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Design Standards Manual: Chapter 9 – Electrical Design

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Table of Contents

Page

List of Figures

Page

List of Tables

Page

Change Log

Rev	By	Date	Type	Change Description	ID
0	EB/JCG	12/13/11	Subst	Formatted, branded, and edited. Updated requirements for motor disconnects, outdoor enclosures, protection of dry transformers, and pilot lights on starters.	

9.0 Electrical Design Standards

9.1 Introduction

The primary objective of this chapter of the *Design Standards Manual* is to achieve consistency and accuracy in electrical facilities engineering design through awareness and standardization. For general design requirements see chapter 1, "Introduction," and chapter 2, "General Design Standards and Procedures," in this *Design Standards Manual*. Because the requirements for each job vary, descriptions of the following items are not included in this chapter:

- Power master substations
- Power transmission or overhead distribution lines

Refer to the electrical section of the project-specific design criteria for these requirements. For products and construction methods, see Sandia National Laboratories (SNL) standard specifications.

9.2 Construction Drawings

Refer to the *CADD Standards Manual* for specific drawing requirements. Table 9.1 presents the plans, drawings, or both, required for a typical electrical job.

Table 9.1 Electrical Construction Drawings

Drawing	Scale	Remarks
Electrical Site Plan	1 inch = 20 feet	
Lightning Protection and Counterpoise Composite Plan	1 inch = 20 feet	
Grounding Plan	1 inch = 20 feet	
Power: One-Line Diagram	--	
Grounding: One-Line Diagram	--	
Power Plans	¼ inch = 1.0 feet	
Lighting Plans	¼ inch = 1.0 feet	
Special Systems Plans as required	¼ inch = 1.0 feet	
Grounding Details	--	
Low-Voltage Switchgear Details	--	Show elevation and 1-line
Motor Control Center (MCC) Details	--	Show elevation and 1-line
Miscellaneous Elementary and Wiring Diagrams	--	
Miscellaneous Details: Lightning Protection	--	
Equipment List	--	
Power Duct Plan and Profile (Civil Work Drawing)	1 inch = 50 feet horizontal	
High-Voltage Switchgear, Transformer, Metering Pad Details	--	
Primary (High-Voltage) Electrical System One-Line Diagram	3/4 inch = 1 foot	

Locate all electrical symbols and equipment locations to scale on plan drawings.

9.3 General Electrical Design Requirements

9.3.1 Code Conflicts

Resolve code conflicts by using the more-stringent applicable portion of conflicting codes unless SNL New Mexico (SNL/NM) grants a written waiver.

- Use the list of standard symbols shown on SNL Standard Drawing E-0006STD, and include the drawing in the construction package.
- Add other symbols not shown as needed.
- Keep abbreviations to a minimum.
- Use only standard technical abbreviations from the American National Standards Institute (ANSI) and IEEE on all drawings.

9.3.2 Wiring

- Wiring must be in electrical metallic tubing (EMT), wireways, or other approved raceways.
- Connections to building equipment that can be moved by hand for access and servicing must be connected to building wireways by flexible metal conduit of sufficient length to permit the required movement without disconnecting the wiring.
- Branch circuit conductors must be minimum 12 AWG and must be copper, type THHN/THWN, unless otherwise noted.
- Control wiring must be minimum 14 AWG, stranded.
- Reduced-size neutrals are prohibited without prior and specific SNL/NM approval.
- Run equipment-grounding conduit sized per the National Electrical Code® (NEC®) with all power and control circuits over 50 volts.
- Terminal branch circuit wiring to receptacles and lights in a NEMA® 1 environment may be a manufactured metal-clad cable assembly, such as MC cable. When used, it must run vertically and be concealed in walls or above accessible ceilings. It must not be used where surface-mounted conduit is required. The minimum conductor size is 12 AWG THHN with ground, with conductor jacket colors matching SNL's standard voltage/phase colors. See SNL Standard Drawing E-0006STD.

9.3.3 Circuiting

- Home runs for receptacle, power, and lighting may be indicated with an arrowhead, panel/terminal cabinet number, and circuit/terminal block number. This method may be used for branch circuits and terminal loads; all feeders and conduit 2 inches or larger must have designed runs designated on the drawings.
- Identify the conduit size and the numbers and types of conductors it contains.
- For typical circuits, this information may be listed by general note. For example, "All conductors are 12 AWG THHN/THWN in ½-inch conduit unless otherwise noted."
- Use of MC and AC cable is restricted to exposed runs of terminal branch circuits, such as to receptacles and light switches. These types of cable may be run concealed only vertically and from junction boxes visible above ceilings where the use of the cable can be seen. These types of

cable may be used as short jumpers to connect modular furniture panels to the building when the manufacturers have no similar cable assembly, and may be run in Dowcraft® and similar modular wall sections.

- All horizontal runs concealed in walls must be in EMT as a minimum protection.
- Individual circuits between light fixtures and to light switches may be indicated by showing switch letter and circuit number at each fixture.
- Show exterior conduits running to or from a building on electrical and civil work (exterior utilities) site plans.
- Circuitry must run overhead; do not run in slab, and avoid under slab when possible.
- Group 120V branch circuitry into multiple ABC sets, with a shared ground and individual neutrals where possible. Identify each neutral with a color stripe that is the same as the phase color it supports. Multiple circuit sets must originate from adjacent ABC circuit breakers. If all loads are single-phase, such as through three-phase whips supplying modular furniture, the adjacent breakers must also be three 1ϕ circuits; however, if neutrals must be shared, a single multipole circuit breaker must remove power from all phases returning through that neutral. Calculations must show whether a shared neutral must be upsized (superneutral).
- Group circuit home runs where feasible, derated as required, and show on drawings. Do not leave the derating calculation up to the construction contractor.

9.3.4 Exclusions

The following practices are excluded unless specifically approved by Sandia National Laboratories/New Mexico (SNL/NM):

- Welding or cutting of structural steel for electrical systems
- Installing busway systems
- Using cable tray systems for power cables
- Installing underfloor duct systems

9.3.5 Other Requirements

- Size all junction and pull boxes shown on drawings.
- A mounting detail is not necessary for small devices normally mounted on a wall; a simple statement about the mounting height is sufficient.
- Prepare elevations and details to show the mounting method for all other equipment, such as large transformers and large control cabinets.
- Specify that all floor-mounted electrical equipment be installed on a 3½" housekeeping pad.
- Indicate all fire-barrier penetrations on electrical plan drawings.
- Specify that openings around electrical penetrations through fire-resistance-rated walls, partitions, floors and ceilings are to be firestopped to maintain the fire-resistance rating.
- Specify the method of sealing openings on electrical plan drawings, and coordinate all sealants used with the Architectural Designer.
- In general, equipment specified must meet the energy-efficiency requirements of 10 CFR 436, Subpart A.

- Provide a telecommunications drop for metering at service entrance electrical equipment rooms that are 100 square feet or larger. Provide an additional telecommunications drop adjacent to a Facilities Control System (FCS) cabinet, preferably in an equipment room. See chapter 10, "Telecommunications Design Standards," in this *Design Standards Manual* for details.
- Make adjustments to manufacturer's altitude rating as required for the altitude of 5,500 feet above mean sea level at the SNL/NM campus.
- Provide a separate and local disconnecting means for mechanical equipment requiring line electrical power. The disconnecting means must be separate from the equipment, but may be mounted on it, and must be operable without any disassembly or opening of the equipment access covers. It must have provisions for lockout-tagout (LOTO), and must be rated for the service and location, including any motors in the equipment. In addition to those disconnecting means required by NFPA 70,® SNL's requirement includes, but is not limited to, fan-coil units, variable-air-volume boxes, lighting fixtures, damper and valve actuators, small exhaust fans, and the like. The branch-circuit circuit breaker servicing the assembly must not be used to satisfy this requirement. Coordinate the requirements for this disconnect with the assigned SNL Electrical Systems Engineer.
- Install electrical sources of 50 volts or greater for a terminal equipment controller (TEC) in a separate NEMA 1 enclosure with a line side disconnect.
- Install a maximum of 5 TECs per disconnect or 24-volt power circuit. Reference FCS drawing MI5001STD.
- Refer to SNL Standard Specification 16001, *Electrical Work*, part 2.06, for information about motor disconnects and safety switches.
- Junction boxes, disconnect switches, separately enclosed gear, and similar equipment designed for outdoor use must be specified as NEMA 3, 3S, or 4. The intent is to prevent the entry of water and windblown soil.

9.4 Lighting Systems Design

This section describes the philosophy, required performance and features, and prohibited features and equipment for interior and exterior lighting systems design.

9.4.1 Interior Lighting Systems Design

SNL Standard Specifications

- 16501, *Fluorescent Luminaires*
- 16514, *High-Intensity Discharge (HID) Luminaires*

SNL Standard Drawings

- N/A

System Drawings

- Locate lighting fixtures on reflected ceiling plans (EL-series drawings).

Design Philosophy

This section strives to provide adequate, comfortable, and reliable indoor illumination levels for tasks without over-lighting the workspace and wasting energy, and in a manner that can be serviced regularly without extraordinary maintenance procedures or equipment.

The preferred indoor general lighting fixture is the straight, 3500°K 48-inch F32T8 lamp as described in SNL Standard Specification 16501, *Fluorescent Luminaires*. The 24-inch F17T8 lamp is to be used in 2-by-2 fixtures. When ceiling height, equipment clearances, or both, dictate, certain high-output and MHID fixtures may be authorized indoors, but only in the following situations:

- In fixtures where the lamp is shielded from direct view
- In high bays where the lamp is some distance from the observer **and**
- With specific approval of the SNL Lighting Committee

If the lighted area contains small rooms enclosed by fixed partitions, is occupied by fixed structures or equipment, or both, follow a nonsymmetrical pattern according to the *Illuminating Engineering Society (IES) Lighting Handbook*, using the recommended practice for office lighting. If the lighted area is a large bay and a suggested layout is not present in the electrical design criteria, use a modular system, so a bay or sectional area can be cut into equal sections without disturbing the fixture pattern.

Use natural or daylighting as much as possible, both for energy management and for architectural esthetics. Provide lighting controls that react to the presence of sufficient daylight contribution to the workspace. Take advantage of task lighting over specified work stations and of daylighting in spaces with skylights or exterior windows. Aggressively design energy management and lighting controls to sense occupancy, time of day, ambient conditions, master controller inputs, or other conditions, so energy is conserved and maintenance intervals lengthened when full lighting is not needed. Realize that building residents might conserve lighting in areas for which they are personally responsible, but may not do so in common spaces. No space is too insignificant for occupancy sensors or other automatic lighting controls.

Maintenance of fixtures, such as cleaning and replacing lamps and ballasts, is one of the most important design considerations and can override architectural considerations when life cycle cost is considered. Do not locate fixtures where they cannot be safely reached by ladders or lamp snatcher poles. Do not permit other disciplines to occupy space below the fixture-mounting planes. Ensure that fixtures are placed in areas that do not conflict with air diffuser patterns, sprinkler heads, and other utilities above the ceilings. Coordinate with Mechanical if heat-removal fixtures are anticipated. Do not specify exotic or expensive lamps and components when standard equipment can be used without sacrificing adequate performance. If special access or handling equipment is needed to service luminaires, specify this information as part of the project design. Proactively determine the programmatic use of the space, and do not locate fixtures where later installation of programmatic equipment might block fixture access. If this cannot be avoided or fully anticipated during the design phase, provide alternative access, such as catwalks.

Present or describe a fixture mounting detail for every fixture, using standard drawing details wherever possible. In areas that may be subject to vibration (for example, equipment rooms and rooms near large motors), evaluate the need for a suitable adhesive for all nuts and screwed fittings involved in the fixture mounting. Proper seismic bracing must be supplied for all fixture types. For lay-in fixtures connected by flexible conduit, the use of type BX, AC, or MC cable is permitted in lieu of flexible conduit and separate conductors, except the cable assembly must have an integral, insulated green ground, and the wire gauge of the circuit must not be reduced.

Where night lights are required, or where inverter-powered emergency fixtures are part of the general illumination layout, connect these lights to the inverter's normally on output. **Where possible architecturally**, provide dedicated emergency fixtures, so they are not required as part of the general illumination and connect these lights to the inverter's normally off output. Be sure that the sum of the power requirements for the normally on and off circuits do not exceed the inverter's rating. Identify all inverter-powered fixtures with a SNL-furnished label visible from the floor.

> **NOTE** High-intensity discharge fixtures may not be placed on an inverter circuit unless specifically required by the design criteria and equipped with a quartz restrike unit. Most emergency lights should be fluorescent.

As noted in section 9.15, inverters are typically Sandia-Furnished Material and are placed into operation by SNL. Specify that all final connections to the inverter be made with flexible conduit. Install a dual-channel digital communication control circuit from each inverter to the nearest FID cabinet. The cables must be two Belden 88442-002 with red jacket. The final connections at the FID cabinet are completed by SNL/NM. Refer to subsection 9.6.10 for blue circuit connection requirements to emergency light fixtures. Refer to the High-Lites web site for the current specification sheet for the inverter models SNL currently buys. Provide an input circuit that is rated, protected, and coordinated at 125% to 135% of the inverter's rated maximum current.

Self-ballasted compact fluorescent (CF) lamps of 17 to 26 watts may be used in fixtures that normally would use an A-19 incandescent lamp, base up or horizontal. Separately ballasted CF lamps of 9 to 26 watts may be used in downlights, sconces, bollards, pathway markers, and similar accent fixtures where the mounting provisions permit ready access to both the lamp and the ballast.

When two discrete illumination levels are wanted from a 3- or 4-lamp fluorescent fixture, the use of Advance VEL-4P32-2LS ballast and one switch are preferred in lieu of two ballasts and two switched conductors. When a continuously variable illumination range is wanted, use in-line dimmers and ballasts where the circuit to be dimmed can be held to 1,000 watts or fewer. Where this is not practicable, such as in theater-style conference rooms, use 0- to 10-volt ballasts and master dimming controllers. Apply a maintenance warning label, if the controller's 10-volt power is provided from other than the main lighting circuits being dimmed.

Required Performance and Features

- Provide these average illumination levels in the following spaces, measured at the work surface with all fixtures at full brightness, 15% variance permissible:
  - 20 footcandles (fc) in halls at floor level, with 1 fc for night emergency egress
  - 30 fc at floor level in occupied warehouses, dropping to 10 fc when unoccupied, except that any requirement for vertical illumination in the design criteria takes precedence over this general requirement
  - 30 fc in conference rooms, lobbies, and informal meeting centers
  - 35 fc in small offices with indirect lighting and furniture-mounted task lighting, but measured with the task lighting off
  - 45 fc in general offices; maintain 3:1 ratio between general and task lighting
  - 60 fc in light laboratories

- Allow for sunlight contribution in windowed offices, but do not automatically turn all lights completely off in an occupied sunlit office.

- Occupancy sensor time delay for fluorescent lights must be 30 to 45 minutes to reduce lamp-ignition events.
- Design maximum power consumption not to exceed the following levels, excluding special-purpose rooms and offices for the visually handicapped:
  - 1.7 watts/square foot for light laboratories
  - 1.3 watts/square foot for general offices
  - 1.0 watts/square foot for industrial high bays
  - 1.0 watts/square foot for storage areas, conference rooms, and low bays
  - 0.6 watts/square foot for corridors and stairwells
- Color rendition index (CRI) for general interior lighting must be 75% or better.

Prohibited Features and Equipment

The following features and equipment are prohibited:

- Incandescent lamps and fixtures, except for HID restrike units, low-voltage MR fixtures used for display highlighting, or where an incandescent spectrum is specifically required by the design criteria
- F96T12, F96T12HO, F96T12VHO, F40T12, F34T12, and F54T5HO lamps and fixtures
- T12U6 or U8, T8U3, and circular fluorescent lamps and fixtures
- Compact fluorescent lamps over 26 watts, unless the fixture provides adequate cooling
- Downlights with CFs mounted horizontally high in the can close to an unvented reflector
- Downlights or other fixtures with ballasts not accessible from the lamp opening, when used in a hard ceiling
- Fixtures where the lamps are very close together and luminaire efficiency is thereby reduced, unless specifically required by the design criteria
- Fixtures with specular egg-crate grids (use low-iridescent diffuse silver models)
- Preheat magnetic ballasts
- Rapid-start or program-start ballasts, unless specifically required by the design criteria
- Any rapid-start ballast that fails to turn off heater power after lamp ignition
- High-pressure sodium (HPS) or other "nonwhite" lighting inside a regularly occupied building, unless specifically required by the design criteria
- Self-powered battery life safety fixtures, except where an inverter is not available
- High-intensity discharge fixtures on an inverter circuit

9.4.2 Exterior Lighting Systems Design

SNL Standard Specifications

- 16514, *High-Intensity Discharge (HID) Luminaires*
- 16521, *Exterior Lighting Units*

SNL Standard Drawings

- WJ5010STD, *Exterior Lighting Details*
- WJ6001STD, *Exterior Lighting Equipment Schedule*

System Drawings

- Locate fixtures not mounted on buildings on civil work (exterior utilities) site plans (WJ-series drawings)

Local Regulations and Requirements

- New Mexico Statute 74-12-1, *The Night Sky Protection Act*
- Albuquerque (NM) Ordinance 14-16-3-9, *Area Lighting Regulations*

Design must consist of HPS "shoebox" full-cutoff light fixtures on round, steel, tapered poles that meet the standards of the American Association of State Highway and Transportation Officials. Pole height and lamp wattage are determined by the size of the area to be illuminated and must consist of equipment specified in the Exterior Lighting Equipment Schedule. Standard lamp wattages allowed for exterior lights are 250-, 400-, and 1,000-watt. Exterior lighting design must also follow the provisions of *The Night Sky Protection Act*.

If solar-powered light fixtures are used, contact the Facilities Exterior Lighting Systems Engineer to specify the fixtures.

Exterior building lighting must be switched by an integral, individual photocell with an override switch accessible to qualified maintenance personnel. Alternatively, the building's exterior lighting circuits may be controlled by a common photocell and contactor or by the Facilities Control System. The preferred fixture for exterior doors is the 50- to 70-watt MHID wall-pack with lamp shield, polycarbonate lens, and a body color that coordinates with the building's color scheme. For walkway illumination, a bollard 50- to 70-watt MHID fixture with lamp shield and polycarbonate lens can be used (maximum height of 5 feet, otherwise design must be the HPS shoebox fixture with round, tapered, steel pole as indicated above). When the fixture must be mounted low and close to personnel so the MHID fixture's brightness is objectionable, and when MHID illumination levels are not required architecturally or by Security, a similar compact fluorescent fixture may be used.

Coordinate exterior lighting and pole-mounted lighting with the Facilities Electrical Systems Engineering department. If applicable, the Safeguards and Security department might have additional requirements for minimum illumination levels and for maximum illumination variance between fixtures as needed for intruder assessments. Technical Area I perimeter security lighting must be 277v and connected to one of the perimeter lighting circuits, PGTL-1 and PGTL-2, unless voltage drop calculations prohibit.

A photoelectric controller and contactor are normally used for security systems in remote areas and for fixtures not connected to PGTL-1 or -2. Provide a maintenance handoff-auto switch in an enclosure rated for outdoor use per subsection 9.3.5.

Provide these average illumination levels in the areas shown, measured at grade with all fixtures at full brightness, zero sky contribution, 15% variance permissible:

- 5 fc at building entrances, with 1 fc for night emergency egress
- 2 fc at gates and perimeter fences where security assessment is an issue; maintain 4:1 ratio between maxima and minima
- 1 fc in parking lots; maintain 4:1 ratio between maxima and minima
- ¼ fc along illuminated roadways, with 2 fc at major intersections

9.5 Receptacle System Design

SNL Standard Specifications

- 16001, *Electrical Work*

SNL Standard Drawings

- E-0006STD, *Electrical Standard Symbol List/General Notes*

System Drawings

- Locate on power plan (EP-series drawings)

Design the receptacle system per the following minimum requirements:

- Outlets are preferred to be wired vertically in and on walls; do not run circuits horizontally within walls except for terminal branch circuits to 120-volt receptacle circuits of 20 amps maximum. See also subsection 9.3.3, "Circuiting."
- Flush-mount outlets in areas such as lobbies, conference rooms, user hallways and office spaces.
- Surface-mount outlets in areas including user labs, manufacturing spaces, equipment chases, and electrical or mechanical rooms.
- Provide dedicated outlets for janitorial equipment in hallways and aisles a maximum of 50 feet apart; mount at 36 inches above finished floor (AFF), and segregate from other receptacles.
- Provide ground-fault circuit interrupter (GFCI)-protected general-purpose outlets in electrical and mechanical rooms.
- Provide general-purpose outlets outside each external door; outlets must be GFCI-protected and equipped with a cover that retains its weather-resistant quality with cords plugged in.
- Provide rooftop maintenance outlets per NEC; outlets must be weatherproof and GFCI-protected.
- For new construction, do not provide outlets within 6 feet of the vertical axis of emergency showers and eyewash stations. For modifications, remove, relocate, or both, outlets that fall within 6 feet of new emergency showers and eyewash stations.
- Ground-fault circuit interrupter protection is required on all 120-volt, 15- and 20-amp receptacles located within 6 feet of sinks, water fountains, vending machines, and any equipment holding a pool of water and connected to building plumbing as required by the NEC; such protection is not required for bottled-water coolers and similar free-standing equipment.

Additional Considerations

In buildings where electric personnel vehicles (GEM® carts) are assigned, provide one dedicated 120-volt 20-amp GFCI-protected simplex receptacle per cart station on the exterior of the building at cart parking locations. Provide a weather cover, so the receptacle meets NEMA weatherproofing standards with or without the cart-charger cord plugged in. Carts draw 8 to 13 amps at the maximum charge rate.

Where the building is expected to have wall-mounted television sets connected to the SNL Video Network, provide a duplex receptacle high on the wall (96"AFF nominal) at the television's location. This circuit need not be dedicated. The duplex receptacle is required for the television and for its fiber-optic modem.

Where the building is expected to have wall-mounted Tone Alert Radios, provide a simplex receptacle high on the wall (72" to 96"AFF nominal) at the device location. The radio need not be on a dedicated circuit. If the building is to have a central public address (PA) system, consider locating a single Tone Alert Radio at the PA chassis and connecting its output through the PA system as an economy measure. Note that the Tone Alert Radios themselves must be mounted nominally at 72" AFF, so their controls are within reach.

Where the building is expected to have special and Twist-Lock® single- and multiphase receptacles, select receptacles from NEMA configuration families L5, L6, L7, L21, and L22. Wiring service to the j-box on which these receptacles are mounted must include a neutral and ground, regardless of whether the receptacles require these conductors. Multiphase receptacles rated for more than 50 amps per phase should be of the pin-and-sleeve type, with a sleeve length sufficient to conceal the pins during make-and-break operation, and provided with a 15° back box and hub for surface mounting.

9.6 Low-Voltage Power Systems Design (<600 Volts)

9.6.1 General

This section describes general power requirements for low-voltage systems (those having fewer than 600 volts).

9.6.2 Metering

SNL Standard Specifications

N/A

SNL Standard Drawings

- EI6004STD (previously 105732/01), *Metering Equipment List*
- EI7011STD (previously 105733/E01), *Metering Connection Point Wiring Diagram*
- EI5001STD (previously 105731/E01), *Metering Circuit Monitor Enclosure and Details*

System Drawings

- Show Current Transformer (CT), Potential Transformer (PT), and meter connections, also indicate CT and PT ratios on one-line diagrams.
- For indoor installation, locate meter, communication circuit connection points, and termination points on power plans.
- For outdoor installations, locate meter, communication circuit connections, and termination points on civil work (exterior utilities) plans.
- For metering specific to the building or facility, place details on EI-series drawings.

Electric metering is provided at all building service entrances and at disconnecting means downstream of the service entrances, as necessary to separately meter building and process loads. General requirements for electric service entrance metering are described in chapter 2 of this *Design Standards Manual* in subsection 2.8.6, "Energy Service Meters."

- When metering at switchboards or switchgear and panelboards, the meters must, where feasible, be supplied by the original equipment manufacturer and installed in the equipment, as specified below. For other metering locations or equipment, the meter location and enclosure are as specified by SNL/NM.
- The Square D® PowerLogic® CM3250 circuit monitor is specified for all new metering installations, as well as for retrofitting, when an existing CM2000-series meter is to be replaced.
- If the CM3250 is specified as part of a new installation, the following equipment is required:
  - CM3250 – Meter (includes standard mounting bracket)
  - CMDVF – VF Display with OCI port (includes 12-foot cable)
  - CM3LA – Mounting adapter (may replace standard mounting bracket, depending on where meter is to be located in equipment)
  - MCTAS-485 – Terminator (one required per daisy chain)

- If the CM3250 is to be retrofitted into an existing CM2000-series meter opening, the following equipment is required:
  - CM3250 – Meter (includes standard mounting bracket)
  - CMDVF – VF Display with OCI port (includes 12-foot cable)
  - CM3MA – Mounting adapter kit (consists of a blank mounting panel for VF display and CM3LA mounting adapter)
  - MCTAS-485 – Terminator (one required per daisy chain)

- For low-voltage (120/208V and 277/480V) service-entrance installations, a 4-wire, wye-connected, 3-PT, 3-CT metering configuration is used. On medium-voltage (>600V) systems, a 3-wire, delta-connected, 2-PT, 2-CT configuration is used. Reference the manufacturer's installation manual for detailed connection and other information pertinent to the CM3250.
- The installation includes properly sized CTs, CT shorting blocks, PT/VT fuse blocks, and other standard hardware and wiring necessary to install the meter per the manufacturer's recommendations, and as constrained by this document.
- For CM3250 installations of 600V or fewer, no PTs are required for voltage conversion. When required, PTs are selected to transform the line-neutral (4-wire installations) or line-line (3-wire installations) primary voltage to 120V. The voltage or PT primary connection is made on the line side of the service-entrance disconnect.

- Metering CTs should be sized for the full load current of the metered transformer, or the bus rating of the metered equipment, whichever is larger. Select CTs to reduce the rated primary current to 5 amps. The CTs may be located on either side of the service entrance disconnect.
- A RS-485 communications circuit or other dataway specified by the Systems Engineer is extended from the meters to the nearest telephone terminal cabinet or Intermediate Distribution Room (IDR). Where several meters are being installed in the same facility, meters are interconnected locally using an RS-485 data circuit, and a single communications home run is extended from the telephone terminal cabinet or IDR to the nearest meter. The communications circuit is terminated per the manufacturer's specifications.

9.6.3 Panelboards

SNL Standard Specifications

- 16440, *Electrical Panelboards*

SNL Standard Drawings

- ES7001STD, *Standard Grounding One-Line Diagram*
- ES7002STD, *Grounding One-Line Diagram*

System Drawings

- Locate on power plan (EP-series drawings).
- Provide completed panel schedules using SNL's current Microsoft® Excel® template.

Panelboards must be designed as follows:

- Locate indoors where possible. Avoid outdoor or rooftop locations.
- When outdoor location is necessary, specify a NEMA enclosure rated for outdoor use per subsection 9.3.5.
- Locate in hallways and dedicated electrical rooms or closets where possible; avoid user spaces.
- Flush-mount only in areas such as user hallways and office spaces. When flush-mounted, provide spare conduits, skirting, or other provisions to facilitate future modifications.
- Surface-mount in all other areas, including user labs, manufacturing spaces, equipment chases, and electrical or mechanical rooms.
- Panelboards located in areas accessible to users must be designed to have less than 10,000A available fault-duty current.
- Panelboards with greater than 10,000A available fault-duty current must be located in electrical rooms or closets or mechanical or electrical spaces accessible only to qualified personnel.
- Multiple section panels are not permitted. Where it is necessary to have more than 42 circuits in a lighting or appliance panelboard in the same location, use additional, separately circuited panelboards.
- Avoid subfeed or dual-feed lugs.
- Avoid individually mounted subfeed circuit breakers.

- Main circuit breakers are to be sized according to NEC 450.3 (A) for any location. If a larger breaker is installed, the appropriate trip plug must be installed as well. It is not permitted for the trip settings to be dialed-down to meet the intent of this section.
- Panelboard naming and labeling conventions must follow this scheme:

  FSVnnn where

  - F = Building floor number or letter, such as B, 1, 2, P
  - S = Load-serviced letter, where B=Building and P=Process
  - V = Voltage, where H=277/480v and L=120/208v or 120/240v
  - N = Sequence number within this building and on this floor
- The panel schedule file naming convention must follow this expanded scheme:

  NNN_FSVnnn.xls where

  - NNN_ = Building number and trailing underline (no spaces in file name)
  - FSVnnn = as above
  - .xls = Microsoft Excel file name extension, lowercase

Install SNL-provided arc-flash hazard data label on the cover.

Oversize neutrals only when required per harmonic analysis. See subsection 9.13.7 for guidelines on harmonic analyses calculations.

Design panelboards with size and number of single-, double-, or three-pole circuit breakers required, and show on SNL schedule templates. When multipole breakers are scheduled with no further qualifications, provide same with a single operating handle. When multipole breakers are specifically called out as handle-tied single-pole breakers, provide same listed for such use. Single-handle multipole breakers must not be substituted for handle-tie requirements.

Design new panelboards so approximately 20% of the panel capacity is spare, both in connected load and in unused, installed circuit breakers or unpopulated spaces.

9.6.4 Low-Voltage Switchgear and Switchboards

SNL Standard Specifications

- Provide a construction Special Spec for each new installation.

SNL Standard Drawings

- ES7001STD, *Standard Grounding One-Line Diagram*
- ES7002STD, *Grounding One-Line Diagram*

System Drawings

- Locate on power plan (EP-series drawings).
- Detail on one-line diagram, include all loads, circuit numbering and spaces.

- Provide elevation showing all circuit breaker locations and circuit numbering.
- Provide additional details, schedules, or other information on drawings as necessary for construction.

Low-voltage switchgear and switchboards must be as follows:

- Locate indoors where possible; avoid outdoor locations.
- Locate in dedicated electrical rooms accessible only to qualified personnel.
- Make front-accessible where possible, except service-entrance equipment.
- For service-entrance equipment, provide rear access when possible.
- Copper main bus; 100% capacity full length.
- Copper neutral bus, if required; 100% capacity full length.
- Copper ground bus; full length.
- Main and feeder circuit breakers arranged for compression connectors.
- All circuit breakers must be NEMA construction.
- All circuit breakers must have provisions for lockout/tagout (LOTO).
- All circuit breakers must include electronic interchangeable trip with adjustable LTPU, LTD, STPU, STD, and INST functions. When required, provide integral GFPU and GFD functions.
- When ground fault is required, provide two-level protection (main and feeders).
- Provide service-entrance label when required.
- Provide minimum 25 % spare capacity.
- Provide minimum 1 spare circuit breaker of each frame size (excluding main) used.
- Provide future bus extension and dedicated space for at least one future section.
- Provide integral Square D Power Logic metering located on the line side of the main (see subsection 9.6.2 for more information on metering).
- Provide integral surge protection device (SPD) to meet requirements of NFPA 780, when required.
- Where draw-out circuit breakers are specified, provide manufacturer's overhead lifting device suitable for all circuit breaker sizes and locations.
- Provide manufacturer's test kit for all circuit breaker types and functions used.
- All circuit breakers larger than 200 amps must be tested.
- Main circuit breakers are to be sized according to NEC 450.3 (A) for any location. If a larger breaker is installed, the appropriate trip plug must be installed. It is not permitted for the trip settings to be dialed-down to meet the intent of this article.
- Switchboard naming must follow a similar scheme as for panelboards, except the sequence number must include the letters **_SWBnnn**.

Install SNL-provided arc-flash hazard data label on the cover.

- Oversize neutrals must be used only when required per harmonic analysis. See subsection 9.13.7 for guidelines on harmonic analyses calculations.

9.6.5 One-Line Power Diagram

SNL Standard Specifications

N/A

SNL Standard Drawings

- E-0006STD, *Electrical Standard Symbol List/General Notes*
- E-0007STD, *Electrical One-Line/Wiring Diagram Symbols*

System Drawings

- Develop or add to one-line diagram drawing (EP-series drawings) as noted below.

Starting at the top of the drawing with the building transformers, show all pertinent electrical equipment down to the panelboard level. This equipment includes switchboard/switchgear, panelboards, MCCs, generators, transfer switches, uninterruptible power supplies, and inverter systems.

For transformers, note kVA size, primary and secondary voltages, phasing (building service entrance only), and impedance. Show the distribution switchboard and switchgear in "expanded" form. On the drawing detail the main breaker, tie breaker, feeder breakers, spare breakers, CTs, PTs, and meter. Note switchboard rated amperage, voltage, and short-circuit capability. Include frame and trip size of all breakers in the gear.

Note service entrance, feeder wire and conduit sizes.

For larger buildings, additional one-line diagram drawings may be required. If the building uses motor control centers (MCCs), separate one-line diagrams may be required. When MCCs are necessary, provide them in "expanded" form. Drawings should be called "MCC One-Line Diagram" and be numbered sequentially with the main one-line diagram. Indicate starter and breaker sizes, bus tap sizes, wire, and conduit size ending with each motor or other load. If the building has a large standby power system or blue system, provide an "expanded" one-line diagram of this system also.

In general, use the following guidelines:

- If a building transformer is not associated directly with the building, start the one-line diagram with the largest distribution panelboard.
- If all details can be shown on one sheet, it is allowable to use "expanded" details on all necessary equipment.
- Place the highest-voltage lines at the top of the drawing with successively lower voltages placed downward.
- Use standard symbols listed on SNL Standard Drawing E-0007STD and in ANSI standards.
- All "expanded" gear must be shown with a dashed outline. All singular items must be shown with solid outlines.
- Draw circuits in the most direct and logical sequence. Draw lines between symbols either vertically or horizontally with a minimum of line crossing.

- Note panelboards and major equipment locations (Column D4, NE Equipment Room, and so on). Try to group equipment on drawings by physical locations.
- To avoid clutter, do not put specialty symbols and construction notes on the one-line diagram. Grounding, controls, metering, and miscellaneous details should all be on separate drawings.

9.6.6 Low-Voltage Dry Transformers

SNL Standard Specifications

- Provide construction Special Spec or specify on drawings and equipment lists.

SNL Standard Drawings

N/A

System Drawings

- Locate on power plan (EP-series drawings).
- Provide additional elevation or mounting details as required for construction.

Low-voltage dry transformers must be as follows:

- Locate indoors where possible; avoid outdoor locations.
- Energy-efficient; meeting NEMA TP-1 and DOE minimum efficiency standards.
- Specify transformer to include +2/-4 at 2.5 percent taps.
- Transformers located in areas accessible to users must be designed to produce less than 10,000A available short-circuit current.
- Transformers allowing more than 10,000A available short-circuit current must be located in electrical rooms, closets, or mechanical or electrical spaces accessible only to qualified personnel.
- When a panelboard fed from a dry transformer cannot be installed in sufficient proximity to its associated transformer to allow the secondary conductors to be protected per section 240.21(C)(2) of the National Electrical Code (“10-foot rule”), an enclosed circuit breaker installed adjacent to the transformer must be used. Fused safety switches must not be used for this purpose.

The sizing of step-down or step-up dry transformers must consider the current or expected normal and harmonic loading. The decision to use "K" transformers is based on harmonic analyses of the connected and forecast load. See subsection 9.13.7 for guidelines on harmonic analyses calculations.

9.6.7 Motors

SNL Standard Specifications

- 16001, *Electrical Work*
- 16269, *Variable-Frequency Controllers*

SNL Standard Drawings

- E-0006STD, *Electrical Standard Symbol List/General Notes*

System Drawings

- Locate on power plan (EP-series drawings)

Motors that are controlled by across-the-line motor starters and are 25 HP or larger must include power-factor-correction capacitors at the motor starter to achieve 95% power factor. Motors controlled by VFCs are excluded from the power-factor-correction requirement.

Specify motors per chapter 8, subsection 8.5.2 of this *Design Standards Manual*. Nominal voltages for motors not a part of programmatic equipment must be as follows, unless unique and specific design considerations require otherwise and are stated on the drawings:

- Fractional-horsepower, single-phase – 120v
- 1 to 5 horsepower, three-phase – 208v preferred, 480v permitted
- 5 to 150 horsepower, three-phase – 480v
- Above 150 horsepower – 4,160v preferred, 480v permitted. Equipment with motors of this size and larger must be specified by a construction Special Spec.

See SNL Standard Specifications 16001, *Electrical Work*, and 16269, *Variable-Frequency Controllers*, for additional motor requirements. In particular, induction motors driven by a VFC must have provision for rotor shaft grounding and VFC output filtering to prevent bearing fluting from inductive buildup and discharge. Motors expected to operate continuously or nearly so should be specified as premium efficiency types.

9.6.8 Motor Control Centers

SNL Standard Specifications

- Provide a construction Special Spec for each new installation.

SNL Standard Drawings

N/A

System Drawings

- Locate on power plan (EP-series drawings).
- Detail on one-line diagram, include all loads, circuit numbering, and spaces.
- Provide elevation showing all starter locations and circuit numbering.
- Provide additional details, schedules, or other information on drawings as needed for construction.

Motor control centers (MCCs) must be as follows:

- Locate MCCs indoors where possible; avoid outdoor locations.
- Locate MCCs in dedicated electrical rooms accessible only to qualified personnel.
- Make front-accessible where possible.
- Use copper main bus; 100% capacity full length, minimum 600A.
- Use copper neutral bus, if required; 100% capacity full length.
- Use copper ground bus; full length.
- Wire MCCs for NEMA Class I, Type B.
- Starters must be combination type with motor circuit protector, contactor, and LOTO provisions.
- Circuit protectors, contactors, overload blocks, and all accessories must be of NEMA construction.
- Starters must include overload reset button, red and green LED pilot lights—red for run mode and green for stop. Pilot-light assemblies must be supplied with removable lenses allowing lamps to be replaced from controller exterior.
- Provide HOA in cover; minimum 2-N/O and 2-N/C auxiliary contacts and individual control power transformer (CPT) if above 150V to ground.
- A control power transformer, if required, must be sized for 100 VA extra capacity and include 2 primary and 1 secondary fuses for 120V control.
- Avoid circuit breakers only in MCCs; instead, feed from a power panel.
- Do not mount panelboards or associated transformers in MCCs.
- Do not mount VFCs in MCCs; VFCs must be individually mounted at controlled motor.
- Provide future bus extension and dedicated space for at least one future section.
- To avoid introduction of foreign materials, all gaps on the top of the MCC between MCC sections and between sheet metal parts must be smaller than 0.0625" (1/16"). This may be met by design or by the addition of closure strips firmly attached to one side of a gap.
- Provide minimum 25% spare amperage capacity.
- Typically, provide 10% spare buckets for each size provided.
- Motor control center naming must follow a scheme similar to that for panelboards, except the sequence number must include the letters **_MCCnnn**.

9.6.9 Individual Motor Starters

SNL Standard Specifications

- 16269, *Variable-Frequency Controllers*
- For non-VFC starters, provide specifications on drawings.

SNL Standard Drawings

N/A

System Drawings

- Locate on power plan (EP-series drawings)
- Individual motor starters (non-VFC) must be as follows:
  - Locate indoors where possible; avoid outdoor locations.
  - Starters must be combination type with motor circuit protector, contactor, and LOTO provisions.
  - Circuit protectors, contactors, overload blocks, and all accessories must be of NEMA construction.
  - Starters must include overload reset button, red and green LED pilot lights—red for run mode and green for stop.
  - Provide HOA in cover; minimum 2-N/O and 2-N/C auxiliary contacts and individual CPT if above 150V to ground.
  - A control power transformer, if required, must be sized for 100 VA extra capacity and include 2 primary fuses and 1 secondary fuse for 120V control.

The use of "intelligent" starters or other control devices that operate by a remote or on-board microprocessor must be plainly identified, along with provision for communications dataways necessary to support the proper programming, operation, and monitoring of the device by the FCS, process control equipment, or both.

Variable frequency controllers must be as follows:

- Locate indoors where possible; avoid outdoor locations.
- Typically VFCs are only installed when requested by the Mechanical Engineer.
- Contrary to previous requirements, a manual by-pass is not usually required on a VFC. A by-pass should only be specified after discussing the requirements with the Mechanical Engineer.
- Do not install VFCs closer than 5 feet to an FID cabinet for heat protection.
- The use of "intelligent" VFCs that operate by a remote or on-board microprocessor must be plainly identified, along with provision for communications dataways needed to support the proper programming, operation, and monitoring of the device by the FCS, process control equipment, or both. This addresses control and monitor features separate from the simpler 4-20ma or pneumatic circuit that commands VFC motor speed. See SNL Standard Specification 16269, *Variable-Frequency Controllers*, for VFC requirements.

9.6.10 Blue (Maintenance) Circuit System

SNL Standard Specifications

N/A

SNL Standard Drawings

N/A

System Drawings

- Locate on power plan (EP-series drawings).
- Detail on one-line diagram.

Provide a blue circuit in (1) multiple story structures, unless otherwise noted, (2) in Sensitive Compartmented Information Facility (SCIF) areas, and (3) where specified in the design criteria. The blue circuit is a dedicated receptacle and lighting circuit used by Facilities maintenance personnel during scheduled preventive maintenance power outages and during unscheduled outages to provide lighting and receptacle power in key areas. The blue circuit reduces the setup time to provide temporary lighting and power for tools to perform maintenance activities.

Provide one duplex receptacle in each electrical room, maintenance area, penthouse, equipment chase, hallway, or similar area containing panelboards, transformers, or VFCs. Provide one duplex receptacle inside each SCIF area or closed area (formerly called vault-type room) containing panelboards, transformers, or VFCs. In large areas receptacles must be spaced a maximum of 50 feet apart. Provide blue-colored receptacles, and paint associated outlet boxes blue; do not paint receptacles.

Provide lighting powered by the blue circuit in each stairwell, electrical room, maintenance area, penthouse, equipment chase, hallway, or similar area (if not provided by an emergency lighting inverter circuit). Paint or otherwise mark lighting fixture as being on the blue circuit system.

A portable external generator provides power to the blue circuit. Provide a 100A, 208Y/120V, 3-phase, 5-wire, pin-and-sleeve receptacle rated for NEMA weatherproof standards with or without the generator feeder cable plugged in, located on the outside of the building in a location easily accessible by a vehicle for connection to the generator. Provide a 100A, 208Y/120V, 3-phase, 4-wire panelboard in the building main electrical equipment room. Paint the panelboard blue to identify panel as being part of blue circuit system. Completely isolate the blue circuit from regular and emergency or standby power circuits. The blue circuit must not share raceway systems with other electrical systems within the building.

9.7 Control System Design

SNL Standard Specifications

- 16001, *Electrical Work*

SNL Standard Drawings

- E-0006STD, *Electrical Standard Symbol List/General Notes*
- E-0007STD, *Electrical One-Line/Wiring Diagram Symbols*

System Drawings

Show on control (EI- or MI-series drawings) or power plans (EP-series drawings) as detailed in this section.

9.7.1 General

Control systems include, but are not limited to, the following:

- Laser interlocks
- Facilities Control System (FCS)
- Motor control other than HVAC controlled by FCS

For interior lighting controls, see subsection 9.4.1, "Interior Lighting Systems Design."

9.7.2 HVAC and Facilities Control Systems

Electrical and Mechanical Designers are jointly responsible for HVAC controls:

- Prepare elementary diagrams per subsection 9.7.3.
- Refer to subsection 8.22.2 for FCS details.
- Coordinate electrical equipment noted in the mechanical plans.

9.7.3 Elementary Control Diagrams

Use a ladder layout when preparing elementary control diagrams. Simple power wiring and control circuits (for example, those that use only one simple control switch or a normal light switch) are exempt from these requirements.

9.7.4 Sequence of Operations

On simple control systems, the sequence of operations shown on the mechanical drawings suffices, if the elementary control diagram is properly cross-referenced.

Always present a sequence of operations on the electrical drawings for other than simple control systems and for control systems involving only electrical apparatus.

Begin the sequence with the system turned off, carry it through each operational step, and explain the operation of each component throughout its normal operating conditions.

9.7.5 Symbols

Use the symbols shown on electrical standard drawings E-0006STD and E-0007STD for elementary diagrams. If components are required that are not included on this drawing, use symbols included in ANSI Y32.2, *Graphic Symbols for Electrical and Electronics Diagrams*.

9.7.6 Control Wiring Conduit Layout—All Systems

If possible, show control plans on power plan drawings. If not workable, create a separate set of control plans.

9.7.7 Laser Interlock Systems

Contact the Laser Safety Officer in the ES&H Customer Support Teams (3127), for the latest laser-safety requirements.

9.8 Lightning Protection Systems Design

SNL Standard Specifications

- 13100, *Lightning Protection*
- 16289, *Surge-Protection Devices*
- 16742, *Intrabuilding Telecommunications System*

SNL Standard Drawings

N/A

System Drawings

- Show components on Lightning Protection and Counterpoise Composite Plan.
- Draw details as required.
- Show lightning protection system connection to the building counterpoise system.
- Show lightning protection and ground systems and details on ES-series drawings.

Lightning protection systems are provided when directed by the design criteria or the Facilities Fire Protection Engineer and Electrical System Engineer. Lightning protection systems must be designed to conform to the nationally recognized standards listed in SNL Standard Specification 13100, *Lightning Protection*.

Surge-Protection Devices

Surge-protection devices (SPDs) must be installed in the following cases:

- At the service entrance of each metallic power line, signal line, or communication line conductor entering the protected structure
- At all points where a conductor leaves the protected structure to supply an unprotected structure, if the length of the conductor is more than 100 feet. If less than 100 feet, protection is assumed to be provided by the service entrance SPD.
- At all points where a conductor leaves the protected structure to supply an unprotected exterior pole-mounted device, including but not limited to, lighting fixtures, cameras, warning beacons, and antennae

In the following cases SPDs must comply with the indicated specifications and standards:

- Those SPDs associated with FMOC electrical service entrances and feeders and their installation must comply with SNL Standard Specification 16289.

- Those SPDs associated with data and telephone communication service entrances and their installation must comply with SNL Standard Specification 16742.

- Those SPDs associated with data system facility entrances (including, but not limited to, CATV, alarm, and antenna systems, and their installation) must comply with NFPA 780.

9.9 Building Grounding System Design

SNL Standard Specifications

- 13100, *Lightning Protection*
- 16001, *Electrical Work*

SNL Standard Drawings

- ES7001STD, *Standard Grounding One-Line Diagram*
- ES7002STD, *Grounding One-Line Diagram*

System Drawings

- Grounding plans
- Grounding one-line diagram
- Grounding details
- Grounding plans and grounding details to be placed on ES-series drawings

The drawings must show interconnection of the following:

- All metal systems of the building, such as the following:
  - Interior and exterior water system
  - Metal ductwork
  - Building steel
  - Lightning protection system
  - Made electrodes
  - Building foundation rebar
- Where in the electrical system bonding is required
- Where the grounding electrode system connects into the rest of the grounding system
- Any other special requirements for the building grounding system (that is, static or signal grounds)
- The size of all required grounding conductors (grounding electrode conductor, equipment grounding conductors, and main bounding jumpers)

The design must address the NEC as a minimum requirement, and must address other factors when designing the system, such as 60 Hz grounds, harmonics, shielding, signal and data grounds, and lengths of grounding conductors to ground.

Given that the purpose of the insulated equipment grounding conductor is to conduct fault currents back to their point of origin; therefore, all separately derived systems (including a building's service entrance equipment) must have an equipment grounding conductor run from the source of the separately derived system through the distribution and control equipment to the loads. The equipment grounding conductor must be bonded to the grounded circuit conductor (neutral) at the source of the separately derived system.

Where a lightning protection system is required, provide a ground counterpoise per SNL Standard Specification 13100. Where a lightning protection system is not required, provide grounding per the NEC and SNL Standard Specification 16001.

9.10 Identification and Labeling

SNL Standard Specifications

- 16001, *Electrical Work*

SNL Standard Drawings

- E-0006STD, *Electrical Standard Symbol List/General Notes*
- E-0011STD, *Sample Electrical Equipment Schedule*
- WP5021STD, *Example Feeder Labeling*
- WU5006STD, *Utility Markers for Buried Pipe and Cable*

System Drawings

- Numerous

9.10.1 General

To ensure a minimum standard of quality, identify devices, fittings, fixtures, and equipment on equipment list drawings with their electrical sizes, ratings, manufacturers, and catalog numbers. This level of identification is not necessary for items such as panelboards, where complete specifications are written.

Identify motor starters on the motor control schedule. Identify all equipment by using standard symbols and equipment schedules. In addition to the items already mentioned, the schedule should include information to help the contractor obtain the equipment and materials intended by the design.

Specify nameplates on all control items used on the job. Specify each nameplate either on the motor schedule or on the equipment list. Each nameplate identifies the system and the function of that device to the system.

9.10.2 Electrical Equipment Labeling Designations

The labeling for all panelboards, switchboards, motor control centers, and switchgear must have a consistent nomenclature and circuit designation to provide a basis for systematic identification of components in the field. This requirement also applies to control stations, transfer switches, and equipment of communications and auxiliary systems. See the labeling instructions in Attachment 9.

9.10.3 Electrical Equipment Labels

Labels are required on each unit of equipment, including the central or master unit of each system. This requirement includes power, lighting, telecommunications, signal, and alarm systems, unless units are specified with their own self-explanatory identification.

Refer to Standard Symbols List drawings E-0006STD, *Electrical Standard Symbol List/General Notes*, and E-0011STD, *Sample Electrical Equipment Schedule*. Equipment installed as part of a "blue" circuit must consist of the following:

- Receptacles must have the required circuit and panel identification, as well as blue-colored faceplates.
- Lighting fixtures (typically industrial fluorescent fixtures) must have a blue identifier, such as a blue ballast pan cover or a blue adhesive sticker, identifying the fixture as being part of the "blue" circuit system.

9.10.4 Wiring Device Identification

On the plan view, identify each device, its corresponding source, and the circuit number accompanying it. For example, in "BBH1-1" the BBH1 represents the panel name, 1 represents the circuit number.

9.10.5 Wiring Device Labeling

Labeling of wiring devices must comply with CSI MasterSpec® 16075-5, section 3.1-A through D.

9.10.6 Conductor Identification

All conductors must be identified with the source the conductor is fed from and circuit number information. Refer to CSI MasterSpec 16000-1.

Multiple power or lighting circuits in the same enclosure: Identify each conductor with source, voltage, circuit number, and phase.

9.10.7 Conductor Labeling

Refer to CSI MasterSpec 16000-1.

9.10.8 Conductor Color Coding

Color-coding of power circuit and secondary-phase conductors to be as noted in the panel schedules and on standard drawing E-0006STD, *Electrical Standard Symbol List/General Notes.*

9.11 Medium- and High-Voltage Power Systems Design (> 600 Volts)

9.11.1 Underground Distribution Systems

SNL Standard Specifications

- 02584, *Underground Ducts and Utility Structures*
- 16124, *Medium-Voltage Cable*
- 16310, *15kV Metal-Enclosed Stand-up or Padmounted Switchgear*
- 16401, *Electrical Distribution System, Aerial*
- 16475, *Primary System Safety Requirements*

SNL Standard Drawings

- WP1001STD, *Power Manhole Plan and Section*
- WP3004STD, *Power Manhole Details*
- WP3005STD, *Power Manhole Construction Details*
- WP5004STD, *Typical Concrete Encased Duct*
- WP5019STD, *S&C Switchgear Configuration and Clearance*
- WP5020STD, *S&C Padmount Switchgear Details*
- WP5024STD, *Duct to Conduit Installation Detail*
- WP6010STD, *S&C Padmount Equipment List and Details*
- WP9001STD, *Power Manhole Cable Connections*

System Drawings

- Show plan views and equipment pads on civil work drawings and site utility/electrical plan (WP-series drawings).
- Show profiles on civil work (power) drawings.
- Develop or modify manhole drawings depicting cable routing (provided by SNL/NM).
- Include primary electrical system one-line diagram (provided by SNL/NM).

Power manhole drawings and primary electrical system one-line drawings are provided by SNL/NM. Submit design modifications to the one-line diagrams or manhole drawings, in Portable Document Format (.pdf) format, to the SNL CADD Operator. The SNL CADD Operator then incorporates the changes to the one-line or manhole drawings and submits them to the A/E to be included in the design package. Allow a two-week turnaround from the time design modifications have been submitted to the SNL CADD Operator. Refer to the *CADD Standards Manual* on procedures for requesting CADD files.

All medium- and high-voltage (more than 600V) designs must be coordinated with the Facilities High-Voltage Operations Engineer or Technologist.

Technical Areas I and IV are fed by a looped underground 12.47 kV distribution system. The existing distribution system consists of electrical manholes and duct banks, and S&C padmounted switchgear. Facilities standard drawings WP1001STD, WP3004STD, WP3005STD, and WP9001STD show manhole,

duct bank, and termination details that must be followed in the design of any addition to the existing 12.47 kV distribution system. Facilities standard drawings WP5019STD, WP5020STD, and WP6010STD show the S&C details and clearances that must be followed. The installation of PMH switchgear other than a PMH-5, PMH-10, and PMH-19 requires prior approval by the Facilities Systems Engineer.

Primary electrical service within Technical Areas I, II, and IV must be at 12.47 kV with each looped circuit consisting of 3-#4/0 CU shielded, EPR-type MV-90 or MV-105, 220 mil, 133% insulation, and 1-#2 THWN, 600V ground. Each end of the 12.47 kV circuit within a manhole must be terminated with a 600 AMP nonload-break T-splice as shown on standard drawing WP9001STD. The integrity of the loop underground configuration must be maintained by installing at a minimum two 5-inch PVC concrete-encased conduit from the nearest electric manhole. Cable management must be depicted using power manhole drawings, duct bank, and switchgear details. Radial feeds to transformers must be sized in accordance with the maximum ampacity of the transformer.

Technical Areas III and V are fed by a looped underground 4.16 kV distribution system. The distribution system consists primarily of one 3-inch or 4-inch duct bank and underground and aboveground pull boxes. Standard drawing WP5004STD shows the duct bank details that must be followed in the design of duct banks.

Primary electrical service within Technical Areas III and V must be 4.16 kV with the circuit within the loop consisting of 3#2/0 CU shielded, EPR-type MV-90 or MV-105, 115 mil, 133% insulation and 1-#4 THWN, 600V ground. The loop underground configuration must be maintained by installing one 3-inch or 4-inch PVC concrete-encased conduit from the nearest S&C switchgear. Termination from an underground or aboveground pull boxes requires prior approval from SNL/NM.

Secondary service voltage within all technical areas must be 208/120V wye, 480/277V wye, 2400V delta, or 4160/2400V wye. All transformers must be fuse- protected using an S&C padmounted PMH-19, PMH-5 or stand-up fused switch. Switchgear and transformer clearances and pad dimensions must be in accordance with standard drawings WP3003STD, WP4001STD, WP5019STD, and WP5020STD.

No common wall power and telecommunications manhole installations are allowed. It is desirable to maintain a minimum of 15 feet between the center of power and telecommunications manholes both vertically and horizontally in the plan view.

9.11.2 Transformers

SNL Standard Specifications

- 16272, *Padmount Transformers*

SNL Standard Drawings

- WP3003STD, *Transformer Fire Barrier Wall*
- WP4001STD, *Plan and Profile for Transformer Pad*

System Drawings

- Show transformer pads on civil work drawings, Site Utility/Electrical Plan (WP-series drawings)

Padmount transformers must be 1500 kVA or below. Outdoor, oil-filled, padmounted transformers are the preferred method for supplying power to buildings. Refer to SNL Standard Specification 16272, *Padmount Transformers*, for additional requirements. Transformers in distribution substations larger than 1,500 kVA are discouraged. More than one transformer is necessary if capacity requirements exceed 1,500 kVA. Padmount oil-filled transformers must be SNL/NM-furnished.

To reduce the arc-flash hazards at the secondary of the transformer, see the maximum fuse sizes allowed to serve as primary protection for 12.47 KV padmount transformers in Table 9.2. These fuses must coordinate with the devices downstream of the transformer secondary. Supply a coordination study to the Facilities Systems Engineer for review and approval.

Table 9.2 Primary Fuse Sizes for 12.47 KV Transformers

Primary Fuse Sizes for 12.47 KV Transformers				
KVA	**KV (high)**	**Volts (low)**	**Primary Full-Load Amps**	**Max Fuse Rating***
1500	12.47	480	69.45	100E
1000	12.47	480	46.30	65E
1000**	12.47	208	46.30	65E
750	12.47	480	34.72	50E
750	12.47	208	34.72	65E
500	12.47	480	23.15	40E
500	12.47	208	23.15	30E
300	12.47	480	13.89	20E
300	12.47	208	13.89	20E
150	12.47	480	6.94	20E
150	12.47	208	6.94	20E
75	12.47	480	3.47	10E
75	12.47	208	3.47	10E

*S&C SMU-20 Standard Speed Fuse
**This size transformer not recommended.

The use of high-voltage dry transformers requires the approval of the Facilities Electrical Operations Engineer.

Transformer sizes must be based on historical SNL/NM load data that is provided by the Facilities Electrical Operations Engineer.

The maximum allowable single-phase pole-mount transformer is 50 kVA. The maximum allowable three-phase pole-mount transformer bank is 3-50 kVA. Transformers above 150 kVA must be padmounted. Refer to the Facilities System Engineer on installation requirements. Primary voltages above 15,000 V are considered special and require special designs.

The decision to use "K" transformers is based on a harmonic analysis. See subsection 9.13.7 for guidelines on harmonic analyses calculations.

The maximum rating or setting of Overcurrent Protection Devices for transformers over 600V must comply with the NEC, Article 450.3(a), Any Location.

Transformers must be located and fire-protected in accordance with standard drawing WP3003STD.

9.12 Standby and Emergency Power Systems

SNL Standard Specifications

N/A

SNL Standard Drawings

N/A

System Drawings

- Locate building generators on power plans (EP-series drawings) or on the electrical site plan (ES- or WP-series drawings).
- Prepare detail drawings as needed for construction.
- Locate transfer switches, inverters, and feeders on power plan.
- Show transfer switches and identify equipment fed from emergency power system on the one-line diagram.

9.12.1 Standby Power

Standby power for Technical Area I is typically provided from the medium-voltage Building 862 standby generator system. Standby power for all other sites is typically provided by a dedicated diesel generator set. If standby power is determined to be required for an SNL/NM facility, conduct a preliminary standby load study for presentation to the SNL/NM Infrastructure Operations Team (IOT) by the assigned Facilities Electrical System Engineer. The IOT then determines the appropriate source of standby power for the proposed standby power loads.

9.12.2 Emergency Power

Emergency power requirements for all facilities are provided by the facility in question, or by a central utility building (CUB) serving a facility complex. If emergency power is determined to be required, conduct a preliminary emergency load study for presentation to the assigned Facilities Electrical System Engineer who determines the appropriate source of emergency power for the proposed facility. Any new standby or emergency generator systems are to have diesel engines as the prime mover and load banks rated for 100% of the generator output. Once the decision has been made to install a standby or emergency generator system, contact SNL Environmental Management for assistance in obtaining a permit from the U.S. Air Force and the city of Albuquerque. Obtaining a permit may be an extended process.

Automatic transfer switches for standby and emergency power systems must be four-pole switches. For emergency power systems, the automatic transfer switches must have bypass and isolation switches. For standby power systems, evaluate and recommend the need for isolation and bypass switches.

9.12.3 Emergency Lighting Power

Provide inverters for all facilities requiring emergency and egress lighting, except for very small buildings more economically served by battery-powered emergency and egress lights. Inverters are provided by SNL as SFE from the High-Lites product line. Provide the luminaires, space, housekeeping pads, normal power circuits, and distribution circuits required to accommodate the inverters. Design the terminal connections to the inverters with flexible conduit to facilitate inverter servicing. Provide the rated normal power feeders for the respective inverter models shown in Table 9.3.

Table 9.3 Rated Normal Power Feeders by Inverter Model

Inverter Model	Full-Load	Circuit Rating
1.5 kVA, 120v: HCI-1500-A-P-CTS-OTR-FB-081704	16 amp	20amp
1.5 kVA, 277v: HCI-1500-R-P-CTS-OTR-FB-081704	7 amp	15amp
4.8 kVA, 120v: HCI-4800-A-P-CTS-OTR-FB-012908	50 amp	60amp
4.8 kVA, 277v: HCI-4800-R-P-CTS-OTR-FB-012908	22 amp	30amp

All models must be supplied with battery packs with 48-volt segmentation.

Line-in and load-out voltages are the same and are single-phase. Figure 9.1 illustrates the inverter general one-line diagram.

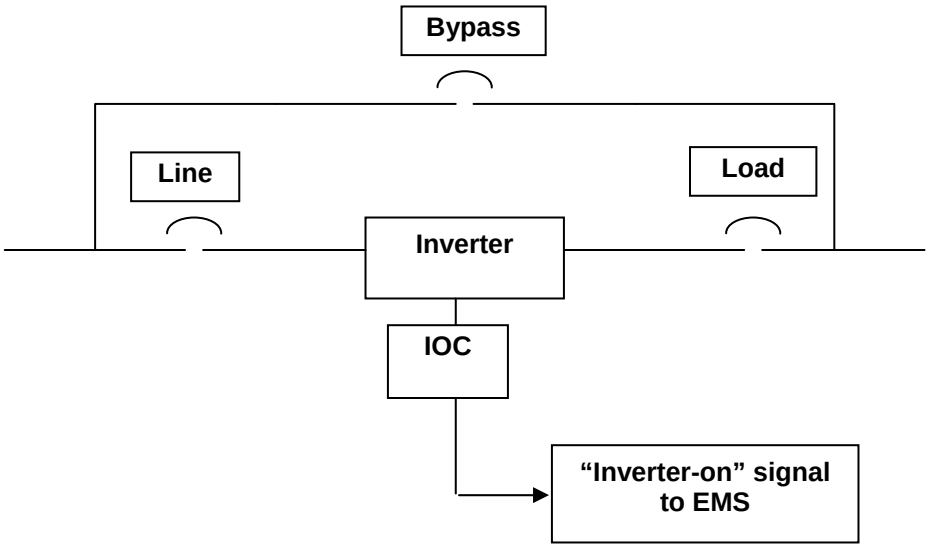

Figure 9.1 Inverter General One-Line Diagram

9.13 Design Calculations

9.13.1 General

Present all electrical calculations using the guidelines in this section. Provide two 8½-inch by 11-inch, three-hole-bound reports that contain all electrical calculations, time-coordination curves, and protective device settings. Provide one-line diagrams and electronic files with all calculations. At the end of the project, update both reports and electronic files in the same manner as other as-built drawings.

9.13.2 Voltage-Drop Calculations

Prepare a complete set of voltage-drop calculations. When both normal and standby primary feeders serve a facility, provide calculations for both feeders. The preferred calculation method is the SKM Systems Analysis Dapper software program.

The maximum allowable steady state voltage drop must not exceed 5% total for building wiring.

The maximum allowable transient voltage drop must not exceed 15% at the utilization equipment. If a problem is identified, notify the assigned Facilities System Engineer for resolution.

Design the standard voltage profile for regulated power distribution systems to comply with ANSI/IEEE Standard 141-1993 (Red Book) or the latest edition.

Calculate voltage drops for the longest-branch circuit to include the drop in feeders, subfeeders, and transformers back to the first bus with automatic regulation (usually the primary master unit substation). Do not use a building transformer to correct secondary voltage drops. Set transformer voltage taps to nominal voltage values under no-load conditions.

Unless loading can actually be predicted, assume the full load for all branch circuits as that limited by the maximum load on the conductors by these standards, applicable codes, or both. The power factor for future loading is considered to be the same as when designed.

9.13.3 Short-Circuit and Arc-Flash Calculations

Prepare a complete set of short-circuit and arc-flash calculations. When both normal and standby primary feeders serve a facility, provide calculations for both. The preferred fault-duty calculation method is SKM Systems Analysis Dapper and Captor software programs.

Calculations must consider both bolted three-phase and single-phase-to-ground fault current on secondary systems. State the base MVA or KVA available at the fault. Arc-flash calculations must include the calorie levels, PPE requirements, hazard categories, and boundary dimensions for all equipment that may be serviced or used for troubleshooting while energized. The calculations must include the data necessary to completely execute the information and warning label to be applied to the equipment covers as shown on SNL Standard Drawing E-0006STD.

Prepare protective device coordination graphs that demonstrate that the protective devices are properly coordinated for interrupting faults. Prepare these graphs for all new or modified primary and secondary systems. Curve plots from the software program Captor are an acceptable alternative.

The design must include the use of S&C, SMU-20, 12.47 kV, E-type, standard-speed fuses in 15 kV S&C padmount or stand-up switchgear, unless approved otherwise by the Facilities Systems Engineer.

Additionally, present the manufacturer's catalog data on the affected protective devices to show they have adequate fault-current interrupting capacity for the available short-circuit current.

9.13.4 Wire-Pulling Calculations

When new ducts are required for primary power system (>600V), submit a set of calculations showing the maximum tension placed on the cables during pulling and the maximum allowable tension the cables can withstand. Calculate also, from a pressure standpoint, the force exerted in each elbow or bend during pulling and the radius of each bend. The minimum radius for electrical duct banks is 3 feet. Calculations must be performed in both directions with resultants indicating either direction of pull is allowable. Indicate the resultant radii on the plans, plus the pulling instructions that are required for the method and direction.

9.13.5 Lighting Calculations

Calculate the horizontal illumination levels for each room using the zonal-cavity method described in the *Illuminating Engineering Society (IES) Lighting Handbook*. Similar-sized rooms may be reported under a single spreadsheet calculation when the illumination level does not vary more than 5% to 10% across the group of rooms. When intense point sources, such as MHID lights, are used for indoor lighting, perform an additional spot check for hot spots and uniformity using the point-by-point method.

Constants, such as lumen output per lamp, fixture efficiency, maintenance factor, or coefficient of utilization, must be shown with the source of the constants identified, such as a product cut sheet. In most cases, the maintenance factors should be chosen on the basis of a medium-intensity maintenance program, full-rated voltage applied, no temperature derating, and a 5% tolerance for lamp burnout. Coordinate expected wall, ceiling, and floor reflectance with architectural finishes, and explain significant excursions from the 80/50/20% standard.

Calculate the vertical illumination level for those rooms and spaces where adequate illumination on walls, display cases and boards, or shelves is important to the mission of the room.

Calculate the visual comfort probability in the manner described in the *IES Lighting Handbook* for all rooms in excess of 40 feet in length and width, or when directed by the electrical design criteria. Where other than "white light" (low CRI, or significantly off 3,500°K) is used, calculate the human eye response to the spectrum provided, and provide the equivalent effective illumination level had "white light" been used.

Specify the operating point of adjustable automatic switching controllers, such as at what ambient conditions the controllers are to function both on and off. Include delay times and sensitivity settings for occupancy sensors, ambient light levels for daylight-harvesting controls, timer settings, and Facilities Control System interconnections.

Use the point-to-point method to develop isolux curves for design of parking, ground, flood, or perimeter fence lighting systems to design the required horizontal footcandle levels and uniformities at ground level. Submit the isolux curves as part of the design package.

Options for calculations include commercial software programs explained in the *IES Lighting Handbook*. Identify the program used by trade name and version number.

9.13.6 Exterior Lighting Calculations

Use isolux curves to design ground or fence lighting systems to obtain the required minimum footcandle level, horizontal, at ground level. Submit the isolux curves used for cross-checking.

9.13.7 Harmonic Analyses Calculations

Prepare harmonic study calculations when a significant amount of harmonic (nonlinear) load is added to the distribution or building power system. A harmonic study is also required when the new load exceeds the recommended voltage or current distortion levels as allowed by IEEE Standard 519-1992, *IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems*.

The design must include a system that limits the voltage and current distortion at the point of common coupling per the limits recommended by IEEE 519-1992. SNL/NM provides the existing power system information.

The results of the harmonic study dictate when additional harmonic correction measures are required.

9.14 Access and Layout

- Electrical equipment must be accessible for periodic maintenance, repair, and replacement. This accessibility includes consideration of NEC 110.26 clearances; paths of entry and egress to and from the clearance space; and the types of maintenance, repair, and replacement that might be needed over the useful life of the equipment.
- Anticipate and eliminate head-bumping and tripping hazards.
- Locate lighting fixtures so access for relamping and repair activities is maintained.
- Prepare elevations of crowded walls, particularly where the mechanical and structural equipment used for the maintenance of electrical equipment is located.
- Coordinate information on electrical drawings with structural drawings, so sleeves through walls and floors are accurately detailed and specified.
- Coordinate with mechanical and HVAC drawings, so each system properly fits into common spaces.

9.15 Sandia-Furnished Material

Unless specifically indicated in the electrical design criteria, SNL/NM furnishes the following equipment:

- Emergency light system inverter
- S&C switchgear
- Oil-filled padmounted transformers (primary >600 volts)

9.16 Acceptance Testing

Acceptance testing is required on all new electrical equipment prior to energizing it and placing it into service. Testing must be performed by a third-party testing firm, meeting all qualifications stated in the latest edition of the ANSI/InterNational Electrical Testing Association (NETA) document, *ANSI/NETA Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*. Also, all acceptance testing must be performed in accordance with the latest edition of *ANSI/NETA Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*.

- End of Chapter -