PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

In an effort to minimize the cost of process industry facilities, this Practice has been prepared from the technical requirements in the existing standards of major industrial users, contractors, or standards organizations. By harmonizing these technical requirements into a single set of Practices, administrative, application, and engineering costs to both the purchaser and the manufacturer should be reduced. While this Practice is expected to incorporate the majority of requirements of most users, individual applications may involve requirements that will be appended to and take precedence over this Practice. Determinations concerning fitness for purpose and particular matters or application of the Practice to particular project or engineering situations should not be made solely on information contained in these materials. The use of trade names from time to time should not be viewed as an expression of preference but rather recognized as normal usage in the trade. Other brands having the same specifications are equally correct and may be substituted for those named. All Practices or guidelines are intended to be consistent with applicable laws and regulations including OSHA requirements. To the extent these Practices or guidelines should conflict with OSHA or other applicable laws or regulations, such laws or regulations must be followed. Consult an appropriate professional before applying or acting on any material contained in or suggested by the Practice.

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1. **Introduction**

1.1 **Purpose**
This Practice provides general requirements and the basis for the design of an electrical system.

1.2 **Scope**
This Practice describes the general design requirements for electrical systems. This Practice includes requirements for system components and typical configurations.

2. **References**

Applicable parts of the following Practices, industry codes and standards, and references shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

2.1 **Process Industry Practices (PIP)**
- PIP ELCGL01D - Data Sheet for Electrical Design Criteria
- PIP ELEGL02 - Arc Flash Implementation Guideline
- PIP ELEHA01 - Engineering Procedure for Developing Electrical Area Classifications
- PIP ELEMT01 - Guidelines for Selecting IEEE and API Standards for AC Motors 250 HP (185kW) and Larger
- PIP ELIGD000 - Grounding Installation Details
- PIP ELIMTD00 - Motor Installation Details for Class I, Division 1 Area
- PIP ELIMTG00 - Motor Installation Details for Class I, Division 2; Class II, Division 2; and Unclassified Areas
- PIP ELIMTN00 - Motor Installation Details - Nameplate Details
- PIP ELIMTS00 - Motor Installation Details - Stand
- PIP ELIMTT00 - Motor Installation Details - Motor Termination Detail – 600 Volts
- PIP ELSAP01 - Design and Fabrication of Battery Chargers
- PIP ELSAP04 - Uninterruptible Power Supply (UPS) System Specification
- PIP ELSAP11 - Design and Fabrication of Flooded-Cell Lead-Acid Batteries
- PIP ELSAP20 - Low-Voltage Automatic Transfer Switches
- PIP ELSBD01 - Design and Fabrication of Metal-Enclosed Nonsegregated-Phase Bus Duct Assemblies
- PIP ELSGS01 - Design and Fabrication of High-Resistance Grounding System (600 Volts or Below)
- PIP ELSGS07 - Design and Fabrication of High Resistance Grounding System (1 to 5 kV)
- PIP ELSGS11 - Design and Fabrication of Low Resistance Neutral Grounding Resistor 2.4 to 15kV
– PIP ELSHT01 - Self-Regulated Electric Heat Trace System Specification
– PIP ELSMC11 - Medium-Voltage Motor Control Center Specification
– PIP ELSMC13 - Low-Voltage Circuit Breaker Motor Control Centers
– PIP ELSMC20 - Low-Voltage AC Adjustable Speed Drive Specification
– PIP ELSMT01 - AC Squirrel Cage Induction Motors (4000 Volts and Below) Specification
– PIP ELSPF01 - Medium-Voltage Metal-Enclosed Power Factor Correction Capacitor Specification from 2.4 kV to 35 kV
– PIP ELSPS01 - Electrical Requirements for Packaged Equipment
– PIP ELSSG01 - Design and Fabrication of Low-Voltage Metal-Enclosed AC Power Circuit Breaker Switchgear
– PIP ELSSG02 - Design and Fabrication of Medium Voltage Metal-Clad Switchgear from 4.76 kV to 38 kV
– PIP ELSSG03 - Design and Fabrication of Medium Voltage Metal-Enclosed Load Interrupter Switchgear
– PIP ELSSG04 - Automatic Transfer Systems for Secondary Selective Substations
– PIP ELSSG11 - Design and Fabrication of Electrical Power Center
– PIP ELSSG12 - Design and Fabrication of Outdoor Enclosures for Motor Controllers and Switchgear
– PIP ELSTR01 - Design and Fabrication of Liquid-Immersed Substation Power Transformers 34.5 kV and below, 500 kVA through 15,000 kVA
– PIP ELSWC03 - 600-Volt Power and Control Cable Specification
– PIP ELSWC05 - 300-Volt Instrumentation Tray Cable Specification
– PIP ELSWC06 - Nonshielded Power Cable Specification (2001 Volts and Above)
– PIP ELSWC07 - Shielded Power Cable Specification (5 to 46 kV)
– PIP ELTFT01 - Field Inspection and Testing of New Electrical Equipment
– PIP PCCEL001 - Instrumentation Electrical Requirements

2.2 Industry Codes and Standards

• American Petroleum Institute (API)
  – API RP500 - Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities as Class I, Division 1 and Division 2
  – API RP505 - Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1, and Zone 2
  – API RP540 - Electrical Installations in Petroleum Processing Plants
  – API RP2003 - Protection Against Ignitions Arising out of Static, Lightning, and Stray Currents
- American Society for Testing and Materials (ASTM)
  - ASTM C94 - *Standard Specification for Ready-Mixed Concrete*

- Institute of Electrical and Electronic Engineers (IEEE)
  - IEEE Std 80 - *IEEE Guide for Safety in AC Substation Grounding*
  - IEEE Std 141 - *Recommended Practice for Electrical Power Distribution in Industrial Plants (IEEE Red Book)*
  - IEEE Std 242 - *Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book)*
  - IEEE Std 519 - *Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems*
  - IEEE Std 979 - *IEEE Guide for Substation Fire Protection*
  - IEEE Std 980 - *IEEE Guide for Containment and Control of Oil Spills in Substations*
  - IEEE Std 1584 - *IEEE Guide for Performing Arc-Flash Hazard Calculations*
  - IEEE C37.1 - *IEEE Standard for SCADA and Automation Systems*

- National Electrical Manufacturers Association (NEMA)
  - NEMA VE1 - *Metal Cable Tray Systems*
  - NEMA VE2 - *Cable Tray Installation Guidelines*

- National Fire Prevention Association (NFPA)
  - NFPA 70 - *National Electrical Code (NEC)*
  - NFPA 70E - *Standard for Electrical Safety in the Workplace*
  - NFPA 77 - *Recommended Practice on Static Electricity*
  - NFPA 496 - *Standard for Purged and Pressurized Enclosures for Electrical Equipment*
  - NFPA 497 - *Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installation in Chemical Process Areas*
  - NFPA 499 - *Classification of Combustible Dust and of Hazardous (Classified) Locations for Electrical Installation in Chemical Process Areas*
  - NFPA 780 - *Standard for the Installation of Lightning Protection Systems*
  - NFPA 110 - *Standard for Emergency and Standby Power Systems*
3. Requirements

3.1 System Design

3.1.1 General

3.1.1.1 The complete electrical system shall be designed to enhance personnel safety and to minimize environmental exposure of the electrical equipment.

3.1.1.2 In addition, the electrical systems shall be designed for safe, continuous, and reliable service, equipment protection, ease of maintenance and operation, mechanical protection of equipment, interchangeability of equipment, and the addition of future loads.

3.1.1.3 Equipment listed or labeled by a nationally recognized testing laboratory (NRTL) shall be used if available.

3.1.2 Electrical Codes

All electrical systems and installations shall be in accordance with NFPA 70 (NEC) as applicable and all other applicable codes that are specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.1.3 System Protection and Coordination

3.1.3.1 System protection and coordination shall be as in accordance with IEEE Std 242 - Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems.

3.1.3.2 Electrical system studies shall be provided if specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.1.3.3 When an arc flash risk assessment is specified, it shall be done in accordance with NFPA 70E or IEEE Std 1584 as specified on the purchaser’s PIP ELCGL01D Data Sheet. See PIP ELEGL02 for an arc flash implementation guideline.

3.1.3.4 Software program(s) as specified on the purchaser’s PIP ELCGL01D Data Sheet shall be used for any required studies.

3.1.3.5 Any files and libraries created in system studies shall be provided to the owner. Such files shall include paper files, electronic files, and native files required to run system studies.

3.1.3.6 System protective devices (e.g., relays, fuses, etc.) shall be selected and coordinated to ensure that the upstream-interrupting device nearest the point of fault (or overload) opens first and minimizes system disturbance.

3.1.4 Utility Interface Parameters

Utility interface parameters shall be as specified on the purchaser’s PIP ELCGL01D Data Sheet.
3.1.5 System Parameters

3.1.5.1 System voltage levels, motor horsepower range for each voltage level, and system grounding methods shall be as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.1.5.2 Unless otherwise modified in accordance with Section 3.1.6, system voltages shall be within the tolerances specified in IEEE Std 141, Chapter 3.

3.1.6 Steady State Voltage

3.1.6.1 Voltage drop from the substation bus to the loads supplied from the substation shall not be greater than 5% total, typically split as 2% feeder and 3% branch circuit.

3.1.6.2 The rise in transformer secondary side no-load voltage shall not be greater than 8% above the nominal system voltage at the transformer secondary terminals.

3.1.7 Motor-Starting Voltage Drop

3.1.7.1 Motor-starting conditions shall be evaluated based on system and process conditions that result in the minimum motor acceleration torque.

3.1.7.2 Acceleration studies shall be performed for motors and their driven loads when specified on the purchaser’s PIP ELCGL01D Data Sheet. Acceleration studies shall verify adequate motor acceleration torque and acceptable system voltage drops for specified system configurations and specified process conditions.

3.1.7.3 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, for motors of ≤600-volt rating, the system shall be designed to provide, as a minimum, 90% nominal system voltage at the substation bus during starting.

3.1.7.4 For motors of ≤600-volt rating, the system shall be designed to provide, as a minimum, 85% of nominal motor-rated terminal voltage at the motor terminals during starting.

3.1.7.5 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, for motors of >600-volt rating that cannot be started across the line, electronic soft starters shall be used.

3.1.7.6 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, for motors of >600-volt rating, the system shall be designed to provide, as a minimum, 85% nominal system voltage at the substation bus during starting.

3.1.7.7 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, for motors of >600-volt rating, the system shall be designed to provide, as a minimum, 80% of system nominal voltage at the motor terminals during starting.
3.1.7.8 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, for motors of >600-volt rating that cannot be started across the line because of system voltage drop requirements, a captive transformer shall be used.

3.1.8 Design Allowance

3.1.8.1 New electrical systems shall be designed with a minimum spare capacity as specified on the purchaser’s PIP ELCGL01D Data Sheet. Design allowances beyond the minimum requirements of the NEC shall be applied in sizing feeder circuits, transformers, panelboards, switchgear buses, and motor control center (MCC) buses to allow for future load growth.

3.1.8.2 Spare devices as specified on the purchaser’s PIP ELCGL01D Data Sheet shall be included with the following equipment:
   a. Medium-voltage (MV) switchgear, motor starters, and switch lineups
   b. Low-voltage (LV) switchgear
   c. LV MCC branch breakers, fused switches, and starters

3.1.8.3 Equipped and unequipped spaces as specified on the purchaser’s PIP ELCGL01D Data Sheet shall be included in the following equipment:
   a. MV switchgear and motor starters
   b. LV switchgear

3.1.8.4 Future unit spaces as specified on the purchaser’s PIP ELCGL01D Data Sheet shall be included in LV MCCs.

3.1.8.5 Equipped spaces shall be furnished with all hardware, wiring, doors, and miscellaneous equipment, including current transformers and monitoring devices required to permit completion of the unit by the addition of only a circuit breaker or medium-voltage starter.

3.1.8.6 Equipped spaces shall be capable of being safely placed in service without shutdown of switchgear or motor control center lineup.

3.1.8.7 Unequipped spaces shall be provided with doors but with no other equipment for future use except the power stabs.

3.1.8.8 Unequipped spaces shall not be used for mounting control switches and other auxiliary equipment.

3.1.8.9 Power stabs (both line and load side) shall be provided with shutters or covers to prevent accidental contact with live parts when door is opened.

3.1.8.10 For MCCs, future unit spaces shall be provided with bus and blank doors.
3.1.9 Power Factor

Power factor shall be corrected as specified on the purchaser’s PIP ELCGL01D Data Sheet. Unless otherwise specified on purchaser’s PIP ELCGL01D Data Sheet, MV power factor correction capacitors shall be in accordance with PIP ELSPF01.

3.1.10 Harmonics

Power systems that include electronic switching devices shall be designed so that the total harmonic distortion is in accordance with IEEE Std 519.

3.1.11 Electrical Equipment Rooms

3.1.11.1 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, electrical equipment rooms or walk-in enclosures shall have a minimum of two doors at opposite ends of the room.

3.1.11.2 Doors shall be equipped with panic hardware and shall be self closing.

3.1.11.3 If specified on the purchaser’s PIP ELCGL01D Data Sheet, doors shall be lockable and equipped with “night latch action (self locking).”

3.2 Electrical Area Classification

3.2.1 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, electrical area classification shall be defined in accordance with PIP ELEHA01. PIP ELEHA01 shall be used in conjunction with other standards that define the basis for area classification (e.g., NFPA 497, NFPA 499, API RP500, and API RP505).

3.2.2 The classification method, whether Division or Zone, shall be as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.2.3 Preferably, all buildings containing only electrical equipment (e.g., electric rooms and control rooms) shall be located in unclassified areas.

3.2.4 Electrical and control rooms located in classified areas shall be designed in accordance with NFPA 496 or as otherwise approved by the owner.

3.3 Power Distribution

3.3.1 System Configuration

The power distribution system configuration shall be as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.3.2 Utility Interface and Process Area Substations

3.3.2.1 Process area substations (the substation that serves the loads) shall be centrally located in the area where the loads to be served are situated.

3.3.2.2 Preferably, process area substations shall be located in unclassified areas.

3.3.2.3 Utility interface and process area substations shall be designed as specified on the purchaser’s PIP ELCGL01D Data Sheet. If specified
on the purchaser’s PIP ELCGL01D Data Sheet, HVAC and pressurization systems shall be provided.

3.3.2.4 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, single-ended process area substations shall be designed for expansion in at least one direction. In this case, floor space shall be reserved for the addition of one or more vertical sections as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.3.2.5 If specified on the purchaser’s PIP ELCGL01D Data Sheet, design of single-ended substations shall allow for future conversion to double-ended (secondary selective) substations.

3.3.2.6 If specified on the purchaser’s PIP ELCGL01D Data Sheet, design of double-ended substations shall allow for future expansion.

### 3.3.3 Transformers

3.3.3.1 The system power transformers shall be selected as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.3.3.2 Transformers shall be sized in accordance with the designed operating load on the substation and the following:

a. Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, liquid-filled transformers shall be sized based on their 55°C rating.

b. Dry type transformers shall be sized based on their 80°C rating.

c. If the forced-cooled rating is required for future load growth, provisions shall be made for the future addition of fans.

3.3.3.3 For double-ended substations or similar arrangements having more than one transformer serving interconnected buses, if one transformer is out of service, the remaining transformer(s) shall have sufficient capacity at the highest temperature rise ONAF rating to serve the maximum designed operating load on the substation.

3.3.3.4 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, liquid-filled transformers shall be filled with mineral-based dielectric oil.

3.3.3.5 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, system power transformers shall be located outdoors. Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, outdoor transformers shall be specified in accordance with PIP ELSTR01.

3.3.3.6 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, control power and lighting transformers shall be indoor, 80°C rise with 220°C insulation.

3.3.3.7 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, outdoor control power and lighting transformers shall be epoxy-encapsulated.
3.3.3.8 When specified on the purchaser’s PIP ELCGL01D Data Sheet, fire protection for mineral-oil-filled transformers shall be in accordance with IEEE Std 979-1994, Sections 1, 3, and 4.

3.3.3.9 When specified on the purchaser’s PIP ELCGL01D Data Sheet, containment and spill control for mineral-oil-filled transformers shall be in accordance with IEEE Std 980-1994, Sections 1, 2, 3, 4, 5.1, 5.4, 6, 7, 8.2.2.2, 8.3, and 8.4.

3.3.3.10 When specified on the purchaser’s PIP ELCGL01D Data Sheet, transformer differential protection shall be provided above the MVA level specified on the Data Sheet.

3.3.4 Metering, Monitoring, Relaying, and SCADA.

3.3.4.1 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, metering shall incorporate microprocessor-based multifunction devices.

3.3.4.2 If specified on the purchaser’s PIP ELCGL01D Data Sheet, metering and protective devices shall have digital communication capabilities.

3.3.4.3 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, protective relaying shall incorporate microprocessor-based multifunction devices.

3.3.4.4 If specified on the purchaser’s PIP ELCGL01D Data Sheet, substation SCADA requirements shall be specified in accordance with IEEE C37.1 IEEE Standard for SCADA and Automation Systems.

3.3.5 Switchgear

3.3.5.1 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, low-voltage switchgear shall be metal-enclosed drawout type in accordance with PIP ELSSG01.

3.3.5.2 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, medium-voltage switchgear shall be metal-clad drawout type in accordance with PIP ELSSG02.

3.3.5.3 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, switchgear-tripping voltages shall be 125-volt battery-supported DC.

3.3.5.4 If specified on the purchaser’s PIP ELCGL01D Data Sheet, switchgear shall be of arc-resistant construction. Voltage levels at which arc-resistant switchgear is required shall be indicated on the Data Sheet.

3.3.6 Batteries and Chargers

3.3.6.1 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, switchgear and substation batteries shall be lead-acid flooded-cell type in accordance with PIP ELSAP11.

3.3.6.2 Unless otherwise specified on purchaser’s PIP ELCGL01D Data Sheet, switchgear and substation battery chargers shall be in accordance with PIP ELSAP01.
3.3.7 Switchgear Buildings and Enclosures

Switchgear shall be housed as specified on the purchaser’s PIP ELCGL01D Data Sheet and in accordance with the following as applicable:

a. In prefabricated buildings in accordance with PIP ELSSG11
b. In outdoor enclosures in accordance with PIP ELSSG12
c. In built-in-place buildings

3.3.8 Bus Duct

Unless otherwise specified on purchaser’s PIP ELCGL01D Data Sheet, bus duct shall be in accordance with PIP ELSSB01.

3.3.9 Low-Voltage Automatic Transfer Switch

Unless otherwise specified on purchaser’s PIP ELCGL01D Data Sheet, LV ATS shall be in accordance with PIP ELSDA02.

3.4 Motors

3.4.1 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, AC motors shall be specified in accordance with PIP ELSMT01 or PIP ELEMT01, and with the horsepower requirements and system supply voltages specified on the purchaser’s PIP ELCGL01D Data Sheet in accordance with Section 3.1.5 of this Practice.

3.4.2 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, motors shall be installed in accordance with PIP ELIMTG00, PIP ELIMTD00, PIP ELIMTN00, PIP ELIMTS00, and PIP ELIMTT00 installation details.

3.5 Motor Control

3.5.1 Single-Phase Motor Control

3.5.1.1 Controllers for single-phase motors should be manual motor starters with overload protection, located near the motors.

3.5.1.2 Manual starters shall be used only if the motor can restart automatically after a power failure without creating a safety problem.

3.5.1.3 Short-circuit protection shall be in accordance with the NEC.

3.5.1.4 Local magnetic starters may be provided if required for the application.

3.5.2 480-Volt Motor Control

3.5.2.1 MCCs shall be in accordance with PIP ELSMC13, or other, as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.5.2.2 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, MCCs located indoors shall be NEMA 1 gasketed. MCCs shall be located in accordance with the following:

a. If possible and practical, MCCs shall be centrally located.

b. MCCs shall preferably be located within an environmentally controlled, separate electrical equipment room.
c. MCCs shall not be located in:
   (1) Classified areas
   (2) In areas exposed to corrosive chemicals, dust, or water
   (3) In areas subject to damage by moving equipment

3.5.2.3 If an MCC is to be located in a building or room within a Class I, Division 2 or Zone 2 area, the building or room shall be purged and/or pressurized in accordance with NFPA 496 to permit the use of general purpose equipment.

3.5.2.4 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, if an MCC is to be located outdoors in a non-classified area, the MCC shall be provided with a NEMA 3R enclosure.

3.5.2.5 MCCs shall be supplied in front-only or back-to-back configurations as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.5.2.6 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, floor space shall be allocated for 20% potential MCC growth of the installed vertical sections.

3.5.2.7 If groups of individually enclosed motor starters are located outdoors, the starters shall be mounted on switchracks.

3.5.2.8 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, individually enclosed motor starters located outdoors in non-classified areas shall be provided with NEMA 4X enclosures.

3.5.2.9 Motor starters located in classified areas shall be as follows:
   a. Have explosion-proof enclosures
   b. Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, enclosures shall be bolted type.
   c. Explosion-proof starters shall be applied within the short-circuit rating of the starter assembly as listed by an NRTL.

3.5.2.10 Methodology of interfacing between the MCC and the control system shall be in accordance with other specifications furnished by the purchaser.

3.5.2.11 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, minimum starter size shall be NEMA Size 1.

3.5.2.12 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, motors shall be protected by electronic overloads.

### 3.5.3 Low-Voltage Adjustable Speed Drives

3.5.3.1 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, low-voltage adjustable speed drives shall be in accordance with PIP ELSMC20.

3.5.3.2 Adjustable speed drives, motors, and associated equipment shall be designed as a coordinated system and in accordance with manufacturers’ recommendations.
3.5.4 Medium-Voltage Motor Control

3.5.4.1 For 2.3-kV and 4-kV motors, the horsepower ranges where circuit breakers shall be used as motor starters shall be as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.5.4.2 If a contactor is to be used as motor starter, the controller shall be in accordance with the following:
   a. NEMA Class E2 fused
   b. Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, stationary type
   c. Have a separate isolation switch

3.5.4.3 Medium-voltage motors greater than 7.2 kV shall be controlled using 15-kV class or greater switchgear.

3.5.4.4 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, medium-voltage motor starters shall be provided in accordance with PIP ELSMC11.

3.5.4.5 A microprocessor-based motor protective relay as specified on the purchaser’s PIP ELCGL01D Data Sheet shall be provided for motor and motor circuit protection.

3.5.4.6 Unless otherwise specified on purchaser’s PIP ELCGL01D Data Sheet, differential protection shall be provided for medium-voltage motors equal to or greater than 1500 hp.

3.6 Grounding

Grounding shall be designed in accordance with IEEE Std 142 - Recommended Practice for Grounding of Industrial and Commercial Power Systems.

3.6.1 Substation

3.6.1.1 A substation shall be provided with a ground ring, grid or loop designed in accordance with IEEE Std 80 and the NEC.

3.6.1.2 Grid conductors shall be bare or covered stranded copper as specified on the purchaser’s PIP ELCGL01D Data Sheet and sized to accommodate the worst case fault condition.

3.6.1.3 If a substation fence is provided, the grid shall include a perimeter loop located 3 feet (0.9 m) outside the fence and bonded to the fence and gates.

3.6.2 System Grounding

3.6.2.1 Electrical systems shall be grounded and bonded in accordance with NEC Article 250.

3.6.2.2 System grounding shall be as specified on the purchaser’s PIP ELCGL01D Data Sheet. See Section 3.1.5 of this Practice.

3.6.2.3 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, 480-volt systems shall be wye-connected, high-resistance grounded using equipment in accordance with PIP ELSGS01.
3.6.2.4 Alarms from high-resistance grounding systems shall be connected to plant monitoring system.

3.6.2.5 Unless otherwise specified on the purchaser’s *PIP ELCSGL01D Data Sheet*, medium-voltage motor control buses shall be low resistance grounded using NGRs in accordance with *PIP ELSGS11*. When medium-voltage motor control buses are specified to be high-resistance grounded the grounding system shall be in accordance with *PIP ELSGS07*.

3.6.2.6 Unless specified otherwise on the purchaser’s *PIP ELCSGL01D Data Sheet*, medium-voltage distribution systems that are derived from transformers shall be low-resistance grounded using transformer neutral grounding resistors in accordance with *PIP ELSGS11*.

### 3.6.3 Equipment Grounding

3.6.3.1 The path to ground from circuits, equipment, and enclosures shall be as follows:

   a. Permanent and continuous
   b. Have ample capacity to conduct any ground fault current likely to be imposed on it
   c. Of low impedance

3.6.3.2 Equipment-grounding conductors shall be of the types permitted in *NEC Article 250* and as specified on the purchaser’s *PIP ELCSGL01D Data Sheet*.

3.6.3.3 Equipment-grounding conductors shall be connected to the grounding electrode at the service-supplied or separately derived system.

3.6.3.4 Ground fault current path continuity shall be maintained in circuits passing through non-metallic enclosures or raceways.

3.6.3.5 If specified on the purchaser’s *PIP ELCSGL01D Data Sheet* or for motors rated 2300 volts and higher, motor frames shall also be bonded to one of the following:

   a. Adjacent building or structure steel
   b. Reinforcing mesh or bars in the concrete foundation
   c. Adequately sized bare, tin-coated or green-colored, covered copper conductor around the equipment foundation and connected to at least two ground rods or the ground grid

3.6.3.6 If specified on the purchaser’s *PIP ELCSGL01D Data Sheet*, all 460-volt motors shall also be bonded by one of the methods mentioned in Section 3.6.3.5.
3.6.4 Plant Grounding System

3.6.4.1 The grounding system shall be as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.6.4.2 If a ground loop system is specified on the purchaser’s PIP ELCGL01D Data Sheet, taps from the ground loop to all major equipment and structural steel shall be provided.

3.6.4.3 For facilities outside of plant ground grid, a grounding system shall be provided. Connection of the remote grounding system to the plant grounding system is recommended.

3.6.4.4 The plant grounding system impedance to earth shall not exceed 5 ohms unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet. Results shall be obtained by methods in accordance with PIP ELTFT01.

3.6.4.5 Connections to the grounding system and the minimum depth of the buried grounding system shall be as specified on the purchaser’s PIP ELCGL01D Data Sheet or as detailed in PIP ELIGD000.

3.6.4.6 Instrument grounding shall be installed in accordance with PIP PCCEL001.

3.6.4.7 Cathodic protection systems in plants shall not be electrically isolated from the grounding system. Where bare underground cables are connected to cathodically protected systems, the cathodic protection current flow to the cable can be significantly reduced by use of tin-coated copper cable. If specified on the purchaser’s PIP ELCGL01D Data Sheet, tinned copper cable shall be installed.

3.6.5 Static Electricity Grounding

All equipment including tank trucks, tank cars, portable containers, marine craft, storage tanks, vessels, agitators, piping systems, etc., shall be protected against static electricity, lightning, and stray currents. See API RP2003, NFPA 77, and NFPA 780.

3.7 Lighting

3.7.1 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, illumination levels shall be in accordance with API RP540-2004, Table 4.

3.7.2 Luminaire type and voltage rating for each area of the facility shall be as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.7.3 Outdoor Lighting

3.7.3.1 Outdoor lighting shall be controlled automatically.

3.7.3.2 The preferred method for lighting control is photocell control, provided with time delay and other protection to negate the effect of lightning. The method of photocell control shall be as specified on the purchaser’s PIP ELCGL01D Data Sheet.
3.7.3.3 For areas where plant flares, clouds of dust, and similar conditions can interfere with a photocell, an astronomical clock shall be used. Astronomical clocks shall be used if specified on the purchaser’s PIP ELCGL01D Data Sheet.

### 3.7.4 Emergency Lighting

3.7.4.1 If specified on the purchaser’s PIP ELCGL01D Data Sheet, emergency lighting shall provide minimal egress lighting in operating areas in the event of a power failure. If indicated on purchaser’s PIP ELCGL01D Data Sheet, include time delay off for the emergency egress lighting to allow for HID lighting restrike.

3.7.4.2 Emergency lighting shall be circuited and run separately from general lighting.

3.7.4.3 The type of emergency lighting shall be as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.7.4.4 Battery-powered emergency lights shall be provided in the control room, substation buildings, and other locations as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.7.4.5 Exit signs shall be illuminated during the loss of normal lighting.

3.7.4.6 The loss of a luminaire or lighting circuit shall not leave any enclosed room containing power distribution or control equipment in darkness.

### 3.8 Power Receptacles, Feeder Breakers, and Convenience Outlets

#### 3.8.1 120-Volt Receptacles

3.8.1.1 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, 120-volt receptacles shall be located in process units so that equipment at grade can be reached with extension cords not longer than 50 feet.

3.8.1.2 All receptacles located in washdown areas or in other areas having wet atmospheric conditions shall be equipped with weatherproof covers and boxes.

3.8.1.3 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, all 120-volt receptacles located in non-classified areas shall be NEMA 5-20R.

3.8.1.4 If required by the NEC or specified on the purchaser’s PIP ELCGL01D Data Sheet, ground-fault circuit-interrupter (GFCI) protected receptacles shall be provided.

#### 3.8.2 480-Volt Receptacles and Feeder Breakers

3.8.2.1 All 480-volt receptacles shall be three-phase, with ground and shall be installed in convenient locations less than 100 feet from areas in which 480-volt power to portable equipment is required.

3.8.2.2 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, 480-volt receptacles shall be 60A.
3.8.2.3 All four-pole receptacles shall be of the same size and rating.

3.8.2.4 A maximum of four receptacles shall be connected to one feeder.

3.8.2.5 Feeder cable sizes shall be based on a demand factor of 0.5.

3.8.2.6 480-volt receptacles shall match the plug type specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.8.2.7 480-volt receptacles and feeder breakers shall be applied within the short-circuit rating of the assembly as listed by an NRTL.

3.8.3 Specialty Receptacles

Receptacles for use at voltages other than nominal 120 or 480 volts shall be selected in accordance with the application.

3.9 Wiring Methods

3.9.1 Cable Tray and Conduit Separation Requirements

Spacing between different electrical and instrument cable trays or conduit systems shall be as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.9.2 Cable Tray

3.9.2.1 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, cable tray shall be heavy-duty-rated NEMA 20C and NRTL-listed and labeled. Metallic tray shall be labeled as an equipment-grounding conductor.

3.9.2.2 The cable tray shall be secured with clips at every support.

3.9.2.3 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, cable tray shall be sized for a minimum of 20% spare capacity after the completion of project.

3.9.2.4 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, cable tray shall be of the ladder type with 9-inch rung spacing suitable for indoor or outdoor installations.

3.9.2.5 The cable tray shall have a minimum load safety factor of 1.5 based on the load capacity defined in accordance with NEMA VE1.

3.9.2.6 The cable tray shall also be capable of a 200-pound (90 kg) static load located at mid-span.

3.9.2.7 All bolts, nuts, and washers for cable tray systems shall be 316 stainless steel.

3.9.2.8 Expansion joints shall be provided as required by NEMA VE2-2006, Table 4-2, for long, straight tray runs.

3.9.2.9 Cable tray shall be installed to permit a minimum of 12 inches (0.3 m) of access above the top of each tray.

3.9.2.10 Installation of cables in cable trays shall be in accordance with the NEC.
3.9.2.11 Cable tray systems shall be installed above or to the side of process lines if possible and a minimum of 12 inches (0.3 m) from hot surfaces.

3.9.2.12 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, cable trays shall not have covers.

3.9.2.13 Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, separate trays shall be provided for each voltage class of cables.

3.9.3 Aboveground Conduit and Fittings

3.9.3.1 Acceptable sizes, material, and construction of conduit systems shall be as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.9.3.2 If specified on the purchaser’s PIP ELCGL01D Data Sheet, electrical metallic tubing (EMT) may be used in indoor unclassified locations (e.g., office buildings, administration buildings, guardhouses, change houses, etc.) if the EMT is not subject to vibration, corrosion, or physical damage.

3.9.3.3 Flexible Conduit

1. Flexible conduit shall be liquid-tight, type UA for metal type, and suitable for the area classification where installed.

2. Flexible conduit shall be used to connect vibrating equipment to the conduit system.

3. The length of flexible conduit shall not be greater than 6 feet (1.9 m).

3.9.3.4 All conduit connections to cabinets and junction boxes located outdoors or in washdown areas shall be made with factory hubs or weather-tight rigid conduit hubs.

3.9.3.5 Conduits shall not enter the top of cabinets or junction boxes located outdoors or in washdown areas. Bottom entry of cabinets or junction boxes is preferred.

3.9.3.6 Conduit drains shall be installed at the low point in all conduit systems and before entering electrical enclosures installed outdoors.

3.9.3.7 Drainage provisions shall be provided in the bottom of all pull boxes, junction boxes, control panels, etc., installed outdoors.

3.9.3.8 For long conduit runs, a method of support shall be provided that permits expansion and contraction. Expansion fittings, with bonding jumpers around the fittings, shall be installed as required.

3.9.3.9 For fireproofed structures, the design shall permit conduit supports to be installed before fireproofing and in such a manner that the conduit cannot become imbedded in fireproofing materials.

3.9.3.10 Conduit for corrosive areas shall be as specified on the purchaser’s PIP ELCGL01D Data Sheet.

3.9.3.11 All coated conduit shall be coated on the outside and the inside.
3.9.4 Underground Conduit and Duct Banks

3.9.4.1 Underground conduit materials shall be as specified on the purchaser’s *PIP ELCGL01D* Data Sheet.

3.9.4.2 Unless otherwise specified on the purchaser’s *PIP ELCGL01D* Data Sheet, stub-ups shall be made using rigid galvanized steel conduit elbows and galvanized fittings as required and shall include an insulated bushing on any exposed end of the conduit.

3.9.4.3 Minimum size of underground conduit shall be 1 inch (25.4 mm). Acceptable conduit sizes shall be as specified on the purchaser’s *PIP ELCGL01D* Data Sheet.

3.9.4.4 Concrete Encasement

1. Unless otherwise specified on the purchaser’s *PIP ELCGL01D* Data Sheet, all conduit runs installed below grade (except in floor slabs) shall be encased in a minimum of 3 inches (76 mm) of concrete on all sides.

2. Concrete shall be 3000 psi (20.4 MPa) with a slump of 5 inches (127 mm) and shall be in accordance with *ASTM C94*.

3. The concrete shall be either colored throughout or colored at the top of the encasement. The coloring shall be a shade of red.

4. Reinforced concrete shall be used for all underground duct banks.

3.9.4.5 The minimum spacing between conduits in underground duct banks shall be 1-1/2 inches (38 mm).

3.9.4.6 The minimum depth for all underground conduits, measured from grade to the top of the top conduit, shall be as specified on the purchaser’s *PIP ELCGL01D* Data Sheet.

3.9.4.7 All horizontal bends in underground conduits shall be made using long radius sweeps.

3.9.4.8 For duct banks passing through manholes, the duct banks shall slope downward toward the manholes at a minimum slope of 3 inches (76 mm) per 100 feet (30.4 m).

3.9.4.9 Unless otherwise specified on the purchaser’s *PIP ELCGL01D* Data Sheet, a minimum 20% but not less than one spare conduit(s) shall be installed in all underground duct banks except for the following:

   a. Single or double conduit duct banks for street lighting
   
   b. Duct banks to individual, remotely located equipment

3.9.5 Installation of direct burial cable shall be as specified on the purchaser’s *PIP ELCGL01D* Data Sheet.

3.9.6 Installation of overhead pole lines shall be as specified on the purchaser’s *PIP ELCGL01D* Data Sheet.

3.9.7 Installation of messenger-supported cable shall be as specified on the purchaser’s *PIP ELCGL01D* Data Sheet.
3.10 Power and Control Wiring

3.10.1 Multiconductor cable shall be in accordance with PIP ELSWC06, PIP ELSWC07, and PIP ELSWC03.

3.10.2 Grounding conductor(s), sized in accordance with NEC, Article 250, shall be included in all multiconductor power cables.

3.10.3 All power/control wiring shall have copper conductors and construction as specified on the purchaser’s PIP ELCLG01D Data Sheet.

3.10.4 The minimum conductor size for power wiring shall be as follows:
   a. No. 12 AWG except for individual luminaire drops
   b. Conductors for individual luminaire drops may be No. 14 AWG

3.10.5 Unless otherwise specified on the purchaser’s PIP ELCLG01D Data Sheet, the minimum conductor size for control in multiconductor cables shall be No. 14 AWG.

3.10.6 Composite power and control cable shall be permitted only as specified on the purchaser’s PIP ELCLG01D Data Sheet.

3.10.7 Bottom entry of cables into cabinets or junction boxes is preferred. Top entry of cables into cabinets or junction boxes located outdoors or in washdown areas shall not be permitted.

3.10.8 Power cable termination methods shall be as specified on the purchaser’s PIP ELCLG01D Data Sheet.

3.10.9 Ring tongue compression lugs shall be used for CT secondary wiring.

3.10.10 If long barrel compression lugs are not available, indent type lugs shall be used for power wiring.

3.11 Instrumentation

Instrumentation design requirements shall be specified in accordance with PIP PCCEL001.

3.12 Freeze Protection and Process Heat-Tracing Systems

3.12.1 Freeze protection and process heat-tracing systems shall be designed in accordance with IEEE Std 515 and NFPA 70-2011 (NEC), Article 427. Unless otherwise specified on the purchaser’s PIP ELCLG01D Data Sheet, self-regulating heat tracing shall be in accordance with PIP ELSHT01.

3.12.2 Heat-tracing system components shall be provided as specified on the purchaser’s PIP ELCLG01D Data Sheet.

3.12.3 The heat-tracing systems shall include power transformers, electric heat trace control panels, electric heat cables, temperature sensors, temperature controllers, circuit breakers, enclosures, conduit, wire, insulation, and all necessary auxiliary equipment and controls.

3.12.4 Electric heat-tracing control panels, power transformers, and power distribution equipment shall be centrally located to minimize the lengths of heating power circuits in the area.
3.12.5 All tracing design shall use a minimum 25% safety factor in calculated heat input. Heat loss calculation shall be submitted to the purchaser for compliance verification.

3.12.6 Installation of heating cable, components, and controls shall begin after pressure testing of the pipeline and installation of all the instruments.

3.12.7 Thermal insulation shall be installed after the electrical installation and initial testing is complete. The heat tracing shall also be tested after thermal insulation is installed.

3.12.8 Heat tracing for pipes shall include all inline components.

3.12.9 All flanges, pumps, valves, devices, supports, and appurtenances shall be traced with appropriate additional lengths of heater cable as required to permit removal of the equipment without disconnecting and removing the heat tracing.

3.12.10 Heater cable design shall be suitable to deliver rated performance and service life if subjected to voltage variations from 90% to 110% of nominal distribution voltages.

3.12.11 Components of the electric heat-tracing systems shall be approved for the area classification in which they are installed.

3.12.12 Heating requirements and sectionalizing shall be in accordance with process requirements.

3.12.13 Each heat-tracing circuit shall be equipped with a suitable device for isolation and installation of a lockout device.

3.13  **Cathodic Protection**

If required, cathodic protection shall be in accordance with specifications separately furnished by the purchaser.

3.14  **Uninterruptible/Standby Power Supply**

3.14.1 Critical power supply systems shall be in accordance with the purchaser’s *PIP ELCGL01D* Data Sheet.

3.14.2 If specified on the purchaser’s *PIP ELCGL01D* Data Sheet, an uninterruptible power supply (UPS) shall be provided in accordance with the following:

   a. Sized to accommodate the process control loads and 20% spare capacity
   b. Shall have a dedicated battery and distribution panel
   c. A separate detailed specification shall be issued if required.
   d. Specification shall refer to *PIP ELSAP04*.
   e. Unless specified otherwise on the purchaser’s *PIP ELCGL01D* Data Sheet, battery type shall be flooded cell in accordance with *PIP ELSAP11*.

3.14.3 If specified on the purchaser’s *PIP ELCGL01D* Data Sheet, standby power shall be provided by an alternate utility/plant feeder or a turbine-driven or standby generator. Transfer switches shall be provided for critical loads not
requiring uninterruptible power. Refer to NFPA 110 for guidance on Emergency and Standby Power Systems.

3.14.4 If a UPS is to be used on a high resistance grounded power system, the UPS vendor should be made aware of that fact in order to furnish a compatible UPS.

3.15 Skid-Mounted or Packaged Systems

Unless otherwise specified on the purchaser’s PIP ELCGL01D Data Sheet, electrical requirements for skid-mounted or packaged systems shall be in accordance with PIP ELSPS01.

3.16 Lightning Protection

3.16.1 Tall or isolated structures and the high-voltage switchyard shall be protected against lightning in accordance with NFPA 780.

3.16.2 Down conductors from air terminals or lightning masts shall be connected to individual ground rods and to the plant grounding system.