ELECTRICAL ENGINEERING DESIGN CRITERIA

1.0 INTRODUCTION

Control of the design, engineering, procurement, and construction activities on the Carrizo Energy Solar Farm (CESF) project will be completed in accordance with various predetermined standard practices and project specific practices. An orderly sequence of events for the implementation of the project is planned consisting of the following major activities:

- Conceptual design;
- Licensing and permitting;
- Detailed design;
- Procurement;
- Construction and construction management;
- Startup, testing, and checkout; and
- Project completion.

The purpose of this appendix is to summarize the codes and standards, and standard design criteria and practices that will be used during the project. The general electrical design criteria defined herein form the basis of the design for the electrical components and systems of the project. More specific design information will be developed during detailed design to support equipment and erection specifications. It is not the intent of this appendix to present the detailed design information for each component and system, but rather to summarize the codes, standards, and general criteria that will be used.

Section 2.0 summarizes the applicable codes and standards and Section 3.0 includes the general design criteria for motors, power and control wiring, protective relaying, classification of hazardous areas, grounding, lighting, freeze protection, lightning protection, raceway, cable tray and conduit, and cathodic protection.

2.0 DESIGN CODES AND STANDARDS

The design and specification of all work shall be in accordance with all applicable laws and regulations of the federal government, the State of California, and applicable local codes and ordinances. A listing of the codes and industry standards to be used in design and construction follows:

- The Anti-friction Bearing Manufacturers Association (AFEMA)
- American National Standards Institute (ANSI)
- American Society for Testing and Materials (ASTM)
- Edison Electric Institute (EEI)
- Insulated Cable Engineers Association (ICEA)
- Institute of Electrical and Electronics Engineers (IEEE)
- Illuminating Engineering Society (IES)
- National Electrical Code (NEC)
- National Electrical Manufacturers Association (NEMA)
- National Electrical Safety Code (NESC)
- National Fire Protection Association (NFPA)
- Occupational Safety and Health Act (OSHA)

- Underwriters' Laboratories (UL)
- National Association of Corrosion Engineers (NACE)

In addition to the general codes and standards listed above, the following specific standards will be utilized:

Batteries

- NEMA IB 4-Determination of Ampere-hour and Watt-hour Capacity of Lead-Acid Industrial Storage Batteries for Stationary Service
- IEEE 450-Recommended Practice for Maintenance, Testing and Replacement of Large Lead-Acid Storage Batteries
- IEEE 484-Recommended Practice for Installation Design and Installation of Large Lead-Acid Storage Batteries for Generating Stations and Substations

Battery Chargers

- NEMA AB 1-Molded Case Circuit Breakers
- NEMA PV 5-Constant-Potential Type Electric Utility (Semiconductor Static Converter) Battery Chargers

Cable, Low Voltage Power, Control and Instrument

- ASTM B8-Concentric-Lay Stranded Copper Conductors, Hard, Medium-Hard, or Soft
- ASTM B33-Tinned Soft or Annealed Copper Wire for Electrical Purposes
- ICEA S-19-81, NEMA WC-3-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
- ICEA S-68-516, NEMA WC-8-Ethylene-Propylene-Rubber Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
- NFPA 258-Standard Test Method for Measuring the Smoke Generated by Solid Materials
- NFPA 70-National Electric Code (NEC)
- ANSI/UL 44-Safety Standard for Rubber-Insulated Wires and Cable

Cable, Medium Voltage Power

- ICEA 6-Ethylene Propylene Rubber Insulated Shielded Power Cables, Rated 5 through 69 kilovolt (kV)
- ASTM B8-Concentric Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
- ASTM B33-Tinned Soft or Annealed Copper Wire for Electrical Purposes
- ICEA S-66-524-Cross Linked-Thermosetting, Polyethylene-Insulated Wire and Cable for Transmission and Distribution of Electrical Energy
- ICEA S-68-516-Ozone-Resistant Ethylene-Propylene Rubber Insulation for Power Cables Rated 0 to 35,000 Volts

- ICEA S-19-81, NEMA WC-3-Rubber Insulated Wire and-Cable for the Transmission and Distribution of Electrical Energy
- NFPA 70-National Electric Code (NEC)

Cable Tray

- NEMA VE-1 Cable Tray Systems

Cathodic Protection Equipment

- ANSI B1.1-Unified Inch Screw Threads
- ANSI B2.1-Pipe Threads
- ASTM A518-Corrosion-Resistant High Silicon Cast Iron
- ASTM B418-Cast and Wrought Galvanic Zinc Anodes for Use in Saline Electrolytes
- NEMA AB-1-Molded Case Circuit Breakers
- NEMA ICS-Industrial Controls and Systems
- NEMA WC-5, ICEA S-61-402-Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
- NEMA WC-7, SS-66-524-Cross-Linked-Thermosetting, Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

Circuit Breakers, High Voltage

- ANSI/IEEE C37.04-Rating Structure for alternating current (AC) High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
- ANSI C37.06-Preferred Ratings and Related Required Capabilities for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
- ANSI/IEEE C37.09-Test Procedure for AC High Voltage Circuit Breakers rated on a Symmetrical Current Basis
- ANSI/IEEE C37.010-Application Guide for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
- ANSI C37.11-Requirements for Electrical Control for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis and a Total Current Basis.

Conduit

- UL 6, ANSI C80.1-Rigid Steel Conduit
- UL 797, ANSI C80.3-Electrical Metallic Tubing
- UL 514, ANSI C80.4-All Fittings
- UL 886-Hazardous Area Fittings
- UL 360-Flexible Liquid-tight Conduit
- NEMA TC6-PVC and ABS Plastic Utilities Duct for Underground Installation
- NEMA TC9-Fittings for ABS and PVC Plastic Utilities Duct for Underground Installation
- UL 651-Electrical Rigid Nonmetallic Conduit
- NEMA TC2, UL 514-Fittings for Electrical Rigid Nonmetallic Conduit.

Distribution Panels

- ANSI C971-Low Voltage Cartridge Fuses, 600 volts or less
- NEMA AB1-Molded Case Circuit Breakers
- NEMA PB1-Panelboards
- UL 50-Electrical Cabinets and Boxes
- UL 67-Panelboards
- NEMA ICS-Industrial Controls and Systems
- NEMA KSI-Enclosed Switches

Grounding

- ASTM B8-Specifications for Concentric-Lay Stranded Copper Conductors
- NEC-National Electric Code
- NEMA CC-1-Electrical Power Connectors for Substations
- IEEE 80-IEEE Guide for Safety in AC Substation Grounding

Lighting Fixtures

- NEMA FA1-Outdoor Floodlighting Equipment
- NEMA LE1-Fluorescent Luminaries
- UL 57-Standard for Safety, Electric Lighting Fixtures
- UL 844-Standard for Safety, Electric Lighting Fixtures for Use in Hazardous Locations
- UL 924-Standard for Safety, Emergency Lighting Equipment

Lightning Arresters

- ANSI/IEEE C62.1-Surge Arresters for AC Power Circuits

Secondary Unit Substations

- ANSI C37.13-Low-Voltage AC Power Circuit Breakers Used in Enclosures
- ANSI C37.16-Preferred Ratings, Related Requirements, and Application Recommendations for Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors
- ANSI/IEEE C37.20-Switchgear Assemblies
- ANSI C37.50-Test Procedures for Low-Voltage AC Power Circuit Breakers Used in Enclosures
- ANSI C37.51-Conformance Testing of Metal-Enclosed Low-Voltage AC Power Circuit Breaker Switchgear Assemblies
- ANSI C57.12.00-General Requirements for Distribution, Power and Regulation Transformers
- ANSI/IEEE C57.12.01-General Requirements for Dry-Type Distribution and Power Transformers
- ANSI/IEEE C57.12.90-Test Code for Liquid Immersed Distribution, Power and Regulating Transformers
- ANSI/IEEE C57.12.91-Test Code for Dry-Type Distribution and Power Transformers
- ANSI C57.13-Requirements for Instrument Transformers

- NEMA CC1-Electrical Power Connectors for Substations
- NEMA TR-1-Transformers, Regulators, and Reactors
- NEMA ICSI-General Standards for Industrial Controls and Systems
- NFPA 70-National Electric Code

Metal-Clad Switchgear and Nonsegregated Phase Bus

- ANSI C37.04-Rating Structure for AC High-Voltage Circuit Breakers on a Symmetrical Current Basis
- ANSI C37.04 Preferred Ratings and Related Required Capabilities for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
- ANSI C37.20-Switchgear Assemblies Including Metal-Enclosed Bus
- ANSI C57.13-Requirement for Instrument Transformers

Motor Control Centers

- NEMA ST-20-Dry-Type Transformers for NEMA General Purpose Applications
- NEMA AB-1-Molded Case Circuit Breakers
- NEMA ICS-1-General Standards for Industrial Controls and Systems
- NEMA ICS-2-Industrial Control Devices, Controllers, and Assemblies
- UL 67-Electric Panelboards
- UL 489-Molded Case Circuit Breakers and Circuit Breaker Enclosures
- UL 508-Industrial Control Equipment
- UL 845-Motor Control Centers
- NFPA 70-National Electric Code

Motors, Low Voltage

- NEMA MG1-Motors and Generators
- AFBMA 9/ANSI B3.15-Antifriction Bearing Manufacturers Association
- NEMA MG2 AFBMA 11/ANSI B3.16-Safety Standard for Construction and Guide for Selection, Installation and Use of Electrical Motors and Generators
- NEMA MG13-Frame Assignment for Alternating Current Integral Horsepower Induction Motors

Motors, Medium Voltage

- ANSI/IEEE C50.41-Polyphase Induction Motors for Electric Power Generating Stations
- IEEE 112-Test Procedure for Polyphase Induction Motors and Generators
- NEMA MG1-Motors and Generators
- NEMA MG2-Safety Standard for Construction and Guide for Selection, Installation and Use of Electrical Motors and Generators

Neutral Grounding Resistors

- ANSI C76.1-Requirements and Test Codes for Outdoor Apparatus Bushings
- IEEE 32-Requirements, Terminology, and Test Procedures for Neutral Grounding Devices
- NEMA CC1-Electric Power Connectors

Relay Panels

- ANSI C37.20-Switchgear Assemblies Including Metal-Enclosed Bus
- ANSI 37.90-Relays and Relay Systems associated with Electric Power Apparatus
- NEMA WC-3, ICEA S-19-81-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

Transformers, Dry-Type

- ANSI U1-General Requirements for Dry-Type Distribution and Power Transformers
- NEMA ST20-Dry-Type Transformers for General Application
- UL 506-Standard for Safety, Specialty Transformers

Other recognized standards will be utilized as required to serve as design, fabrication, and construction guidelines when not in conflict with the above listed standards.

The codes and industry standards used for design, fabrication, and construction will be the codes and industry standards, including all addenda, in effect as stated in equipment and construction purchase or contract documents.

3.0 ELECTRICAL DESIGN CRITERIA

3.1 ELECTRIC MOTORS

3.1.1 General Motor Design Criteria

These paragraphs outline basic motor design guide parameters for selection and purchase of electric motors.

The following design parameters shall be considered:

- Motor manufacturer;
- Environment, including special enclosure requirements;
- Voltage, frequency, and phases;
- Running and starting requirements and, limitations and duty cycle;
- Motor type (synchronous, induction, direct current [DC], etc.) and construction;
- Power factor;
- Service factor;
- Speed and direction of rotation;

- Insulation;
- Bearing construction, rating life of rolling elements, and external lube oil system for sleeve or plate bearings;
- Ambient noise level and noise level for motor and driven equipment;
- Termination provisions for power, grounding, and accessories;
- Installation, testing, and maintenance requirements;
- Special features (shaft grounding, temperature and vibration monitoring, etc.); and
- Motor space heater requirements.

3.1.1.1 Safety Considerations for Motors

The OSHA will be adhered to for personnel protection. Belt guards shall be specified for personnel safety and, when required, to prevent foreign objects from contacting belt surfaces. Guard screens will be provided over motor enclosure openings that would otherwise allow direct access to rotating parts. All electrical motors will be adequately grounded.

Motors that are located in hazardous areas will be UL labeled and conform to all applicable regulatory requirements. Motor electrical connections are to be terminated within conduit boxes, mounted to the motor frame.

3.1.1.2 Codes And Standards

All motors will be designed, manufactured, and tested in accordance with the latest applicable standards, codes, and technical definitions of ANSI, IEEE, NEMA, and AFBMA, and where supplemented, by requirements of the project specifications.

3.1.1.3 Testing Requirements

Each type of alternating current and direct current machine will be tested at the supplier's factory to determine that it is free from electrical or mechanical defects and to provide assurance that it meets specified requirements. The following criteria and tests will be used in testing each type of machine:

- Fractional horsepower (HP), single-phase induction motors (less than 1 HP). Test procedures will be in accordance with IEEE 114. Test Procedure for Single-Phase Induction Motors.
- Integral horsepower, three-phase, 460 volt induction motors (from 1 HP to 200 HP).
- Routine tests listed in NEMA MG1-1251, Routine Tests for Polyphase Integral Horsepower Induction Motors.
- Test procedures will be in accordance with IEEE 112, Test Procedure for Polyphase Induction Motors and Generators.
- Induction motors rated above 600 volts (250 HP and above).
- Routine tests listed in NEMA MG1-20.46, Polyphase Induction Motors for Power Generating Stations, will be performed on each motor.
- The following additional tests and inspections will be performed on each motor larger than 500 horsepower.
  - Locked-rotor current at fractional voltage.

  - Current balance.
  - Final value of motor noise levels including statement that there is no objectionable single frequency noise.
- Direct current motors.

The standard routine tests and inspections will be performed on each motor. These shall include the following:

- High potential dielectric test.
- Measurement of resistance of all windings.
- Inspection of bearings and bearing lubrication system:
  - No-load running armature current, shunt field current and speed in revolutions per minute, at rated voltage.
  - Full load armature current, shunt field current, and speed in revolutions per minute, at rated voltage.
- Test procedures will be in accordance with IEEE 113, Test Code for Direct Current Machines.

3.1.1.4 Electrical Design Criteria

Special requirements for individual motors and specifications for special application motors will be included in the individual specification's technical sections.

3.1.1.4.1 Rating Motors shall be selected to permit the connected load to develop its specified output continuously without encroaching on the service factor under normal operating conditions. The service factor shall be 1.15 for motors 200 horsepower and less. Motors larger than 200 horsepower shall have a service factor of 1.0.

Motors will be designed for full voltage starting and frequent starting, where required. Motors will be suitable for continuous duty in the specified ambient conditions. Intermittent duty motors will be selected where recognized and defined as standard by the equipment standards and codes.

The torque of all induction motors will be required to accelerate inertia loads of both motor and driven equipment to full speed without damage to the motor or other equipment. This will be accomplished at any voltage from 90 percent to 110 percent of motor nameplate voltage, except those to be individually considered. A 20 percent voltage drop from the specified motor nameplate rating will be allowed for motor starting.

3.1.1.4.2 Temperature Considerations Integral horsepower motors will be designed for an ambient temperature of 40 degrees Celsius (°C). Motors located in areas where the ambient temperature exceeds 40°C will be designed for that ambient condition.

3.1.1.4.3 Windings and Insulation All insulated windings will have a minimum of Class F non-hygroscopic insulation systems rated for temperature rise and ambient temperature in accordance with NEMA MG1 standards. When ambient temperatures greater than 40°C are specified, the allowable temperature rise will be reduced in accordance with NEMA MG1 standards.

All insulated stator winding conductors and wound-rotor motor secondary windings will be copper. Where required, the windings will be treated with a resilient, abrasion resistant material.

3.1.1.4.4 Overspeeds Squirrel-cage and wound-rotor induction motors, except crane motors, will be so constructed that, in an emergency of short duration, they will withstand, without mechanical injury, overspeeds above synchronous speed in accordance with the table as listed in NEMA MG1-12.48, Overspeeds for Motors.

3.1.1.4.5 Space Heaters Space heaters, if required, will be sized as required to maintain the motor internal temperature above the dew point when the motor is idle. Motor space heaters will not cause winding temperatures to exceed rated limiting values or cause thermal protective device over-temperature indication when the motor is not energized.

In general, all motors 25 horsepower or larger will have 120 volt, single-phase, 60 hertz, space heaters. The voltage rating of the heaters shall be at least twice its operating voltage of 120 volts. All 13,200 and 4,000 volt motors will have space heaters. Space heaters rated 1,200 watts and less will be suitable for operation on 120 volts, single-phase, 60 hertz. Heaters rated above 1,200 watts will be suitable for operation on 208 volts, three-phase, 60 hertz.

Space heater leads will be stranded copper cable with 600-volt insulation and shall include terminal connectors. Space heater leads will be wired to a separate terminal housing on 13,200 and 4,000 volt motors.

3.1.1.4.6 Nameplates All motor nameplate data will conform to NEMA MG1-20.60 requirements. The following additional nameplate data will be included for 13,200 and 4,000 volt rated motors:

- Frame size number;
- Service factor;
- Starting limitations;
- Direction of rotation and voltage sequence;
- AFBMA bearing identification number for motors furnished with rolling element bearings;
- For motors with connections to an external lubricant recirculating system, or with an integral forced lubrication system, oil pressure and oil flow required; and
- For motors designed for service in hazardous areas:
  - Location class and group designation; and
  - Maximum operating temperature value or operating temperature code number.

3.1.1.4.7 Environment Location of individual motors within the project site will determine ambient temperature, corrosive environment, hazardous environment, and humidity to be experienced by the motors. These conditions will be considered in the purchase specification.

3.2.2 4,000 and 13,200 Volt Squirrel Cage Induction Motors

3.2.2.1 Design and Construction

Design and construction of 13,200 and 4,000-volt motors will be coordinated with the driven equipment requirements.

All motor power lead terminal housings will be adequately sized to terminate the power conductors. For 4,000 volt and 13,200-volt motors, the power lead terminal housing will also be large enough to provide space to contain the stress cones after installation.

Separate terminal housings will be provided for the following:

- Motor power leads;
- Motor accessory leads; and
- Motor temperature detector leads.

All leads will be wired into their respective terminal housings. All motor leads and their terminals will be permanently marked in accordance with the requirements of NEMA MG1, Part 2.

All motors will have the direction of rotation marked by an arrow or on the nameplate and the leads marked for phase sequence T1, T2, T3 to correspond to the direction of rotation and supply voltage sequence.
All 13,200 volt and 4,000 volt motors will be totally enclosed fan cooled (TEFC) or NEMA WPII.

Weather protected NEMA Type II enclosures will have standard space heaters, and removable, cleanable air filters.

Squirrel-cage induction motors will have rotors of fabricated copper alloy, cast aluminum or fabricated aluminum alloy.

3.2.2.2 Bearings

All horizontal motors will be provided with sleeve bearings when available and applicable.

Sleeve bearings on horizontal motors will be designed and located centrally, with respect to running magnetic center, to prevent the rotor axial thrust from being continuously applied against either end of the bearing. The motors will be capable of withstanding, without damage, the axial thrusts that are developed when the motor is energized.

Horizontal motors may be furnished with antifriction bearings if standard for motor size, enclosure, and speed.

Kingsbury type or antifriction thrust bearings will be provided for vertical motors.

Thrust bearings for vertical motors will be capable of operating for extended periods at any thrust loading imposed by the specific piece of driven equipment. This will be true during starting and normal operation and will not cause damage to the bearings, the motor frame, or other motor parts.

Bearing lubricants will contain a corrosion inhibitor. The type and grade of lubricant will be indicated on a nameplate attachment to the motor frame or end shield adjacent to the lubricant-filling device.

Insulation will be provided on bearing temperature detectors and on oil piping connections when required to prevent circulation of shaft current through bearings.

Bearings and bearing housings will be designed to permit disassembly in the field for inspection of the bearings or removal of the rotor.

3.2.2.3 Bearing Temperature Detectors

Thermocouple type bearing temperature detectors, complete with detector head and holder assemblies as required will be furnished when specified. Thermocouple lead wire insulation will be color coded with standard colors to represent the thermocouple metals.

3.2.2.4 Winding Temperature Detectors

Winding temperature detectors will be furnished, installed, and completely wired when specified. Temperature detectors will normally be three-wire resistance temperature detectors (RTDs).

3.2.2.5 Temperature Detector and Terminal Block Requirements

All temperature detectors will be ungrounded with detector leads wired to terminal blocks furnished in the accessory terminal housings. A grounding terminal for each temperature detector will be included with the detector lead terminals. The grounding terminals will be provided with internal wiring to a common ground connection in each terminal box. The internal wiring will be removable.

3.2.3 460-Volt Integral Horsepower Motors

3.2.3.1 Design and Construction

Design and construction of each 460-volt integral horsepower motor will he coordinated with the driven equipment requirements and the requirements of NEMA MG1 Standards.

The motors shall he totally enclosed, non-ventilated (TENV) or totally enclosed fan cooled (TEFC).

Motors for service in hazardous areas will he individually considered for type of enclosure depending upon the classification, group, and division of the hazardous area in question.

Motor power lead terminal housing will be sized to allow for ease in terminating the incoming power cable. Space heater leads will also be wired into this terminal housing.

3.2.3.2 Bearings

Horizontal motors will he provided with oil or grease lubricated sleeve bearings where required. Antifriction bearings may be furnished if standard for motor size, enclosure, and speed.

Sleeve bearings on horizontal motors will be designed and located centrally, with respect to the running magnetic center, to prevent the rotor axial thrust from being continuously applied against either end of the bearings. The motors will be capable of withstanding without damage the axial thrusts that are developed when the motor is energized.

Thrust bearings for vertical motors will be capable of operating for extended periods at any thrust loading imposed by the specific piece of driven equipment. This will be true during starting and normal operation and will not cause damage to the bearings, the motor frame, or other motor parts.

Bearings and bearing housings will be designed to permit disassembly in the field for inspection of the bearings or removal of the rotor.

3.2.4 Direct Current Machines

3.2.4.1 Design and Construction

All direct current machines will be designed and constructed for continuous operation and in accordance with the requirements of NEMA MG1.

3.2.4.2 Service Factor

For motors furnished with a service factor greater than 1.0, the motor nameplate will indicate the horsepower rating at 1.0 service factor, and the service factor. The motor will be designed to provide a continuous horsepower capacity equal to the rated horsepower at 1.0 service factor without exceeding the total limiting temperature rise stated in these specifications for the insulation system and enclosure specified.

3.2.4.3 Insulation and Windings

All insulated windings will have a minimum of Class B nonhygroscopic, or acceptable equivalent, sealed insulation system. All insulated winding conductors will be copper.

3.2.4.4 Bearings

Sleeve bearings for horizontal motors will be oil ring lubricated types or grease lubricated type unless otherwise required. The oil ring will be one piece construction.

3.2.5 Fractional Horsepower Motors

Type, design and construction of each general, special and definite purpose fractional horsepower motor will be coordinated with the driven equipment requirements and will be in accordance with the requirements of NEMA MG1. Motors for service in hazardous areas will be individually considered for type of enclosure depending upon the classification, group and division of the hazardous area in question. All bearings will be self-lubricating with provisions for re-lubrication, and will be designed to operate in any position or any angle.

3.2.6 Motor Operators for Non-modulating Valve, Gate, Or Damper Service

The following requirements are applicable to all electric operators required for non-modulating motor operators.

3.2.6.1 Rating, Design, and Construction

Motors will be designed for high torque, reversing service in a 50°C ambient temperature. Motors will have Class B or higher non-hygroscopic standard insulation plus two coats of epoxy resin. Requirements of NEMA MG1 and MG2 will apply.

Motors will be rated 460 volts, three-phase, 60 hertz unless otherwise required. The DC motors will be rated 120 volts DC to operate from a nominal 125 volt battery.

The motor time rating for normal opening and closing service will not be less than whichever of the following is greatest:

- As required for three successive open-close operations
- As required for the service
- Not less than 15 minutes

Sufficient torque will be provided to operate against system torque at 90 percent nominal voltage for AC motors and at 85 percent nominal voltage for DC motors.

Motors will be totally enclosed unless specified otherwise.

Motors for service in hazardous areas will be individually considered for type of enclosure depending upon the classification, group, and division of the hazardous area in question.

3.2.6.2 Bearings

Double-shielded, grease prelubricated, regreaseable, antifriction bearings will be furnished. Motor leads will be terminated in the limit switch compartment.

3.2.6.3 Space Heaters

All motor operators will be supplied with 120 volt AC, single-phase, space heaters. Space heater leads will be terminated in the limit switch compartment.

3.3 POWER AND CONTROL WIRING

3.3.1 Design Conditions

In general, conductors will be insulated on the bases of a normal maximum conductor temperature of 90°C in 40°C ambient air with a maximum emergency overload temperature of 130°C and a short circuit temperature of 250°C. In areas with higher ambient temperatures, larger conductors will be used or higher temperature rated insulation will be selected. Conductor size and ampacity will be coordinated with circuit protective devices. Cable feeders from 13.8 kV and 4.16 kV power equipment will be sized so that a short circuit fault at the terminals of the load will not result in damage to the cable prior to normal operation of fault interrupting devices.

Instrument cable will be shielded to maximize electrical noise attenuation.

To be effective, instrument cable shields will be grounded on one end as follows:

- The shields on grounded as well as ungrounded thermocouple circuits will be grounded at the thermocouple well.
- Multi-pair cables used with thermocouples will have individually isolated shields so that each shield will be maintained at the particular couple ground potential.
- Each RTD (resistance temperature detector) system consisting of one power supply and one or more RTDs will be grounded at only one point.
- RTDs embedded in windings of transformers and rotating machines will be grounded at the frame of the respective equipment.
- The low or negative potential side of a signal pair will be grounded at the same point where the shield is grounded. Where a common power supply is used, the low side of each signal pair and its shield will be grounded at the power supply.

3.3.2 CONDUCTORS

3.3.2.1 Design Basis

Electrical conductors will be selected with an insulation level applicable to the system voltage for which they are used and ampacities suitable for the load being served.

3.3.2.2 Cable Ampacities

The maximum ampacities for any cable will be determined in accordance with the NEC and depend upon the worst case in which the cable will be routed (tray, conduit, duct, or direct buried). In addition to ampacity, special requirements such as voltage drop, fault current availability and environment will be taken into consideration in sizing of cable.

3.3.3 INSULATION

Cable insulation and construction will be as follows:

3.3.3.1 Flame Retardance

To minimize the damage that can be caused by a cable fire, all cables will have insulation and jackets that have non-propagating and self-extinguishing characteristics. As a minimum, these cables will meet the flame test requirements of IEEE 383. These characteristics are essential for all cables installed in electrical cable tray in the CESF.

3.3.3.2 Medium Voltage Power Cable

Power cable with 15 kV class insulation will be furnished for all 13.8 kV service and may be routed in trays, conduits or ducts. Power cable with 5 kV class insulation will supply all 4.16 kV service and may be routed in trays, conduits or ducts.

3.3.3.3 Low Voltage Power Cable 600 Volts

Power cable with 600 volts-class insulation will supply power to loads at voltage levels of 480 voltsAC and below, and 125 volts DC and below. Cables may be routed in trays, conduits, or ducts.

3.3.3.4 Control Cable 600 Volts

Non-shielded control cable with 600 volts class insulation will be used for control, metering, and relaying. Cables may be routed in trays, conduits or ducts.

3.3.3.5 Instrument Cable 600 Volts

Instrument cable will be used for control and instrument circuits that require shielding to avoid induced currents and voltages.

Individual circuit requirements and individual equipment supplier’s recommendations will determine the type of cable used.

3.3.3.6 Thermocouple Extension Cable

Thermocouple extension cable will be used for extension leads from thermocouples to junction boxes and to instruments for measurements of temperature. Cables may be routed in trays, conduits or ducts.

3.3.3.7 High Temperature Cable

High temperature cable will be used for wiring to devices located in areas with ambient temperatures above 70°C. Cables may be routed in conduit. Cable lengths will be minimized by terminating the cable at terminal boxes or conduit outlet fittings located outside the high temperature area and continuing the circuit with control or thermocouple extension cable.

3.3.3.8 <u>Lighting and Receptacle Cable</u>

Lighting and receptacle cable will be 600 volts, 75°C, type THWN insulation, or equal.

3.3.3.9 <u>Grounding Cable</u>

Grounding cable will be insulated or uninsulated bare copper conductor sized as required.

3.3.3.10 <u>Switchboard and Panel Cable</u>

Switchboard and panel cable will have 600 volts insulation. Cable will be NEC, Type SIS or XHHW, meeting the UL VW-1, flame test.

3.3.3.11 <u>Special Cable</u>

This type of cable will include cable supplied with equipment, prefabricated cable, coaxial cable, communication cable, etc. This cable will normally be supplied by a particular supplier.

Special cable will be routed in accordance with supplier's recommendations.

3.3.3.12 <u>Miscellaneous Cable</u>

If other types and construction of cable are required as design and construction of the CESF progress, they will be designated and routed as required.

3.3.4 TESTING REQUIREMENTS

Pre-operational tests will be performed on insulated conductors after installation.

- Insulated conductors with insulation rated 5,000 volts and above will be given a field DC insulation test after installation as specified in Part 6 of ICEA Standards S-68-516 and S-66-524.
- Low voltage cables will be either insulation resistance tested prior to connecting cables to equipment or functionally tested (at equipment operation voltage) as part of the checkouts of the equipment system.

3.3.5 INSTALLATION

Cable installation will be in accordance with the following general rules:

- Cables will be routed as indicated in a cable schedule or on the drawings.
- The pulling tension of cable will not exceed the maximum tension recommended by the cable supplier, and the pulling tension in pounds at a bend will not exceed the cable supplier's recommendations for sidewall pressures. Minimum bend radii shall not exceed the supplier's recommendations.
- Care will be exercised during the placement of all cable to prevent tension and bending conditions in violation of the supplier's recommendations.

- All cable supports and securing devices will have bearing surfaces located parallel to the surfaces of the cable sheath and will be installed to provide adequate support without deformation of the cable jackets or insulation.
- Nylon ties will be used to neatly lace together conductors entering panelboards, control panels, and similar locations after the conductors have emerged from their supporting raceway and before they are attached to terminals.
- The Electrical Construction Contractor will physically identify both ends of all circuits.
- All spare conductors of a multi-conductor cable will be left at their maximum length to facilitate replacement of any other conductor in the cable. Each spare conductor will be neatly coiled and taped to the conductors being used.
- In addition to the above requirements, cables will be installed in accordance with supplier's requirements and recommendations.

3.3.6 CONNECTORS

This subsection defines methods of connecting cable between electrical systems and equipment. In this subsection, the term "connector" is applied to devices that join two or more conductors, or are used to terminate conductors at equipment terminals. This is done to provide a continuous electrical path.

Connector material will be compatible with the conductor material to avoid the occurrence of electrolytic reaction between metals.

Connectors will meet the bolt hole requirements of Paragraph CCl-4.05 of NEMA standard publication for Electric Power Connectors, Publication CC1.

All medium voltage and low voltage connectors will be pressure type and secured by using a crimping tool.

Medium voltage cables require stress cones at the termination of the cables. Stress cones will be of the pre-formed type suitable for the cable to which they are to be applied.

Cables will not be spliced in cable trays or conduits. Control and low-level instrument cable will be spliced only at pigtails and at the transition to high temperature wire. Connections and splices will be made in conduit outlet fittings or junction boxes utilizing terminal blocks or an appropriate connector.

3.4 PROTECTIVE RELAYING

The selection and application of protective relays are discussed in the following paragraphs. These relays protect equipment in the Auxiliary Power Supply System, Generator Terminal Systems, High Voltage Transmission System, Turbine-Generator System, and the electrical loads powered from these systems.

The following general requirements apply to all protective relay applications:

- The protective relaying scheme will be designed to remove or alarm any of the following abnormal occurrences:
  - Three Phase, Phase-to-Phase and Phase-to-Ground electrical faults

  - Overcurrent
  - Undervoltage or overvoltage
  - Frequency variations
  - Overtemperature
  - Abnormal pressure
  - Open circuits and unbalanced current
  - Abnormal direction of power flow
- The protective relaying system will be a coordinated application of individual relays. For each monitored abnormal condition, there will exist a designated primary device for detection of that condition. A failure of any primary relay will result in the action of a secondary, overlapping scheme if possible to detect the effect of the same abnormal occurrence. The secondary relay may be the primary relay for a different abnormal condition. Alternate relays may exist which detect the initial abnormal condition but which have an inherent time delay so that the alternate relays will operate after the primary and secondary relays. Similar to secondary relays, the alternate relays may be primary relays for other abnormal conditions. All protective relays will be selected to coordinate with protective devices supplied by suppliers of major items and the thermal limits of electrical equipment, such as transformers and motors.
- Secondary current produced by current transformers will be in the 5 ampere range, and voltage signals produced by potential transformers will be in the 120 volt range.

3.4.1 GENERATOR PROTECTIVE RELAYS

Protective relay packages will be provided to minimize the effects from the following faults and malfunctions:

- Generator phase faults;
- Generator stator ground faults;
- Stator open circuits and unbalanced currents;
- Loss of excitation;
- Backup protection for external system faults;
- Reverse power;
- Generator potential transformer circuit monitoring;
- Under/Over frequency; and
- Breaker failure.

Equipment furnished with the generator's excitation equipment will provide the following additional protection:

- Under-excitation;
- Over-excitation;
- Generator field ground faults; and
- Excessive volts per hertz.

Additional generator protective monitoring equipment will be provided to protect against the following:

- High-bearing temperatures;
- Over-speed conditions;
- Excessive vibrations; and
- Generator overheating.

A typical complement of protective relay functions for the turbine generator may be as follows. The actual protective relaying to be used will be developed during design stages; a microprocessor based Digital Generator System, solid state or electromechanical type relays may be used for the generator protection.

- **Generator Differential Relay (Device 87-G1**). A generator differential relay will provide primary generator protection against three-phase and phase-to-phase faults within the generator. This relay will not detect ground faults within its zone of protection.
- **Generator Ground Relays (Device 64-G).** Device 64-G will be a low voltage pickup, overvoltage relay. It will sense voltage across the generator neutral grounding transformer secondary resistor when a ground fault occurs in the generator, isolated phase bus duct, generator transformer low voltage windings, or the surge protection and potential transformer equipment.
- **Negative Sequence Relay (Device 46).** The negative sequence relay provides protection against unbalanced phase currents that result from unbalanced loading, unbalanced faults, a turn-to-turn winding fault, and an open circuit. Negative sequence currents exceeding the generator allowable limits result in overheating of the generator rotor.
- **Loss-of-Field Relays (Device 40).** The loss-of-field relay complete with timer will provide protection against thermal damage caused by Under-excitation and loss-of-field. These relays provide backup protection for excitation system protective devices finished with the generator.
- **Reverse Power Relays (Device 32).** Reverse power relays (Device 32) will provide protection of the turbine generator by detection of reverse power flow and motoring of the generator. Reverse power (Device 32) will initiate a normal sequential shutdown.
- **Voltage Balance Relays (Device 60).** Voltage balance relay (Device 60) will monitor potential transformer circuits to the generator voltage regulator and protective relays. Upon loss of relaying potential, Device 60 will disable the loss-of-field relay (Device 40) to avoid false tripping of the unit. Upon loss of potential to the voltage regulator, Relay 60 will transfer the voltage regulator from the automatic to manual mode of operation. An alarm will be actuated upon loss of either potential.
- **Underfrequency Relays (Device 81).** Under-frequency conditions will be detected by Device 81.
- **Overvoltage and Undervoltage Protection (Devices 27 and 59).** The voltage regulator and excitation system includes interlocks and protective circuits to prevent operating the generator beyond its design limits. An under-voltage relay (Device 27) and an overvoltage relay (Device 59) will alarm if the voltage regulator fails to maintain voltage within design limits.
- **Field Ground Fault Protection (Device 64F).** Grounds on the generator field will be alarmed by Device 64F, ground detection relay.
- **Generator Backup Distance Relay (Device 21G).** This relay will provide backup protection against external system faults. The relay will operate only if an external system fault persists after

all other primary system relays, including breaker failure, have failed to operate. The relay will trip the generator lockout relay.

3.4.2 POWER TRANSFORMER RELAYS

3.4.2.1 Generator Transformer

The generator transformer is protected against the effects of the following conditions:

- Phase faults;
- Ground faults; and
- Sudden pressure.

This protection will be provided by the relays that are discussed in the following paragraphs.

Transformer Differential Relay (Device 87-T1) - a differential relay that provides transformer primary protection. It detects three-phase and phase-to-phase faults in the generator transformer low voltage delta-connected windings, three-phase, phase-to-phase, and phase-to-ground faults in the generator transformer high voltage wye-connected windings.

Transformer Ground Relay (Device 51-T1N) - a ground overcurrent relay that will provide sensitive backup protection for ground faults in the external system.

Transformer Sudden Pressure Relay (Device 63-T1) - rapid increase in pressure within the transformer tank associated with an internal fault will be detected by the sudden-pressure relay. This relay will be furnished with the transformer.

Loss of cooling and resulting high temperature will be alarmed.

3.4.2.2 Auxiliary Transformers

The auxiliary transformers are protected against the effects of the following conditions:

- Phase faults;
- Ground faults; and
- Sudden pressure.

This protection will be provided by the relays, which are discussed in the following paragraphs.

Transformer Differential Relay (Device 87) – a relay provides primary protection for the high voltage and low voltage windings of the auxiliary transformers; and, for the cable connecting each low voltage winding to each incoming main breaker in the CESF metal-clad switchgear lineups. This relay offers protection against phase-to-phase and three-phase faults. It is relatively insensitive to ground faults on the secondary side of the transformer should the fault current magnitudes be less than the maximum available ground fault current.

Transformer Ground Fault Relay (Device 51-N) - provides primary overload protection to its neutral winding's resistor for ground faults on the switchgear buses or on feeders emanating from the switchgear lineups. This relay also provides backup protection for ground faults in the transformer low voltage winding, in the cable, on the switchgear buses, or on feeders emanating from the switchgear lineups. This one time overcurrent relay will be connected to the bushing current transformer on the neutral of the low voltage winding of the station auxiliary transformer.

A rapid increase in pressure within the transformer tank associated with an internal fault will be detected by a sudden-pressure relay, Device 63. This relay will be furnished with the transformer.

3.4.3 5 kV and 15 kV Motor Controllers

Each induction motor will be protected by main line fuses and a solid-state trip device (SSTD). The SSTD or Current Transformer (CT) operated motor protection module will provide primary equipment and cable time overcurrent, instantaneous overcurrent, open phase, and zero sequence protection. Both the long-time and instantaneous elements for phase protection will be adjustable.

3.4.4 480 VOLT SYSTEM

3.4.4.1 480 Volt Motor Control Centers

Motor control centers will be protected by their incoming feeder breakers having adjustable long-time and short time SSTD elements for phase protection and ground fault protection. The SSTD protects the Motor Control Center (MCC) feeder circuit and the bus against sustained short-circuit currents and serves as backup protection for MCC feeder circuits.

Each magnetic starter within an MCC which supplies power to a motor will be equipped with an adjustable motor circuit protector and a thermal overload element in the starter to protect motors against overload.

Non-motor loads will be fed from MCC feeder circuit breakers. The feeder breakers will be thermal magnetic molded case breakers sized to protect supply cable and individual loads.

Motors, 200 horsepower and less, will be powered from MCC starters.

3.5 CLASSIFICATION OF HAZARDOUS AREAS

Areas where flammable and combustible liquids, gases, and dusts are handled and stored will be classified for determining the minimum criteria for design and installation of electrical equipment to minimize the possibility of ignition. The criteria for determining the appropriate classification are specified in Article 500 of the NEC (NFPA/ANSI C1).

In addition to defining hazardous areas by class and division, each hazardous element is also assigned a group classification (A, B, C, etc.). The group classifications of hazardous elements are specified in Article 500 of the NEC.

Electrical equipment in areas classified as hazardous will be constructed and installed in accordance with the requirements of Articles 501 and 502 of the NEC.

References for use in classification of areas, as well as specification of requirements for electrical installation in such areas, include the following:

- National Electrical Safety Code ANSI C2;
- National Electrical Code ANSI C1, NFPA 70/ANSI C1;
- National Fire Codes, National Fire Protection Association codes, standards, and recommendations; and
- American Petroleum Institute Recommended Practices.

3.6 GROUNDING

The station grounding system will be an interconnected network of bare copper conductors and copper clad ground rods. The system will be provided to protect CESF personnel and equipment from hazards, which can occur during power system faults and lightning strikes.

3.6.1 Design Basis

The station grounding grid will be designed for adequate capacity to dissipate heat from ground current under the most severe conditions in areas of high ground fault current concentrations, with grid spacing such that safe voltage gradients are maintained.

Bare conductors to be installed below grade will be spaced in a grid pattern to be indicated on the construction drawings. Each junction of the grid will be bonded together by an exothermic welding process.

Grounding stingers will be brought through the ground floor and connected to the building steel and selected equipment. The grounding system will be extended, by way of stingers and conductor installed in cable tray, to the remaining CESF equipment. Equipment grounds will conform to the following general guidelines:

- Grounds will conform to the NEC and NESC.
- Major items of equipment, such as switchgear, secondary unit substations, motor control centers, relay panels, and control panels, will have integral ground buses which will be connected to the station ground grid.
- Electronic panels and equipment, where required, will be grounded utilizing an insulated ground wire connected in accordance with the manufacturer's recommendations.
- Motor supply circuits to 460 volt motors, which utilize three-conductor cable with a ground conductor, will utilize this ground conductor for the motor ground. For 460 volt motor supply circuits that utilize three single-conductor cables, a separate ground cable will be utilized.
- All 4,000 volt motors will have a minimum of one 2/0 AWG bare copper ground conductor connected between the motor frame and the station ground grid.
- All 13,200 volt motors will have a minimum of one 4/0 AWG bare copper ground conductor connected between the motor frame and the station ground grid.

- A grounding conductor will be routed parallel to all power conductors operating above 208/120 volts.
- All ground wires installed in conduit will be insulated.

3.6.2 Materials

Grounding materials furnished are described below:

- Rods will be copper clad steel. Ground rod length and diameter will be determined by soil resistivity and subsurface mechanical properties.
- Cable will be soft-drawn copper with Class B stranding.
- Exothermal welds, where required, will use molds, cartridges, and materials as manufactured by Cadweld or equivalent.
- Clamps, connectors, and other hardware used with the grounding system will be made of copper and purchased from an approved supplier.
- Ground wires installed in conduit will be soft-drawn copper with Class B stranding, and green colored 600 volt PVC insulation.

3.7 SITE LIGHTING

The site lighting system will provide personnel with illumination for the performance of general yard tasks, safety, and CESF security. Power used to supply outdoor roadway and area lighting fixtures will be at 208 or 480 volts.

3.7.1 Light Source

The lighting system will be designed in accordance with the Illuminating Engineering Society (IES) to provide illumination levels recommended by the following standards and organizations:

- ANSI/IES RP-7, 1979, Industrial Lighting;
- ANSI/IES RP-8, 1977, Roadway Lighting; and
- OSHA.

Light source size and fixture selections will be based on the applicability of the luminaries for the area under consideration during detail design.

3.7.2 Roadway and Area Lighting

Roadway and area lighting will be designed using high-pressure sodium light source. The light fixtures will be the cutoff types designed to control and direct light within the property line of the facilities. Roadway light fixtures will be installed on hot-dipped galvanized steel poles. Local task lighting will be installed on structures or equipment.

3.7.3 Lighting Control

Electric power to light fixtures located outdoors will be switched on and off with photoelectric controllers. Local task lighting will be controlled with conveniently located manual switches.

3.8 FREEZE PROTECTION

A freeze protection system will be provided for selected outdoor piping as required.

Parallel circuit type heating cable will be utilized where possible. These heating cable circuits can be assembled and installed in the field using the appropriate connection kits.

Power distribution panelboards will furnish power to the freeze protection circuits.

3.9 LIGHTNING PROTECTION

Lightning protection will be provided as required in NFPA 78.

3.10 RACEWAY AND CONDUIT

The design and specifications for the raceway and conduit systems used in supporting and protecting electrical cable will be in accordance with the provisions of the NEC.

3.10.1 Cable Tray

All cable trays except electronic trays will be of trough or ladder type construction with a maximum rung spacing of 9 inches, nominal depths of 4 to 6 inches, and various widths as required.

Cable tray shall be supported in accordance with NEMA standards.

Cable tray fittings will have a radius equal to or greater than the minimum bending radius of the cables they contain.

Solid bottom trays will be provided for all electric systems such as special noise-sensitive circuits and analog instrumentation circuits.

At any cross section of the tray, number of cables shall be limited as per NEC Article 318.

The minimum design vertical spacing for trays will be 9 inches measured from the bottom of the upper tray to the top of the lower tray. At least a 9-inch clearance will be maintained between the top of a tray and beams, piping, or other obstacles to facilitate installation of cables in the tray. If possible, a working space of not less than 24 inches will be maintained on at least one side of each tray.

Ventilated covers will be provided for vertical trays. Solid covers will be provided for all solid bottom trays. Solid covers will also be provided for the top tray of horizontal tray runs located under grating floor or insulated piping.

3.10.2 Conduit

Rigid Steel Conduit (hot dipped galvanized) will be used to protect cable routed to individual load/devices, in hazardous areas, and where the quantity of cable does not economically justify the use of cable tray.

Electrical Metallic Tubing (EMT) will be used indoors in non-hazardous areas for lighting branch circuits and communication circuits.

PVC conduit will be used for underground duct banks and some below grade concrete encased conduit.

Liquid-tight flexible metallic conduit will be used for connections to accessory devices such as solenoid valves, limit switches, pressure switches, etc. It will also be used for connections to motors or other vibrating equipment; and across areas where expansion or movement of the conduit is required.

Plastic or aluminum conduit will be used for specific environmental requirements.

Exposed conduit will be routed parallel or perpendicular to dominant surfaces with right angle turns made of symmetrical bends or fittings.

Conduit in finished areas, such as the offices and Control Room, will be concealed. Conduit will be routed at least six inches from the insulated surfaces of hot water and other hot surfaces. Where conduit must be routed parallel to hot surfaces, high temperature cable will be used. Conduit will be sized in accordance with the conduit fill requirements of the National Electrical Code.

3.10.3 Duct Bank and Manholes

Underground duct banks may be used for cable routed between outlying areas and other remote areas as necessary.

All underground duct banks will consist of PVC pipe encased in red dyed concrete. Minimum size of the plastic pipe will be 2 inches.

All underground duct banks will be installed in accordance with the following methods:

- Ducts will be sloped to manholes to provide adequate drainage. Low spots in duct runs will be avoided.
- Reinforcing steel, if required, will not form closed magnetic paths between ducts. Nonmetallic spacers will be used to maintain duct spacing.
- Reinforced concrete manholes and electrical vaults will be provided, where required, so that cable may be installed without exceeding allowable pulling tensions and cable sidewall pressure. Each manhole will have the following provisions:
  - Provisions for attachment of cable pulling devices
  - Provisions for racking of cables

- – Manhole covers of sufficient size to loop feed the largest diameter cable through the manhole without splicing
- – Sealed bottoms and sumps

Conduit from manholes to the equipment at remote locations will be changed to rigid galvanized steel prior to emerging from below grade. All below grade rigid galvanized steel conduit will be wrapped and encased in concrete.

Ductbank and manholes shall be designed in accordance with the seismic criteria defined in Appendix E, Structural Design Criteria.

Ductbank will be designed to include at least 20 percent spare capacity to allow for future growth and expansion.

3.11 CATHODIC PROTECTION SYSTEM

Consideration will be given to the need for cathodic protection and other corrosion control measures for all CESF structures, including the following structures:

- The exterior surface of underground welded carbon steel pipe, copper pipe, stainless steel pipe, cast iron and ductile iron pipe, and prestressed concrete cylinder pipe.
- The bottoms of surface mounted steel tanks.

It is expected that buried bare copper ground grid components will be in close proximity to, but not in contact with, underground welded steel piping and welded steel tank bottoms. Measures will be taken for the control of corrosion so as not to materially reduce the total effectiveness of the CESF electrical safety grounding systems.

The methods to be used for cathodic protection will be a sacrificial anode system or an impressed current cathodic protection system, or both. The detailed design will be determined after tests to determine minimum average soil resistivity or layer resistivity, which may be expected in pipe burial zones.