Appendix P
Electrical Engineering Design Criteria

APPENDIX P – ELECTRICAL ENGINEERING DESIGN CRITERIA **Page**

1.0 INTRODUCTION

Control of the design, engineering, procurement, and construction activities on the 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
- 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 of this Appendix summarizes the applicable codes and standards and Section 3.0 of this Appendix 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)

2.1 SPECIFIC CODES AND STANDARDS

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

2.1.1 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

2.1.2 Battery Chargers

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

2.1.3 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
- ANSI/UL 44 - Safety Standard for Rubber-Insulated Wires and Cable

2.1.4 Cable, Medium Voltage Power

- ICEA 6 - Ethylene Propylene Rubber Insulated Shielded Power Cables, Rated 5 through 69 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)

2.1.5 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

2.1.6 Circuit Breakers, High Voltage

- ANSI/IEEE C37.04 - Rating Structure for 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
- ANSI C37.12 - Specifications for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis and a Total Current Basis

2.1.7 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

2.1.8 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

2.1.9 Grounding

- ASTM B8 - Specifications for Concentric-Lay Stranded Copper Conductors
- NFPA 70 - National Electric Code
- NEMA CC-1 - Electrical Power Connectors for Substations
- IEEE 80 - Guide for Safety in AC Substation Grounding.
- IEEE 81 - Recommended Guide for Measuring Ground Resistance and Potential Gradients in Earth

2.1.10 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

2.1.11 Lightning Arresters

- ANSI/IEEE C62.1 – Standard for Surge Arresters for AC Power Circuits
- IEEE C62.11 - Standard for Metal-Oxide Surge Arresters for Alternating-Current Power Circuits
- IEEE C62.22 - Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems

2.1.12 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 C37.20.2 - Standard for Metal-Clad and Station-Type Cubicle Switchgear
- 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 Liquid-Immersed Distribution, Power and Regulating 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

2.1.13 Switchgear and Non-segregated Phase Bus

- ANSI C37.04 - Preferred Ratings and Related Required Capabilities for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
- ANSI C37.20.2 - Standard for and Station-Type Cubicle Switchgear
- ANSI C57.13 - Requirements for Instrument Transformers

2.1.14 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

2.1.15 Motors, Low Voltage

- NEMA MG1 - Motors and Generators
- IEEE 112, Test Procedure for Polyphase Induction Motors and Generators
- IEEE 113, Test Code for Direct Current Machines
- IEEE 114, Test Procedure for Single-Phase Induction Motors
- 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

2.1.16 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

2.1.17 Neutral Grounding Resistors

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

2.1.18 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

2.1.19 Substations, High Voltage

- IEEE 525 – Guide for the Design and Installation of Cable System in Substation
- IEEE 605 – Guide for Design of Substation Rigid-Bus Structures
- IEEE 693 – Recommended Practices for Seismic Design of Substations
- IEEE 979 – Guide for Substation Fire Protection
- IEEE 980 – Guide for Containment and Control of Oil Spills in Substations
- IEEE 998 – Guide for Direct Lightning Stroke Shielding of Substations
- IEEE 1109 - Guide for the Interconnection of User-Owned Substations to Electric Utilities

- IEEE 1264 – Guide for Animal Deterrents for Electric Power Supply Substations
- ANSI C2 – National Electrical Safety Code

2.1.20 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

2.1.21 Other Standards

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, 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.)
- Motor space heater requirements.

3.1.1.1 Safety Considerations for Motors

The Occupational Safety and Health Act 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. To ensure safety conditions for all plant electrical motors operations will observe the following: Measure velocity, horsepower, revolutions per minute (rpm), amperage, circuitry, and voltage of units or parts to diagnose problems, using ammeters, voltmeters, wattmeters, and other testing devices.
- Record repairs required, parts used, and labor time.
- Reassemble repaired electric motors to specified requirements and ratings, using hand tools and electrical meters.
- Maintain stocks of parts.
- Repair and rebuild defective mechanical parts in electric motors, generators, and related equipment, using hand tools and power tools.
- Rewire electrical systems, and repair or replace electrical accessories.
- Inspect electrical connections, wiring, relays, charging resistance boxes, and storage batteries, following wiring diagrams.
- Read service guides to find information needed to perform repairs.
- Inspect and test equipment in order to locate damage or worn parts and diagnose malfunctions, or read work orders or schematic drawings to determine required repairs.
- Solder, wrap, and coat wires to ensure proper insulation.

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, 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, 575/480 -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.

3.1.1.5 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.

CLASS I (Gases, Vapors)	
Group A	Acetylene
Group B	Butadiene, ethylene oxide, hydrogen, propylene oxide
Group C	Acetaldehyde, cyclopropane, diethel ether, ethylene, isoprene
Group D	Acetone, acrylonitrite, ammonia, benzene, butane, ethylene dichloride, gasoline, hexane, methane, methanol, naphtha, propane, propylene, styrene, toluene, vinyl acetate, vinyl chloride, xylene.
CLASS II (Combustible Dusts)	
Group E	Aluminum, magnesium and other metal dusts with similar characteristics.
Group F	Carbon black, coke or coal dust
Group G	Flour, starch or grain dust The motor ambient temperature is not to exceed +400C or -250C unless the motor nameplate specifically permits another value, and is noted on the nameplate and in the literature. LEESON explosion-proof motors are approved for all classes noted except Class I, Groups A & B.

3.1.1.6 Temperature Considerations

Integral horsepower motors will be designed for an ambient temperature of 40 degrees C. Motors located in areas where the ambient temperature exceeds 40 degrees C will be designed for that ambient condition.

Standard Options:

- NEMA 42 Frame
- NEMA 140 Frame
- NEMA 180 Frame
- NEMA 210 Frame
- NEMA 250 Frame
- NEMA 280 Frame
- NEMA 320 Frame

3.1.1.7 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 degrees 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.

3.1.1.8 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.

3.1.1.9 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

- **<u>Nameplates</u>.** All motor nameplate data will conform to NEMA MG1-20.60 requirements.

3.1.1.10 <u>Environment</u>

Location of individual motors within the plant 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.

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

3.1.1.11 <u>Bearings</u>

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.
- 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.

3.1.2 480 and 575 Volt Integral Horsepower Motors

3.1.2.1 Design and Construction

Design and construction of each 480 and 575-volt integral horsepower motor will he coordinated with the driven equipment requirements and the following requirements of NEMA MG1 Standards.

- The motors shall be 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.

3.1.2.2 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.
- Bearings and bearing housings will be designed to permit disassembly in the field for inspection of the bearings or removal of the rotor.

3.1.3 Direct Current Machines

3.1.3.1 Design and Construction

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

3.1.3.2 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. The service factor - *SF* - is a measure of periodically overload capacity at which a motor can operate without overload or damage. The NEMA (National Electrical Manufacturers Association) standard service factor for totally enclosed motors is 1.0.

A motor operating continuously at a service factor greater than 1 will have a reduced life expectancy compared to operating at its rated nameplate horsepower.

NEMA Service Factor at Synchronous Speed (RPM) for drip proof motors:

Power (HP)	Synchronous Speed (RPM)			
	3,600	1,800	1,200	900
1/6, 1/4, 1/3	1.35	1.35	1.35	1.35
1/6	1.25	1.25	1.25	1.25
3/4	1.25	1.25	1.15	1.15
1	1.25	1.15	1.15	1.15
1 1/2 and up	1.115	1.15	1.15	1.15

Example - Service Factor

A 1 HP motor with a 1.15 *SF* can operate at *1 HP x 1.15 = <u>1.15</u> HP* without overheating or otherwise damaging the motor if rated voltage and frequency are supplied to the motor. Insulation life and bearings life are reduced by the service factor load.

3.1.3.3 Insulation and Windings

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

3.1.3.4 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.

Bearings and Lubrication Application Industrial Electric Motors | Bearings Knowledge Electric Generators Suppliers | Motor Generator Set Distributor Application bearings and lubrication used on generators. Several types of bearings, each with specific lubrication requirements, are used on the generators. Usually, a generator has two bearings, one to support each end of the armature shaft. On some generators, the coupling to the prime mover supports one end of the shaft and one bearing is used at the other end. The selections of bearing type and lubrication are based on generator size, type of coupling to prime mover, and expected usage. A generator is usually equipped with either sleeve or ball bearings, which are mounted in, end shields attached to the generator frame. Sleeve bearings are usually bronze and are lubricated with oil. Most unit s with sleeve-type bearings has a reservoir for the oil and a sight gauge to verify oil level. Bearings and the reservoir are fully enclosed. Distribution of oil to shaft and bearings from the reservoir is by an oil-slinger ring mounted on the generator shaft. Rotation of the slinger ring throws the oil to the top of the bearing. Holes in the bearing admit oil for lubrication. Some units with sleeve-type bearings have an absorbent fiber packing, saturated with oil, which surrounds the bearing. Holes in the bearing admit oil for lubrication. Ball bearings (or roller-type bearings) are fully enclosed and lubricated with grease. Most units with ball or roller-type bearings are equipped with a fitting at each bearing to apply fresh grease. Old grease is emitted from a hoie (normally closed by a plug or screw) in the bearing enclosure. Some units are equipped with pre-packed, lifetime lubricated bearings.

3.1.4 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.

3.1.4.1 Rating, Design, and Construction

- Motors will be designed for high torque, reversing service in a 50 degrees 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 480 volts, three-phase, 60 hertz unless otherwise required. The direct current (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 alternating current (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.

Temperature Tolerance Class	Maximum Operation Temperature Allowed		Allowable Temperature Rise at full load 1.0 service factor motor 1)	Allowable Temperature Rise 1.15 service factor motor 1)
	°C	°F	°C	°C
A	105	221	60	70
B	130	266	80	90
F	155	311	105	115
H	180	356	125	-

3.1.4.2 Bearings

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

3.2 POWER AND CONTROL WIRING

3.2.1 Design Conditions

- In general, conductors will be insulated on the bases of a normal maximum conductor temperature of 90 degrees C in 40 degrees C ambient air with a maximum emergency overload temperature of 130 degrees C and a short circuit temperature of 250 degrees 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 34.5 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.

3.2.2 Conductors

3.2.2.1 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.

3.2.2.2 Cable Ampacities

The maximum ampacities for any cable will be determined in accordance with the National Electric Code 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.

Ampacity Calculations

The recommends that wire and cable ampacities be determined using the latest NEC tables and text. In particular, attention should be given to Articles 310, 392, 400-5 (flexible cords), and 501-4 Class I, II and III, Divisions 1 and 2 hazardous locations. Also use the “Ampacity Correction Factors” when the Ambient Temperature is different than those indicated in the Tables. Also, derating is required when using more than three conductors in a Raceway or Cable. Appendix B also contains helpful tables for Ampacity.

ARTICLE 310: Conductors for General Wiring

Table 310.15(B)(2)(a)	Adjustment Factors for More Than Three Current-Carrying Conductors in a Raceway or Cable
Table 310.16	Allowable Ampacities of Insulated Conductors Rated 0 Through 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)
Table 310.17	Allowable Ampacities of Single-Insulated Conductors Rated 0 Through 2000 Volts in Free Air, Based on Ambient Air Temperature of 30°C (86°F)
Table 310.18	Allowable Ampacities of Insulated Conductors Rated 0 Through 2000 Volts, 150°C Through 250°C (302°F Through 482°F). Not More Than Three Current-Carrying Conductors in Raceway or Cable, Based on Ambient Air Temperature of 40°C (104°F)
Table 310.19	Allowable Ampacities of Single-Insulated Conductors, Rated 0 Through 2000 Volts, 150°C Through 250°C (302°F Through 482°F), in Free Air, Based on Ambient Air Temperature of 40°C (104°F)
Table 310.20	Ampacities of Not More Than Three Single Insulated Conductors, Rated 0 Through 2000 Volts, Supported on a Messenger, Based on Ambient Air Temperature of 40°C (104°F)
Table 310.21	Ampacities of Bare or Covered Conductors in Free Air, Based on 400°C (1040°F) Ambient, 800°C (1760°F) Total Conductor Temperature, 610 mm/sec (2 ft/sec) Wind Velocity
Figure 310.60	Cable installation dimensions for use with Tables 310.77 through 310.86.
Table 310.64	Thickness of Insulation for Shielded Solid Dielectric Insulated Conductors Rated 2001 to 35,000 Volts
Table 310.67	Ampacities of Insulated Single Copper Conductor Cables Triplexed in Air Based on Conductor Temperatures of 90°C (194°F) and 105°C (221°F) and Ambient Air Temperature of 40°C (104°F)

Table 310.69	Ampacities of Insulated Single Copper Conductor Isolated in Air Based on Conductor Temperatures of 90°C (194°F) and 105°C (221°F) and Ambient Air Temperature of 40°C (104°F)
Table 310.71	Ampacities of an Insulated Three-Conductor Copper Cable Isolated in Air Based on Conductor Temperatures of 90°C (194°F) and 105°C (221°F) and Ambient Air Temperature of 40°C (104°F)
Table 310.73	Ampacities of an Insulated Triplexed or Three Single-Conductor Copper Cables in Isolated Conduit in Air Based on Conductor Temperatures of 90°C (194°F) and 105°C (221°F) and Ambient Air Temperature of 40°C (104°F)
Table 310.75	Ampacities of an Insulated Three-Conductor Copper Cable in Isolated Conduit in Air Based on Conductor Temperatures of 90°C (194°F) and 105°C (221°F) and Ambient Air Temperature of 40°C (104°F)
Table 310.77	Ampacities of Three Single-Insulated Copper Conductors in Underground Electrical Ducts (Three Conductors per Electrical Duct) Based on Ambient Earth Temperature of 20°C (68°F), Electrical Duct Arrangement per Figure 310.60, 100 Percent Load Factor, Thermal Resistance (RHO) of 90, Conductor Temperatures of 90°C (194°F) and 105°C (221°F)
Table 310.79	Ampacities of Three Insulated Copper Conductors Cabled Within an Overall Covering (Three-Conductor Cable) in Underground Electrical Ducts (One Cable per Electrical Duct) Based on Ambient Earth Temperature of 20°C (68°F), Electrical Duct Arrangement per Figure 310.60, 100 Percent Load Factor, Thermal Resistance (RHO) of 90, Conductor Temperatures of 90°C (194°F) and 105°C (221°C)
Table 310.81	Ampacities of Single Insulated Copper Conductors Directly Buried in Earth Based on Ambient Earth Temperature of 20°C (68°F), Arrangement per Figure 310.60, 100 Percent Load Factor, Thermal Resistance (RHO) of 90, Conductor Temperatures of 90°C (194°F) and 105°C (221°C)

Table 310.83	Ampacities of Three Insulated Copper Conductors Cabled Within an Overall Covering (Three-Conductor Cable), Directly Buried in Earth Based on Ambient Earth Temperature of 20°C (68°F), Arrangement per Figure 310.60, 100 Percent Load Factor, Thermal Resistance (RHO) of 90, Conductor Temperatures of 90°C (194°F) and 105°C (221°F)
Table 310.85	Ampacities of Three Triplexed Single Insulated Copper Conductors Directly Buried in Earth Based on Ambient Earth Temperature of 20°C (68°F), Arrangement per Figure 310.60, 100 Percent Load Factor, Thermal Resistance (RHO) of 90, Conductor Temperatures 90°C (194°F) and 105°C (221°F)

3.2.3 Insulation

Cable insulation and construction will be as follows:

Electric Motor Insulation Resistance Testing
Electric motor insulation exhibits a negative temperature coefficient, meaning as temperature increases, resistance decreases. This would lead you to believe that insulation resistance of a de-energized motor will decrease after starting the motor. However, most often the resistance will initially increase after running due to moisture being evaporated by the increasing temperature of the windings. The governing standard (IEEE43) on insulation resistance testing requires a temperature correction to 40 degrees Celsius, which could quickly turn acceptable measured resistance readings into unacceptably low corrected resistance readings. Before sending a motor to be refurbished, consider space heaters.

3.2.3.1 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 trays in the plant.

3.2.3.2 Cable Flame Tests

Factory Mutual Cable Fire Propagation Test: A unique test standard whereby a Fire Propagation Index (FPI) is determined based upon a combination heat release and ignition test. The FPI is used to determine a 1, 2, or 3 Group rating. The lower Group ratings are the better performing cables.

ICEA T-29-520 Vertical-Tray Flame Test (210,000 BTU): Similar to 70,000 BTU per hour test but heat source increased to 210,000 BTU per hour.

IEEE 383 Vertical Flame Test: The Institute of Electrical and Electronic Engineers (IEEE) has established IEEE-383, "IEEE Standards for Type Test of Class IE Electric Cables, Field Splices and Connections for Nuclear Generation Stations". Although originally intended for cables essential for emergency operations in nuclear power plants, this test procedure is used for other non-nuclear installations.

In the IEEE-383 fire test cables are supported by a one-foot wide vertical rack eight feet high. The cables are positioned in the center six inches off the rack, spaced one-half cable diameter apart. The rack is centered in an eight foot cube enclosure recommended by Underwriters Laboratories. A ten inch ribbon burner fuel with an air-propane mixture ignites the cable with a 21 kW (70,000 BTU/hr) flame. The burner is positioned two feet above the floor and 9 to 12 inches of cable are exposed to the direct flames for 20 minutes. Cables on which flame extends above the top of the eight foot rack fail this test. NELPIA (ANI) test is a (210,000 BTU/hr) vertical flame test corner configuration.

UL Flammability Tests	BTU/hr	Locations
UL 1581 (VW-1)	(Bunsen Burner)	Residential & Non-Residential in Conduit UL Flammability Tests BTU/hr Locations
UL 1581 (Vertical Tray)	70,000 (IEEE 383)	General Purpose
UL 1666 (Vertical Chamber)	527,500	Riser and General Purpose UL Flammability Tests BTU/hr Locations
UL 910 (Steiner Tunnel)	320,000	Plenum, Riser and General Purpose

UL-910 Plenum Test: A plenum is defined as any space used as part of an air-handling system. This includes heating/air conditioning ducts and air returns, which frequently include the space between suspended ceilings and the floor above in modern office buildings. The National Electrical Code (NEC) requires that exposed cables (those not in conduit) in plenums be listed as “having adequate fire-resistant and low-smoke producing characteristics...”.

A “Standard For Test Method For Fire and Smoke Characteristics of Cables Used in Air-Handling Spaces.” was developed by Underwriters Laboratories (UL) to classify cables for this NEC requirement. This test is performed in a 25 foot Stein Tunnel test furnace (also specified in ASTM E-84 test for building materials). Designed to match the rigors of the application, this test is quite demanding.

In the UL-910 test, a single layer of 24 foot lengths of cable are supported by a one foot wide cable rack, which is filled with cables. The cables are ignited by an 88 kW (300,000 BTU/hr) methane flame. Flame spread is aided by a 240 ft/minute draft. During the 20 minute test, flame spread is observed through small windows spaced one foot apart. Smoke is measured by a photocell installed in the exhaust duct.

To qualify, cables must have a flame spread of less than 5 feet beyond the end of the 4-1/2 foot ignition flame, a peak optical density of 0.5 maximum (33% light transmission) and a maximum average optical density of 0.15 (70% light transmission).

UL Riser Test: Underwriters Laboratories (UL) has established a fire test facility for the purpose of listing cables that meet NEC requirements.

This test chamber is an eight by four simulated shaft, twelve feet high between the source of ignition and the floor above. A very large propane burner, 145 kW (495,000 BTU/hr) is ignited for a period of 30 minutes. Flames must not extend above the 12 foot mark if the cable is to be UL Classified for this duty.

UL VW-1 Vertical Wire Flame Test: The purpose of the UL VW-1 Vertical Wire Flame Test is to screen out flammable wires. The ignition source is small (under 1 kW) and is applied for only 75 seconds.

In the UL VW-1 Flame Test, a tirrill burner (similar to a Bunsen burner) is used as the ignition source. The wire sample is mounted and the flame is applied for 15 seconds and then removed. The flame is then reapplied, either after 15 seconds or when the sample ceases to flame (whichever is longer), for a total of five 15-second applications. After the above procedure is completed, a wire sample that passes this test must not burn for more than one minute and must not burn more than 25% of the Kraft indicator flag. In addition, the surgical cotton at the base of the burner must not be ignited.

3.2.3.3 Medium Voltage Power Cable

Power cable with 35 kV class insulation will be furnished for all 34.5 kV service and may be routed in trays, conduits or ducts or may be direct buried. Power cable with 5 kV class insulation will supply all 4.16 kV service and may be routed in trays, conduits or ducts.

3.2.3.4 Low Voltage Power Cable Insulation Rating of 600 Volts

Power cable with 600V-class insulation will supply power to loads at voltage levels of 480 VAC and below, and 125 VDC and below. Cables may be routed in trays, conduits, or ducts or may be direct buried.

3.2.3.5 Control Cable Insulation Rating of 600 Volts

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

Application
For use in harsh environments where maximum conductor protection is required. Impervious armor prevents the entrance of water, gas and corrosive elements into the electrical core. Used for power, control and lighting circuits in a broad range of commercial and industrial pulp and paper, mining, and petroleum applications. Approved for use in wet or dry locations at 90°C, for installation indoors or outdoors, aerially, in conduits, ducts, cable trays or direct burial in circuits not exceeding 600 volts. UL listed, Type MC-HL per UL Standard 2225 for use in Class I, Division I hazardous locations. UL approved for use at 90°C for continuous operation, 130°C for emergency overload conditions, and 250°C for short circuit conditions. Impervious continuously welded corrugated armor cable is recommended as an economical alternative to wire in conduit systems.

Conductors
Soft bare annealed copper per ASTM B-3, Class B stranding per ASTM B-8 (compressed) or ASTM B-496 (compact).

Insulation
Cross-linked polyethylene (XLP) per ICEA S-95-658 and UL Standard 44 for Type XHHW-2 conductors.

Grounding Conductor
Soft bare annealed copper per ASTM B-3, Class B stranding per ASTM B-8 sized in accordance with NEC requirements.

Armor
Impervious continuously welded and corrugated aluminum.

Jacket
Black flame-retardant and sunlight-resistant PVC.

Flame Tests
UL 1581 70,000 BTU/hr flame test
ICEA 70,000 BTU/hr and 210,000 BTU/hr flame test
IEEE 383 70,000/hr flame test

Color Code
Control Conductors: red, blue, orange and yellow
Power Conductors: ICEA Method 4

Additional Standards
UL listed Type CWCMC to IEEE 45/IEEE 1580 (46 CFR Part 111.60-23) Marine Shipboard Cable. Meets requirements of CSA-C22.2 No. 0.3, -40°C cold impact test

Connectors
Explosion Proof, Class 1 Division 1: 424MA series - all nickel-plated brass
Rain Tight: 416MC series - all nickel-plated brass

3.2.3.6 Instrument Cable Insulation Rating of 600 Volts

Instrument cable application will be 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.

3.2.3.7 Thermocouple Extension Cable

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

3.2.3.8 High Temperature Cable

High temperature cable will be used for wiring to devices located in areas with ambient temperatures above 70 degrees C. Cables may be routed in conduit. Cable lengths application 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.

Application
For use in high and low temperature environments where moisture and abrasion resistance is required in internal wiring of appliances and electrical equipment, motor lead and fixture applications.

Conductor
Tin-coated, soft annealed copper per ASTM B-33, Class H stranding per ASTM B-173.

Insulation
Silicone rubber

Jacket
K-fiber braid treated with a flame-, heat-, moisture-, and abrasion-resistant finish.

Flame Tests
VW-1 flame test

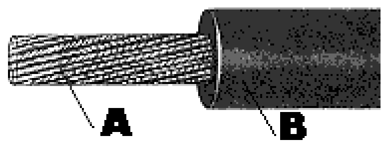
3.2.3.9 Lighting and Receptacle Cable

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

3.2.3.10 Grounding Cable

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

GROUNDING CABLE



Legend: A: Conductor B: PVC Insulation / Jacket

Description
This specification covers single conductor grounding cable insulated with clear Polyvinyl Chloride. These cables are suitable for use as a temporary grounding cable whenever an overhead line or other electric equipment is being repaired to prevent accidents which might occur if the equipment should become energized. Since cables of this type are predominantly subject to mechanical stresses, the clear PVC covering is designed to allow for quick location of conductor damage. During normal usage, these cables are at ground potential, but may have to momentarily withstand full line voltage in the event that the equipment is accidently energized.

Conductor
Soft annealed copper per ASTM B-3, rope lay stranded per ASTM B- 1 72, Class K.

Insulation
Ultra-violet stabilized, clear Polyvinyl Chloride with a Blue Tint meeting the following requirements:

	TYPICAL VALUE	TEST METHOD
Tensile	2500 PSI	ASTM D-412
Elongation	375%	ASTM D-412
Hardness (Shore "A" Duro +3)	80	ASTM D-2240
Brittle Point Model "E"	−37°C	ASTM D-746

CONDUCTOR SIZE	STRANDING (NO. OF WIRES)	APPROX. O.D. (INCHES)	APPROX. NET WT. (LBS./M')
#6 AWG	266/#30	.380	145
#4 AWG	420/#30	.440	190
#2 AWG	665/#30	.530	270
#1 AWG	836/#30	.580	370
#1/0 AWG	1064/#30	.640	450
#2/0 AWG	1323/#30	.700	560
#3/0 AWG	1666/#30	.770	700
#4/0 AWG	2107/#30	.840	900
250 MCM	2499/#30	.970	1050

3.2.3.11 Switchboard and Panel Cable

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

3.2.3.12 Special Cable

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.

3.2.3.13 Miscellaneous Cable

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

3.2.4 Testing Requirements / Program 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.

- High Voltage Cable Commissioning / Maintenance Optimization:

The primary objective of a commissioning test is to check the integrity of the main insulation of individual system components as well as the quality of the installation. By applying an AC over voltage continuously for a period of 60 minutes, latent defects may be identified via partial discharge testing before the cable is placed in commercial service. Kinectrics is uniquely qualified to perform Hi-Pot qualification and "proof of function" tests on high voltage power cables, and now offers testing services using an advanced high power Mobile Resonant Power Supply system rated 260 kV at 83 amps for transmission class cable lines. Kinectrics' testing services encompass cables with extruded insulation and high-pressure self-contained fluid-filled (HPFF) cables as well as the associated accessories.

Electric Motor Testing has diminished with the ever-increasing frequency of corporate re-engineering. What this means for electric motor testing maintenance programs is billions of dollars of lost revenue through increased electrical repair costs, downtime, and waste in industrial and commercial companies. Modern electrical maintenance practices often do not take into account the importance of electric motor testing for proper equipment uptime and plant competitiveness.

Electric motor testing maintenance and management programs are designed to improve equipment readiness and uptime while reducing capital overhead. This program consists of particular maintenance and management tools designed to aid the maintenance engineer in electric motor systems and their care. The following are some important electric motor testing items:

Electric Motor Testing Recommended Items: (Test platform for all SES Motors)

Electric Motor Impulse Testing

Electric Motor impulse testing is an integral part of predictive maintenance of electrical motors. Through the following questions the influence that extensive impulse testing has on a motor is investigated. Can impulse testing damage healthy or deteriorated insulation? Can DC Resistance, Inductance, Megger or HiPot tests diagnose weak turn-to-turn insulation?

After failing an impulse test, are motor with weak insulation able to operate? Are motors with a turn-turn short capable of continued operation? This was accomplished by putting a low voltage motor through extensive testing rigors, until inducing a failure. Following the failure, additional testing investigated the possible deteriorating effects on turn-turn insulation due to impulse testing beyond the motor's dielectric breakdown. NOTE: This paper was edited from the original version of the IEEE paper published in 2003.

Electric Motor Rotation Testing

Check for fan or pump motor rotation when testing offline with the MCE. Fans may continue to slowly rotate due to drafting in the Plenum. Pumps that are connected to a common header may continue to rotate if other pumps connected to the header are operating. This will adversely affect the Standard Test results, possibly creating higher than normal resistive and inductive imbalances.

Wound Rotor Motor Testing

Wound rotor motors have a three-phase winding wound on the rotor which is connected to three phases of start-up resistors in order to provide current and speed control on start-up. Failed components in the resistor bank are common and often overlooked when troubleshooting. These faults can have a significant impact on the overall operation of the motor and should be given considerable focus when troubleshooting these motors.

The recommended off-line in-service electric motor tests are -

- Stator winding resistive imbalance
- Stator winding insulation resistance (Meg-Ohm checks)
- Polarization Index (PI)
- Step Voltage test
- Surge test

The recommended spare electric motor tests are -

- Stator winding resistive imbalance
- Stator winding insulation resistance (Meg-Ohm checks)
- Polarization Index (PI)
- Step Voltage test
- Surge test

The recommended new/refurbished electric motor tests are -

- Stator winding resistive imbalance
- Stator winding insulation resistance (Meg-Ohm checks)
- Polarization Index (PI)
- Step Voltage test
- Surge test

3.2.5 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.

3.2.6 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. The following methods will be used:

- Connector material will be compatible with the conductor material to avoid the occurrence of electrolytic action 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 will be made in conduit outlet fittings or junction boxes utilizing terminal blocks or an appropriate connector.

3.3 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, Generator System, and the electrical loads powered from these systems. On the high voltage transmission network, the issue is quite different:

Firstly, an overhead line, which runs on the public domain, is periodically the target of short circuits, due to lightning, unpruned trees, cranes or great height engines working in the neighborhood, wind, pollution. A good design of the line may lower their probability, but not remove them; e.g., on the network of a normal network, an average of 7 short circuits per year and per 100 km may be observed.

Secondly, when the temperature of a line increases, it becomes longer, and its lowest point, between two towers, drops. If the line is not tripped in time, it becomes dangerous for the persons. The consequences must be then evaluated no more in millions of US dollars, but in loss of human lives and that is why the protection systems must include back-up functions.

The failure of a relay is palliated by the back-up operation of relays which may be located on other points of the network. This can lead to the tripping of many assets. The supply of a whole region can be jeopardized. A false operation of a protective relay may then provoke the tripping of one or several customers, or a whole town, comprising the priority customers hospitals, traffic lights, and more.

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.

3.3.1 Power Transformer Relays

3.3.1.1 Generator Transformer

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

- Phase faults
- Ground faults
- 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.

3.3.1.2 Auxiliary Transformers

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

- IEEE Guide for Safety in AC Substation Grounding
  - Phase faults
  - Ground faults
  - 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 plant 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.

3.3.2 480/575 Volt System

3.3.2.1 480/575 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 MCC feeder circuit and the bus against sustained short-circuit currents and serves as backup protection for MCC feeder circuits.

CENTERLINE Motor Control Centers (One of a variety of MCC used during Design)

CENTERLINE Bus Design

CENTERLINE MCCs use the time proven and industry leading CENTERLINE bus design. This bus design allows for improved heat dissipation, easier installation and maintenance and increased current carrying capacity.

Safety

No other MCC offers the same protection for personnel and equipment including high levels of isolation from hazardous voltages, superior fault containment and a solid grounding system.

Intelligent Motor Control

CENTERLINE Motor Control Centers include the latest in intelligent motor control devices, such as drives, soft starters and electronic overload relays.

IntelliCENTER Technology and Integrated Architecture

CENTERLINE Motor Control Centers include the latest in intelligent motor control devices, such as drives, soft starters and electronic overload relays.

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 hp and less, will be powered from MCC starters.

3.4 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 National Electrical Code (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 National Electrical Code.

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

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

3.5 GROUNDING

Grounding has always been a controversial topic. With the growth of digital high frequency systems the issues are more complex. Grounding means connected to earth or a conducting body that acts in place of earth. Some international standards refer to grounding as earthing. Bonding is the interconnection of metal parts to establish electrical continuity. These definitions are NEC terminology and apply to power system grounding.

The purpose of grounding is:

- Fire Protection
- Electrical Shock Protection
- Electrical system ground fault protection
- Lighting protection-building and electrical system
- Electrical Noise and EMI protection
- Voltage Stabilization

Power System Grounding
Power circuit grounding of cable trays is explained in CTI Technical Bulletins, Titles No. 8, 11, and 12, and the National Electrical Code Sections 318-3-© and 318-7. It is also covered in NEMA Standard VE-2.

The purpose of power grounding is to minimize the damage from wiring or equipment ground fault. Cable tray systems are in the path of ground fault currents. Cable tray systems are bonded together through their bolting, connectors splice plates, clamps, and bonding jumpers where there are gaps in the cable tray system. Cable tray systems are not required to be mechanically continuous, but shall be electrically continuous.

Grounding frequencies: (Considered during Design)

- Power system sub-harmonics and offset (dc to 60 Hz)
- Power system harmonics (from 120 up to 3 kHz)
- Analog communication circuits (from a few up to hundreds of kHz)
- Single point grounding for low voltage level circuits

- High-speed digital circuits (high kHz to GHz)
- Single and multi-layer planes (common surface) on PCB

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

3.5.1 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.

The station grounding grid will be designed to meet the safe step and touch potentials identified in IEEE 80 - Guide for Safety in AC Substation Grounding.

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 plant equipment. Equipment grounds will conform to the following general guidelines: 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.

- 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.

3.5.2 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.

3.6 SITE LIGHTING

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

The substation lighting shall conform with the requirements of NFPA 70 – National Electrical Safety Code.

3.6.1 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
- Occupational Safety and Health Act (OSHA).
- NFPA 70 – National Electrical Safety Code

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

3.6.2 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.

These lighting system will be monitored and check by operations on a shift by shift bases to ensure proper operations.

3.6.3 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.

3.7 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. These heating circuits will meet the NFPA and NEC code for installation and procedural operations.

3.8 LIGHTNING PROTECTION (Safety, Performance & Mitigation)

1) Safety

- Reduce fire hazard
- Prevent electric shock
- Avoid equipment damage

2) Performance Control current paths

- Equalize voltage reference
- Reduce communication noise

3) Lightning and Surge Mitigation

- Control transients

- Remove static charge
  - Bond between all services
  - Equalize surge reference points

Lightning protection will be provided as required in NFPA 78 and IEEE 998.

3.9 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.

3.9.1 Cable Tray

Cable Tray Grounding-Signal and Communication Circuits

Where cable tray systems contain only signal and communication circuits that operate at low energy levels, power grounding per NEC Section 318-7 is not appropriate, but cable tray grounding for lightning protection, noise, and electromagnetic interference is necessary. For telecommunications circuits TIA/EIA standard 607, Commercial Building Grounding and Bonding Requirements for Telecommunications, provides grounding for these systems. Voltage disturbances, lightning induced voltages, and radiated EMI are the concern. Lightning protection is a concern if cable trays are located on the top of buildings, in an outdoor exposed area, or in the path of lightning currents. An overhead cable system can provide protection. NFPA 780, Standard for the Installation of Lightning Protection Systems 1997 Edition, provides the criteria for building lightning protection.

Cable tray designs are also available that are EMI/RFI shielded. The tray is totally enclosed and the gaskets and covers are constructed and tested to meet EMI standards for the protection of the sensitive circuits in the cable tray against external electric and magnetic fields. Solid bottom cable trays also provide some degree shielding as do cable tray covers. Steel provides effective shielding at frequencies up to approximately 100 kilohertz however at higher frequencies, in the megahertz range, aluminum or copper shielding is more effective.

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.

3.9.2 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.

3.9.3 Duct Bank and Manholes

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

All underground power cable duct banks will consist of PVC tubing encased in concrete. Minimum size of the plastic duct will be two-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.

Duct bank and manholes shall be designed in accordance with the seismic criteria defined in Appendix D, Structural Design Criteria.

Duct bank will be designed to include spare capacity to allow for future growth and expansion.

3.10 CATHODIC PROTECTION SYSTEM

CP systems work on the principle that corrosion is an electrochemical reaction in which one part of a piece of iron or steel acts as an anode while adjacent metal acts as a cathode. At the anode corrosion occurs as iron gives up electrons and forms soluble iron ions (Fe - Fe^{2+} + 2e). At the cathode the electrons released by the corrosion process combine with water and oxygen to form hydroxide ions (½ O_2 + H_2O +2e - 2OH $^-$). In CP systems the metal to be protected is forced to act as the cathode, as on this side of the reaction the surface of the metal is unaffected by the reaction, preventing further corrosion. When used to protect structural iron and steel this is achieved by applying small DC electric currents, via the building material.

There are two methods of achieving this, either sacrificial anode cathodic protection (SACP) or impressed current cathodic protection (ICCP).

SACP systems use sacrificial anodes (zinc, aluminum or magnesium) which are placed in close proximity to the corroding metalwork and electrically connected to it. As the sacrificial anode corrodes, it generates a current that passes through the building material to provide protection to the embedded metalwork. The current is ionically conducted by means of pore water contained within the building material.

Consideration will be given to the need for cathodic protection and other corrosion control measures for all plant 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 plant 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.

Reference Material:

Lightning and Grounding:

Injunction and Order; U.S. District Court of Arizona; Heary Bros, et al. vs. NFPA, et al.

NFPA Standards Council Final Decision; Re: New Project Request for DAS/CTS Lightning Systems; January 14, 2005

Order, U.S. District Court of Arizona; Heary Bros, et al. vs. LPI, et al; Oct 10, 2003

Warning of the ICLP Scientific Committee; Re: ESE & CTS/DAS Installations Are In Conflict With IEC's L.P. Standards; 9/14/05

Zipse's Project for a Standard for CTS Is Dead; March 23, 2005

"A Critical Review of Nonconventional Approaches to Lightning Protection" By Uman & Rakov; December, 2002