Switchgear data, including conductor phase spacing, type of grounding, and appropriate working distances