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USACE / NAVFAC / AFCEC / NASA **UFGS-26 11 14.00 10 (November 2021)**

Preparing Activity: USACE **Superseding**
UFGS-26 11 14.00 10 (October 2007)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2022

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SECTION 26 11 14.00 10

MAIN ELECTRIC SUPPLY STATION AND SUBSTATION
11/21

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NOTE: This guide specification covers the requirements for main electric supply stations or substations having a nominal voltage class of 15 kV up to 115 kV.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).
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PART 1 GENERAL

1.1 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also

use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C12.1	(2014; Errata 2016) Electric Meters - Code for Electricity Metering

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B31.3	(2020) Process Piping
ASME BPVC SEC IX	(2017; Errata 2018) BPVC Section IX-Welding, Brazing and Fusing Qualifications

AMERICAN WELDING SOCIETY (AWS)

AWS D1.1/D1.1M	(2020; Errata 1 2021) Structural Welding Code - Steel

ASTM INTERNATIONAL (ASTM)

ASTM A36/A36M	(2019) Standard Specification for Carbon Structural Steel
ASTM A123/A123M	(2017) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A153/A153M	(2016a) Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A572/A572M	(2021; E 2021) Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
ASTM A575	(2020) Standard Specification for Steel Bars, Carbon, Merchant Quality, M-Grades
ASTM A576	(2017) Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
ASTM A633/A633M	(2013) Standard Specification for Normalized High-Strength Low-Alloy Structural Steel Plates
ASTM B8	(2011; R 2017) Standard Specification for

	Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
ASTM B117	(2019) Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM B188	(2015; E 2016) Standard Specification for Seamless Copper Bus Pipe and Tube
ASTM B231/B231M	(2016; R 2021) Standard Specification for Concentric-Lay-Stranded Aluminum 1350 Conductors
ASTM B317/B317M	(2007; R 2015; E 2016) Standard Specification for Aluminum-Alloy Extruded Bar, Rod, Tube, Pipe, Structural Profiles, and Profiles for Electrical Purposes (Bus Conductor)
ASTM D923	(2007) Standard Practice for Sampling Electrical Insulating Liquids
ASTM D1654	(2008; R 2016; E 2017) Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments
ASTM D2472	(2000; R 2014) Standard Specification for Sulphur Hexafluoride
ASTM D4059	(2000; R 2018) Standard Test Method for Analysis of Polychlorinated Biphenyls in Insulating Liquids by Gas Chromatography

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 32	(1972; R 1997) Standard Requirements, Terminology, and Test Procedures for Neutral Grounding Devices
IEEE 80	(2013) Guide for Safety in AC Substation Grounding
IEEE 81	(2012) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
IEEE 242	(2001; Errata 2003) Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems - Buff Book
IEEE 399	(1997) Brown Book IEEE Recommended Practice for Power Systems Analysis
IEEE 484	(2019) Recommended Practice for Installation Design and Implementation of Vented Lead-Acid Batteries for Stationary Applications

IEEE 485	(2020) Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications
IEEE 525	(2007) Guide for the Design and Installation of Cable Systems in Substations
IEEE C2	(2017; Errata 1-2 2017; INT 1 2017) National Electrical Safety Code
IEEE C37.04	(2018; Erta 2019; Corr 2021) Ratings and Requirements for AC High-Voltage Circuit Breakers with Rated Maximum Voltage Above 1000 V Corrigendum 1
IEEE C37.06	(2009) Standard for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis - Preferred Ratings and Related Required Capabilities for Voltage Above 1000 V
IEEE C37.081	(1981; Supp 1997; R 2007) Guide for Synthetic Fault Testing of AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
IEEE C37.09	(2018; Errata 2019; Corr 2021) Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
IEEE C37.1	(2007) Standard for Supervisory Control, Data Acquisition (SCADA) and Automatic Systems
IEEE C37.2	(2008) Standard for Electrical Power System Device Function Numbers, Acronyms and Contact Designations
IEEE C37.13	(2015) Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures
IEEE C37.16	(2009) Standard for Preferred Ratings, Related Requirements, and Application Recommendations for Low-Voltage AC (635 V and below) and DC 3200 V and below) Power Circuit Breakers
IEEE C37.20.2	(2015) Metal-Clad Switchgear
IEEE C37.20.3	(2013) Standard for Metal-Enclosed Interrupter Switchgear
IEEE C37.23	(2015) Metal-Enclosed Bus
IEEE C37.30	(1997; INT 1 2011) Standard Requirements for High-Voltage Switches

IEEE C37.32	(2002) High-Voltage Switches, Bus Supports, and Accessories - Schedules of Preferred Ratings, Construction Guidelines and Specifications
IEEE C37.34	(1994) Standard Test Code for High-Voltage Air Switches
IEEE C37.41	(2016; Corr 2017) Design Tests for High-Voltage (>1000 V) Fuses and Accessories
IEEE C37.46	(2010) Standard for High Voltage Expulsion and Current-Limiting Type Power Class Fuses and Fuse Disconnecting Switches
IEEE C37.90	(2005; R 2011) Standard for Relays and Relay Systems Associated With Electric Power Apparatus
IEEE C37.90.1	(2013) Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C37.121	(2012) American National Standard for Switchgear-Unit Substations - Requirements
IEEE C57.12.00	(2021) General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
IEEE C57.12.01	(2020) General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid-Cast and/or Resin-Encapsulated Windings
IEEE C57.12.10	(2017) Requirements for Liquid-Immersed Power Transformers
IEEE C57.12.80	(2010) Standard Terminology for Power and Distribution Transformers
IEEE C57.12.90	(2021) Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers
IEEE C57.13	(2016) Standard Requirements for Instrument Transformers
IEEE C57.15	(2018) Standard Requirements, Terminology, and Test Code for Step-Voltage Regulators
IEEE C57.19.00	(2009; INT 1 2009; Errata 2010) Standard General Requirements and Test Procedures for Outdoor Power Apparatus Bushings
IEEE C57.19.01	(2000; R 2005; INT 1 2010) Standard

	Performance Characteristics and Dimensions for Outdoor Apparatus Bushings
IEEE C57.93	(2007) Guide for Installation and Maintenance of Liquid-Immersed Power Transformers
IEEE C57.98	(2011) Guide for Transformer Impulse Tests
IEEE C62.11	(2020) Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits (>1kV)
IEEE C135.30	(1988) Standard for Zinc-Coated Ferrous Ground Rods for Overhead or Underground Line Construction

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 60255-21-3	(1993; ED 1.0) Electrical Relays - Part 21: Vibration, Shock, Bump And Seismic Tests On Measuring Relays And Protection Equipment - Section 3: Seismic Tests

INTERNATIONAL SOCIETY OF AUTOMATION (ISA)

ISA 18.1	(1979; R2004) Annunciator Sequences and Specifications

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C29.1	(2018) Test Methods for Electrical Power Insulators
ANSI C29.9	(2017) Wet Process Porcelain Insulators - Apparatus, Post-Type
NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA C12.4	(1984; R 2011) Registers - Mechanical Demand
NEMA C29.2B	(2013) Wet Process Porcelain and Toughened Glass - Transmission Suspension Type
NEMA LA 1	(2009) Standard for Surge Arresters
NEMA PB 1	(2011) Panelboards
NEMA ST 20	(2014) Dry-Type Transformers for General Applications
NEMA WD 1	(1999; R 2020) Standard for General Color Requirements for Wiring Devices
NEMA/ANSI C12.10	(2011; R 2021) Physical Aspects of Watthour Meters - Safety Standard

NEMA/ANSI C12.11	(2006; R 2019) Instrument Transformers for Revenue Metering, 10 kV BIL through 350 kV BIL (0.6 kV NSV through 69 kV NSV)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2020; ERTA 20-1 2020; ERTA 20-2 2020; ERTA 20-3 2020; TIA 20-1; TIA 20-2; TIA 20-3; TIA 20-4; TIA 20-5; TIA 20-6; TIA 20-7; TIA 20-8; TIA 20-9; TIA 20-10; TIA 20-11; TIA 20-12; TIA 20-13; TIA 20-14; TIA 20-15; TIA 20-16; ERTA 20-4 2022) National Electrical Code

U.S. DEPARTMENT OF DEFENSE (DOD)

UFC 3-301-01	(2019, with Change 1, 2022) Structural Engineering

UNDERWRITERS LABORATORIES (UL)

UL 6	(2007; Reprint Sep 2019) UL Standard for Safety Electrical Rigid Metal Conduit-Steel
UL 50	(2015) UL Standard for Safety Enclosures for Electrical Equipment, Non-Environmental Considerations
UL 67	(2018; Reprint Jul 2020) UL Standard for Safety Panelboards
UL 467	(2022) UL Standard for Safety Grounding and Bonding Equipment
UL 486A-486B	(2018; Reprint May 2021) UL Standard for Safety Wire Connectors
UL 489	(2016; Rev 2019) UL Standard for Safety Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures
UL 1236	(2015; Reprint Feb 2021) UL Standard for Safety Battery Chargers for Charging Engine-Starter Batteries

1.2 SYSTEM DESCRIPTION

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NOTE: Select the features and fill in blanks with selections appropriate for the design condition and in accordance with guidance contained in UFC 3-550-01.
****

1.2.1 General

Configure the system as specified, and include structures, incoming and outgoing lines, transformers, regulators, fuses, circuit breakers, switches, switchgear, and appurtenances to provide a fully functional

system.

1.2.2 Service Conditions

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NOTE: See UFC 3-550-01 for guidance regarding service conditions. Retain or add the required conditions.

Provide seismic requirements, if a Government designer (either Corps office or A/E) is the Engineer of Record, and show on the drawings. Delete the bracketed phrase if seismic details are not included. Pertinent portions of UFC 3-301-01 and Sections 13 48 73, 23 05 48.19 and 26 05 48.00 10, properly edited, must be included in the contract documents.

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Items provided under this section must be specifically suitable for the following service conditions. Seismic details must conform to UFC 3-301-01 and Sections 13 48 73 SEISMIC CONTROL FOR MECHANICAL EQUIPMENT, 23 05 48.19 [SEISMIC] BRACING FOR HVAC, and 26 05 48.00 10 SEISMIC PROTECTION FOR ELECTRICAL EQUIPMENT [as indicated].

Fungus Control	[_____]
Altitude	[_____] m feet
Ambient Temperature	[_____] degrees C F
Frequency	[_____] Hz
Ventilation	[_____] cubic meters/sec cfm
Seismic Parameters	[_____]
Humidity Control	[_____]
Corrosive Areas	[_____]
[_____]	[_____]

1.2.3 Incoming and Outgoing Circuit Compliance

[Aerial line circuits must comply with the requirements of Section 33 71 01 OVERHEAD TRANSMISSION AND DISTRIBUTION.] [Underground circuits must comply with the requirements of Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION.] [Circuits in cable trays must comply with the requirements of Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION for cable and with the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM for cable trays.]

1.2.4 Detail Drawings

Submit detail drawings consisting of equipment drawings, illustrations,

schedules, instructions, diagrams, and other information necessary to define the installation. Show on the detail drawings the ratings of items and systems and how the components of an item and system are assembled, function together, and how they will be installed on the project. Data and drawings for component parts of an item or system must be coordinated and submitted as a unit. Multiple submissions for the same equipment or system are not acceptable except where prior approval has been obtained from the Contracting Officer. In such cases, a list of data to be submitted later must be included with the first submission. Detail drawings must show physical arrangement, construction details, connections, finishes, materials used in fabrication, provisions for conduit or busway entrance, access requirements for installation and maintenance, physical size, electrical characteristics, foundation and support details, and equipment weight. Drawings must be drawn to scale and dimensioned. Optional items must be clearly identified as included or excluded. Detail drawings must as a minimum include:

a. Incoming line and station bus structures and integral equipment.

b. Transformers.

c. Switchgear.

d. Battery system including calculations for the battery and charger.

e. Voltage regulators.

f. Grounding resistors.

g. Station single line electrical diagrams including primary, metering, sensing and relaying, control wiring, and control logic.

h. Structural or physical features of major items of station equipment and components of equipment or equipment assemblies and structures, including foundations or other types of supports for equipment and conductors. Those structural drawings must include accurately scaled or dimensioned outline and arrangement or layout drawings to show the physical size of station equipment and component parts of the equipment and the relative arrangement of components and any physical connection of related components. Weights of equipment and components of equipment assemblies must be provided when required to verify the adequacy of design and proposed construction of foundations or other types of supports. Dynamic forces must be stated for switching devices when such forces must be considered in the design of support structures. The appropriate detail drawings must show the provisions for leveling, anchoring, and connecting all items of station equipment during installation, and must include any recommendations made by the manufacturer of the equipment.

i. Electrical drawings must include single-line and three-line diagrams of the station and station equipment, schematics or elementary diagrams of each electrical system; internal wiring and external connection diagrams of each electrical device when published by the manufacturer; wiring diagrams of cabinets, panels, units, or other separate mountings; interconnection diagrams that show the wiring between separate components of assemblies; external connection diagrams that show the termination of wiring routed between separate items of station equipment; internal wiring diagrams of equipment showing wiring as actually provided for this project. External wiring

connections must be clearly identified.

j. If departures from the contract drawings are deemed necessary, submit complete details of such departures, including changes in related portions of the project and the reasons therefore. Approved departures must be made at no additional cost to the Government.

1.2.5 As-Built Drawings

The as-built drawings must be kept at the job site and updated daily. The as-built drawings must be a full sized set of prints marked to reflect all deviations, modifications, and changes. The as-built drawings must be complete and show the location, size, dimensions, part identification, and other information. Additional sheets may be added. The as-built drawings must be jointly inspected for accuracy and completeness by the Contractor's quality control representative and by the Contracting Officer prior to the submission of each monthly pay estimate. Upon completion of the work, submit three full sized sets of the marked prints to the Contracting Officer for approval. Keep as-built drawings prepared as a record of the construction as installed. Include in the drawings all the information shown on the contract drawings as well as all deviations, modifications, and changes from the contract drawings, however minor. If upon review, the as-built drawings are found to contain errors or omissions, they will be returned to the Contractor for correction. Correct and return the as-built drawings to the Contracting Officer for approval within ten calendar days from the time the drawings are returned to the Contractor.

1.3 RELATED REQUIREMENTS

Section 26 08 00 APPARATUS INSPECTION AND TESTING, Section 25 05 11 CYBERSECURITY FOR FACILITY RELATED CONTROL SYSTEMS and 33 73 00.00 40 UTILITY TRANSFORMERS applies to this section, with the addition and modifications specified herein.

1.4 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for

Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

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Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

General Installation Requirements

Detail Drawings

As-Built Drawings

SD-03 Product Data

Support Structures; G[, [_____]]

Fault Current Analysis

Protective Devices

Coordination Study

Battery; G[, [_____]]

Nameplates

Materials and Equipment

General Installation Requirements

Onsite Tests; G[, [_____]]

SD-06 Test Reports

Factory Tests

Field Testing

Field Test Reports

SD-07 Certificates

Materials and Equipment

SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals; G[, [_____]]

1.5 DELIVERY, STORAGE, AND HANDLING

Visually inspect devices and equipment when received and prior to acceptance from conveyance. Protect stored items from the environment in accordance with the manufacturer's published instructions. Replace damaged items. Oil filled transformers and switches must be stored in accordance with the manufacturer's requirements.

1.6 EXTRA MATERIALS

One additional spare fuse or fuse element for each furnished fuse or fuse element must be delivered to the Contracting Officer when the electrical system is accepted. Provide two complete sets of all special tools required for maintenance, complete with a suitable tool box. Special tools are those that only the manufacturer provides, for special purposes (to access compartments, or operate, adjust, or maintain special parts).

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

Provide materials and equipment which are the standard product of a manufacturer regularly engaged in the manufacture of the product and that essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening.

a. Submit a complete itemized listing of equipment and materials proposed for incorporation into the work. Each entry must include an item number, the quantity of items proposed, and the name of the manufacturer of each such item. Products must conform to the following requirements. Items of the same classification must be identical including equipment, assemblies, parts, and components. Products for aerial construction must conform to IEEE C2 for [heavy] [medium] [light] loading districts, Grade B construction.

b. Where materials or equipment are specified to conform to the standards of the Underwriters Laboratories, Inc., (UL) or to be constructed or tested, or both, in accordance with the standards of the American National Standards Institute (ANSI), the Institute of Electrical and Electronics Engineers (IEEE), or the National Electrical Manufacturers Association (NEMA), submit proof that the items provided under this section of the specifications conform to such requirements.

c. The label of, or listing by, UL will be acceptable evidence that the items conform thereto. Either a certification or a published catalog specification data statement, to the effect that the item is in accordance with the referenced ANSI or IEEE standard, will be acceptable evidence that the item conforms thereto. A similar certification or published catalog specification data statement to the effect that the item is in accordance with the referenced NEMA standard, by a company listed as a member company of NEMA, will be acceptable evidence that the item conforms thereto.

d. In lieu of such certification or published data, the Contractor may submit a certificate from a recognized testing agency equipped and competent to perform such services, stating that the items have been tested and that they conform to the requirements listed, including methods of testing of the specified agencies. Compliance with above-named requirements does not relieve the Contractor from compliance with any other requirements of the specifications.

2.2 NAMEPLATES

Submit data composed of catalog cuts, brochures, circulars, specifications, product data, and printed information in sufficient detail and scope to verify compliance with the requirements of the contract documents.

2.2.1 General

Each major component of this specification must have the manufacturer's name, address, type or style, model or serial number, and catalog number on a nameplate securely attached to the equipment. Nameplates must be made of noncorrosive metal. As a minimum, provide nameplates for transformers, regulators, circuit breakers, capacitors, meters, switches, switchgear, and grounding resistors.

2.2.2 Liquid-Filled Transformer Nameplates

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NOTE: Coordinate Nameplate C information with the manufacturer. Select 50 ppm for Army projects and 2 ppm for Air Force projects.
****

Provide power transformers, with Nameplate C information in accordance with IEEE C57.12.00, indicating the number of gallons and composition of liquid-dielectric, permanently marked with a statement that the transformer dielectric to be supplied is non-polychlorinated biphenyl. If transformer nameplate is not so marked, furnish manufacturer's certification for each transformer that the dielectric is non-PCB classified, with less than [50] [2] ppm PCB content in accordance with paragraph MISCELLANEOUS Liquid Dielectrics. Certifications must be related to serial numbers on transformer nameplates. Transformer dielectric exceeding the [50] [2] ppm PCB content or transformers without certification will be considered as PCB insulated and will not be accepted.

2.3 CORROSION PROTECTION

2.3.1 Aluminum Materials

[Aluminum must not be used in contact with earth or concrete. Where aluminum conductors are connected to dissimilar metal, use fittings conforming to UL 486A-486B.] [Aluminum must not be used.]

2.3.2 Ferrous Metal Materials

2.3.2.1 Hardware

Ferrous metal hardware must be hot-dip galvanized in accordance with ASTM A153/A153M and ASTM A123/A123M.

2.3.2.2 Equipment

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NOTE: A 120-hour test will be specified in a noncorrosive environment and a 480-hour test will be specified in a corrosive environment.

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Equipment and component items, including but not limited to transformer stations and ferrous metal luminaires not hot-dip galvanized or porcelain enamel finished, must be provided with corrosion-resistant finishes which must withstand [120] [480] hours of exposure to the salt spray test specified in ASTM B117 without loss of paint or release of adhesion of the paint primer coat to the metal surface in excess of 1.6 mm 1/16 inch from the test mark. The scribed test mark and test evaluation must be in accordance with ASTM D1654 with a rating of not less than 7 in accordance with TABLE 1, (procedure A). Cut edges or otherwise damaged surfaces of hot-dip galvanized sheet steel or mill galvanized sheet steel must be coated with a zinc rich paint conforming to the manufacturer's standard.

2.3.3 Finishing

Painting required for surfaces not otherwise specified and finish painting of items only primed at the factory must be as specified in Section 09 90 00 PAINTS AND COATINGS.

2.4 STATION ARRANGEMENT

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NOTE: Coordinate with paragraph SUBSTATION EQUIPMENT.

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The main electric supply [station] [substation] must be of the [substation transformer type with an open-type bus-and-switch arrangement] [articulated primary unit substation arrangement with close-coupled high-voltage and low-voltage sections] [primary unit substation arrangement with close-coupled low-voltage section].

2.4.1 Support Structures

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NOTE: Connections to aerial lines will be run underground to new stations (35 kV or less), thus deleting the requirement for aerial buses and line structures. Delete wire brackets if not required.

Maximum use will be made of "standard," "custom," or "pre-fabricated" structure designs. Coordinate with the local utility as well as with structure manufacturers. Also, coordinate with SD-04, Detail Drawings. Modify or delete subparagraphs as required. Structures will be designed for not less than 4.4 kN 1000 pounds tension per conductor. Normally, short slack spans from the utility system should be provided to ensure that conductor tensions are kept to a minimum.

Foundations will be designed based on available data from soil borings and detailed on the project drawings. Where soil-bearing pressures are not known, foundations for a soil-bearing pressure of not more than 191.5 kPa 4000 psf should be provided. The large overturning moments created by the incoming aerial conductors will be considered in the foundation design and a safety factor of not less than 1.5 should be provided. The designer will ensure that Section 03 30 00 CAST-IN-PLACE CONCRETE covers the class of concrete required for foundations associated with a main electric supply station, but concrete must have not less than 17.2 MPa 2500 psi compressive strength.

****

Provide structures to support incoming line conductors, switches, instrument transformers, air terminals and aerial buses. Steel structural items must conform to Section 05 12 00 STRUCTURAL STEEL. Structures, except for incoming primary lines, must be of the low-profile type. Structures must utilize round or rectangular tubular steel construction or equivalent H/I-beam support elements. Lattice type supports are not acceptable. Submit manufacturer's design analysis and calculations for structures, foundations, anchor bolts, and supports differing from those indicated in the contract drawings, and for prefabricated structures. Calculations must be made by a registered professional engineer with demonstrated experience in substation structural design in the last three years. The manufacturer must provide a list of projects complete with points of contact, addresses and telephone numbers. Structural steel and miscellaneous items must comply with ASTM A36/A36M, ASTM A572/A572M, ASTM A575, ASTM A576or ASTM A633/A633M, or equivalent aluminum. General configurations are indicated. Exact dimensions and arrangements may be varied, dependent upon site limitations, to permit use of a manufacturer's standard equipment and structures. Air terminals, [not less than 1.8 m 6 feet in length] [of the length shown], must be provided on each structure column for lightning protection. [Static wire brackets for incoming overhead ground wires must be provided on each incoming dead-end line structure and elsewhere as indicated.]

2.4.1.1 Pre-fabricated Structure Design

Design structures for a maximum tension of [4.5] [_____] kN [1000] [_____] pounds per conductor. Overhead ground or static wires must be counted as conductors in determining strength requirements. Detail drawings must show markings of units for placement, location and sizes of attachments, and complete data on fabrications.

2.4.1.2 Structure Finish

Aluminum structures must have a uniform satin finish and must not be painted. Steel structures must be hot-dip galvanized in accordance with ASTM A123/A123M after drilling is completed and must not be painted.

2.4.1.3 Structure Foundation Design

Structure foundation design must be as indicated. If the manufacturer's standard structures differ in dimensions from those shown, modify foundation design to suit the structures provided, at no additional cost to the Government. Maximum earth-bearing pressure must be calculated at

[191.5] [_____] kPa [4000] [_____] psf.

2.4.2 [Conductors][Tubular Bus Conductors]

****
NOTE: Justify selection of copper or aluminum, based upon an analysis using life, environmental, and cost factors. Refer to UFC 3-550-01 regarding substation conductors and buses.
****

Conductors must be [aluminum-conductor-steel-reinforced (ACSR)] [copper] [high-strength aluminum alloy] with sizes as indicated, and must comply with IEEE 525. Base span lengths on a limiting deflection of 1/150 for spans having two supports and 1/200 for spans having three supports, under maximum wind, ice, and short-circuit loadings, including suitable allowances for any taps. Where required, install larger or stronger bus to maintain specified deflections for the indicated span lengths. Other bus shapes for electrical conductors may be used if detail drawing submittals indicate equivalent ampacity and strength. Short connections, consisting of bare stranded conductors of equivalent bus ampacity, may be used between incoming line conductors and buses or between buses and equipment. Copper flexible braid or aluminum strap expansion couplers, as required to match the bus material, must be installed in bus runs where required to allow for expansion and contraction, and at all connections to transformer bushings.

2.4.2.1 Suspension Insulators

****
NOTE: Refer to UFC 3-550-01 for guidance regarding substation insulators.
****

Provide suspension insulators for dead-end incoming line conductors. Utilize suspension insulator strings and string supports which provide a mechanical strength exceeding the ultimate strength of each dead-end conductor. Minimum ratings of Provide suspension insulators with a minimum rating of not less than NEMA C29.2B Class [52-3-L] [52-3-H] [or] [52-4-L] [52-4-H]. Each suspension string must have not less than [_____] insulators in tandem.

2.4.2.2 Apparatus Post Insulators

Apparatus post insulators must be provided to support conductors, and their mechanical strength must exceed the ultimate strength of the conductor supported and, where necessary, high-strength or ultra high-strength insulators must be provided. Minimum ratings of apparatus post insulators must be not less than ANSI C29.9, Technical Reference Number [_____].

2.5 INCOMING SWITCHING/CIRCUIT INTERRUPTING EQUIPMENT

****
NOTE: Incoming line equipment may be provided by the utility or by the Government. Delete paragraphs not applicable to project. Operating characteristics and ratings of incoming line interrupting/switching must be coordinated with the

requirements of the serving utility and the transformer and bus protection requirements. On the drawings, identify the required instruments, relays, instrument transformers, and controls for each switching/interrupting unit, and modify the following paragraphs to reflect the station control and instrumentation schemes and the station single-line diagram.

****

Incoming line switching equipment must be of the outdoor weatherproof type. Operating characteristics and ratings of incoming line switching equipment must be as indicated.

2.5.1 Metal-Enclosed Interrupter Switchgear

****

NOTE: Metal enclosed switchgear with SF6 interrupters is available for voltage levels of 5 kV through 25 kV. Select either air-insulated, vacuum-insulated, or SF6 interrupters.

****

Metal-enclosed interrupter switchgear must comply with IEEE C37.20.2 for metal clad switchgear, IEEE C37.20.3 for metal-enclosed interrupter switchgear, IEEE C37.32for load-interrupter switches, [_____] for power fuses, and must be of the outdoor no-aisle type that meets or exceeds the requirements of applicable publications listed. Switch construction must be of the manually-operated, "OPEN-CLOSED," [air-insulated, load-interrupter type] [vacuum-insulated, load-interrupter type] [SF6-insulated, load-interrupter type], equipped with a stored energy operator for quick-make-quick-break to make operating speeds independent of manual switch operations. Where indicated, bus or lug connections to mount field-installed, slip-on, medium-voltage cable terminations for cable entering from below [and a flanged throat for direct connection to the associated transformer] [and a bus throat for connection to the associated metal-enclosed bus] [and roof bushings for aerial line connections] must be provided. [Roof bushings must [have the same BIL as] [be one BIL higher than] the associated switchgear and must conform to IEEE C57.19.00 and IEEE C57.19.01 when bushings are rated at or above 110 kV BIL.] Primary buses must comply with the requirements for buses in paragraph OUTGOING METAL-CLAD SWITCHGEAR. Refer to specification Section 33 73 00.00 40 UTILITY TRANSFORMERS for requirements.

2.5.1.1 Ratings

****

NOTE: Preferred ratings are listed in IEEE C37.2, Table 6. A short-circuit study is required to specify ratings. For projects where multiple ratings are required for different applications, delete the table below and provide rating requirements on the drawings in tabular form.

****

Switch ratings at 60 Hz must be in accordance with IEEE C37.2, and IEEE C37.06 and as [follows:] [indicated.]

Nominal voltage	[_____]
Rated maximum voltage	[_____]
Maximum symmetrical interrupting capacity	[_____]
Maximum asymmetrical interrupting capacity	[_____]
3-Second short time current carrying capacity	[_____]
Rated continuous current (kA)	[_____]
BIL (Impulse Level)	[_____]

2.5.1.2 Operating Mechanism Controls and Devices

****

NOTE: The switchgear control switch, status lights, metering, and relaying will be located on the secondary metal-clad switchgear; additionally, a control switch, status lights, and a local-remote selector switch will be mounted at the interrupter switch. If this equipment cannot be mounted on the secondary metal-clad switchgear, then these devices will be installed in an instrument and relay cabinet adjacent to the interrupter switch operating mechanism cabinet. Transformer differential and differential lockout relays will be located in the metal-clad switchgear. Where there is no metal-clad switchgear, the appropriate material from the paragraph will be included as a part of paragraph SUBSTATION EQUIPMENT.

****

An operating mechanism cabinet must house the electrical devices listed below, which must be rated for the application and must be suitable for the ac or dc control voltage available as shown or specified. Unless otherwise noted, provide manufacturer's standard devices for the rating specified including the following:

a. A light connected to a cabinet door-actuated switch, so that the light is energized only when doors are open.

b. A heater continuously energized to prevent condensation within the cabinet over ambient temperature ranges from [minus 29] [_____] to [40] [_____] degrees C [minus 20] [_____] to [104] [_____] degrees F at 90 percent relative humidity and connected to a cabinet door-actuated switch, so the heater is de-energized when doors are open. High-temperature thermal protection must be included.

c. An operator charging motor with thermal-overload relays.

d. A motor control contactor with relays, solenoids, and any other control devices required.

e. Necessary motor-alarm and interlock switches.

f. One-pole or two-pole thermal-magnetic molded-case circuit breakers suitable for the operating voltage for control, heater, and light circuits.

g. A minimum of eight spare circuit breaker auxiliary contacts, four normally open (52a) and four normally closed (52b), wired to interface terminals.

h. Terminal facilities wired for devices installed in the cabinet, and to permit corresponding connections of incoming conductors from remote items of equipment.

i. A key interlock if indicated.

j. A switch-operating handle with provisions for locking in either the open or closed position.

k. Safety devices as necessary to ensure that the load interrupter switch is in the open position whenever unit doors are in the open position.

l. An interface terminal block wired for required exterior connections.

m. Devices specified under specific unit requirements below.

2.5.1.3 Sulfur Hexafluoride (SF6) Interrupter Switchgear

Provide SF6 interrupters of the puffer type where the movement of the contact plunger will initiate the puff of SF6 gas across the contact to extinguish the arc. Switchgear must be provided with a loss-of-pressure alarm remote as shown on the drawings. Before the pressure in the interrupter drops below the point where the interrupter cannot open safely without damage, the switchgear must activate the loss-of-pressure alarm, open automatically, and remain in the locked open position until repaired. The SF6 must meet the requirements of ASTM D2472, except that the maximum dew point must be minus 60 degrees C minus 76 F (corresponding to 11 ppm water by volume), with only 11 ppm water by volume, and the minimum purity must be 99.9 percent by weight. Switchgear must have provisions for maintenance slow closing of contacts and have a readily accessible contact wear indicator. Tripping time must not exceed [3] [5] [8] cycles.

2.5.1.4 Vacuum Circuit Interrupter Switchgear

****
NOTE: See IEEE 37.04 for preferred ratings.
****

Vacuum interrupters must be hermetically-sealed in a high vacuum to protect contacts from moisture and contamination. Switchgear must have provisions for maintenance slow closing of contacts and have a readily accessible contact wear indicator. Tripping time must not exceed [3] [5] [8] cycles.

2.5.1.5 Specific Unit Requirements

****
NOTE: Revise this paragraph and paragraph POWER TRANSFORMERS to include listing of unit items if an

articulated primary unit substation is not provided and interrupter switchgear is to be specified. Placing CT's and ammeters/switches in metal-enclosed interrupter switchgear is costly and often leads to additional cubicles. Unlike the metal-clad design which puts grounded metal barriers around bus, switchgear, incoming line, outgoing line, and control sections, metal-enclosed interrupter switchgear is not so compartmentalized. Thus, building a safe compartment for ammeters/switches is not really consistent with the basic design. Ammeter and switch will be located on the secondary main breaker.

****

In addition to basic requirements, switchgear must contain other devices as appropriate to the application and as specified in paragraph SUBSTATION EQUIPMENT.

2.5.2 Devices and Accessories for Switching/Interrupting Equipment

2.5.2.1 Incoming Line

****

NOTE: Delete Items "e" and "f" if not required.

****

Coordinate incoming line units with the requirements of the serving utility, and to the protected transformer, and include the following control and monitoring system items that must be mounted in the instrument and relay cabinet specified below.

a. An ammeter and an ammeter switch.

b. A control switch for local or remote control operation.

c. Microprocessor-based, multi-function overcurrent relay

d. [Microprocessor-based transformer differential relay.]

e. [Single-] [Three-] phase secondary potential test blocks with associated test plug, quantity as shown.

f. [Single-] [Three-] phase secondary current test blocks with associated test plug for [each current transformer circuit] [each three-phase set of current transformers], as indicated.

[g. [_____]]

2.5.2.2 Line Tie

****

NOTE: Delete either 86B or 87B relays if not required.

****

The line tie units must be rated [as indicated] [the same as the incoming

line units], and must be electrically or mechanically interlocked with other high-voltage items of equipment as shown. The line tie unit must be equipped with control and monitoring system items the same as described for the incoming line unit. The instrument and relay cabinet must house the same equipment listed for the incoming line unit cabinet except [_____]. The cabinet must also house three bus differential relays, device 87B, and an auxiliary lockout relay, device 86B.

2.5.2.3 Instrument and Relay Cabinet

****

NOTE: The control switch, status lights, metering, and relaying will be located on the secondary metal-clad switchgear; additionally, a control switch, status lights, and a local-remote selector switch will be mounted at the device. If this equipment cannot be mounted on the secondary metal-clad switchgear, then these devices will be installed in an instrument and relay cabinet adjacent to the operating mechanism cabinet. Transformer differential and differential lockout relays will be located in the metal-clad switchgear. Where there is no metal-clad switchgear, the appropriate material from the paragraph will be included as a part of paragraph SUBSTATION EQUIPMENT.

****

Provide enclosures for housing instruments, relays, and devices specified. Install devices such as instruments, relays, and control and transfer switches in the [metal-clad switchgear lineup where indicated] [an instrument and relay cabinet]. Enclosures must comply with NEMA 250 for Type [3R] [4] [_____], and paragraph CABINETS AND ENCLOSURES. Rigid supports, conduits, fittings, raceways, troughs, must be provided for mounting and connection to the associated equipment. Standard enclosure equipment must include the following:

a. A light connected to a cabinet door-actuated switch, so that the light is energized only when doors are open.

b. A heater continuously energized to prevent condensation within the cabinet over an ambient temperature range of [minus 29] [_____] to [40] [_____] degrees C [minus 20] [_____] to [104] [_____] degrees F. Connect the heater and thermostat contact to a cabinet door-actuated switch, so that the heater is de-energized when the cabinet door or doors are open. High temperature thermal protection must be included.

c. One-pole or two-pole thermal-magnetic molded-case circuit breakers suitable for the operating voltage for heater and light circuits.

d. Devices identified under specific unit requirements hereinafter.

2.5.3 Power Fuse Disconnecting Units

Incoming line power fuse disconnecting units, consisting of power fuses and fuse disconnecting switches, must comply with [_____]. [Expulsion-type] [Current-limiting] power disconnecting units and fuses must have ratings in accordance with IEEE C37.46.

2.5.3.1 Power Fuse Disconnecting Unit Ratings

****
NOTE: For projects where multiple ratings are required for different applications, provide rating requirements on the drawings in tabular form.
****

Power disconnecting units must have ratings [as indicated] [as follows]:

Nominal voltage	[_____]
Rated maximum voltage	[_____]
Maximum symmetrical interrupting capacity	[_____]
Rated continuous current (kA)	[_____]
BIL (Impulse Level)	[_____]

2.5.3.2 Construction

Units must be suitable for outdoor use and must be of the stick (hook) operated, disconnecting, single-pole, single-throw, drop-out type. Fuses must have visible blown-fuse indicators. All ratings must be clearly visible. Units must be suitable for [vertical] [or] [45 degree] [or] [horizontal underhung] mounting [as indicated].

2.5.3.3 E-Rated, Current-Limiting Power Fuses

E-rated, current limiting, power fuses must conform to IEEE C37.46.

2.5.3.4 C-Rated, Current-Limiting Power Fuses

C-rated, current-limiting, power fuses must open in 1000 seconds at currents between 170 and 240 percent of the C rating.

2.5.3.5 Additional Requirements

****
NOTE: Specify three spare fuses for each power fuse current rating. Coordinate this requirement with paragraph EXTRA MATERIALS.
****

Provide at least one fuse tong or other fuse removal and replacement device of sufficient length, and suitable design and voltage rating, for disconnection and replacement of fuses, and where units mounted at different elevations require different lengths, additional devices must be provided as necessary. One set of any special tools, necessary for servicing the unit, must be provided.

2.5.4 Line Switches

2.5.4.1 Ratings

****

NOTE: Preferred ratings are listed in IEEE C37.32, Table 1, but not all ratings may be available for all methods of switching. A short-circuit study is required to specify ratings.

****

Ratings at 60 Hz must be in accordance with IEEE C37.32 and as follows:

Nominal voltage	[_____]
Rated maximum voltage	[_____]
Maximum symmetrical interrupting capacity	[_____]
Maximum asymmetrical interrupting capacity	[_____]
3-Second short time current carrying capacity	[_____]
Rated continuous current (kA)	[_____]
BIL	[_____]

2.5.4.2 Standard Devices and Accessories

One set of special tools, as necessary for servicing, must be provided.

2.5.4.3 Stick (Hook) Operated Line Switches

****

NOTE: Stick (hook) operated switches manufactured especially for bypassing regulators are not listed with a 3-second current rating by manufacturers, but with closed and momentary ratings. Ratings obtainable should be checked with manufacturers. Delete the hook stick requirement for voltage regulator switches if hook sticks are provided for stick operated switches and are of a suitable length.

****

Stick (hook) operated line switches must comply with IEEE C37.32 and must be a stick-operated, single-pole, single-throw, vertical-break switch suitable for [vertical] [or] [horizontal underhung] mounting [as indicated].

2.5.4.4 Group-Operated Line Switches

****

NOTE: Delete switch paragraphs as required. Group-operated line switches are structure-mounted for overhead, incoming-line applications. They may be used for switching and protection of transformers, lines, cables, single-shunt capacitor banks, and line-connected or tertiary connected shunt reactors. Group-operated air-insulated switches are available for voltages from 15 through 345 kV. Group-operated SF6-insulated switches are

available for voltages ranging from 15 thru 230 kV. Refer to UFC 3-550-01 for guidance regarding Group-Operated Line Switches.

****

Group-operated line switches must be [air-insulated] [SF6 insulated] with [manual] [and] [motor] -type operators. Group-operated line switches must comply with IEEE C37.32, IEEE C37.30, and IEEE C37.34, and must be three-pole, single-throw, provided with a mechanism which opens the three phases simultaneously. Group-operated switches must be [manually operated] [and] [motor operated] [as indicated].

2.5.4.4.1 Air-Insulated

Air-insulated switches must be of the [vertical-break] [or] [side-break] [or] [indicated-break] type, with either tilting or rotating insulators, for [horizontal upright] [or] [vertical] [or] [horizontal underhung] mounting [as indicated]. Contact surfaces must be silver. The switching capability required must be of the [load interrupter] [or] [disconnecting] type. Switches must be provided with replaceable contacts, arc horns, and other moving parts which have a limited life expectancy.

2.5.4.4.2 SF6-Insulated

Switches must be puffer-type SF6 interrupters. The interrupter must be factory filled with SF6 gas and then permanently sealed. The interrupters must be driven by a single, stored-energy mechanism located at ground level in an operator. The mechanism in the operator must have instantaneous trip-free capability (should the switch be inadvertently closed into a fault).

2.5.4.4.3 Load Interrupter Type, Air-Insulated

Load interrupter switches must be capable of interrupting load currents equal to their continuous current ratings, which meet the requirements of IEEE C37.30.

2.5.4.4.4 Disconnecting Type, Air-Insulated

Disconnecting switches must be provided with quick-break arcing horns rated for interrupting transformer exciting currents or line charging currents, dependent upon the application. A switch used to protect a power transformer must be key-interlocked with its associated transformer's tap changer for de-energized operation (TCDO) and its load side circuit breaker disconnect, so that the manual TCDO can be operated only when the transformer is de-energized, and so that the switch can be only opened or closed after its associated circuit breaker has been placed in the open position. A permanent warning sign having letters at least 50 mm 2 inches high and reading as follows: "WARNING - DISCONNECTING SWITCH - DO NOT OPEN UNDER LOAD" must be mounted on the switch operating mechanism.

2.5.4.4.5 Manually-Operated Type, Air-Insulated

The switch operating handle must be located approximately 1.1 m 3 feet 6 inches above its grounded platform plate. Insulation of the switch operating mechanism must include both insulated interphase rod sections and the insulated vertical shaft.

2.5.4.5 Switch Operators

****

NOTE: Indicate remote control of the motor operator on the project drawings. Delete electrical interlocking if not required. Select stored-energy type operators for use with SF6 interrupters. Delete the requirement for remote telemetry units and SCADA control where not applicable.

****

[Motor operators must be stored-energy mechanisms having a [[24-volt] [48-volt] [125-volt] dc] [120 volt ac], charging motor, with a manual operating mechanism. Opening and closing operating time must be not more than [6] [_____] cycles for each operation.] [Motor operators must be [120-volt] [240-volt] ac, gear-coupled motor operators, with a manual operating mechanism. Opening and closing operating time must be not more than [10] [_____] seconds for each operation.] Operators must be configured so that the switch actuator is padlockable.

2.5.4.5.1 Operation

The operating mechanism must permit both manual and electrical operation of the switch at its operating mechanism cabinet, and electrical operation by the indicated remote control circuitry. The operating shaft or operator cabinet must be clearly and permanently marked to indicate continuously the positions of the switch. An externally operable decoupler must be provided at or near the point of entrance of the shaft into its operator housing so as to permit disengagement of the shaft for inspection, tests, maintenance, or repair of equipment located within the operator enclosure. Where indicated, a switch must be electrically interlocked with [_____] as shown. Switch operators must be provided with remote telemetry units (RTUs) for remote operation and integration with supervisory, control, and data acquisition systems. Systems, components, and equipment must conform to the requirements and recommendations of IEEE C37.1.

2.5.4.5.2 Operating Mechanism Cabinet

A NEMA 250 type [_____] enclosure complying with paragraph CABINETS AND ENCLOSURES must be provided [where indicated] [as suitable for the required operation]. The electrical devices listed below must be rated for the application and must be suitable for the available low-voltage alternating or direct current, [as shown] [specified.] Unless otherwise noted, manufacturer's standard devices for the rating specified must be provided and must include the following:

a. "Trip" and "Close" pushbuttons or switch and position indication lights.

b. A switch-operation counter.

c. Shaft travel limit switches and any required safety devices.

d. A light connected to a cabinet door-actuated switch, so that the light is energized only when doors are open.

e. A heater continuously energized to prevent condensation within the cabinet over an ambient temperature range of [minus 29] [_____] to

[40] [_____] degrees C [minus 20] [_____] to [104] [_____] degrees F at 90 percent relative humidity and connected to a cabinet door-actuated switch, so that the heater is de-energized when doors are open. High-temperature thermal protection must be included.

f. An operator charging motor with thermal-overload relays.

g. A motor control contactor, with relays, solenoids, and any other control devices required.

h. Necessary motor-alarm and interlock switches.

i. One-pole or two-pole thermal-magnetic, molded-case circuit breakers suitable for the operating voltage for control, heater, and light circuits.

j. A minimum of eight spare motor operator auxiliary contacts, four normally open and four normally closed, wired to an interconnection terminal block.

k. An interconnection terminal block wired to permit remote open and close operations of the switch and for other required exterior connections.

l. A key interlock if indicated or specified.

m. A local-remote selector switch and position indication lights.

n. Manual trip lever and manual charging handle (in case of loss of control power.

o. "Charged" and "Discharged" indicators for stored energy mechanism.

p. Gas pressure indicator, or low gas pressure indicator.

q. Local/Remote operation selector switch.

2.5.4.6 Grounded Iron Platform Plate

****
NOTE: Provide a detail on the drawings for securing the plate to finished grade.
****

The manually-operated, group-operated switch must be provided with a grounded platform plate located where the switch operator would stand to manually operate the switch. The plate must be constructed of hot-dip galvanized iron at least 6 mm 1/4 inch thick and must be approximately 1.2 m 4 feet in length by 750 mm 2 feet 6 inches in width. The plate must be laid on finished grade and so secured as shown. Two ground clamps must be provided on the plate on the side adjacent to the switch operating mechanism. Each clamp must be connected to the station grounding grid with a No. 4/0 AWG bare copper wire. Separate clamps and a flexible copper braid conductor must be used to connect the plate to the switch operating handle mechanism. The cross sectional area of the braid must be equivalent to a No. 4 AWG conductor, minimum.

2.6 SUBSTATION EQUIPMENT

****

NOTE: Make selections in this paragraph and in paragraph STATION ARRANGEMENT as appropriate for the installation. For this specification an articulated primary unit substation has both high-voltage and low-voltage sections mechanically coupled to the transformer. A primary unit substation has only the low-voltage section mechanically coupled to the transformer. For any given installation, only paragraph Primary Unit Substation or Substation Transformer or Articulate Primary Unit Substation will apply. For voltages through 34.5 kV, the primary switch/breaker should be mechanically-coupled or bus-duct-connected to the transformer primary. For 46 kV and above, the primary circuit breaker/switch should be cable-or aerial-bus-connected to the transformer primary. In general, the transformer secondary should be mechanically-coupled or bus-duct-connected to the secondary switchgear through and including 34.5 kV.

****

The installation must be [of the switching station] [of the primary unit substation] [of the substation transformer] [an articulated primary unit substation of the [radial] [distributed-network] [spot-network] [secondary-selective] [duplex]] type. [The initial capacity of the substation is based on the [55/65 degrees C] [self-cooled] [single-stage cooled] [two-stage cooled] [transformer capacity shown]]. The number of outgoing [lines] [distribution feeders] must be as shown. Outgoing circuits must be three-phase [three-wire] [four-wire] type [with [a bare] [an insulated] neutral] having a voltage rating of [_____] kV phase-to-phase. The insulated neutral must have insulation rated not less than 1000 volts. Outgoing circuit equipment must be rated for a nominal voltage class of [_____] kV and must have a BIL of not less than [_____] kV. Outgoing circuits must leave the station [aerially] [underground] [in cable trays].

2.6.1 Power Transformer

****

NOTE: Coordinate with paragraph Specific Unit Requirements.

Since some POWER TRANSFORMER manufacturers prefer the use of forced-oil-cooling over forced-air-cooling for the second stage, allow either option. Specify an oil preservation system for self-cooled capacities greater than 5000 kVA. Coordinate load-tap-changing type with Voltage Regulator section of paragraph AUXILIARY SUBSTATION EQUIPMENT.

****

The power transformer must comply with IEEE C57.12.00 and must be of the 55/65 degrees C rise, three-phase, two-winding, mineral-oil-immersed, [load-tap-changing type] and must be [solidly grounded] [resistance grounded through its associated neutral grounding resistor specified

below]. [The oil preservation system must be either of the sealed-tank, inert-gas-pressure system as defined in IEEE C57.12.80, or conservator/diaphragm type]. Temperature monitoring, indication, and automatically-controlled cooling equipment must be as specified. The color of the transformer case and auxiliary items must match the color used for switchgear and cabinets as specified for cabinets in paragraph CABINETS AND ENCLOSURES. Refer to specification Section 33 73 00.00 40 UTILITY TRANSFORMERS for requirements.

2.6.1.1 Ratings

****

NOTE: Standard ratings are listed in IEEE C57.12.10. Refer to UFC 3-550-01 for guidance regarding transformer losses. Coordinate with paragraph FACTORY TESTS. Delete loss requirement when not needed.

****

Transformer losses and impedances must be measured in accordance with IEEE C57.12.90. Ratings at 60 Hz must be in accordance with IEEE C57.12.10 and as follows:

High-voltage winding	[_____] volts
High-voltage BIL	[_____] volts
High-voltage winding connection	[_____]
Low-voltage winding	[_____] volts
Low-voltage BIL	[_____] volts
Low-voltage winding connection	[_____]
Base kVA	[_____]
Percent impedance range	[_____] to [_____]
Maximum no-load (core) losses	[_____]
Maximum full-load (winding) losses	[_____]

2.6.1.2 Auxiliary Cooling Equipment

[Cooling] [Provision for future cooling] equipment must be provided for [single-stage, forced-air-cooling] [two-stage, forced-air-cooling/forced-air-cooling] [or] [forced-air-cooling/forced-oil cooling] utilizing automatic control. Automatic controls, motors, heaters, and their protective devices must be rated for the application and must be suitable for the alternating current available as shown or specified. Radiator isolation valves must be provided for bolted-on radiators. Controls for auxiliary cooling equipment must combine the transformer top oil thermometer, device 26Q, and the transformer winding temperature simulator, device 49, suitable for responding either to the transformer's top liquid or winding temperature, and must include

auxiliary devices necessary for sensing temperature changes. These devices must be mounted on the transformer case in a suitable housing so that maintenance is possible without removing the transformer cover or handling oil. Devices 26Q and 49 must have three electrically independent contacts operating and wired as follows:

a. First set of contacts set to close at the manufacturer's recommended setting and wired for starting [future] [first-stage] forced-air-cooled fans.

b. Second set of contacts set to close at the manufacturer's recommended setting and wired to [start the second-stage forced-air-cooling fans] [start pumps for forced-oil-cooling] [alarm terminals in the transformer terminal cabinet] [alarm terminals in the metal-clad switchgear].

c. Third set of contacts set to close at the manufacturer's recommended setting and wired to energize an auxiliary relay, device 49X. The relay must be mounted in the [transformer terminal cabinet] [metal-clad switchgear]. Device 49X must be properly rated and equipped with not less than three normally open and three normally closed sets of electrically independent contacts. One set of contacts must be wired to annunciate excessive transformer temperature.

2.6.1.3 Neutral Grounding Resistor

****

NOTE: Time ratings greater than 10-seconds are required only when the system is not taken off line by a ground fault, but merely monitored.

****

The neutral grounding resistor assembly must comply with IEEE 32and must be [factory-mounted on the associated transformer] [mounted adjacent to the associated transformer] [mounted as indicated]. The assembly must meet the following:

a. The resistor element must be [stainless steel] [cast-iron] and rated [_____] amperes for a [10-second] [1-minute] [10-minutes] [extended time] duty.

b. The resistor must be installed in an aluminized screened or expanded galvanized steel enclosure of the personnel safety type and must be provided with any necessary supports and mounting hardware. The enclosure, including screening and support framing, must have two finish coats applied over a prepared substrate. The color of the finish coats must be the same as the color of the associated transformer.

c. A stress-relief terminator must be provided and arranged to permit the proper termination of the No. [_____] AWG, [_____] [5] [15] kV shielded transformer neutral cable entering the enclosure [from the [bottom] [top]] [as recommended by the manufacturer]. If the terminal bushing is external to the enclosure, the bushing and terminal provisions must be enclosed by a solid metal cable box equipped with conduit fittings correctly sized for the conduit required. An approved type and size of terminal lug must also be provided and arranged for the field termination of the No. 4/0 AWG bare copper grounding cable entering the enclosure from the bottom.

d. One current transformer conforming to the requirements of paragraph INSTRUMENT TRANSFORMERS must be provided and housed in the resistor enclosure. The current transformer must have the ratio shown and be connected as indicated to the associated overcurrent relay, device 51G, located in the [metal-clad switchgear] [instrument and relay cabinet specified above]. The terminals of the current transformer must be wired with not less than No. 10 AWG conductors to the proper terminals of device 51G through a short-circuiting type of terminal block [and test block] located in the [metal-clad switchgear] [instrument and relay cabinet] [transformer terminal cabinet].

2.6.1.4 Load-Tap-Changing Equipment

****

NOTE: The application will determine whether load-tap-changers will be paralleled. System configuration may require reverse power flow equipment. Specify only when required.

****

Load-tap-changing equipment must be provided to provide automatic adjustment of a transformer's low-voltage winding voltage. In addition to the basic load-tap-changing equipment requirements listed in IEEE C57.12.10, the load-tap-changing equipment must include the following:

a. A light wired in series with the control cabinet door-actuated switch, so that the light is energized only when the door or doors are open.

b. A heater continuously energized to prevent condensation within the control cabinet over ambient temperature ranges from [minus 29] [_____] to [40] [_____] degrees C [minus 20] [_____] to [104] [_____] degrees F, with both the heater and thermostat contact wired in series with the control cabinet door-actuated switch, so that the heater is de-energized when doors are open. High-temperature thermal protection must be included.

c. One-pole or two-pole thermal-magnetic molded-case circuit breakers suitable for the control voltage, when required by the manufacturer, and for low-voltage alternating-current power to control devices, motor, heater, and light circuits.

d. Terminal blocks wired for proper interconnection with remote items of equipment.

e. Circulating-current equipment necessary to allow parallel operation of the transformer.

f. Reverse power flow equipment wired so that the load-tap-changer functions only when electric power flows from high-voltage to low-voltage windings in the transformer.

2.6.1.5 Bushings and Equipment Connection Provisions

****

NOTE: A power transformer will require bushings and equipment connection provisions. Substation transformers require only bushings; articulated primary unit substations require only equipment

connection provisions.
****

[Bushings] [and equipment connection provisions] [Equipment connection provisions] must be provided as specified for [Primary Unit Substation] [Substation Transformer] [Articulated Primary Unit Substation] in paragraph SUBSTATION EQUIPMENT. Primary and secondary cover bushings for high- and low-voltage line and neutral connections must conform to the requirements of IEEE C57.19.00 and IEEE C57.19.01 and must [have the same BIL as] [be one BIL higher than] the associated power transformer's high- and low-voltage BIL ratings respectively.

2.6.1.6 Accessories

****
NOTE: Delete inapplicable items. Provide devices 63X and 86T when protective device tripping is required. Delete when only an alarm actuation is required.
****

Transformers must be provided with the accessories listed below. Contact devices for remote control features must be rated for the application and must be suitable for the low-voltage ac or dc available, as shown or specified.

a. A tap-changer for de-energized operation (TCDO) provided with padlock provision [and key-interlocked with the disconnecting switch protecting the associated transformer].

b. A liquid-level indicator and relay (device 71L), must be provided with two sets of normally-open and normally-closed contacts, one set for low-liquid-level and the other set for high-liquid-level. The contacts must be rated for the application and wired to one annunciator alarm point.

c. A pressure-vacuum gauge when the transformer is provided with a sealed-tank or inert gas-pressure oil preservation system.

d. Drain and filter valves.

e. Lifting, moving, and jacking facilities.

f. Two transformer case grounding lugs for termination of No. 4/0 AWG bare copper cables.

g. Sudden Pressure Relay: A sudden pressure relay, device 63SPR, must be provided as an integral part of the transformer. A set of contacts of device 63SPR must be [wired to energize an auxiliary relay, device 63X,] [located in the] [transformer terminal cabinet] [metal-clad switchgear] [instrument and relay cabinet]. [A set of contacts of device 63X must be wired to energize the transformer lockout relay, device 86T. In turn, contacts of device 86T must be wired to annunciate abnormal transformer pressure and trip the main secondary breaker and the circuit breaker on the primary side of the faulted transformer.]

2.6.1.7 Miscellaneous Items

****
NOTE: Follow Using Agency policy regarding protective device tripping and annunciation. Show remote control features including any annunciator system connections on the drawings.
****

Miscellaneous items for a transformer must include the following:

2.6.1.7.1 Terminal Cabinet

A weatherproof transformer terminal cabinet for circuits which are connected to devices not mounted integrally on a transformer, but remotely (such as in switchgear units) including interconnection terminals for any future cooling circuits. The gauge of metal for the cabinet must be the manufacturer's standard. Color of the cabinet must match the color of the associated transformer. The door or doors of the cabinet must be equipped with padlocking provisions.

2.6.1.7.2 Connections

Raceway connections and associated interconnection wiring between a transformer terminal cabinet and any remote devices which operate in conjunction with transformer-mounted devices, including necessary wiring for remote control features [and for [future] [cooling circuits]]. Remote control features include the [tripping of associated [primary] [and] secondary circuit breakers] [and] [the actuation of the associated annunciator circuits] by the indicated transformer control or accessory contact.

2.6.1.7.3 Delivery State

The transformer must be shipped from the factory already filled with oil, if possible. If the transformer must be vacuum filled in the field, a four inch NPT nipple, with cap for the vacuum line, must be added to the cover, away from the fill valve.

2.6.2 Primary Unit Substation

****
NOTE: Normally, specify primary unit substations for incoming nominal line voltages of 46 kV or higher.
****

Primary unit substations must comply with IEEE C37.121, must be suitable for outdoor installation, and must consist of transformer section equipment [directly connected] [connected by metal-enclosed bus duct] to outgoing section equipment.

2.6.2.1 Transformer Section Equipment

Transformer section equipment must comply with the requirements for power transformers in paragraph SUBSTATION EQUIPMENT.

2.6.2.2 Outgoing Section Equipment

Outgoing section equipment must comply with the requirements of paragraph OUTGOING METAL-CLAD SWITCHGEAR.

2.6.3 Substation Transformer

****
NOTE: Where single-phase transformers or aerial secondary connections are required, use substation transformer. Where contrary to criteria for new substations, their usage must be justified.
****

Substation transformer must comply with the requirements for power transformers in paragraph SUBSTATION EQUIPMENT.

2.6.4 Articulated Primary Unit Substation

****
NOTE: Normally, specify articulated primary unit substations for incoming nominal line voltages of 35 kV or less.
****

Articulated primary unit substation must comply with IEEE C37.121 and must be of the outdoor [radial] [secondary-selective] [distributed-network] [spot-network] [duplex] type.

2.6.4.1 Incoming Section Equipment

Incoming section equipment must comply with the requirements [for Metal-Enclosed Interrupter Switchgear in paragraph INCOMING SWITCHING/CIRCUIT INTERRUPTING EQUIPMENT.] [in paragraph OUTGOING METAL-CLAD SWITCHGEAR.]

2.6.4.2 Transformer Section Equipment

Transformer section equipment must comply with the requirements for power transformers in paragraph SUBSTATION EQUIPMENT. Primary and secondary equipment connection provisions must be suitable for direct connection to the specified incoming and outgoing switchgear.

2.6.4.3 Outgoing Section Equipment

Outgoing section equipment must comply with the requirements of paragraph OUTGOING METAL-CLAD SWITCHGEAR.

2.6.5 Metal-Enclosed Bus

****
NOTE: Metal-enclosed bus may be necessary between the transformer section and outgoing section for a primary unit substation or where the incoming line section of an articulated primary unit substation is located remote to the power transformer. Provisions for Articulated Primary Unit Substation and Metal-Enclosed Bus in paragraph SUBSTATION EQUIPMENT should be modified as required. Industry standards

for continuous, self-cooled, metal-enclosed bus ratings are listed in ANSI C37.23.

****

Metal-enclosed bus must have ratings that equal or exceed the ratings of the buses, circuit breakers, and switchgear to which the bus is connected, unless otherwise indicated. The bus must conform to the requirements of IEEE C37.23. Bus must be of the nonsegregated-phase type. [A ground bus [is] [is not] required.] [A neutral bus [is] [is not] required.] The enclosure is to be the nonventilated type constructed of selected smooth sheet steel not less than [_____] mm gauge, and must be equipped with continuously energized space heaters (with high-temperature thermal protection) to prevent condensation over an ambient temperature range of [minus 29] [_____] to [40] [_____] degrees C [minus 20] [_____] to [104] [_____] degrees F. The finish of the enclosure must be in accordance with the manufacturer's standard. The finish, type, and gauge of the metal enclosure and the details of transitional elements and connections and the lengths and ratings of the bus and enclosure proposed must be as shown on detail drawings.

2.7 OUTGOING METAL-CLAD SWITCHGEAR

****

NOTE: Designer will show on contract drawings the locations of all items specified in other paragraphs that will be located in the metal-clad switchgear. Where two-high units are used, consult manufacturer's literature and catalogs for available options. Ancillary devices such as PTs and metering will not fit in the switch compartment and require a separate compartment or top hat section.

****

Switchgear must comply with IEEE C37.20.2 and must be of the outdoor [no-aisle][protected-aisle][common-aisle] type consisting of incoming line [, tie,] auxiliary compartments and feeder circuit breaker units. Compartments must be provided to accommodate specified or indicated auxiliary equipment. The indicated number of active and [future] circuit breakers and equipped cubicles must be provided.["Future" circuit breaker means sufficient concrete pad space and duct line stubouts for future sections.][The use of two-high circuit breaker units is acceptable.] [Two-high circuit breaker units must be provided.][When two-high circuit breaker units are installed, equipped space units must be provided when necessary to make adjacent sections equal in height.][Units denoted as equipped space or future must consist of fully provisioned space ready for inserting a circuit breaker at a future date without any future modifications. A blank door must close off the front of the compartment.][Current transformers, instruments, instrument switches, and relays must be provided for equipped space or future units as shown.][Continuous current rating of future units must be as indicated.][Continuous current rating of equipped space units must match the most common basic breaker unit ampere rating used elsewhere in the associated switchgear unless otherwise indicated.] Switchgear must be vented according to the manufacturer's standard practice. Intake and exhaust openings must be screened. Switchgear must have relaying as shown. The control voltage must be [120 V ac][240 V ac][24 V dc][48 V dc][125 V dc][250 V dc].

2.7.1 Ratings

****
NOTE: IEEE C37.06, Table 2, lists preferred ratings for indoor oilless circuit breakers. A short-circuit study is required to specify ratings.
****

Main buses must be three-phase [three-wire] [four-wire] with a continuous current rating of [_____] amperes rms. [The neutral bus must be rated for [_____] amperes, continuous.] Switchgear ratings at 60 Hz must be in accordance with IEEE C37.06 and as follows:

Maximum voltage	[_____]
Nominal voltage class	[_____]
BIL	[_____]
Maximum symmetrical interrupting current	[_____]
3-second short-time current	[_____]
Continuous current	[_____][as indicated]

2.7.2 Circuit Breakers

****
NOTE: Cell-mounted switches are seldom needed. Circuits protected by vacuum and SF6 circuit breakers are susceptible to multiple arc re-ignitions and high transient recovery voltages under certain conditions. The designer must evaluate the distribution system and provide surge suppressors or other means recommended by the manufacturer to minimize or eliminate these effects. (Surge suppressors are normally added on the load side of the switch.)
****

Circuit breakers must comply with IEEE C37.04 and IEEE C37.06. Where indicated, bus or lug connections to mount field-installed, slip-on, medium-voltage cable terminations for cable entering from below [and a flanged throat for direct connection to the associated transformer] [and a bus throat for connection to the associated metal-enclosed bus] [and roof bushings for aerial line connections] must be provided. [Roof bushings must [have the same BIL as] [be one BIL higher than] the associated switchgear and must conform to IEEE C57.19.00 and IEEE C57.19.01.] Circuit breakers must be of the [vacuum] [sulfur hexafluoride (SF6)] drawout type having electrically charged, stored-energy mechanisms which are mechanically and electrically trip free. A means for manual charging of each trip mechanism must be provided. Circuit breakers of the same ampere rating must be interchangeable, both mechanically and electrically. [Each circuit breaker must have a cell-mounted switch assembly for control and interlocking.] [Cell switches may be connected either in parallel or in series with control contacts that are used for

interlocking, but either connection must permit operation of a circuit breaker when it is in a test position.] In addition to any contacts used or shown, each circuit breaker must be provided with four spare auxiliary [and cell contacts], two normally open and two normally closed, wired to interconnection terminals. If auxiliary relays are used to provide additional contacts, such relays must not be of the latching type. Interconnection terminal blocks must be wired to permit remote open and close operations of each circuit breaker and for other required exterior connections or connections between switchgear sections.

2.7.2.1 Vacuum Circuit Interrupters

Vacuum interrupters must be hermetically-sealed in a high vacuum to protect contacts from moisture and contamination. Circuit breakers must have provisions for maintenance slow closing of contacts and have a readily accessible contact wear indicator. Tripping time must not exceed [3] [5] [8] cycles.

2.7.2.2 Sulphur Hexafluoride (SF6) Interrupters

SF6 interrupters must be of the puffer type where the movement of the contact plunger will initiate the puff of SF6 gas across the contact to extinguish the arc. Breakers must be provided with a loss-of-pressure-alarm remote as shown on the drawings. Before the pressure in the interrupter drops below the point where the breaker or switch cannot open safely without damage, the breaker must activate the loss-of-pressure-alarm, open automatically, and remain in the locked open position until repaired. The SF6 must meet the requirements of ASTM D2472, except that the maximum dew point must be minus 60 degrees C minus 76 degrees F (corresponding to 11 ppm water by volume), with only 11 ppm water by volume, and the minimum purity must be 99.9 percent by weight. Circuit breakers must have provisions for maintenance slow closing of contacts and have a readily accessible contact wear indicator. Tripping time must not exceed [3] [5] [8] cycles.

2.7.3 Buses

Copper bus must comply with ASTM B188. Equivalent aluminum bus must comply with ASTM B317/B317M. Bolted or pressure joints for main and ground buses, interconnections, and external connections to equipment must be of the silver-to-silver or the silver-to-tin high-pressure type. Bolted connections must have a minimum of two bolts, except for the ground bus where one bolt will suffice. Each nut on any bolted connection must be secured with a belleville washer or other locking means torqued in accordance with manufacturer's recommendations. Bus supporting elements must be bolted to switchgear enclosures and must comply with IEEE C37.20.2.

2.7.3.1 Main Buses

Main buses and connections must have at least the same short-circuit current rating as circuit breakers. Buses may be copper or aluminum, but a combination of both metals is not acceptable unless silver-to-silver or silver-to-tin plating is used wherever aluminum and copper buses are connected.

2.7.3.2 Ground Buses

Uninsulated copper ground buses, not less than 51 by 6.2 mm 2 by 1/4 inch in cross-sectional area, must be provided for the full length of a

switchgear lineup. Ground buses of aluminum are not acceptable. The short-circuit current rating of the ground bus must be at least equal to the short circuit current rating of the primary bus. Compression indent type cable lugs must be provided at each end of a ground bus for connection of [No. 4/0 AWG] [_____] copper ground cables.

2.7.3.3 Control Buses

****
NOTE: Refer to UFC 3-550-01 for guidance regarding control buses.
****

Control buses must be provided as necessary to supply power to control devices. [Buses must be supplied from low-voltage panelboards. Where one panelboard serves more than one bus, each group of units on each bus must be served by different branch circuit breakers.] For double-ended buses, both buses must be supplied from one low-voltage panelboard and each bus must be served by different branch circuit breakers. The low-voltage panelboard must be served from an automatic transfer [relay] [contactor] [switch], which, in turn, must be served from two control power transformers (CPT). One CPT must be connected via fuses ahead of each main circuit breaker. Each CPT, fuse, transfer device, panelboard, and wiring system must be sized to handle 125 percent of the total load of both buses. The "Normal" and "Backup" sources must be as indicated. Upon the loss of the "Normal" source, transfer to the "Backup" source must be instantaneous. Retransfer back to the "Normal" source must be [automatic upon the restoration of the "Normal" source] [automatic after a [_____] time delay once the "Normal" source is restored]. [The "Normal" and "Backup" source must be selectable.] [An alarm must be provided to indicate a transfer operation.] [An alarm must be provided to indicate loss of a source.] Insulated wire buses must be wired to interface terminal blocks for connection between switchgear units and exterior components. Wire bus must not be less than [No. 8 AWG] [_____], nor less than required to serve the complete switchgear lineup plus 25 percent spare capacity.

2.7.4 Control Power Transformers

****
NOTE: Where an outdoor structure-mounted oil-immersed distribution transformer is used for control power, such as when metal-clad switchgear is not provided, specify requirements using data from Section 33 71 01 ELECTRICAL DISTRIBUTION SYSTEM AERIAL and protect such transformers with power fuse disconnecting units.
****

Control power transformers must comply with IEEE C57.12.01, must be of the ventilated dry type, and must provide [240/120-volt, single-phase] [208Y/120-volt, 3-phase] electric power for station ac control power requirements. The transformer primary voltage rating must be [_____] kV and the transformer capacity must be [_____] kVA [as indicated]. The BIL rating must equal or exceed the BIL rating of the switchgear. Transformer current-limiting primary fuses must be drawout type and must be interlocked with a secondary molded case circuit breaker provided as a part of the transformer installation. Molded case circuit breakers must comply with UL 489. It must not be possible to open the primary fuse

compartment unless this secondary circuit breaker is in the open position. Construction must be of the drawout type for either the complete assembly or for primary fuses only, according to the manufacturer's standard. Mechanical interlocks must prevent removal of primary fuses, unless the associated assembly is in a drawout or disconnected position. Transformer compartments must have hinged doors.

2.7.5 SUBSTATION AND SWITCHGEAR PROTECTIVE RELAYS

****
NOTE: Ranges selected will be based on the coordination study. Refer to UFC 3-550-01 and UFC 3-520-01 for guidance regarding protective relays.
****

2.7.5.1 General

[Solid-state] [and] [Electromechanical] [and] [Microprocessor-based] protective relays must be provided as shown and must be of a type specifically designed for use on power switchgear or associated electric power apparatus. Protective relays must conform to IEEE C37.90. Relays and auxiliaries must be suitable for operation with the instrument transformer ratios and connections provided.

2.7.5.2 Construction

Relays must be of the semi-flush, rectangular, back-connected, dustproof, switchboard type. Cases must have a black finish and window-type removable covers capable of being sealed against tampering. Relays must be of a type that can be withdrawn, through approved sliding contacts, from fronts of panels or doors without opening current transformer secondary circuits, disturbing external circuits, or requiring disconnection of any relay leads. Necessary test devices must be incorporated within each relay and must provide a means for testing either from an external source of electric power or from associated instrument transformers. Each relay must be provided with an operation indicator and an external target reset device. Relays must have necessary auxiliaries for proper operation. Relays and auxiliaries must be suitable for operation with the instrument transformer ratios and connections provided.

2.7.5.3 Ratings

Relays must be the manufacturer's standard items of equipment with appropriate ranges for time dial, tap, and other settings. Relay device numbers must correspond to the function names and descriptions of IEEE C37.2.

2.7.5.4 Overcurrent Relays

****
NOTE: Ranges selected will be based on the coordination study. Refer to UFC 3-550-01 and UFC 3-520-01 for guidance regarding protective relays.
****

2.7.5.4.1 Phase Overcurrent Relays for Main [and Tie] Circuit Breakers

Phase overcurrent relays for main [and tie] circuit breakers must be single-phase, nondirectional, [induction] [solid-state]

[microprocessor-based] type, time delay, device 51, current taps [[_____] to [_____] amperes] [as indicated] with characteristic curves that are [definite time] [moderately inverse] [inverse] [very inverse] [extremely inverse] [as indicated].

2.7.5.4.2 Ground Overcurrent Relays for Main Circuit Breakers

Ground overcurrent relays for main circuit breakers must be nondirectional, [induction] [solid-state] [microprocessor-based] type, time delay, device [51G wired to a current transformer in the source transformer neutral-to-ground connection] [51N, residually connected], with current taps [[_____] to [_____] amperes] [as indicated] and with characteristic curves that are [definite time] [moderately inverse] [inverse] [very inverse] [extremely inverse] [as indicated].

2.7.5.4.3 Ground Overcurrent Relays for Tie Circuit Breakers

Ground overcurrent relays for tie circuit breakers must be nondirectional, [induction] [solid-state] [microprocessor-based] type, time delay, device 51N, residually connected, with current taps [[_____] to [_____] amperes] [as indicated] and with characteristic curves that are [definite time] [moderately inverse] [inverse] [very inverse] [extremely inverse] [as indicated].

2.7.5.4.4 Phase Overcurrent Relays for Feeder Circuit Breakers

Phase overcurrent relays for feeder circuit breakers must be single-phase, nondirectional, [induction] [solid-state] [microprocessor -based] type, time delay, device 50/51, with instantaneous-current pick-up range [[_____] to [_____] amperes] [as indicated], with time-delay-current taps [[_____] to [_____] amperes] [as indicated] and with characteristic curves that are [definite time] [moderately inverse] [inverse] [very inverse] [extremely inverse] [as indicated].

2.7.5.4.5 Ground Overcurrent Relays for Feeder Circuit Breakers

Ground overcurrent relays for feeder circuit breakers must be nondirectional, [plunger] [solid-state] [microprocessor-based] type instantaneous, device [50GS wired to a ground sensor current transformer] [50N, residually connected], with current pick-up range [[_____] to [_____] amperes] [as indicated].

2.7.5.5 Directional Overcurrent Relays

2.7.5.5.1 Directional Phase Overcurrent Relays

Single-phase, [induction] [solid-state] [microprocessor-based] type with instantaneous units. Phase relays, device 67, must have an instantaneous-current pick-up range [[_____] to [_____] amperes] [as indicated], with time-delay-current taps [[_____] to [_____] amperes] [as indicated] and with characteristic curves that are [definite time] [moderately inverse] [inverse] [very inverse] [extremely inverse] [as indicated].

2.7.5.5.2 Directional Ground Overcurrent Relays

Device 67N, must have an instantaneous-current pick-up range [[_____] to [_____] amperes] [as indicated], with time-delay-current taps [[_____] to [_____] amperes] [as indicated] and with characteristic curves that are

[definite time] [moderately inverse] [inverse] [very inverse] [extremely inverse] [as indicated].

2.7.5.6 Automatic Reclosing Relay

Relay, device 79, must be of the three-phase, four-reclosure type, providing immediate initial reclosure, and three time-delay reclosures. Adjustable time delays must be 10 to 60 seconds for reset and 0 to 45 seconds for reclosing. Units must have instantaneous trip lockout after any preset trip or when closing in on a fault. Auxiliary devices must provide for lockout when an associated circuit breaker is tripped after three reclosures and automatically reset when an associated circuit breaker is not tripped after any reclosure.

2.7.5.7 Transformer Differential and Lockout Relays

Differential relays, device 87T, must be of the three-phase or the single-phase high-speed [_____] [percentage] [_____] differential type suitable for the protection of two-winding transformers, and must be provided with a harmonic-restraint feature. Lockout relay, device 86T, must be of the type which, when used in conjunction with the 87T relay, trips and locks out the indicated circuit breakers.

2.7.5.8 Bus Differential and Lockout Relays

Bus differential relay, device 87B, must be of the three-phase or single-phase, high-speed impedance differential type suitable for protection of buses. Lockout relay, device 86B, must be of a type which, when used in conjunction with the 87B relay, trips and locks out the indicated circuit breaker.

2.7.6 Control and Instrument Switches

Control and instrument switches must be of the rotary switchboard type rated for alternating-current operation at 600 volts, or direct-current operation at 250 volts for dc circuits, as applicable. Contacts must be rated for not less than a continuous current of 20 amperes, must be of the silver-to-silver type, and must have positive means for maintaining contact. Each switch must be provided with a black operating handle, and an escutcheon clearly marked to show each operating position. Switch identifications and handle positions must be engraved on escutcheons or may be provided on separate nameplates. Escutcheon engravings must be white on a black background or black on a white background. Instrument switches for potential phase selection must be provided with an oval handle. Ammeter switches for phase selection must have round, notched, or knurled handles and equipped with short-circuiting type of contacts to prevent open-circuiting of current transformer secondary circuits in any position of the ammeter switches. Switches provided for circuit breaker control and local-remote selector switches must have a pistol-grip handle and a mechanical target to indicate the last operating position of the switch. Red and green circuit breaker position indication LED lights must be installed immediately above each circuit breaker switch. Local-remote selector switches must be provided only when shown or specified. Position indication lights must be installed immediately above selector switches, with blue LED lights indicating remote control and amber LED lights indicating local control.

2.7.7 Electrical Indicating Instruments

Electrical indicating instrument relays must comply with ANSI C12.1, NEMA C12.4, and NEMA/ANSI C12.10.[Electrical indicating instruments must be of the semiflush, back-connected, dustproof, direct-reading, switchboard type, approximately 108.0 mm square 4-1/4 inches square, with white dials, black markings, black pointers, and scale arcs of approximately 250 degrees. Cases must have a black finish and shadowproof viewing covers. The accuracy of each instrument must be within 1 percent of full scale. Moving elements must be provided with zero adjustments readily accessible from instrument fronts without disassembly. Each instrument must be accurately calibrated for use with the associated instrument transformers, and must have the indicated scale or a scale suitable for the application, where a specific scale is not indicated. Except for ammeters and voltmeters or unless otherwise specified or approved, the nominal or full-load values must appear at the approximate mid-point, or the 12 o'clock position, of the scales.][Electrical instrumentation devices must be compatible as a system, sealed, dust and water tight, utilize modular components with metal housings and digital instrumentation. Date display must utilize LED or back-lit LCD. Numeral height must be [13 mm 1/2 inch][_____].]

2.7.7.1 Wattmeters

Wattmeters must comply with ANSI C12.1 and NEMA/ANSI C12.10 except for mounting and must be the three-phase, [four-wire type with three current coils and three potential coils] [three-wire type with two current coils and two potential coils].

2.7.7.2 Varmeters

Varmeters must be the center-zero type and provided with integral or separate phase-shifting transformers or compensators. Varmeter must be the three-phase, [four-wire type with three current coils and three potential coils] [three-wire type with two current coils and two potential coils]. Varmeters must have dial markings and be so wired that incoming VAR readings must be to the left of zero and outgoing VAR readings must be to the right of zero. Dials must be so labeled. Meter must be capable of communicating with Lonworks and RS-485 networks.

2.7.7.3 Ammeters and Ammeter Switches

****

NOTE: Normally, 3/4 of full-scale should be specified. Mid-scale should be specified when current transformers will be operating at currents exceeding their ratings.

****

Ammeters must be calibrated to indicate full-load current when supplied with a current of 5 amperes. Full-load current must be indicated by the pointer at approximately [mid-scale] [75 percent of the full-scale range]. Ammeter switches must be of the short-circuiting type provided with an off position, wired for indication of current in each phase, and must be provided for each ammeter shown or specified.

2.7.7.4 Voltmeters and Voltmeter Switches

Voltmeters must be provided with expanded scales and calibrated to

indicate the nominal [phase-to-phase] [and] [phase-to-neutral] voltages at approximately mid-scale. A voltmeter switch must be provided with an off position, wired for indication of applicable voltages, and must be provided for each voltmeter shown or specified.

2.7.7.5 Demand Registers

Demand registers must comply with NEMA C12.4.

2.7.8 Electrical Recording Instruments

****
NOTE: Recording instruments should be provided when specifically requested by the Using Agency. Coordinate various types and characteristics with the manufacturer.
****

Electrical recording instruments must be of the [direct-acting] [null-balancing] type. Instrument switches must be provided when shown or required to select between different quantities to be recorded, and must comply with the preceding requirements for instrument switches, as applicable.

2.7.8.1 Basic Requirements

Electrical recording instruments must be of the semi-flush, back-connected, dustproof, switchboard and inkless type. The case must have a black finish and shadowproof viewing windows [and, insofar as is practicable, must be of the same size, style, and appearance]. The driving motor must be rated for 120-volt ac operation. Where ungrounded input is required to an instrument, an isolating transformer must be provided. An instrument must have a high visibility scale of a suitable range, and indicating pointer, and an internal fluorescent light for chart illumination. Chart speed must be [20.8] [_____] micrometers/second [3] [_____] inches/hour. An instrument must be correctly calibrated for use on the secondary of any instrument transformer to which it is connected and must have the indicated scale or a scale suitable for the application, where a specific scale is not indicated. Necessary maintenance accessories and a 6-month supply of charts must be provided for each chart-recording instrument. Chart length must be sufficient to permit not less than 30 days of continuous operation at the normal chart speed without the need for replacement.

2.7.8.2 Direct-Acting Type

Direct-acting type instruments must be of the [single-channel,] [two-channel,] strip-chart, self-contained, continuous-marking type with a chart channel calibrated width of not less than 100 mm 4 inches.

2.7.8.3 Null-Balancing Type

****
NOTE: The third and following sentences in this paragraph should also be included in project specifications when a direct-acting type of recorder is to be specified.
****

Null-balancing type instruments must be of strip-chart, self-contained, direct-current potentiometer, periodic-marking type provided with an associated and coordinated transducer for conversion of the measured alternating-current quantity to the direct-current input required for the instrument. Charts must have a calibrated width of not less than 225 mm 9 inches. An instrument must be provided with an internal lamacoid legend plate suitably engraved, a chart supply indicator, a chart tear-off without indices, a rubber chart identification stamp reading the same as the legend plate, a chart reroll, a writing table, and an electric power "ON-OFF" switch. The chart reroll must be self-aligning, smooth in operation, self-contained in the instrument case, and accessible for the changing of chart rolls. The writing table must be located under the uncovered part of the chart between the indicator and reroll in such manner as to permit convenient writing on the chart by merely opening the front hinged cover, and must be designed so that it will not interfere with replacement of charts or access to the recorder mechanism. The chart drive motor must drive the chart through suitable reduction gearing and must have sufficient torque to start the chart when operating on 80 percent of its rated voltage. The motor control switch must be located [within the case so that it can be conveniently reached to start or stop the motor] [_____]. A recorder operation selector switch must be interlocked with its associated medium-voltage circuit breaker to allow either continuous operation of the instrument or automatic isolation of the instrument when the circuit breaker is in the tripped or test position.

2.7.8.4 Transducers

****

NOTE: Transducers will be specified only when remote metering is required.

Watthour, varhour, watt, and varmeters and transducers will be specified as 2, 2-1/2, or 3 element devices as follows:

a. Two element if used on a 3-phase, 3-wire system serving only balanced 3-phase load (requires 2-VTs).

b. Two and one-half element if used on a 3-phase, 3-wire system serving single-phase-to-phase loads (requires 2-VTs)

c. Three element if used on a 3-phase, 4-wire system (requires 3-VTs).

****

Transducers may be integral with an instrument or may be a separate unit and must be of the [unidirectional] [bidirectional] constant-current type providing an analog signal directly proportional to the instantaneous quantity measured. Ratings at 60 Hz must be for a 120-volt nominal input voltage, a 150-volt overload voltage, a 5-ampere nominal input current, a 10-ampere continuous overload current, a 250-ampere 1-second instantaneous overload current, and provide an accuracy of plus or minus 0.5 percent. The maximum individual instrument transformer burden must not exceed 4 volt amperes. Output at full scale must not exceed one mA.

2.7.9 Accumulative Meters

Accumulative type meters must be provided as shown to measure real [and

reactive] power consumed, and must be rated for use with instrument transformers shown. [Meters must be equipped with demand pointers.] [Compensators or phase-shifting transformers must be provided for instruments used to measure reactive power.] [Meters must be equipped with detents to prevent negative registration.]

2.7.9.1 Construction

Meters must be of the semiflush, back-connected, dustproof, drawout switchboard type. Cases must have black finish and window-type removable covers capable of being sealed against tampering. Meters must be of a type that can be withdrawn, through approved sliding contacts, from fronts of panels or doors without opening current-transformer secondary circuits, disturbing external circuits, or requiring disconnection of any meter leads. Necessary test devices must be incorporated within each meter and must provide means for testing either from an external source of electric power or from associated instrument transformers.

2.7.9.2 Ratings

****
NOTE: Coordinate with paragraph Transducers.
****

Meters must be [_____]-stator, three-phase, [_____]-wire, [_____] element rated for 120-volt, 2.5 ampere, 60 Hz ac operation calibrated for use with associated instrument transformers. Meters must have primary-rated, direct-reading registers with not less than four dials. The register multiplying factor must be [_____]. Demand meters must have [15-minute] [[_____]-minute] demand registers.

2.7.9.3 Adjustments, Registration Errors, and Other Requirements

Calibrating adjustments for light load and for full load must be of the micrometer type, and adjustable from the front of the meter. Adjustments must be provided for power factor and torque balance. The periphery of the discs must be provided with standard notching to permit direct comparison with a stroboscopic type standard meter. Potential indicating lamps must be provided in the potential coil circuits. The current coils must be capable of withstanding the mechanical and thermal stresses imposed by a current 35 times normal applied for at least 0.5 second. The registration errors of a meter for both unity and 50 percent lagging power factor must not exceed those listed below when tested at rated voltage, frequency, temperature, and full load current, except as otherwise stated.

a. Errors due to applied current must be not more than 1 percent at 10 percent to 50 percent of the rated current and 0.5 percent at 50 percent to 150 percent of the rated current.

b. Errors due to applied potential must be no more than 0.5 percent over a range of plus or minus 10 percent of the rated voltage.

c. Errors due to applied frequency must be no more than 0.004 percent between 59 and 61 Hz.

d. Errors due to a change in ambient temperature must be no more than 0.5 percent over a range of 20 to 40 degrees C 64 to 104 degrees F.

2.7.10 Test Blocks and Accessories

Test blocks and their associated testing accessories must be provided for testing of instruments and protective relays that require periodic testing or calibration in-place, but which are not equipped with integral testing features. Test blocks with covers must be mounted near the base of the switchgear unit beneath the devices to be tested, and must be provided with a nameplate engraved to identify individual current or potential test blocks, or a combination current/potential test block, as applicable. Combination test blocks must not exceed 10 poles. Current test blocks must be the short-circuiting type. Test devices must be provided for insertion into the associated test block to permit application of the proper current or potential source for testing and calibration. Test devices must be rated not less than 20 amperes and 125 volts dc.

2.7.11 Specific Unit Requirements

****
NOTE: Specify devices to be located on a swinging or interior panel for aisleless switchgear and on unit or compartment doors for switchgear provided with interior aisles.
****

In addition to the basic circuit breaker unit requirements, each individual unit or section must contain other devices as required for the application. The following requirements are not to be considered complete in every detail and miscellaneous equipment and devices necessary for correct operation, as indicated or specified, must be provided as necessary. Protective relays, meters, instruments, and control and instrument switches, must be mounted [on a swinging panel located behind the exterior door of no-aisle switchgear] [on a unit or compartment door]. [Where space is not available for these devices, indicated devices may be installed on auxiliary compartment doors as shown.] [Devices specified in paragraph [INCOMING LINE SWITCHING EQUIPMENT] [and paragraph] [SUBSTATION EQUIPMENT] to be installed in the metal-clad switchgear must be located where indicated.]

2.7.11.1 Incoming Line and Transformer Main Secondary Units

****
NOTE: Specify "Incoming Lines" for switching stations and "Transformer Main Secondary" for power transformers.
****

Units must be coordinated with the [requirements of the serving utility] [and] [the transformer to be protected] and must include the following:

a. [Three] [Six] [_____] current transformers.

b. Ammeter and an ammeter switch.

c. [Voltmeter] [Voltmeter, recording type] and a voltmeter switch.

d. Watthour [demand] meter.

e. Wattmeter [, recording type].

f. Varmeter [, recording type].

g. Duplex watt-varmeter, recording type.

h. Watt transducer integral with the associated wattmeter or mounted on the [back of a section door] [interior panel].

i. VAR transducer integral with the associated varmeter or mounted on the [back of a section door] [interior panel].

j. Three overcurrent relays, device 51.

k. Three directional overcurrent relays, device 67.

l. Overcurrent relay, device 51 [N] [G] [connected to the associated transformer neutral [grounding resistor] current transformer].

m. Directional overcurrent relay, device 67N.

n. One three-phase or three single-phase transformer differential relays, device 87T, and an auxiliary lockout relay, device 86T, arranged to trip and to lock out this circuit breaker and the associated transformer primary circuit breaker.

o. One three-phase or three single-phase bus differential relays device 87B, and an auxiliary lockout relay, device 86B, arranged to trip and lock out the associated circuit breaker and other circuit breakers as indicated.

p. [Single-] [Three-] phase secondary potential test blocks with associated test devices, quantity as shown.

q. [Single-] [Three-] phase secondary current test blocks with associated test devices, quantity as shown.

r. Key-interlocking must be provided with the primary disconnecting switch serving the associated transformer.

[s. [_____].]

2.7.11.2 Auxiliary Compartments

****

NOTE: Where switchgear aisle space of sufficient area is available, the station battery installation will be mounted there. Coordinate with NFPA 70 and IEEE C2 for clearances. The designer should indicate the panelboard requirements on the project drawings.

****

Control and instrument transformers and panelboards must be provided and housed in compartments, [unless otherwise noted,] and must supply control power and instrument voltage to each bus section of the switchgear lineup and remote devices as required. Compartments must be provided with a hinged door. Any interconnection wiring and conduit needed to connect the switchgear lineup or other devices requiring control power or instrument voltage must be provided and indicated on the detail drawings. Equipment items must include the following:

a. [Three] [_____] potential transformers.

b. [_____] control power transformers.

c. [_____] low-voltage alternating-current panelboards and [_____] low-voltage direct-current panelboards with main and branch circuits as shown [, located in the switchgear aisle where indicated] [, and with equipment as specified in paragraph AUXILIARY SUBSTATION EQUIPMENT].

[d. [_____].]

2.7.11.3 Bus Tie Unit

[The unit must be electrically interlocked with [incoming line] [transformer main secondary] units as indicated.] [The unit must be provided with [_____].]

2.7.11.4 Feeder Units

Units must be provided for the protection of outgoing feeder circuits and must include the following:

a. [Three] [Six] [Nine] current transformers. [One ground sensor current transformer.]

b. Ammeter and an ammeter switch.

c. Three overcurrent relays, device [50] [51].

d. Ground overcurrent relay, device [50GS] [50N].

e. Wattmeter.

f. An automatic-reclosing relay, device 79.

g. [Single] [Three] phase secondary potential test blocks with associated test devices, quantity as shown.

h. [Single] [Three] phase secondary current test blocks with associated test devices, quantity as shown.

[i. [_____].]

2.7.12 Miscellaneous Items

2.7.12.1 Space Heating and Ventilation

Continuously-energized space heaters (with high-temperature thermal protection) must be installed in each switchgear unit and auxiliary compartment in accordance with the manufacturer's standard practice and must be sized to prevent condensation over an ambient temperature range of [minus 29] [_____] to [40] [_____] degrees C [minus 20] [_____] to [104] [_____] degrees F. Heaters must be controlled by a thermostat [and humidistat] located in the section. [Provide humidistat with a range of 30 to 60 percent relative humidity.] Obtain supply voltage for the heaters from a control power transformer within the switchgear. If heater voltage is different than switchgear voltage, provide transformer

rated to carry 125 percent of heater full load rating. Provide transformer with a 428 degrees F220 degrees C insulation system with a temperature rise not exceeding 239 degrees F115 degrees C and conforming to NEMA ST 20. [Energize electric heaters in switchgear assemblies while the equipment is in storage or in place prior to being placed in service. Provide method for easy connection of heater to external power source. Provide temporary, reliable external power source if commercial power at rated voltage is not available on site.] Aisle ventilation fans must be provided where indicated and must be sized to provide at least 10 air changes per hour. Fans must be wired to three-way switches located at each end of the switchgear aisle and adjacent to aisle lighting switches. In addition, fans must be thermostatically controlled to turn fans on when interior temperatures exceed 40 degrees C 104 degrees F.

2.7.12.2 Aisle Lighting

LED luminaires must be a manufacturer's standard fixture installed in the switchgear aisle to provide a maintained lighting intensity level of 538.2 lux 50 footcandles at floor level in the aisle and on faces of units and compartments. Luminaires must be wired to three-way switches located at each end of the switchgear aisle. Light fixtures must be lensed vapor tight type fixtures.

2.7.12.3 Duplex Receptacles

Duplex receptacles must be installed on each end wall of the switchgear aisle and at approximately 1.8 m 6-foot intervals along the exterior wall of the aisle. Receptacles and receptacle plates must be ivory in color. Receptacles must be the two-pole, three-wire, grounded type rated at 20 amperes and 125 volts, NEMA WD 1 configuration 5-20R.

2.7.12.4 Lighting and Appliance Branch Circuit Panelboards

Lighting and appliance branch-circuit panelboards for the protection of the indicated low-voltage circuits must be located as specified or indicated and must conform to the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Ratings of panelboard mains must be compatible with the supply voltage to the panelboard. Circuit breakers in a direct-current panelboard must be rated for [48] [125] volts dc operation.

2.7.13 Accessories

Accessories must be provided for the inspection, testing, maintenance, and repair of circuit breakers, and must include one set of any special tools, as necessary to repair and maintain circuit breakers and major switchgear components. Maintenance and testing accessories must include, but are not limited to the following:

a. Portable gear motor for electric-power positioning of circuit breakers, if required by the breaker design.

b. Secondary test coupler for testing of drawout circuit breakers in the test position.

c. Hand crank for positioning of circuit breakers.

d. Transfer truck, for movement of circuit breaker units.

e. Test cabinet for closing and tripping of circuit breakers by electrical control operations.

f. Lifting and transfer device for two-high circuit breaker units.

2.7.14 Finish Color

Finish color of the switchgear must comply with the requirements for cabinets specified in paragraph CABINETS AND ENCLOSURES.

2.8 INSTRUMENT TRANSFORMERS

2.8.1 General

Instrument transformers must comply with NEMA/ANSI C12.11 and IEEE C57.13. Instrument transformers must be configured for mounting in/on the device to which they are applied. Polarity marks on instrument transformers must be visually evident and shown on drawings.

2.8.2 Current Transformers

****

NOTE: See UFC 3-550-01 regarding guidance on current transformers. Accuracy class ratings of current transformers (CTs) at standard burdens are listed in IEEE C57.13. The minimum standard current transformer accuracies for metal-clad switchgear are listed in IEEE C37.20.2. In general, NEMA/ANSI C12.11 requires a 0.3 accuracy class for up to a B-0.5 burden, except for some 200 and 400 ampere units. Where metering current transformers are provided, this accuracy class should be specified, if available for the ampere rating and burden needed. A "C" classification means the ratio error can be calculated, whereas a "T" classification is one which has to be derived by testing. IEEE C37.20.2 permits either classification up to the indicated ratings.

****

Unless otherwise indicated, bar, wound, or window-type transformers are acceptable; and except for window-type units installed over insulated buses, transformers must have a BIL rating consistent with the rated BIL of the associated switchgear or electric power apparatus bushings, buses or conductors. Current transformers must have the indicated ratios. The continuous thermal-current rating factor must be not less than [1.0] [1.2] [1.5] [2.0] [3.0] [4.0]. Other thermal and mechanical ratings of current transformers and their primary leads must be coordinated with the design of the circuit breaker and must be not less than the momentary rating of the associated circuit breaker. Circuit protectors must be provided across secondary leads of the current transformers to prevent the accidental open-circuiting of the transformers while energized. Each terminal of each current transformer must be connected to a short-circuiting terminal block in the circuit interrupting mechanism cabinet, power transformer terminal cabinet, and in the associated instrument and relay cabinets.

2.8.2.1 Current Transformers for Power Transformers

****

NOTE: IEEE C57.12.10, Table 20 gives recommended values.

****

[Single-ratio] [Multi-ratio] bushing type current transformers must be provided in circuit breaker bushing wells as indicated. [Single-ratio units must have a minimum metering accuracy class rating of [0.6B-0.5] [0.3B-0.5].] [Multi-ratio units must have a minimum relaying accuracy voltage class of [_____] for either a C or T classification.]

2.8.2.2 Current Transformers for Metal-Clad Switchgear

Single-ratio units, used for metering and relaying, must have a metering accuracy class rating of [_____] [B._____]. Single-ratio units, used only for relaying, must have a relaying accuracy class rating of [_____] for [either] a C [or T] classification.

2.8.2.3 Current Transformers for Kilowatthour and Demand Metering

****

NOTE: Use the following guidelines for specifying current transformers.

1. Select the standard current transformer (CT) primary rating which is just below the full load current of the serving power transformer, i.e., for a 500 kVA transformer with a full load of 1387 amps at 208 volts - select a 1200/5 CT ratio; for a 750 kVA transformer with a full load of 902 amps at 480 volts - select a 800/5 CT ratio.

2. Select a continuous-thermal-current rating factor (RF) in accordance with the following table:

RATIO	RF at 30 degrees C
200/5	4.0
300/5	3.0
400/5	4.0
600/5	3.0
800/5	2.0
1200/5	1.5
1500/5	1.5
2000/5	1.5
3000/5	1.33

3. Select an ANSI Metering Accuracy Class in accordance with the following table:

Primary Amp Rating (of CT)	Accuracy Class
200	0.3 thru B-0.1
300-400	0.3 thru B-0.2
600-1200	0.3 thru B-0.5
1500	0.3 thru B-0.9
2000-3000	.3 thru B-1.8

****

Current transformers must conform to IEEE C57.13. Provide current transformers with a metering accuracy Class of 0.3 through [_____], with a minimum RF of [_____] at 30 degrees C, with 600-volt insulation, and 10 kV BIL. Size current transformers as indicated. Provide butyl-molded window type current transformers mounted [on the transformer low-voltage bushings. Route current transformer leads in a location as remote as possible from the power transformer secondary cables to permit current measurements to be taken with hook-on ammeters.] [in the current transformer cabinet.]

2.8.3 Voltage Transformers

****

NOTE: See UFC 3-550-01 for guidance regarding voltage transformers. Minimum standard potential transformer accuracies for metal-clad switchgear are not listed in IEEE C37.20.2. Accuracy classes as listed in IEEE C57.13 are 0.3, 0.6, and 1.2. Standard burdens for each accuracy class are W, X, Y, Z, ZZ, and M. The designer should check the burdens connected to determine the actual accuracy class and burden required. In general, NEMA/ANSI C12.11 requires 0.3 accuracy class for up to Y burdens, except for voltages of 5 kV and below. Where metering potential transformers are provided, a 0.3 accuracy class should be specified, if available for the voltage rating and burden needed.

****

Voltage transformers must have indicated ratios. Units must have an accuracy class rating of [_____]. Voltage transformers must be of the drawout type having current-limiting fuses in both primary and secondary circuits. Mechanical interlocks must prevent removal of fuses, unless the associated voltage transformer is in a drawout position. Voltage transformer compartments must have hinged doors.

2.9 AUXILIARY SUBSTATION EQUIPMENT

2.9.1 Voltage Regulator

****
NOTE: Bypass arresters are normally standard equipment. Incoming line arresters may not be needed. Coordinate with manufacturer.
****

Voltage regulators must comply with IEEE C57.15 and must be of the outdoor, self-cooled, 55/65 degrees C temperature rise, [single-phase] [three-phase] station-type. Two single-phase units connected in open-delta are not acceptable. Windings and the load-tap-changing mechanism must be mineral-oil-immersed. When operating under load, a regulator must provide plus and minus 10 percent automatic voltage regulation in approximately 5/8 percent steps, with 16 steps above and 16 steps below rated voltage. Automatic control equipment must provide Class 1 accuracy. Bypass surge arresters must be suitable for [a grounded] [an ungrounded] system and for the associated regulator voltage. [Station] [Intermediate] class surge arresters must be mounted next to each incoming line bushing on a regulator tank-mounted bracket and connected to a surge arrester ground pad-mounted on the regulator tank.

2.9.1.1 Ratings

Ratings at 60 Hz	
Maximum voltage	[_____]
BIL	[_____]
Current	[_____]

2.9.1.2 Bypass and Isolation Switches

Switches must be of the outdoor, stick-operated, single-pole, single-throw, vertical-break type suitable for the indicted mounting. One switch stick of adequate length must be provided. Switches must be of a type designed to provide bypass of a single-phase regulator circuit by an integral sequence which always occurs when each switch is opened or closed. Each opening sequence must initially bypass the single-phase regulator circuit, then open the input and output circuits, and finally interrupt the exciting current. Opening any single-phase regulator circuit must not be possible until after the bypass circuit is closed. Unless the voltage regulator is equipped with integral line surge protective devices, [surge protectors must be mounted across terminals of each switch rated up to 25 kV.] [station-class surge arresters must be provided to protect each phase of 35 kV switches.] Ratings at 60 Hz must be in accordance with IEEE C37.41 and as follows:

Maximum voltage	[_____]
Nominal voltage class	[_____]

BIL	[_____]
Momentary asymmetrical current in the closed position	[_____]
Momentary asymmetrical current in the bypass position	[_____]
Continuous and interrupting current	[_____]

2.9.1.3 Miscellaneous

Standard accessories and components in accordance with IEEE C57.15 must be provided. The regulator subbase must elevate the lowest live part of the regulator to a height of at least 2.7 m 9 feet above the concrete pad on which it is mounted. Single-phase units must be provided with additional components and accessories required by IEEE C57.15 for three-phase units.

2.9.2 Station Battery

****

NOTE: Normally, an 8-hour requirement will be sufficient. Indicate required annunciator system connections on the project drawings. Coordinate battery types and characteristics with the manufacturer.

****

The station battery installation must include a battery, battery racks, a battery charger, and protective equipment. The station battery installation must be housed [in the metal-clad switchgear] [where indicated].

2.9.2.1 Battery

Submit calculations for the battery and associated charger indicating the basis used in defining loads, selecting cell types, and determining the battery ampere-hour capacity and physical size. Provide calculations to determine capacity for the battery charger to be similar to those shown in the Appendix to IEEE 485, including explanatory data. Calculations for the battery-charger must demonstrate that the output voltage and current provided are adequate to comply with the preceding requirements. The battery must consist of the required number of [lead-calcium] [nickel-cadmium] cells interconnected with proper connectors provided by the battery manufacturer to provide a nominal battery rating of [48] [125] volts. Rubber or plastic numerals, of at least 25 mm 1 inch in height, must be provided by the battery manufacturer for field attachment to permit proper cell identification. The battery must have an ampere-hour capacity equal to at least 125 percent of the station's direct-current requirements including normal continuous loads plus intermittent loads. Normal continuous load capacity must be adequate for an [8-hour] [_____] period. Intermittent load capacity must be adequate so that at least [three] [_____] openings and [three] [_____] closings of each of the station's associated circuit breakers [and motor-operated] [switches] can occur in [an 8-hour] [_____] period with no more than [three] [_____] circuit breaker [or switch] units simultaneously operating. Battery circuits must be ungrounded. Batteries must have a 20-year minimum life and a 5-year no cost replacement warranty.

2.9.2.2 Battery Racks

Battery racks must have welded steel frames and rails finished with two coats of paint of a color matching the battery charger enclosure. Racks must be no more than two tiers high and top tiers must be low enough to permit maintenance to be done by personnel standing at floor level. Rails must have a top covering of plastic or rubber at least 1.6 mm 1/16 inch thick. Paint, rubber, and plastic must resist corrosion and action of the electrolyte. The installation must be provided with a portable hydrometer syringe and thermometer. Where recommended by the manufacturer, the installation must include a cell lifter.

2.9.2.3 Battery Charger

The battery charger must comply with UL 1236 and must be a constant voltage, filtered, voltage-regulated, fully automatic type rated for full-float charging of the associated battery. The battery charger must be convection cooled and suitable for operation on electric power supplied from the associated low-voltage alternating-current panelboard, must have adequate capacity to fully recharge the associated depleted battery in not more than [8 hours] [_____] while supplying normal direct-current loads, and must have an efficiency of not less than 90 percent. The battery charger must have input and output circuit breakers which automatically disconnect the battery charger when faults occur. The battery charger must have an output ammeter and voltmeter, and equalizing-float selector switch, and an equalizing timer with a range of 0 to 24 hours. The battery charger enclosure must be painted as specified for indoor cabinets in paragraph CABINETS AND ENCLOSURES and must be provided with wall mounting brackets or must be free-standing as required by its size and weight. A relay for sensing loss of alternating-current input, and an adjustable relay for sensing that the battery charger output voltage has fallen to a pre-set level, must be installed on the battery charger to actuate the associated annunciator circuits. DC ground detector LED lights must be provided.

2.9.2.4 Protective Equipment

Protective equipment required by IEEE 484 must be provided and installed in a free-standing cabinet mounted where indicated or directed. The cabinet must conform to paragraph CABINETS AND ENCLOSURES. Water facilities required must be of the portable type consisting of one 18.9 liter 5 gallon tank and one 946.4 milliliter (1 quart) 1 quart basin. The tank must have a removable screw top and a spigot. The basin must be suitable for rinsing eyes or skin in case of acid spillage.

2.9.3 Illumination

****
NOTE: Insert the appropriate pages from CE Standard Detail 40-06-04 into this specification. Add references used in 40-06-04 to paragraph REFERENCES.
****

Luminaires, ballasts, lamps, and control devices required for [general area] [and] [_____] lighting [, including floodlighting] must be in accordance with sheet [_____] sheets [_____] of Standard Detail No. 40-06-04, attached to these specifications.

2.9.4 Annunciator System

****
NOTE: Indicate component malfunctions requiring annunciation on the drawings. One station visual indication light should normally be located at each of the four corner points of the fence enclosure.
****

The annunciator system must consist of the station's audible [and visual] indicator and an annunciator cabinet. The cabinet must house an annunciator drop for each component malfunction indicated plus a system pushbutton and flasher and must be located in [the metal-clad switchgear aisle] [where indicated]. [[_____] spare drops must be included.] Electrical devices required must be rated for the application and must be suitable for the low-voltage alternating-current available as shown or specified. Auxiliary devices must be provided as necessary for correct operation.

2.9.4.1 Station Audible and Visual Indication

One station horn [and the indicated number of station red alarm lights] must be installed where shown. The station horn must be weatherproof and must be of the resonating type having an audible output of not less than 100 dB at 3.1 m 10 feet. Station lights must be LED type with guards and red globes, must be UL listed as enclosed and gasketed for use in wet locations, and must be of a style suitable for the indicated mounting. A horn silencing relay must be wired in series with the horn so that, after an adjustable time delay of 5 to 15 minutes, the horn must be silenced. Necessary auxiliary devices provided in conjunction with the horn must permit signaling to a remote central point.

2.9.4.2 Operating Modes

The system must be wired so that when the component being monitored by an annunciator is operating correctly, the associated annunciator relay actuates the normal mode, and when the component malfunctions, the associated annunciator relay actuates the alert mode. During normal mode no part of the system must be energized by the associated annunciator relay. Upon equipment malfunction, the alert mode must energize the system flasher which must turn the associated annunciators lights on and off, and sound the station horn, including turning on the station exterior visual indication lights. Depressing the station pushbutton must turn off the horn, the station visual indication lights, and the flasher, but must leave the associated annunciator lights on. Correction of a malfunction must automatically return the alarm system to the normal mode for the associated annunciator relay. Turning the system pushbutton during a normal mode must simulate an alert mode for all annunciator relays so that correct operation of annunciator lamps, the station exterior visual indication lights, the system flasher, and the station horn can be checked.

2.9.4.3 Annunciators

Annunciators must comply with ISA 18.1 and must be solid-state logic, modular, hermetically sealed, plug-in relays each with two integral long-life lamps for backlighting a white translucent nameplate window of not less than 75 by 75 mm 3 by 3 inches. Nameplates must have black letters at least 3 mm 1/8 inch in height and the inscription must match the indicated malfunction description.

2.9.4.4 Other Requirements

The annunciator cabinet must be suitable for the indicated location and must conform to requirements specified herein for cabinets. The flasher frequency must be between 1 and 5 Hz. The system pushbutton must be provided with a nameplate inscribed "PUSH TO SILENCE" and "TURN TO TEST."

2.10 CABINETS AND ENCLOSURES

Cabinets and enclosures must comply with NEMA 250 and must be of galvanized steel, must be provided with hinged doors, and must be suitable for indoor or outdoor installation as indicated. Where locations are not indicated, cabinets must be suitable for outdoor installation. Thickness of metal and outdoor construction must be in accordance with UL 50. An indoor cabinet exterior must have one finish coat and an outdoor cabinet exterior must have two finish coats. Finish color must be ANSI 61 light gray. The finish color of outdoor equipment must be the same unless otherwise approved. Finish coats must be applied over a prepared substrate. Each cabinet must be a freestanding type or may be supported by attachment to an enclosure fence or a switchgear interior wall where located adjacent thereto. A concrete pad must be provided to support any outdoor cabinet whose base extends to within 75 mm 3 inches of grade level and pads must extend at least 100 mm 4 inches below grade.

2.11 MISCELLANEOUS

2.11.1 Low-Voltage Power Circuit Breakers

2.11.1.1 Power Circuit Breakers

2.11.1.1.1 Construction

Low-voltage power circuit breakers must conform to IEEE C37.13, and IEEE C37.16, and must be three-pole, single-throw, stored energy, [manually][electrically] operated, with drawout mounting. Solid-state trip elements which require no external power connections must be provided. Circuit breakers must have an open/close contact position indicator, charged/discharged stored energy indicator, primary disconnect devices, and a mechanical interlock to prevent making or breaking contact of the primary disconnects when the circuit breaker is closed. Control voltage must be [24 V dc][48 V dc][125 V dc][120 V dc][as indicated]. The circuit breaker enclosure must be suitable for its intended location.

2.11.1.1.2 Ratings

Voltage-ratings must be not less than the applicable circuit voltage. Circuit breakers must be rated for 100 percent continuous duty and must have trip current ratings and frame sizes as shown. Nominal voltage ratings, maximum short-circuit interrupting ratings must be in accordance with IEEE C37.16. Tripping features must be as follows:

a. Long-time current pick-up, adjustable from 50 percent to 100 percent of sensor current rating.

b. Adjustable long-time delay.

c. Short-time current pick-up, adjustable from 1.5 to 9 times long-time current setting.

d. Adjustable short-time delay.

[e. Short-time I square times t switch.]

[e][f]. Instantaneous current pick-up, adjustable from 1.5 to 9 times long-time current setting.

[f][g]. Ground-fault pick-up, adjustable from 20 percent to 60 percent of sensor rating, but in no case greater than 1200 amperes. Sensing of ground-fault current at the main bonding jumper or ground strap must not be permitted. [Zone-selective interlocking must be provided as indicated.]

[g][h]. [Fixed] [Adjustable] ground-fault delay.

[[h][i]. Ground-fault I square time t switch.]

[h][i][j]. [Overload] [and] [Short-circuit] [and] [Ground-fault] trip indicators must be provided.

2.11.1.2 Molded-Case Circuit Breakers

UL 489 and UL 489.

2.11.2 Wiring

Wiring between separate items of station equipment must conform to the requirements of Section [33 71 01 OVERHEAD TRANSMISSION AND DISTRIBUTION] [33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION]. Solid wiring may be used for convenience outlets, heating elements, and lighting circuits. Otherwise, the minimum class of stranding must be Class C. Class K stranding must be used for wiring between items of equipment mounted on swinging panels or doors and items mounted on fixed panels or parts of fixed assemblies. The insulation type must be the type SIS unless otherwise specified, indicated, or proposed and approved for use. The minimum wire gauge must be No. 14 AWG, except No. 18 AWG may be used for circuits that use one ampere or less. Circuits rated less than 115 volts ac or 125 volts dc may be wired with wiring rated 300 volts-to-ground. Otherwise, all wiring must be rated for 600 volts ac and 250 volts dc Current transformer circuit wiring must be not less than No. 10 AWG. Wiring for Close and Trip circuits must be not less than No. 8 AWG. Wire markers must be affixed to each end of wires and must contain wire number or designations shown on contract or detail drawings, or as otherwise approved. Wire numbers must also be permanently marked on terminal block marking strips where wires are connected. Only insulated-barrel, crimp-type, ring lugs must be used.

2.11.3 Single-Line Electrical Diagram

A single-line electrical diagram of the station must be provided. The diagram must be enclosed between matte-surface thermoplastic sheets buttoned or otherwise suitably fastened together to allow easy access to the diagram for making any future changes. The diagram must be suitable for outdoor mounting and must be approximately 350 by 525 mm 14 by 21 inches unless another size is approved. The diagram must be attached with temperature- and moisture-resistant, pressure-sensitive adhesive or with other suitable means to the indicated location at the metal-clad switchgear lineup, except when otherwise shown or directed.

2.11.4 Liquid Dielectrics

Liquid dielectrics for transformers, capacitors, reclosers, and other liquid-filled electrical equipment must be non-polychlorinated biphenyl (PCB) mineral-oil or less-flammable liquid as specified. Nonflammable fluids must not be used. Tetrachloroethylene (perchloroethylene) and 1, 2, 4 Trichlorobenzene (TCB) fluid must not be used. Liquid dielectrics in retrofitted equipment must be certified by the manufacturer as having less than 50 parts-per-million (ppm) PCB content. In lieu of the manufacturer's certification, the Contractor may submit a test sample of the dielectric in accordance with ASTM D923 and have tests performed in accordance with ASTM D4059at a testing facility approved by the Contracting Officer. Equipment with test results indicating PCB level exceeding 50 ppm must be replaced.

2.11.5 Danger Signs

One danger sign inscribed "DANGER-HIGH VOLTAGE" must be permanently and securely mounted approximately 1.5 m 5 feet above finished grade on each outward side of the fence enclosure. Fasteners must be of stainless steel. Signs must be of metal and must have letters of at least 75 mm 3 inches in height. Voltage warning signs must comply with IEEE C2.

2.11.6 Concentric-Lay-Stranded Conductors

Copper conductors must comply with ASTM B8 for soft drawn copper. Equivalent aluminum conductors must comply with ASTM B231/B231M.

2.11.7 Conduits, Rigid Metal

Conduits must comply with UL 6.

2.11.8 Hardware

Ferrous metal threaded items must comply with ASTM A153/A153M and miscellaneous nonthreaded items must comply with ASTM A123/A123M. Other equivalent protective treatment, as required by ASTM A123/A123M or ASTM A153/A153M, or ferrous metals designed to meet ASTM Standards covering corrosion-resisting steel, will be permitted if approved in writing.

2.11.9 Padlocks

Padlocks must comply with Section 08 71 00 DOOR HARDWARE

2.11.10 Panelboards, Circuit-Breaker Type

Panelboards must comply with NEMA PB 1, UL 50 and UL 67.

2.12 GROUNDING AND BONDING

2.12.1 Driven Ground Rods

Ground rods must be [copper-clad steel conforming to UL 467] [zinc-coated steel conforming to IEEE C135.30] [solid stainless steel] not less than 15.9 mm 5/8 inch in diameter by 3.1 m 10 feet in length [of the sectional type].

2.12.2 Grounding Conductors

Grounding conductors must be bare, except where installed in conduit with associated phase conductors. Insulated conductors must be of the same material as the phase conductors and green color-coded, except that conductors must be rated no more than 600 volts. Bare conductors must be ASTM B8 soft-drawn unless otherwise indicated. Aluminum is not acceptable.

2.13 SURGE ARRESTERS

Surge arresters must comply with NEMA LA 1, and IEEE C62.11, and must be provided as indicated. Arresters must be [station][intermediate][distribution] class, rated as shown.[Arresters for use at elevations in excess of 1.8 km 6000 feet above mean sea level must be specifically rated for that purpose.] Arresters must be equipped with mounting brackets for the indicated installations. Arresters must be of the [valve][or][metal-oxide varistor][or][combination valve-metal-oxide varistor] type suitable for outdoor installations.

2.14 COORDINATED POWER SYSTEM PROTECTION

****

NOTE: The requirement for the studies in this section depends on the complexity and extent of the power system. Delete this requirement for: projects of limited scope; projects having protective devices which are not adjustable or for which coordination is not possible (standard molded case circuit breakers); projects involving simple extension of 600 volt level service to a building or facility from an existing transformer (750 kVA or less); or projects involving simple extension of 600 volt level service to a building or facility from a new transformer (750 kVA or less).

The designer will be responsible for showing and specifying the requirements for fuses, circuit breakers, protective relays, or other protective devices associated with the project. The protective devices should be selected and specified to protect electrical power system conductors or equipment against sustained overloads, in-rush conditions, electrical faults, or other abnormal power system or equipment operating conditions, in accordance with UFC 3-520-01, IEEE 242, and IEEE Std 141.

The complexity and extent of coordinated power system protection depends on the type of buildings or facilities or utilities required, on the load demand of facilities, and on the quantity and types of facilities to be constructed. Facilities having a relatively-low power demand (e.g., 2,500 kVA or less) generally require protection of: an incoming aerial distribution line or underground medium-voltage feeder; low-voltage feeders to individual items of equipment, or to power distribution equipment; and branch circuits. More complex projects such as facilities with generating capacity, large motors, or larger load demands, will

require more detailed and extensive coordinated power system protection.

Independent of the type or types of facilities or load demands, the coordinated power system protection will be based on: economics, simplicity, and the electrical power availability dictated by the Using Agency or Service, or by the functional use of the facilities or utilities; required to provide maximum power service with a minimum of power interruptions; and the operating speed of protective devices required to minimize damage to electrical components or items of equipment and to prevent injury to personnel and nuisance tripping.

Unless otherwise approved, a dc power source will be shown and specified to ensure proper closing and tripping of protective devices which require a reliable power source during outage of the normal alternating-current power source.

****

Analyses must be prepared to demonstrate that the equipment selected and system constructed meet the contract requirements for equipment ratings, coordination, and protection. They must include a load flow analysis, a fault current analysis, and a protective device coordination study. The studies must be performed by a registered professional engineer with demonstrated experience in power system coordination in the last three years. Provide a list of references complete with points of contact, addresses, and telephone numbers. The selection of the engineer is subject to the approval of the Contracting Officer.

2.14.1 Scope of Analyses

The fault current analysis, and protective device coordination study must begin at: [the source bus and extend down to system buses where fault availability is 10,000 amperes (symmetrical) for building/facility 600 volt level distribution buses.] [the source bus and extended through the secondary side of transformers for medium voltage distribution feeders.] [the source bus and extend through [outgoing breakers] [outgoing medium voltage feeders, down to the individual protective devices for medium voltage radial taps] [outgoing medium voltage feeders, through the secondary side of transformers] [as indicated] for main electric supply substations.] [the nearest upstream device in the existing source system and extend through the downstream devices at the load end.]

2.14.2 Determination of Facts

****

NOTE: Require the Contractor to obtain an available fault capacity at the power source or provide a fault capacity on which he is to base his analysis. Delete the unused option.

****

The time-current characteristics, features, and nameplate data for each existing protective device must be determined and documented. [Coordinate with the [commercial power company] [_____] for fault current availability at the site.] [Utilize the fault current availability indicated as a

basis for fault current studies.]

2.14.3 Single Line Diagram

A single line diagram must be prepared to show the electrical system buses, devices, transformation points, and all sources of fault current (including generator and motor contributions). A fault-impedance diagram or a computer analysis diagram may be provided. Each bus, device, or transformation point must have a unique identifier. If a fault-impedance diagram is provided, impedance data must be shown. Locations of switches, breakers, and circuit interrupting devices must be shown on the diagram together with available fault data, and the device interrupting rating.

2.14.4 Fault Current Analysis

2.14.4.1 Method

The fault current analysis must be performed in accordance with methods described in IEEE 242, and IEEE 399.

2.14.4.2 Data

Actual data must be utilized in fault calculations. Bus characteristics and transformer impedances must be those proposed. Data must be documented in the report.

2.14.4.3 Fault Current Availability

Balanced three-phase fault, bolted line-to-line, and line-to-ground fault current values must be provided at each voltage transformation point and at each power distribution bus. The maximum and minimum values of fault available at each location must be shown in tabular form on the diagram or in the report.

2.14.5 Coordination Study

Submit Coordination Study along with protective device equipment submittals. No time extensions or similar contract modifications will be granted for work arising out of the requirements for this study. Approval of protective devices proposed must be based on recommendations of this study. The Government will not be held responsible for any changes to equipment, device ratings, settings, or additional labor for installation of equipment or devices ordered and procured prior to approval of the study. The study must demonstrate that the maximum possible degree of selectivity has been obtained between devices specified, consistent with protection of equipment and conductors from damage from overloads and fault conditions. The study must include a description of the coordination of the protective devices in this project. Provide a written narrative that describes: which devices may operate in the event of a fault at each bus; the logic used to arrive at device ratings and settings; situations where system coordination is not achievable due to device limitations (an analysis of any device curves which overlap); coordination between upstream and downstream devices; and relay settings. Recommendations to improve or enhance system reliability, and detail where such changes would involve additions or modifications to the contract and cost changes (addition or reduction) must be provided. Composite coordination plots must be provided on log-log graph paper.

2.14.6 Study Report

a. The report must include a narrative describing: the analyses performed; the bases and methods used; and the desired method of coordinated protection of the power system.

b. The study must include descriptive and technical data for existing devices and new protective devices proposed. The data must include manufacturers published data, nameplate data, and definition of the fixed or adjustable features of the existing or new protective devices.

c. The report must document [utility company data including system voltages, fault MVA, system X/R ratio, time-current characteristic curves, current transformer ratios, and relay device numbers and settings;] [and] [existing power system data including time-current characteristic curves and protective device ratings and settings.]

d. The report must contain fully coordinated composite time-current characteristic curves for each bus in the system, as required to ensure coordinated power system protection between protective devices or equipment. The report must include recommended ratings and settings of all protective devices in tabulated form.

e. The report must provide the calculations performed for the analyses, including computer analysis programs utilized. The name of the software package, developer, and version number must be provided.

2.15 FACTORY TESTS

****

NOTE: Delete tests that are not applicable to the project. Refer to UFC 3-550-01 for guidance. Tests must be justified. Delete transformer losses test when losses are not specified.

****

Factory tests must be performed, as follows, in accordance with the applicable publications and with other requirements of these specifications. The Contracting Officer must be notified at least [10] [_____] days before the equipment is ready for testing. The Contracting Officer reserves the right to witness the tests.

2.15.1 Power Transformer

Manufacturer's standard [routine] [design] [and] [other] tests in accordance with IEEE C57.12.00. Reduce full-wave, chopped-wave, and full-wave impulse test on each line [and neutral] terminal, in accordance with IEEE C57.98. Tests for transformer losses in accordance with IEEE C57.12.90.

2.15.2 High-Voltage Circuit Breakers

Manufacturer's standard tests in accordance with IEEE C37.09 and IEEE C37.081.

2.15.3 High-Voltage Air Switches

Manufacturer's standard tests in accordance with IEEE C37.34 and IEEE C37.41.

2.15.4 Protective Relays

Seismic tests in accordance with IEC 60255-21-3. Surge withstand tests in accordance with IEEE C37.90.1.

2.15.5 Relaying Current Transformers

Manufacturer's standard tests in accordance with IEEE C57.13.

2.15.6 Instrument Current Transformers

Manufacturer's standard tests in accordance with IEEE C57.13.

2.15.7 Voltage Regulators

Manufacturer's standard tests in accordance with IEEE C57.15.

2.15.8 High-Voltage Fuses

Manufacturer's standard tests in accordance with IEEE C37.41.

2.15.9 Neutral Grounding Resistor

Manufacturer's standard tests in accordance with IEEE 32.

2.15.10 Electrical Power Insulators

Manufacturer's standard tests in accordance with ANSI C29.1.

2.15.11 Factory Test Submittal Package

Submit [6] [_____] copies of the information described below in 215.9 by 279.4 mm 8-1/2 by 11 inch binders having a minimum of 5 rings from which material may readily be removed and replaced, including a separate section for each test. Sections must be separated by heavy plastic dividers with tabs.

a. A list of all equipment used, with calibration certifications.

b. A copy of all measurements taken.

c. The dates of testing.

d. The equipment and values to be verified.

e. The condition specified for the test.

f. The test results, signed and dated.

g. A description of all adjustments made.

2.16 SUBSTATION AUTOMATION AND CONTROLS

The substation must be Supervisory Control and Data Acquisition (SCADA) ready. Input/output (I/O) modules connected to the substation equipment gathers the field data, including, but not limited to, status of switches, circuit breakers, transformers, batteries, voltage magnitudes, current magnitudes, power factor, real power, apparent power. RTUs collect I/O

data and transfer that data to the remote master unit and operator interface panel via network interface modules. All components must be suitable for use in the environment in which the substation is located. The SCADA system will be used to monitor and control the following substation components, provide suitable sensors and auxiliary switches as required for each component to be monitored or controlled.

a. Circuit breaker monitoring of breaker position (i.e. open, closed or tripped).

b. Circuit breaker remote control (i.e. open or close).

c. Station Battery alarm point monitoring.

d. Substation alarm monitoring.

e. Load interrupter switch monitoring of switch position.

f. Load interrupter switch SF6 gas density monitoring.

g. Transformer oil and winding temperatures.

2.16.1 Remote Terminal Units (RTU’s)

RTUs consist of real-time programmable logic controllers (PLCs) which are responsible for properly converting substation information to digital form to transmit the data and also convert the received signals from master units in order to control the process equipment through actuators and switchboxes. Provide RTU’s that have a direct connection with various sensors, meters and actuators associated with the substation.

2.16.2 Master Terminal Units (MTUs)

A central host server referred to as a Master Terminal Unit, is SCADA system central point of control. It communicates with RTUs by performing reading and writing operations during scheduled scanning. In addition, it performs control, alarming, networking with other nodes.

2.16.3 Communications System

The communication network transfers data among central host computer servers and the field data interface devices and control units. The medium of transfer can be cable, radio, telephone, satellite or any combination of these.

2.16.4 Operator Interface Panel

The operator interface panel consists of standard HMI (Human Machine Interface) touchscreen panel The operator interface panel displays all data captured at the input/output (I/O) modules and allows for controlled of each device that is interfaced with the SCADA system. The operator interface panel must be mounted on the substation assembly in a dedicated controls cubicle.

PART 3 EXECUTION

3.1 EXAMINATION

After becoming familiar with details of the work, verify dimensions in the

field, and notify the Contracting Officer of any discrepancy before performing any work.

3.2 GENERAL INSTALLATION REQUIREMENTS

Install and energize equipment and devices in accordance with the manufacturer's published instructions. Submit installation procedures for station buses and insulators, station structures, transformers, switchgear, battery system, voltage regulators and grounding resistors, as a minimum. Procedures must include diagrams, instructions, and precautions required to install, adjust, calibrate, and test the devices and equipment. Circuits installed in conduits or underground and splices and terminations for medium-voltage cable must conform to the requirements of Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION. Secondary circuits installed in conduit on poles must conform to the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

3.2.1 Conformance to Codes

The installation must comply with the requirements and recommendations of NFPA 70 and IEEE C2.

3.2.2 Concrete Foundations

3.2.2.1 Structure Foundation Installation

Bolt each column to a concrete foundation by at least four bolts spaced to transmit structure stresses to the foundation. Diameters and lengths of foundation bolts must be as recommended by the structure manufacturer. Embed bolts in concrete in a manner to develop their full strength. Anchor bolts must be accurately set in foundations using templates supplied by the structure manufacturer. When concrete has cured, structure baseplates must be leveled and grouted in place. Columns must then be set on baseplates, leveled on foundations, and secured with holding nuts. Concrete work and grouting must comply with the requirements of Section 03 30 00 CAST-IN-PLACE CONCRETE.

3.2.2.2 Concrete Pads

****
NOTE: Do not allow rectangular holes in the concrete pad if rodent intrusion is a problem. Specify concrete pad reinforcing requirements.
****

Construct concrete pads for pad-mounted electrical equipment as indicated. Tops of concrete pads must be level and must project four inches above finished [floor] [paving or grade] and sloped to drain. Set conduits for primary, secondary, and grounding conductors in place prior to placing of concrete pads. Concrete work must comply with the requirements of Section 03 30 00 CAST-IN-PLACE CONCRETE.

a. If the equipment primary compartment is not of sufficient height to allow the installation of the medium-voltage terminators, load break elbows or switches, provide adequate space by providing a rectangular hole in the concrete pad below the primary compartment [and][or] a factory prefabricated steel adjustment ring around the entire perimeter of the base of the equipment. Steel rings must be factory manufactured to fit the base of the equipment of which they support

and must be factory painted to match the equipment enclosure. Steel base rings must be constructed using the same or greater thickness of steel as the equipment being supported.

b. Concrete pads to support pad mounted electrical equipment must be reinforced [with [_____] mm inch steel reinforcing rods at [_____] mm inches, on center, each way] [_____]. Where grounding electrode conductors are installed through concrete pads, PVC conduit sleeves must be installed through the concrete to provide physical protection. When the installation is complete, seal all conduit and other entries into the equipment housing with an approved sealing compound. Seals must be of sufficient strength and durability to protect all energized live parts of the equipment from rodents, insects, and foreign matter.

3.2.3 Fencing

****
NOTE: Designer will provide detail for fence grounding.
****

The station must be enclosed by chain-link fence as shown. Fencing is specified in Section 32 31 13 CHAIN LINK FENCES AND GATES and must be grounded in accordance with paragraph GROUNDING.

3.2.4 Surface Treatment

Horizontal spaces between concrete foundations or pads and fences must be excavated to minimum depth of [150] [_____] mm [six] [_____] inches below finished gradelines, must be graded to level surfaces, and filled with well-compacted clean coarse gravel or crushed stone of 13 to 38 mm 1/2 to 1-1/2 inches in size up to finished gradelines.

3.2.5 Spare Accessory Storage

A cabinet must be provided for storage of equipment accessories as necessary, including spare fuses, fuse tongs, switch sticks, and other tools and located where indicated. Shelves or other appropriate supporting methods must provide an individual space for each type of item stored.

3.2.6 Fire Extinguisher Storage

An outdoor cabinet for housing a Government-provided, hand-operated, self-expellent, carbon dioxide fire extinguisher of 4.5 to 6.8 kg 10 to 15 pounds capacity for Class C fires must be provided and located as approved. The cabinet must have a glass cover door and be painted red.

3.2.7 Field Welding

Procedures and welders must be qualified in accordance with AWS D1.1/D1.1M for structural welding and ASME BPVC SEC IX for welding of equipment. Welding procedures qualified by others, and welders and welding operators qualified by a previously qualified employer may be accepted as permitted by ASME B31.3. Notify the Contracting Officer 24 hours in advance of tests; perform the tests at the work site if practical. The Contracting Officer must be provided with a copy of qualifying procedures and a list of names and identification symbols of qualified welders and welding

operators. The welder or welding operator must apply his assigned symbol near each weld he makes as a permanent record. [Structural members must be welded in accordance with Section 05 05 23.16 STRUCTURAL WELDING.] [Welding and nondestructive testing procedures are specified in Section 40 05 13.96 WELDING PROCESS PIPING.] Gas-metal arc welding must be performed by welders certified to perform gas-metal arc welding.

3.2.8 Connections to Utility Lines

****
NOTE: This paragraph will be further developed to suit the conditions of any connections required to the serving utility's lines.
****

Coordinate the work with the Contracting Officer and provide final connections to the [utility] [installation] electric lines.

3.2.9 Disposal of Liquid Dielectrics

PCB contaminated dielectrics must be marked as PCB and transported to and incinerated by an approved EPA waste disposal facility. Furnish certification of proper disposal. Contaminated dielectric must not be diluted to lower the contamination level.

3.3 EQUIPMENT INSTALLATION

****
NOTE: Delete ANSI reference if transformer is less than 10 MVA or not liquid-filled. Specify phase sequence in accordance with the local practice.
****

3.3.1 Transformer Stations

Install transformer stations in accordance with IEEE C57.93, fence-enclosed type and mounted on concrete pads. Three-phase transformer installations must be installed with [_____] phase sequence. Primary taps must be set in accordance with the coordination study.

3.3.2 Equipment Finishes

Equipment must be carefully installed so as not to scratch finishes. After installation, finished surfaces must be inspected and scratches touched up with a finish provided by the manufacturer especially for this purpose.

3.3.3 Supports

Install enclosures and enclosure supports in accordance with manufacturer's instructions. Supports must consist of anchored channels leveled and then embedded in the concrete foundation. Channels, anchors, shims, or other leveling items must be installed in accordance with the recommendations of the equipment manufacturer.

3.3.4 Switchgear Leveling

After leveling items are correctly installed, switchgear lineups must be out-of-plumb by not more than 6 mm 1/4 inch for the entire length and

width. Insertion or withdrawal of removable elements must be easily accomplished, and component devices must operate properly after the switchgear assembly is completely installed.

3.3.5 Incoming Line Surge Arresters

Surge arresters of the [station] [intermediate] type must be provided on each phase of each incoming line circuit, and mounted on station structures as shown.

3.3.6 Transformer Surge Arresters

Surge arresters of the [station] [intermediate] type, suitable for [a grounded] [an ungrounded] system and for the associated transformer primary line-to-ground voltage, must be mounted next to each high-voltage bushing on a transformer tank-mounted bracket and connected to a surge arrester ground pad. Discharge counters must be provided and mounted on the brackets.

3.4 ELECTRICAL BUS CONNECTIONS

All connections to aluminum bus must be cleaned and coated with an inhibitor in accordance with manufacturer's recommended methods. All bolted connections must be torqued to the correct tightness. Establish a checklist to insure that bolted connections have been properly coated and correctly torqued. All welded connections on aluminum buswork must be by the gas metal-arc welding process. The shield inert gas must be argon. The welder must be certified for gas metal-arc welding.

3.5 GROUNDING

****
NOTE: The designer will investigate soil resistivity and other factors in accordance with IEEE 80 and will specify and detail the grounding in accordance with UFC 3-550-01 and IEEE 80.
****

A grounding grid, consisting of the indicated configuration of bare copper conductors and driven ground rods must be installed as shown on the drawings. Grounding grid must comply with IEEE 80. Equipment frames of metal-enclosed equipment, medium-voltage cable terminations, chain-link fencing, metal-structures, and other noncurrent-carrying metal items must be connected to the ground grid as shown. At least two connections must be provided from [a power transformer,] [a switchgear ground bus,] [an oil circuit breaker enclosure,] [and] [a grounded iron platform plate] to the ground grid. Fences must be grounded at each fixed gate post, each corner post, and at intermediate posts as indicated. Each gate section must be bonded to its gate posts with a 3.2 by 25.4 mm 1/8 by 1 inch flexible braided copper strap and ground post clamps. Fence ground clamps must be of a type that inhibits corrosion between metal parts. Outriggers must be grounded as shown.

3.5.1 Grounding Electrodes

****
NOTE: Modify or delete paragraphs in accordance with project requirements.
****

3.5.1.1 Driven Rod Electrodes

Unless otherwise indicated, ground rods must be driven into the earth until the tops of the rods are approximately one foot below finished grade.

3.5.1.2 Grid Grounding Electrodes

A grid grounding electrode must be installed as shown consisting of bare copper conductors installed [300 mm] [450 mm] [600 mm] [12] [18] [24] inches, plus or minus 75 mm 3 inches, below the finished top of soil grade. Grid conductors must be bonded to all rod electrodes, and to all other intersecting grid conductors. Grid conductors must be sized as indicated.

3.5.2 Grounding and Bonding Connections

Connections above grade must be made by the fusion-welding process or with bolted solderless connectors, in compliance with UL 467, and those below grade must be made by the fusion-welding process. Where grounding conductors are connected to aluminum-composition conductors, specially treated or lined copper-to-aluminum connectors suitable for this purpose must be used.

3.5.3 Grounding and Bonding Conductors

****
NOTE: Grounding and bonding conductors will be sized based on the thermal requirements of IEEE 80.
****

Grounding and bonding conductors include all conductors used to bond transformer enclosures, equipment frames and structural members to the grounding grid. Grounding and bonding conductors must be sized as shown. After being located to provide maximum physical protection, exposed grounding conductors must be securely attached to structural supports at not more than two foot intervals with suitable fasteners. Bends greater than 45 degrees in ground conductors are not permitted. Routing of ground conductors through concrete should be avoided. When concrete penetration is necessary, nonmetallic conduit must be cast flush with the points of concrete entrance and exit so as to provide an opening for the ground conductor, and the opening must be sealed with a suitable compound after installation.

3.5.4 Surge Arrester Grounding

****
NOTE: Provide a "detail" for surge arrester grounding. For ungrounded and single-grounded systems modify paragraph in accordance with IEEE C2 and UFC 3-550-01.
****

Surge arresters and neutrals must be bonded directly to the transformer enclosure and then to the grounding grid with a bare copper conductor, minimum size [4/0] [as shown]. Lead lengths must be kept as short as practicable with no kinks or sharp bends.

3.6 TRAINING

Conduct a training course for the operating staff as designated by the Contracting Officer. The training period will consist of a total of [_____] hours of normal working time and must start after the system is functionally completed but prior to final acceptance tests. The course instruction must cover pertinent points involved in operating, starting, stopping, servicing the equipment, as well as all major elements of the operation and maintenance manuals. Additionally, the course instructions must demonstrate all routine maintenance operations.

a. Submit [6] [_____] copies of operation and maintenance manuals, within [7] [_____] calendar days following the completion of tests and including assembly, installation, operation and maintenance instructions, spare parts data which provides supplier name, current cost, catalog order number, and a recommended list of spare parts to be stocked.

b. Manuals must also include data outlining detailed procedures for system startup and operation, and a troubleshooting guide which lists possible operational problems and corrective action to be taken. A brief description of all equipment, basic operating features, and routine maintenance requirements must also be included. Documents must be bound in a binder marked or identified on the spine and front cover. A table of contents page must be included and marked with pertinent contract information and contents of the manual. Tabs must be provided to separate different types of documents, such as catalog ordering information, drawings, instructions, and spare-parts data. Index sheets must be provided for each section of the manual when warranted by the quantity of documents included under separate tabs or dividers.

c. Submit a digital video recording of the entire training session and three additional copies of the instructions manual within 30 days following the approval of the manuals.

3.7 FIELD TESTING

****
NOTE: Select types to suit project conditions and delete all others. Delete all paragraphs not applicable. Tests must be justified.
****

3.7.1 General

a. Submit a detailed description of the Contractor's proposed procedures for onsite tests submitted [20] [30] [_____] days prior to testing the installed system. No field test will be performed until the test plan is approved. The test plan must consist of complete field test procedures including tests to be performed, test equipment required, and tolerance limits.

b. Field testing must be performed in the presence of the Contracting Officer. Notify the Contracting Officer [_____] days prior to conducting tests. Furnish all materials, labor, and equipment necessary to conduct field tests. Perform all tests and inspections recommended by the manufacturer unless specifically waived by the Contracting Officer. Maintain a written record of all tests which

includes date, test performed, personnel involved, devices tested, serial number and name of test equipment, and test results.

c. All field test reports will be signed and dated by the Contractor. Submit [6] [_____] copies of the information described below in 215.9 by 279.4 mm 8-1/2 by 11 inch binders having a minimum of 5 rings from which material may readily be removed and replaced, including a separate section for each test. Sections must be separated by heavy plastic dividers with tabs.

(1) A list of all equipment used, with calibration certifications.

(2) A copy of all measurements taken.

(3) The dates of testing.

(4) The equipment and values verified.

(5) The condition specified for the test.

(6) The test results, signed and dated.

(7) A description of all adjustments made.

(8) Final position of controls, and device settings.

3.7.2 Safety

Provide and use safety devices such as rubber gloves, protective barriers, and danger signs to protect and warn personnel in the test vicinity. Replace any devices or equipment which are damaged due to improper test procedures or handling.

3.7.3 Ground-Resistance Tests

The resistance of [each grounding electrode] [each grounding electrode system] [the grounding grid] must be measured using the fall-of-potential method defined in IEEE 81. Soil resistivity in the area of the grid must be measured concurrently with the grid measurements. Ground resistance measurements must be made before the electrical distribution system is energized and must be made in normally dry conditions not less than 48 hours after the last rainfall. Resistance measurements of separate grounding electrode systems must be made before the systems are bonded together below grade. The combined resistance of separate systems may be used to meet the required resistance, but the specified number of electrodes must still be provided.

Single rod electrode	[25] [_____] ohms
Grid electrode	[_____] ohms

3.7.4 Ground-Grid Connection Inspection

All below-grade ground-grid connections will be visually inspected by the Contracting Officer before backfilling. Notify the Contracting Officer [_____] hours before the site is ready for inspection.

3.7.5 Liquid-Filled Transformer Tests

Perform the following field tests on all liquid-filled transformers [[_____] kVA and above].

a. Insulation resistance test phase-to-ground.

b. Turns ratio test.

c. Correct phase sequence.

d. Correct operation of tap changer.

[e. [_____].]

3.7.6 Dry-Type Transformer Tests

Perform the following field tests on all dry-type transformers [[_____] kVA and above].

a. Insulation resistance test phase-to-ground.

b. Turns ratio test.

[c. [_____].]

3.7.7 Circuit Interrupter Switchgear Tests

Perform the following field tests on circuit interrupters.

a. Insulation resistance test phase-to-phase.

b. Insulation resistance test phase-to-ground.

c. Closed contact resistance test.

d. Power factor test.

e. High-potential test.

f. SF6 dielectric test for SF6 interrupters in accordance with ASTM D2472.

g. Manual and electrical operation of the switchgear.

3.7.8 Protective Relays

Protective relays must be visually and mechanically inspected, adjusted, tested, and calibrated in accordance with the manufacturer's published instructions. Tests must include pick-up, timing, contact action, restraint, and other aspects necessary to insure proper calibration and operation. Relay settings must be implemented in accordance with the coordination study. Relay contacts must be manually or electrically operated to verify that the proper breakers and alarms initiate. Relaying current transformers must be field tested in accordance with IEEE C57.13.

3.7.9 Operating Tests

After the installation is completed, and at such time as the Contracting Officer may direct, conduct operating tests for approval. The equipment

must be demonstrated to operate in accordance with the requirements herein. Submit an operating test report in accordance with paragraph TEST REPORTS.

3.8 MANUFACTURER'S FIELD SERVICE

3.8.1 Installation Engineer

After delivery of the equipment, furnish one or more field engineers, regularly employed by the equipment manufacturer to supervise the installation of the equipment, assist in the performance of the onsite tests, initial operation, and instruct personnel as to the operational and maintenance features of the equipment. Submit a detailed description of the Contractor's proposed procedures for onsite tests.

3.8.2 Pre-Energization Services

Calibration, testing, adjustment, and placing into service of the installation must be accomplished by a manufacturer's product field service engineer or independent testing company with a minimum of two years of current product experience. No part of the electrical system must be energized until all station grounding components have been tested and demonstrated to comply with the specified requirements. The following services must be performed on the equipment listed below. These services must be performed subsequent to testing but prior to the initial energization. The equipment must be inspected to insure that installation is in compliance with the recommendations of the manufacturer and as shown on the detail drawings. Terminations of conductors at station buses and at major equipment must be inspected to ensure the adequacy of connections. Bare and insulated conductors between such terminations must be inspected to detect possible damage caused during installation. If factory tests were not performed on completed assemblies, tests must be performed after the installation of completed assemblies. Components must be inspected for damage during installation or shipment and to verify that packaging materials have been removed. Components capable of being both manually and electrically operated must be operated manually prior to the first electrical operation. Components capable of being calibrated, adjusted, and tested must be calibrated, adjusted, and tested in accordance with the instructions of the equipment manufacturer. Items for which such services must be provided include, but are not limited to, are the following:

Battery, station.
Breakers, circuit.
Bus, metal-enclosed.
Buses, station aerial.
Regulator, step-voltage.
Substation, primary unit.
Substation, primary unit, articulated.
Switches, disconnect [with] [without] power fuses.
Switches, air-break.
Switchgear, metal-clad.
Switchgear, metal-enclosed interrupter.
Transformers, substation.

3.9 ACCEPTANCE

Final acceptance of the facility will not be given until the Contractor has successfully completed all tests and after all defects in installation

material or operation have been corrected.

-- End of Section --