Section 16311 Underground Distribution Switchgear 15 kV Class

Note: Maintenance personnel shall seek Engineering assistance in applying this specification to the procurement and installation of this equipment.

Note: Consultants shall review this specification and revise it in accordance with good engineering practice and scope of the application.

Part: 1 GENERAL

1.1 The switchgear shall be in accordance with the single-line diagram, and shall conform to the following specification.

1.2 The switchgear shall consist of a gas-tight tank containing SF6 gas, load-interrupter switches and resettable fault interrupters with visible open gaps and integral visible grounds, and a microprocessor-based overcurrent control. Load-interrupter switch terminals shall be equipped with bushings rated 600 amperes continuous, and fault-interrupter terminals shall be equipped with bushing wells rated 200 amperes continuous or bushings rated 600 amperes continuous (as specified) to provide for elbow connection. Manual operating mechanisms and viewing windows shall be located on the opposite side of the tank from the bushings and bushing wells, so that operating personnel shall not be required to perform any routine operations in close proximity to high-voltage elbows and cables.

1.3 Ratings

The ANSI ratings for the integrated switchgear shall be as designated below.

Frequency, Hz	60
Short-Circuit Current	
Amperes, RMS, Symmetrical	25 KA
Voltage Class, kV	15.5
Maximum Voltage, kV	15.5
BIL Voltage, kV	95
Main Bus Continuous Current, Amperes	600
Three-Pole Load-Interrupter Switches	
Continuous Current, Amperes	600
Load Dropping Current, Amperes	600
Fault Closing Current, Duty-Cycle	
Three-Time, Amperes, RMS, Symmetrical	25,000
Three-Time, Amperes, Peak	65,000
Ten-Time, Amperes, RMS, Symmetrical	16,000
Ten-Time, Amperes, Peak	41,600
Fault Interrupters	
Continuous Current, Amperes	600
Load Dropping Current, Amperes	600
Fault Interrupting Current, Duty-Cycle	
Three-Time, Amperes, RMS Symmetrical	25,000
Ten-Time, Amperes, RMS, Symmetrical	25,000
Fault Closing Current, Duty-Cycle	
Three-Time, Amperes, RMS, Symmetrical	25,000
Three-Time, Amperes, Peak	65,000
Ten-Time, Amperes, RMS, Symmetrical	16,000
Ten-Time, Amperes, Peak	41,600

Note: Ratings with respect to this gear is based on the fault current available to the system as of October 1, 2009. Fault current analysis shall be necessary to verify these rating and/or increase them.

1.4 Certification of Ratings

- The manufacturer of the switchgear shall be completely and solely responsible for the performance of the load-interrupter switch and fault interrupter as well as the complete integrated assembly as rated.
- The manufacturer shall furnish, upon request, certification of ratings of the load-interrupted, and the integrated switchgear assemble consisting of switches an default interrupters in combination with the gas-tight tank.

1.5 Compliance with Standards and Codes

The switch gear shall conform to or exceed the applicable requirements of the following standards and codes:

- The applicable portions of ANSI C57.12.28 covering enclosure integrity for pad-mounted equipment.
- The applicable portions of ANSI C37.71, ANSI C37.72, ANSI C37.73, IEC 56 and IEC 265-1 (Class A), which specify test procedures and sequences for the load-interrupters switches, fault interrupters, and the complete switchgear assembly.

2.0 CONSTRUCTION

2.1 SF6- Gas Insulation

- The SR6 gas shall conform to ASTM D2472.
- The switchgear shall be filled with SF6 gas to pressure of 7 psig at 68° F.
- The gas-tight tank shall be evacuated prior to filling with SF6 gas to minimize moisture in the tank.
- The switchgear shall withstand system voltage at a gas pressure of o psig at 68° F.
- A gas-fill valve shall be provided.
- A temperature-compensated pressure gauge shall be provided that is color coded to show the operating range. The gauge shall be mounted inside the gas-tight tank (visible through a large viewing window) to provide consistent pressure readings regardless of the temperature or altitude at the installation site.

2.2 Gas-Tight Tank

- The tank shall be submersible and able to withstand up to 10 feet of water over the base.
- The tank shall be of welded construction and shall be made of 7-gauge mild steel or Type 304L stainless, as specified in Section 4.0.
- A means of lifting the tank shall be provided.

2.3 Gas-tight Tank Finish (for mild steel only)

- To remove oils and dirt, to form a chemical and anodically neutral conversion coating to improve the finish-to-metal bond, and to retard underfilm propagation of corrosion, mild-steel 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 mild-steel surfaces of the gas-tight tank shall receive a highly consistent thorough treatment, eliminating fluctuations in reaction time, reaction temperature, and chemical concentrations.

- After pretreatment, protective coatings shall be applied that shall help resist corrosion and protect the mild-steel surfaces of the gas-tight tank. To establish the capability to resist corrosion and protect the mild steel, representative test specimens coated by the manufacturer's finishing system shall satisfactorily pass the following tests:
    - 1500 hours of exposure to salt-spray testing per ASTM B 117 with:
        - Underfilm corrosion not to extend more than 1/32 in. from the scribe, as evaluated per ASTM D 1645, Procedure A, Method 2 (scraping);and
            - Loss of adhesion from bare metal not to extend more than 1/8 in. from the scribe.
    - 1000 hours of humidity testing per ASTM D 4585 using the Cleveland Condensing Type Humidity Cabinet, with no blistering as evaluated per ASTM D 714.
    - Crosshatch-adhesion testing per ASTM D 3359 Method B, with no loss of finish. Certified test abstracts substantiating the above capabilities shall be furnished upon request.
    - The finish shall be inspected for scuffs and scratches. Blemishes shall be touched up by hand to restore the protective integrity of the finish.
    - The finish shall be indoor light gray, satisfying the requirements of ANSI Standard Z55.1 for No. 61.

2.4 Viewing Windows

- Each load-interrupter switch shall be provided with a large viewing window at least 6 inches to allow visual verification of the switch-blade position (closed, open, and grounded) while shining a flashlight on the blades.
- Each fault interrupter shall be provided with a large viewing widow at least 6 inches by 12 inches to allow visual verification of the disconnect-blade position (closed, open and grounded) while shining a flashlight on the blades.
- Viewing windows shall be located on the opposite side of the gear from the bushings and bushing wells so that operating personnel shall not be required to perform any routine operations in close proximity to high-voltage elbows and cables.
- A cover shall be provided for each viewing window to prevent operating personnel from viewing the flash which may occur during switching operations.

2.5 High-Voltage Bus

- Bus and interconnections shall withstand the stresses associated with short-circuit currents up through the maximum rating of the switchgear.
- Before installation of aluminum bus, all electrical contact surfaces shall first be pre-paid by machine-abrading to remove any oxide film. Immediately after this operation, the electrical contact surfaces shall be coated with a uniform coating of an oxide inhibitor and sealant.

2.6 Provisions for Grounding

- One ground-connection pad shall be provided on the gas-tight tank of the switchgear.
- The ground-connection pad shall be constructed of stainless steel and welded to the gas-tight tank, and shall have a short-circuit rating equal to that of the switchgear.
- When an enclosure is provided, no less than one enclosure ground pad shall be provided. The following optional feature should be specified as required:
- One ground-connection pad per way shall be provided.

2.7 Connections

- For gear rated 12.5kA short circuit, load-interrupter switches shall be equipped with 600-ampere bushings, and fault interrupters shall be equipped with 200-ampere bushing wells.
- For gear rated 25kA short circuit, load-interrupter switches and fault interrupters shall be equipped with 600-or 900-ampere bushings.
- Bushings and bushing wells shall be located on one side of the gear to reduce the required operating clearance. The following optional feature should be specified as required:
- Fault interrupters shall be equipped with 600-ampere bushings.
- Load interrupter switches shall be equipped with 200-ampere bushing wells.

2.8 Bushings and Bushing Wells

- Bushings and bushing wells shall conform to ANSI/IEEE Standard 386
- Bushings and bushing wells shall include a semiconductive coating.
- Bushings and bushing wells shall be mounted in such a way that the semiconductive coating is solidly grounded to the gastight tank.

3.0 BASIC COMPONENTS

- Load-Interrupter Switches
  - The three-phase, group-operated load-interrupter switches shall have a three-time and ten-time duty-cycle fault-closing rating as specified under “Ratings.” This rating defines the ability to close the switch the designated number of times against a three-phase fault with asymmetrical (peak) current in at least one phase equal to the rated value, with the switch remaining operable and able to carry and interrupt rated current. Certified test abstracts establishing such ratings shall be furnished up request.
  - The switch shall be provided with an integral ground position that is readily visible through the viewing window to eliminate the need for cable handling and exposure to high voltage to ground the equipment.
  - The ground position shall have a three-time and ten-time duty-cycle fault-closing rating.
  - The switch shall be provided with an open position that is readily visible through the viewing window to eliminate the need for cable handling and exposure to high voltage to establish a visible gap.
  - The open gaps of the switch shall be sized to allow cable testing through a feedthru bushing or the back of the elbow.

- Fault Interrupters
  - Fault interrupters hall have a three-time and ten-time duty-cycle fault-closing and fault interrupting rating as specified under “Ratings.” This rating defines the fault interrupter’s ability to close the designated number of times against a three-phase fault with asymmetrical (peak) current in at least one phase equal to the rated value and clear the resulting fault current, with the interrupter remaining operable and able to carry and interrupt rated current. Certified test abstracts establishing such ratings shall be furnished upon request.
  - The fault interrupter shall be provided with a disconnect with an integral ground position that is readily visible through the viewing window to eliminate the need for cable handling and exposure to high voltage to ground equipment.
  - The ground position shall have a three-time and ten-time duty-cycle fault-closing rating.
  - The disconnect shall be provided with an open position that is readily visible through the viewing window, eliminating the need for cable handling and exposure to high volt-age to establish a visible gap.
  - The fault interrupter, including its three-position disconnect, shall be a single integrated design so that operation between the closed and open positions or the open and grounded positions is accomplished with a single, intuitive movement.

- The open gaps of the disconnect shall be sized to allow cable testing through a feedthru bushing or the back of the elbow.
- An internal indicator shall be provided for each fault interrupter to show when it is in the tripped condition. The indicator shall be clearly visible through the viewing window.

- Operating Mechanisms
  - Load-interrupter switches and fault interrupters shall be operated by means of a quick-make, quick-break mechanism.
  - The manual handle shall charge the operating mechanism for closing, opening, and grounding of the switches and fault interrupters.
  - A single, integrated operating mechanism shall fully operate each fault interrupter or load interrupter switch in a continuous movement, so that additional operations are not required to establish open or grounded positions.
  - Operating mechanisms shall be equipped with an operation selector to prevent inadvertent operation from the closed position directly to the grounded position, or from the grounded position directly to the closed position. The operation selector shall require directly to the grounded position, or from the grounded position directly to the closed position. The operation selector shall require physical movement to the proper position to permit the next operation.
  - Operating shafts shall be padlockable in any position to prevent operation.
  - The operation selector shall be padlockable to prevent operation to the grounded position.
  - The operating mechanism shall indicate switch position which shall be clearly visible from the normal operating position.

- Overcurrent Control
  - A microprocessor-based overcurrent control shall be provided to initiate fault interruption.
  - For dry-vault-mounted style and pad-mounted style switchgear, the control shall be mounted in a watertight enclosure, for UnderCover style and wet-vault-mounted style switchgear, the control shall be mounted in a submersible enclosure. The control shall be removable in the field without taking the gear out to service.
  - Control settings shall be field programmable using a personal computer connected via a data port to the control. The data port shall be accessible from the exterior of the enclosure. Neither external power nor energization of the gear shall be required to set or alter control settings.
  - Power and sensing for the control shall be supplied by integral current transformers.
  - The minimum total clearing time (from initiation of the fault to total clearing) for fault interruption shall be 40 milliseconds (2.4 cycles) at 60 hertz or 44 milliseconds (2.2 cycles) at 50 hertz.
  - The control shall feature time-current characteristic (TCC) curves including standard E speed, K-speed, coordinating-speed tap, coordinating-speed main, and relay curves per IEEE C37.112-1996. Coordinating-speed tap curves shall optimize coordination with load-side weak-link/backup current-limiting fuse combinations, and coordinating-speed main curves shall optimize coordination with tap-interrupter curves and upstream feeder breakers.
  - The standard E-speed curve shall have phase-overcurrent settings ranging from 25E through 400E. The standard K-speed curve shall have phase-overcurrent settings ranging from 25k through 200K. The coordinating-speed tap curve shall have phase-overcurrent and independent ground-overcurrent settings ranging from 50 amperes through 400 amperes. The coordinating-speed main curve shall have phase-overcurrent settings ranging from 100 amperes through 800 amperes and independent ground-overcurrent settings ranging from 100 amperes through 400 amperes.
  - Time-current characteristic curves shall conform to the following IEEE C37, 112-1996 IEEE Standard Inverse-Time Characteristic equations for Overcurrent Relays: U.S. Moderately Inverse Curve U1, U.S. Inverse Curve U2, U.S. Very Inverse Curve U3, U.S. Extremely

Inverse Curve U4, U.S. Short-Time Inverse Curve U5, I.E.C. Class A Curve (Standard Inverse) C1, I.E.C. Class B Curve (Very Inverse) C2, I.E.C. Class C Curve (Extremely Inverse) C3, I.E.C. Long-time Inverse Curve C4, and I.E.C. Short-Time Inverse Curve C5.

- The control shall have field-adjustable instantaneous-trip setting (0.2 kA through 2 kA) and definite-time delay settings (32 ms through 96ms for coordinating-speed tap and 64ms through 128 ms for coordinating-speed main), to allow tailoring of the coordinating-speed tap and coordinating speed main curves to the application.
- Event records shall be easily extractable from the control using a personal computer connected to the data port.

- Optional Voltage Indication (Specify one of the following as required.)
  - Voltage Indication.
  - Voltage indication shall be provided for each load-interrupter switch and fault interrupter by means of capacitive taps on the bushings, eliminating the need for cable handling and exposure to high voltage to test the cables for voltage prior to grounding. This feature shall include a flashing liquid-crystal display to indicate the presence of voltage for each phase, and a solar panel to supply power for testing of the complete voltage-indication circuit.
  - The voltage-indication feature shall be mounted on the covers for the viewing windows, on the opposite side of the gear from the bushings and bushing wells, so that operating personnel shall not be require to perform any routine operations in close proximity to high-voltage elbows and cables.
  - Voltage indication with provisions for low-voltage phasing.
  - Voltage indication with provisions for low-voltage phasing shall be provided for each load-interrupter switch and fault interrupter by means of capacitive taps on the bushings, eliminating the need for cable handling and exposure to high voltage to test the cables for voltage and phasing. This feature shall include a flashing liquid-crystal display to indicate the presence of voltage for each phase, and a solar panel to supply power for testing of the complete voltage-indication circuit and phasing circuit.
  - The voltage-indication feature shall be mounted on the covers for the viewing windows, on the opposite side of the gear from the bushings and bushing wells, so that operating personnel shall not be required to perform any routine operations in close proximity to high-voltage elbows and cables.

4.0 Switchgear Style (Select UnderCover set-vault-mounted, dry-vault-mounted, or pad-mounted style)

- UnderCover Style
- The switchgear shall be suitable for subsurface installation.
- The switchgear shall be operable from grade level without exposure to high voltage.
- Operating personnel shall be able to verify the positions (closed, open, and grounded) of the load-interrupter switches and fault interrupters while standing.
- To guard against corrosion due to extremely harsh environmental conditions, the gas-tight tank shall be made of Type 304L stainless steel.
- The tank shall be designed for use in typical subsurface electrical manholes and vaults that are subject to occasional flooding to a maximum head of 10 ft. (3m) above the base of the tank. The water in these vaults may also contain typical levels of contaminants such as salt, fertilizer, motor oil, and cleaning solvents. Extreme environments such as tidal water, continuous submersion, abnormally high concentration of certain contaminants, or unusually high or low pH levels should be evaluated on a case-by-case basis.
- For gear rated 12.5 kA short circuit, the switchgear shall conform to or exceed the requirements of applicable portions of IEC 298, Appendix AA covering arc resistance, through 12.5 kA for 15 cycles.
- For gear rated 25 kA short circuit, the switchgear shall conform to or exceed the requirements of applicable portions of IEC 298, Appendix AA covering are resistance, through 25 kA for 15 cycles.

4.2 Wet-Vault-Mounted Style

- The switchgear shall be suitable for installation in a vault.
- To guard against corrosion due to extremely harsh environmental conditions, the gas-tight tank shall be made of type 304L stainless steel.
- The tank shall be designed for use in typical subsurface electrical manholes and vaults that are subject to occasional flooding to a maximum head of 10 ft. (3m) above the base of the tank. The water in these vaults may also contain typical levels of contaminants such as salt, fertilizer, motor oil, and cleaning solvents. Extreme environments such as tidal waters, continuous submersion, abnormally high concentration of certain contaminants, or unusually high or low pH levels should be evaluated on a case-by-case basis.
- The following optional features should be specified as required:
- For gear rated 25kA short circuit, the switchgear shall conform to or exceed the requirements of applicable portions of IEC 298, Appendix AA covering arc resistance, through 25kA for 15 cycles.

4.3 Dry-Vault-Mounted-Style

- The switchgear shall be suitable for installation in a vault.
- The gas-tight tank shall be made of 7-gauge mild steel.
- The following optional features should be specified as required:
- To guard against corrosion due to extremely harsh environmental conditions, the gas-tight tank shall be made of type 304L stainless steel.
- For gear rated 12.5kA short circuit, the switchgear shall conform to or exceed the requirements of applicable portions of IEC 298, Appendix AA covering arc resistance, through 12.5 kA for 15 cycles.
- For gear rated 25 kA short circuit, the switchgear shall conform to or exceed the requirements of applicable portions of IEC 298, Appendix AA covering arc resistance, through 25 kA for 15 cycles.

4.4 Pad-Mounted Style

- The gas-tight tank shall be made of 7-guage mild steel.
- The following optional feature should be specified as required:
- To guard against corrosion due to extremely harsh environmental conditions, the gas-tight tank shall be made of type 304L stainless steel.
- For gear rated 12.5kA short circuit, the switchgear shall conform to or exceed the requirements of applicable portions of IEC 298, Appendix AA covering arc resistance, through 12.5 kA for 15 cycles.
- For gear rated 25 kA short circuit, the switchgear shall conform to or exceed the requirements of applicable portions of IEC 298, Appendix AA covering arc resistance, through 25 kA for 15 cycles.
- Enclosure
- The switchgear shall be provided with a pad-mounted enclosure suitable for installation of the gear on a concrete pad.
- The pad-mounted enclosure shall be separable from the switchgear to allow clear access to the bushings and bushing wells for cable termination.
- The basic material shall be 14-gauge hot-rolled, pickled and oiled steel sheet.
- The enclosure shall be provided with removable front and back panels, and hinged lift-up roof sections for access to the operating and termination compartments. Each roof section shall have a retainer to hold it in the open position.
- Lift-up roof sections shall overlap the panels and shall have provisions for pad-locking that incorporate a means to protect the padlock shackle from tampering.

- The base shall consist of continuous 90-degree flanges, turned inward and welded at the corners, for bolting to the concrete pad.
- Panel openings shall have 90-degree flanges, facing outward, that shall provide strength and rigidity as well as deep overlapping between panels and pane openings to guard against water entry.
- For bushings rated 600 amperes continuous, the termination compartment shall be of an adequate depth to accommodate encapsulated surge arresters mounted on 600-ampere elbows having 200-ampere interfaces.
- For bushing wells rated 200-amperes continuous, the termination compartment shall be of an adequate depth to accommodate 200-ampere elbows mounted on feedthru inserts.
- An instruction manual holder shall be provided.
- Non-removable lifting tabs shall be provided.
- The following optional feature should be specified as required:
- To guard against corrosion due to extremely harsh environmental conditions, the entire exterior of the enclosure shall be fabricated from Type 304 stainless steel.
- Enclosure finish.
- All exterior welded seams shall be filled and sanded smooth for neat appearance.
- 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 reaction time, reaction temperature, and chemical concentrations.
- After pretreatment, protective coatings shall be applied that shall 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 manufacturer’s finishing system shall satisfactorily pass the following tests:
- 4,000 hours of exposure to salt-spray testing per ASTM B 117 with:
- Underfilm corrosion not to extend more than 1/32 in. from the scribe, as evaluated per ASTM D 1645, Procedure A, Method 2 (scraping): and
- Loss of adhesion from bare metal not to extend more than 1/8 in. from the scribe.
- 1,000 hours of humidity testing per ASTM D 4585 using the Cleveland Condensing Type Humidity Cabinet, with no blistering as evaluated per ASTM D 714.
- 500 hours of accelerated wreathing testing per ASTM G 53 using lamp UVB-313, with no chalking as evaluated per ASTM D 659, and no more than 10% reduction of gloss as evaluated per ASTM D 523.
- Crosshatch-adhesion testing per ASTM D 3359 Method B, with no loss of finish.
- 160-inch-pound impact, followed by adhesion testing per ASTM D 2794, with no chipping or cracking.
- 3,000 cycles of abrasion testing per ASTM 4060, with no penetration to the substrate. Certified test abstracts substantiating the above capabilities shall be furnished upon request.
- The finish shall be inspected for scuffs and scratches. Blemishes shall be touched up by hand to restore the protective integrity of the finish.
- The finish shall be olive green, Munsell 7GY3.29/1.5.
- The following optional feature should be specified as required:
- The finish shall be outdoor light gray, satisfying the requirements of ANSI Standard Z55.1 for No. 70.

5.0 LABELING

5.01 Hazard-Alerting Signs

- The exterior of the pad-mounted enclosure (if furnished) shall be provided with "Warning-Keep Out- Hazardous Voltage Inside- Can Shock, Burn, or Cause Death" signs
- Each unit of switchgear shall be provided with a "Danger-Hazardous Voltage- Failure to Follow These Instructions Will Likely Cause Shock, Burns, or Death" sign. The text shall further indicate that operating personnel must know and obey the employer's work rules, know the hazards involved, and use proper protective equipment and tools to work on this equipment.
- Each unit of switchgear shall be provided with a "Danger-Keep Away- Hazardous Voltage-Will Shock, Burn, or Cause Death" sign.

5.02 Nameplates, Ratings Labels, and Connection Diagrams

- Nameplates, Ratings Labels, and Connection Diagrams
    - Each unit of switchgear shall be provided with a name plate indicating the manufacturer's name, catalog number, model number, date of manufacture, and serial number.
    - Each unit of switch gear shall be provided with a ratings label indicating the following: voltage rating; main bus continuous current rating; short-circuit rating; fault-interrupter ratings including interrupting and duty-cycle fault-closing; and load-interrupter switch ratings including duty-cycle fault closing and short-time.

6.0 ACCESSORIES (Specify as required)

6.01 A USB cable kit shall be provided for connecting an overcurrent control to a user-furnished personal computer.

7.0 ANALYTICAL SERVICES

7.1 Short-Circuit Analysis

- The Design Engineer manufacturer shall provide a short-circuit analysis to determine the currents flowing in the electrical system under faulted conditions. Since 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 if the equipment can with stand 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.
- Data used in the short-circuit analysis shall be presented in tabular format, and shall include the following information:
    - Equipment identifications
    - Equipment ratings
    - Protective devices
    - Operating voltages
    - Calculated short-circuit currents
    - X/R ratios
- A single-line diagram model of the system shall be prepared, and shall include the following information:
    - Identification of each bus
    - Voltage at each bus
    - Maximum available fault current, in kA symmetrical, on the utility source side of the incoming feeder or first upstream device.
    - Data for each transformer
        - Three-phase kVA rating

  - Percent impedance
  - Temperature rise, 65°C and 55/65°C
  - Primary voltage
  - Primary connection
  - Secondary voltage
  - Secondary connection
  - X/R ratio
  - Tap settings and available settings.
- The manufacturer shall use commercially available PC-based computer software such as Power System Analysis Frame work (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.

7.02 Overcurrent Protective Device Coordination Analysis

- The manufacturer shall provide an overcurrent protective device coordination analysis to verify that 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.
- 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 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 cures shall be plotted with the protective-device time-current characteristic curves, as applicable.
- 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.
- 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.
- 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 cure, as applicable:
  - Device identifications.
  - Voltage and current ratios.
  - Transformer through-fault withstand duration curves.
  - Minimum-melting, adjusted, and total-clearing fuse.
  - Cable damage curves.
  - Transformer inrush points.
  - Maximum available fault current, in kA symmetrical, on the utility source side of the incoming feeder or first upstream device.
  - Single-line diagram of the feeder branch under study.
  - A table summarizing the ratings or settings of the protective devices, including:

    - Device identification.

- Relay current-transformer ratios, and tap, time-dial, and instantaneous-pickup settings.
- Circuit-breaker sensor ratings; long-time, short-time, and instantaneous settings; and time bands.
- Fuse type and rating.
- Ground fault pickup and time delay.
- The manufacturer shall use commercially available PC-based computer software such as CYMTCC from CYME international and/or SKM Captor to create the time-current characteristic curves for all protective devices on each feeder.
- 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.

7.03 Arc-Flash Hazard Analysis

- The manufacturer shall provide an arc-flash hazard analysis to verify that 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 35,000°F. 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.

  - The arc-flash hazard analysis shall include the following:
    - Identification of equipment locations where an arc-flash hazard analysis is required.
    - Collection of pertinent data at each equipment location, including:
      - Transformer kVA ratings, including voltage, current, percent impedance, winding ratio, and S/R ratio, plus wiring connections.
      - Protective device ratings, including current, time-current characteristics, settings, and time delays.
      - Switchgear data, including conductor phase spacing, type of grounding, and appropriate working distances.
    - Preparation of a single-line diagram model of the system.
    - Preparation of a short-circuit study to determine the three-phase bolted fault current at each location.
    - Preparation of arc-flash calculations in accordance with NFPA 70E and IEEE 1584, including:
      - Calculation of arc current in accordance with applicable guidelines.
      - Determination of protective device total-clearing times based upon the time-current characteristics.
      - Calculation of arc-flash incident energy level based on the protective device total-clearing times and appropriate working distance.
    - Determination of appropriate personal protective equipment in accordance with risk levels defined in NFPA 70E.
    - Calculation of the arc-flash protection boundary distance.
    - Documentation of the results of the analysis, including:
      - Preparation of a written report.
      - Preparation of single-line diagrams.
      - Preparation of arc-flash hazard labels to be affixed to the equipment.

    - 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.

7.04 Analytical Service Site Visits

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

End of Appendix Section 16311