Chapter 22
ELECTRICAL DRAWINGS AND DESIGN

SECTION 2201 - GENERAL

2201.1 General Information and Requirements: The electrical drawings shall indicate complete design. Prior written acceptance is required for any design-build component.

2201.2 Completeness: The electrical drawings, in association with the construction specifications, shall:

A. Furnish sufficient information to permit installation of manufactured equipment that requires electrical service without conflict with work of other disciplines.
B. Furnish sufficient information to manufacture equipment that is of special design, made exclusively for the project. Components and systems shall be UL listed.
C. Describe items so that they may be procured.
D. Furnish sufficient information to permit planning, construction, evaluation, recording, repair, and maintenance of facilities.
E. Furnish the above in sufficient completeness for accomplishment without the need of assistance from the Consultant.

2201.4 Sequence: Electrical Drawings are divided into specific groups. Drawings within a group are numbered consecutively, ie E2.01, E2.02, etc. The group designation shall always remain the same, regardless of the size or scope of the individual project. If specific projects do not include work related to a group, that group shall be eliminated from the drawings. When appropriate, the Consultant shall obtain written permission from the Project Manager to vary the sequence.

E0.xx General Notes, Drawing Index, Symbols & Abbreviations
E1.xx Site Plan
E2.xx Floor Plans, Lighting
E3.xx Floor Plans, Power
E4.xx Electrical Rooms
E5.xx Riser Diagrams
E6.xx Fixture/Panel Schedule
E7.xx Details


2201.5 Drawing Types: Electrical drawings shall generally include the following delineations as needed:

1. Legend of symbols
2. Block diagrams
3. One-line diagrams
4. Schematic diagrams
5. Connection diagrams
6. Power distribution plans
7. Lighting plans, outdoor & indoor.
8. Site photometric plans
9. Communications plans and risers
10. Grounding plans and risers
11. Security plans and risers
12. Lightning protection plans
13. Fire alarm plans and risers
14. Panel, circuit and other schedules
15. Detail drawings
Combinations of delineations may be shown on the same drawing sheet. Lighting and power shall always be on separate plans; small projects may have both plans on one drawing sheet. Electrical delineations shall not be incorporated into architectural, structural or mechanical drawings. Electrical utility and exterior lighting shall be fully coordinated with the civil drawings.

SECTION 2202 - ELECTRICAL PLANS

2202.1 Definition: Electrical plans consist of scaled delineations arranged to depict circuits and electrical equipment installation, and are supplemented by diagrams and specifications. The electrical plans shall depict:

1. Electrical equipment arrangement
2. Facility electrical power distribution, including underground distribution
3. Facility grounding
4. Facility lighting, indoor & outdoor
5. Facility lightning protection (may be design/build performance specification, with grounding system by electrical engineer)
6. Fire alarm: may be designed by special systems consultant, or design / build performance specification, with main panels and power by electrical engineer. See Chapter 23.
7. Facility security: may be designed by special systems consultant. See Chapter 23.
8. Facility communications: may be designed by special systems consultant. See Chapter 23.

2202.2 Delineation: Electrical items such as wire, conduit, cable, electrical equipment, etc., shall be delineated by line work distinguishable from lines used to depict items shown for reference or orientation. When screened or "grayed out" background plans are used for reference, the Consultant shall assure the contrast of the reference drawing is sufficient to print and photocopy reliably. Faint, illegible backgrounds are not acceptable.

Lines between boxes on power and lighting circuit plans shall indicate cable, conduit, duct, and wire runs. Separate lines for wires within these carriers are generally not shown except by symbol. Conduit runs shall generally be indicated by straight lines run parallel to building lines, walls, floors, ceilings, etc. in a manner than makes them distinguishable from those building lines.

Circuitry not depicting conduit routing shall be depicted by curved lines. When these lines are used without additional qualification, they may be interpreted as permitting the most direct, non-interfering route compliant with codes and workmanship standards. Therefore, this system may be used ONLY in accordance with the Electrical Engineer's certification that the design is completely coordinated and causes no interference with architectural, structural, mechanical and all other building systems. It is not the Contractor’s responsibility to complete the design in the field.

2202.3 Scale and Coordination: Drawing scale, north orientation and order shall correspond to the architectural drawings.

2203.4 Dimensioned Location:

1. Buried, embedded, penetration and critical clearance installations shall be described by note and dimensioned from project benchmarks, structural grid and layout geometry on the drawings.
2. Show location and elevation of wire ways, electrical bus and cable trays.
3. Reliance on Contractor “workmanship” as the sole provision for aesthetic installation of exposed conduit and enclosures in public areas is discouraged. Exposed conduits, bus and trays shall be located and dimensioned with tolerances in coordination with the architectural elevations and aesthetic principles.
2202.5 Marking: If not fully explained by the specifications, the requirements for electrical safety notices on equipment, doors, enclosures, etc, shall be included on the drawings.

2202.6 Future Space: When space is specifically set aside for future installation of equipment, such space shall be indicated in dashed lines, dimensioned and labeled.

2202.7 Spares: Spare wires, cables, conduits, terminals, circuit breakers, etc., shall be shown and identified as spares.

2202.8 Cross-reference: Provide references to applicable drawings, including other discipline drawings. Reference specific vendor equipment drawings only when equipment is known or received.

2202.9 Arrows on wires: Limit use of arrowheads on lines representing wire, cable or conduits to indication of “home runs” returning to the local panel board without interruption.

2202.10 Completeness: Unless included in the specification, include the following items on the drawings:

1. Extent of National Testing Laboratory acceptance of items.
2. Compliance to the National Electrical Code.
3. Marking or tagging requirements, including Underwriter's Label, wire size, fuse rating, etc.
4. Labeling of circuits and equipment.

2202.11 Load balancing: The plans shall be drawn so proximity to balance load conditions can be determined.

2202.12 Special conditions: Show special conditions on the drawing, including but not limited to:

1. Number, size and location of building expansion joints.
2. Transitional details, such as a conduit passing from a floating floor to a rigid structure.

2202.13 Devices which have different energized and de-energized appearance shall be shown in the de-energized condition. For example, a circuit breaker or a switch that can be shown either closed or open shall be shown open.

SECTION 2203 - POWER DISTRIBUTION PLANS

2203.1 Definition: Power distribution plans depict primary and secondary power distribution, control and grounding, excluding lighting and communications. Plans shall show equipment arrangements, configuration and information to locate position and mount electrical equipment.

1. CSU Engineering Department may design primary utility power for projects. The Electrical Engineer shall coordinate the project drawings and indicate the line of demarcation for design responsibility.

2203.2 Primary Supply: Construction documents shall show the primary supply cables to, and the secondary feeder cables or busways from, service entrance equipment.

2203.3 Secondary Circuits: Show connections of secondary circuits to utilization points and associated equipment such as panelboards, distribution transformers, converting equipment, etc.

2203.4 Panel Board Schedules: Show power panelboard schedules with phases balanced, the total connected load (KVA), NEC demand load (KVA) and the demand factor.
2203.5 Panel Board Drawings: Panel Boards, existing and new, shall be drawn to scale in plan and elevation, showing, identifying and dimensioning all equipment adjacent to the installation. If manufacturer options are specified for panel boards, show the LARGEST panel. Drawings shall clearly depict correct top-to-bottom and front-to-back positioning relative to adjacent equipment. Show clearances required by code in plan and section, including door swings and clear areas required for placement of parts. The Consultant is responsible for assuring coordination of clearances with building systems by other disciplines.

2203.6 Dimensioned Location: Equipment shall be dimensionally located from column lines, walls, ceilings, etc.

2203.7 Grounding: Grounding design shall comply with NEC and be shown on the drawings, including details of grounding bars. Grounding paths shall be shown whether made through wires, buses, conduit, ducts, rods, or other items serving as ground conductors. Include bonding information unless covered in specifications. Show grounding conductor sizes and locations.

2203.8 Raceways: Dimensionally locate and describe raceway systems and components (cable tray, conduit, pull boxes, wireway, etc.) The Consultant is responsible for coordination and elimination of conflicts with building systems designed by other disciplines.

2203.9 Equipment: Identify equipment by note or in a material list. Show clearances and dimensions of the largest “or equal” manufacturer’s equipment on the drawings. Provide concrete housekeeping pads for floor-mounted electrical equipment.

2203.10 Emergency Power: Include and identify standby and emergency power systems.

2203.11 Transformers: Transformers shall be pad mounted on the floor if the transformer is greater than 50 KVA. Document heat load of transformers on the drawings and incorporate transformer heat loads in the HVAC cooling calculations.

2203.12 Receptacles shall be defined by symbol and "home-run" circuit number. Note default (typical) mounting height on the drawings. Note receptacle mounting height at specific location when different from the default height. Indicate the home run panel by panel designation and circuit. Show intermediate pull boxes on the drawings by size and assure access clearance is coordinated with all other building systems.

SECTION 2204 - LIGHTING PLANS

2204.1 Definition: Lighting plans depict lighting circuits, lighting control circuits, fixtures and accessories, beginning with the power source at the source panel or the lighting transformer and panelboards and extending to the light fixtures.

2204.2 Circuits: Lighting circuits shall generally be shown separate from other circuits. Lighting circuits may include feeders, transformers, panelboards, wires, cables, raceways, switches, lamps, outlets, emergency lighting batteries, relays, etc.

2204.3 Delineation: Delineation for lighting systems shall include runs from the service entrance equipment through the lighting control panelboards and conductors to the lights. Indicate size, material, etc. for wire, conduit, and special fittings.

2204.4 Panels: Show panelboard schedule and connection details. Indicate mounting height by note or in elevation if not covered in the specification. Panel schedules shall describe equipment and its location by room number, augmented by position for rooms with multiple lighting circuits.
2204.5 Symbols: The lighting symbols shall include light fixture type number or letter code within or adjacent to them with their "home-run" branch circuit number, and a lower case letter indicating switches by which they are controlled. Note height if different from typical. Night, emergency and security lighting circuits shall be distinguishable from general lighting.

2204.6 Layout and Location: Coordinate lighting layouts with mechanical and other electrical equipment. Indicate mounting height for switches and fixtures on elevations or by note.

2204.7 Emergency Lighting: Indicate the lighting circuits to which emergency battery-powered lighting units activated by power failures are connected and that they are connected on the line side of all switches per applicable code.

2204.8 Lighting Control Symbols: The lighting control symbols shall differentiate between line voltage and low voltage systems. Occupancy sensor symbols shall be unique so as to indicate type of technology used (infra-red, ultrasonic, dual technology, etc.), coverage (large room, corridor, wide angle) and voltage (line or low voltage).

2204.9 Lighting Control Matrix: Drawings shall include a Lighting Control Matrix indicating the intent and performance of the lighting control systems in each space. An example,

<table>
<thead>
<tr>
<th>Area</th>
<th>Normal Operation</th>
<th>Override Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lobby</td>
<td>Auto ON during scheduled Business hours</td>
<td>Occ Sensor Override ON after hours, not to exceed 2 hours</td>
</tr>
</tbody>
</table>

SECTION 2205 - COMMUNICATIONS PLANS

2205.1 Definition: Communication plans depict the interconnecting electrical circuits between devices such as telephones, computers, data network devices, closed-circuit video, audio and public address, etc. as well as the various alarm, control and signaling systems such as fire detection and alarm, energy management and control system, access control, etc. Communication systems may be integrated together into common data communication links.

2205.2 Locations: Show communication equipment and the interconnecting wiring and/or cabling. When more than one system is shown on a plan, the graphic depiction of each shall be clearly differentiated. Raceway systems and components (cable tray, pull boxes, conduit, wireway, etc.) shall be dimensionally located and described.

SECTION 2206 DIAGRAMS

2206.1 General: The Consultant shall provide diagrams depicting the characteristics and relationships of the electrical system by the use of symbols and lines showing flow, function, or physical connections. A set of electrical drawings shall include either a one-line diagram, schematic diagram, or both. Provide block or connection diagrams as needed.

2206.2 Layout: Arrange electrical diagrams so the main features are prominent and there is an even balance between blank space and lines. The blank space around symbols should be sufficient to avoid crowding of notes. Provide blank spaces for planned additions.

1. Diagram line work shall be of medium line width except where otherwise specified in the respective paragraph for a particular diagram type. When connecting lines are drawn parallel, the spacing between lines shall be legible after fifty percent (50%) reduction.

2. Drawing titles shall include the diagram type. When combinations of electrical diagram types are included on the same drawing, the entry for the type of drawing in the title block shall be selected
to adequately define the drawing content. Typically, if a drawing combines all of the diagram types, the entry in the title block shall be ELECTRICAL DIAGRAMS.

3. Use a boundary line enclosure to show circuit parts that are grouped.

4. All lines between blocks or symbols shall be vertical or horizontal. Lines shall be as direct and short as possible without the use of diagonal lines. Lines shall have a minimum number of turns and crossings. Crossings shall be looped.

5. Use nomenclature or other designations for identification of blocks, symbols, equipment, etc. in accordance with the device, equipment marking or standards established for the facility.

6. Use a direction arrow for interface flow lines that are "from" or "to" features not included on the drawing.

7. Provide notes concerning physical or functional information as needed to clarify the diagram.

8. More than one type of diagram may be included on one drawing, but do not place diagrams on plan drawings.

2207 BLOCK DIAGRAMS

2206.1 General: Use a block diagram when needed to give a quick over-all picture of a system and the general interrelationships between components of that system for general arrangement studies, functional explanations, systematization of facilities or for design discussion purposes.

1. Use as simple a form as possible, with rectangular blocks to represent functional electrical systems, parts or major elements of an electrical system or circuit. Various other symbols may be used as supplementary information to increase the utility of the diagram.

2. Place identifying nomenclature within the blocks.

3. Mechanical connections elements shall be illustrated with dashed lines.

4. Tabulations may be used if the form of the circuit involves multiple sources and common or similar circuits, or variations thereof.

5. Lines connecting blocks shall indicate relationships, direction of flow of the system, sequence of operation, etc. The arrangement of lines and blocks shall show action or energy flow in functional sequence from top to bottom and/or left to right of the diagram, starting at the top left or top center and ending at the bottom right of the diagram.

6. Connection lines shall be labeled where necessary to make the meaning clear and unmistakable. When dashed lines are used for more than one purpose on a block diagram, these purposes shall be made clear by label, legend, or note.

7. Connecting lines may include arrows to further define the circuit flow.

8. If a block diagram must be divided and placed on more than one drawing, the division of the circuit should be made at a point of minimum information transfer in a logical manner that will avoid confusion.

SECTION 2208 - ONE-LINE DIAGRAMS

2208.1 General: A single-line diagram is required for all new, remodel or modification design of any service or distribution system for power, control and communication. One-Line diagrams shall include:

1. Service transformer size.

2. Service voltage and phase.

3. Graphic representation of bus arrangement and overcurrent devices on all main and sub distribution equipment.
4. Size and rating for overcurrent main and feeder units (Use of schedules for this data is not acceptable).
5. Available spaces and spares in main and distribution boards and panels.
6. All branch panels (Designators and locations required).
7. Dry type transformers (Designators, sizes and locations required).
8. Available short circuit current at critical points of the system.
9. Arc flash category rating on each piece of equipment down to branch panels.
10. Branch circuit panelboard main breaker or MLO ratings.
11. Metering equipment.
12. System ground components and configuration.
13. Standby engine-generator(s) and transfer switch(es).
14. Transient Voltage Surge Suppression (TVSS) equipment.
15. Ground-fault protection of equipment on solidly grounded wye electric services of more than 150 volts phase-to-ground but not exceeding 600 volts phase-to-phase for each service disconnect rated 1000 amperes or more.
17. Motor Control Centers and other distribution gear.
18. Feeders can be shown by description or by schedule. If a feeder schedule is used, it should be on the same sheet as the One-Line diagram.

2208.2 Requirements: The requirements specified in Section 2209 - Schematic Diagrams shall apply in addition to the following:

1. Only one phase of a multiphase system and one polarity of a DC system shall be used to simplify the circuit and to include the necessary essentials.
2. Descriptive nomenclature shall be placed above or to the right of the subject element or connecting line unless other placement has a distinct advantage for the particular application.
3. All symbols shall be of the single-line type.
4. A single-line diagram is termed functional if various line widths are used to separate categories of circuits. When this type of diagram is made, the line widths shall be defined. No more than two widths of lines shall be used. Heavy-width lines represent power circuits and medium-width lines represent control and measurement circuits.
5. Nominal voltages shall be used for supplementary information in the designations of systems.
6. Power transformer impedance shall be indicated on the Record Drawings. The Consultant shall provide a designated place on the drawings for the Contractor to enter this information on the as-built redline set.
7. Transformer voltage representation shall use the symbols dash (-) and slant (/) as follows:
   a. The dash (-) is used to separate the voltage ratings of separate windings on a transformer (13.8 KV-480V).
   b. The slant (/) is used to separate multiple voltages or indicate taps of the same winding (208Y/120).
   c. Transformation ratios shall use the slant (/) as the separation between the values.
8. A one-line diagram may show only the power circuits, or, if extended, include secondary and control circuits in the simplified form.
9. The one-line diagram may include pertinent rating information about its items, such as voltages of potential transformers, ampere rating of current transformers, fault current, interrupting capacity,
breaker frame and trip ratings of circuit breakers, motor horsepower ratings, load estimates, bus ampere and voltage rating.

10. A one-line diagram may also include wire and cable information, and further descriptions of elements such as: element categories, models, drawing numbers, functional designations, length of cable.

11. Indicate distribution equipment, power, control and metering, and protective relay circuits from the incoming feeder to ultimate motor, lighting panel or other load, including item names.

12. Winding connection symbols shall be used adjacent to the symbols for the transformer windings.

13. The quantity of a particular device may be indicated on a single-line symbol when it is necessary to define its quantity in relation to the graphical symbol. The numeral indicating quantity is placed adjacent to the symbol. The number 3 adjacent to the magnetic overload device indicates that there are three circuits like the one shown. A note shall be included with the legend or notes indicating the function of the quantity numeral, e.g., "THE NUMERAL ADJACENT TO RELAYS DENOTES QUANTITY."

14. Device lists shall be incorporated on the drawings and included as part of the legend, when functional designations per Section 1910 Connection Diagrams are used. In addition, the meaning of each suffix used with a device function number should be listed if it is not included with a complete device function number. The following illustrates a device list.

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Master Element</td>
</tr>
<tr>
<td>1M</td>
<td>Master Element</td>
</tr>
<tr>
<td>23</td>
<td>Temperature Control Device</td>
</tr>
<tr>
<td>38</td>
<td>Bearing Protective Device</td>
</tr>
<tr>
<td>43</td>
<td>Manual Transfer Switch</td>
</tr>
<tr>
<td>47</td>
<td>Phase Sequence Voltage Relay</td>
</tr>
<tr>
<td>49</td>
<td>Machine Thermal Relay</td>
</tr>
<tr>
<td>51</td>
<td>AC Time Overcurrent Relay</td>
</tr>
<tr>
<td>51N</td>
<td>AC Time Overcurrent Relay (Neutral)</td>
</tr>
<tr>
<td>52</td>
<td>AC Circuit Breaker</td>
</tr>
<tr>
<td>52X</td>
<td>Auxiliary Relay for 52</td>
</tr>
<tr>
<td>86</td>
<td>Locking-out Relay</td>
</tr>
</tbody>
</table>

15. Protective relays may be included along with an indication by operator dash lines on the device that the relay acts upon.

16. Electrical values and other functional information shall be included as necessary to allow analysis of the circuit. Examples of some types of information that may apply are as follows:

- Current, voltage and interrupting rating of circuit breakers.
- Primary and secondary voltages and kVA ratings of power transformers.
- Voltage and kVA or kW rating of generators.
- Voltage and HP rating and type of motors.
- Rating and type of load on feeder circuits.
- Ratings of power and control sources.
- Circuit breaker frame trip and interrupting current.
- Switches ampere rating.
- Ratings of instrument transformers, fuses, resistors, capacitors, and contractors, motor starters.
- Resistance to ground, inductance, and temperature ratings.
- Voltage and current waveforms.
- Bus amperage, voltage and fault current capacity.
SECTION 2209 - SCHEMATIC DIAGRAMS

2209.1 General: A schematic diagram shall be provided to show the relationships, circuits and device elements of electrical systems. The schematic diagram emphasizes the device elements of a circuit, as distinguished from the physical arrangement of conductors, devices, etc. of a circuit system. The circuit layout follows the signal or transmission path from input to output, left to right, or in the order of functional sequence without regard to the actual physical shape, size, or location of the device.

2209.2 Symbols: Electrical item symbols shall be shown in their de-energized state unless otherwise noted on the drawing. In general, terminal symbols may be omitted unless required for clarification.

1. The diagram shall be arranged so that the drawing user can follow the functional relationships (input to output, source to load, order of potential utilization, etc.). Layout shall show the path of energy flow from left to right, top to bottom, or a combination thereof.

2. Assign functional designations to circuit items, placed above or to the right of the symbol.

3. Label all inputs and outputs of the schematic diagram with descriptive nomenclature, including physical operating label nomenclature for switches and similar devices that will be so labeled.

4. For interrupted single lines, the line identification may indicate destination. In general, identification practice for interrupted single lines shall be the same as for grouped and bracketed lines described in the paragraph on interrupted grouped lines. When interrupted lines are grouped and bracketed, line identifications shall be shown. Bracket destinations or connections may be indicated either by means of notations outside the brackets or by means of a dashed line. When the dashed line is used to connect brackets, it shall be drawn so that it will not be mistaken for a continuation of one of the bracketed lines. The dashed line shall originate in one bracket and terminate in no more than two brackets. Letters, numbers, abbreviations, or other identifiers for interrupted lines shall be located as close as possible to the point of interruption.

5. The relation of switch position to circuit function shall be shown on schematic diagrams. For simple toggle switches, it may be sufficient to identify position with notations such as ON-OFF. For more complex switches, position-to-function relations may be shown either near the switch symbol or at a more convenient location on the drawing. When rotary switches perform involved functions a tabular form of presenting supplementary information is preferred, such as a selector switch contact development table.

6. When parts of rotary switches are designated S1A, S1B, S1C, etc., the suffix letters A, B, C, etc., shall start from the knob or actuator end and then be assigned sequentially away from this position. Each section of the switch shall be shown viewed from the same end. When both sides of a rotary switch section are used to perform separate switching functions, the front (knob or actuator end) and rear symbols should be differentiated by appropriately modifying the reference designation, for example S1A FRONT and S1A REAR.

7. When portions of connectors and terminal boards are separated on the diagram for drawing convenience, the words "PART OF" shall precede their designation labels or each individual terminal shall be labeled with its reference designation. When the separation of portions of connectors or terminal boards on the same drawings, becomes extensive, the separated parts may be identified as individual terminals. If individual terminals from different parts, such as connectors, are intermixed, mechanical connecting lines shall be omitted.

8. When mechanical functions are closely related to certain electrical functions, the mechanical components shall be linked to the applicable graphic symbols of the schematic diagram.
9. Connecting points of lines should not be purposely laid out to represent actual physical arrangement of wires. This type of information will be provided by connection diagrams.

10. Terminal identifications may be added to graphic symbols to indicate actual physical markings, which appear on or near item terminations.

11. When terminals or leads of multi-lead items are identified on the item by a wire color, code, letter, number, or geometric symbol, this identification shall be shown on or near the connecting line adjacent to the symbol.

12. When rotary-type, adjustable resistors are shown on schematic diagrams, it is desirable to indicate the direction of rotation with respect to an arbitrary reference point. It is customary to refer to the rotary motion as clockwise or counterclockwise when rotation is viewed from the knob or actuator end of the control.

13. Subdivisions of items may be identified by adding a suffix letter to the designation of the part. For example, CB1A and CB1B identify electrically separate sections of a dual circuit breaker designated CB1. In cases where multiple items are physically integral but are shown separately they shall be identified by suffix letters. Where they are shown together within an enclosure, the assignment of suffix letters is optional.

14. Portions of multi-item components may be shown at different locations on the schematic diagram. In such cases, suffix letters added to reference designations will indicate the relationships of the subdivisions to the whole components.

15. In schematic diagrams for switching circuits, reference designations may be aligned along one edge of the circuit instead of being shown at the symbol. Mechanical linkage lines of multi-item switching devices and reference designations for individual contacts may be omitted when the association of parts is clear.

16. Explanatory information in the form of notes, that describe sequence of operations or the dependence of a circuit upon other actions, may be located adjacent to the particular related device, schematic delineation, or with the notes of the drawing.

SECTION 2210 - CONNECTION DIAGRAMS

2210.1 Definition: A connection diagram shows the general physical arrangement and electrical connections of a unit or of its component devices or parts. It may cover internal or external connections, or both, and contains such detail as is needed to make or trace the connections on the equipment. An interconnection diagram is a form of connection diagram, which shows the external wiring connections between different units of an equipment or different equipment of a system. Connection diagrams are used as a guide for installation of wire or cable. They are used for circuit tracing but not for circuit analysis. They serve the following purposes:

1. Furnish information showing electrical connections for an installation in diagram form.
2. Facilitate determination of electrical connection adequacy.
3. Terminals shall be named, spare terminals indicated.
4. Facilitate maintenance of equipment.

Supplement schematic and single-line diagrams by relating circuit information with the actual wiring and relative location of items. Connection diagrams are classified as either "lineless" or "line" types. The "line" type classification includes two subtypes: the point-to-point and the cable (or highway) type. The point-to-point diagram shall be used when the quantity of connections is small. The cable or highway type, as well as the "lineless" type, shall generally be used for a complex connection diagram.
2210.2 Common Requirements:

1. The physical arrangement of device terminals and connections thereto are generally pictorially shown.
2. All connections shall be listed or all lines and symbols required to fully represent wire, cable, and circuit items and their connections within a defined area shall be depicted.
3. Point-to-point wire and/or cable types, connection information, and specific terminal identifications shall be shown.
4. System items, whenever feasible, shall be represented by rectangles and/or circles. Other geometric shapes, which approximate the outline of the item, and are simple in form may be used. These outlines may encompass portions of their internal circuits in single-line or schematic form where more rapid understanding of the drawing will result, e.g., fuses, circuit breakers, switches, etc.
5. Terminations on items shall be represented by attached lines, rectangles, or circles. They shall be identified by letters, numbers, pigtail colors, or other nomenclature. This identification shall agree with actual marking on the item, when possible, and shall be compatible with other designations of the same item within the drawing set.
6. Item symbols shall be identified with the functional designations or other nomenclature assigned to them on single-line and/or schematic diagrams of the facility.
7. Rating and circuit function information, which is indicated, on single-line and/or schematic diagrams shall not be duplicated on connection diagrams. However, polarities and phase indications shall be included.
8. To avoid possible damage to equipment by improper connections, every consideration shall be given to indicating proper phasing. The diagram shall specify wires, which must be grouped in conduits as well as the proper identification of the wires and conduits. If conduits are not used, the wires must be grouped in a convenient manner to facilitate identification.
9. Pre-wired connections are those made by the equipment or item manufacturer. Pre-wired connections may be indicated by drawing notes directed to the connecting line indicating that the connection is pre-wired.
10. Connections shown with solid lines outside of the symbol outline indicate connections which are required to be made by those making the installation.
11. The item symbols may be arranged in the manner, which provides the simplest, most diagrammatic form of representation. They may also be arranged to approximate their actual physical relationship with each other.
12. Information notes may be included for clarification and explanation as required.

2210.3 Requirements for Line-Type Connection Diagram:

1. Continuous lines to represent conductors between the terminals of one item and the terminals of another item shall be shown.
2. The lines shall be drawn horizontal or vertical wherever possible and as direct as practical. Double crossovers should be avoided.
3. Wire sizes shall be indicated in terms of American Wire Gage numbers. Insulation and cable composition shall be defined by the drawing note, which may call for the applicable specification. When a number of wires are the same size, it is recommended that a general note such as the following be included:
4. "ALL WIRES 12AWG (SPECIFICATION NO.) UNLESS OTHERWISE SPECIFIED."
5. Multi-conductor cables shall utilize ICEA/NEMA method 1 (CEA S-19-81 Table 5-2) color coding utilizing colored insulation and contrasting tracers for a total of 127 positive conductor codings. Spare wire shall be indicated.
6. Wire colors shall be indicated for wire other than that which is part of cable assembly information included on another drawing or specification. It is preferred that color designations be shown above the line to which they belong. Wire color designations shall be placed at both ends of a connection line unless the connection shown is short, in which case a single indication is sufficient. Wire colors shall be indicated by showing abbreviations shown below. Shielded wire shall be indicated.
PART II - CSU DESIGN STANDARDS  
CHAPTER 22 - ELECTRICAL DRAWINGS & DESIGN

Abbreviation  | Color
---|---
BK  | Black
W  | White (Neutral Conductor Only)
R  | Red
G  | Green
OR  | Orange
BL  | Blue
Y  | Yellow
BR  | Brown

2210.4 Requirements for Highway Line-Type Connection Diagram:

1. The highway line-type connection diagram is basically the same as the point-to-point line-type diagram with the exception that groups of inter-item connecting lines are merged into paths called highways instead of being shown for the entire run as individual lines.
2. From the device or component terminals, short lines or feed line are drawn perpendicular to the cable or highway line. The junction of the feed line with the highway line shall be indicated with an inclined or curved line. The curved or inclined line indicates the run direction in joining the cable or highway line.
3. Crossing of lines shall be avoided. If this is not possible, they should be looped at 90° with respect to each other.
4. Wire data on feed lines shall include wire destinations, color and wire type.
5. Feed-line destinations may be indicated by specifying function or other designations and terminal number of the component to be connected.
6. Wires which must be segregated for electrical reasons from other wires, or which are otherwise critical, shall be shown separately or run directly from terminal to terminal.
7. More than one cable or highway line may be used to facilitate indication of wire runs or to indicate grouping of particular wires into cable or harness assembles. A drawing note with the aid of a symbol, if necessary, shall identify the highways as being part of the same or different cable assembles.
8. Wire groupings may be shown as in interrupted line, identified with a symbol, and the destination grouping with the same symbol and letters or numbers.

2210.5 Requirements for Lineless-Type Connection Diagram:

1. Continuous connecting lines between items are omitted. Short spur lines from connectors, terminals, terminal boards, etc., shall be used in conjunction with item and item terminal designations to convey the connection information.
2. Destinations shall be indicated in terms of designators or other nomenclature established on the single-line and schematic diagrams and referred to in or near item symbols on the connection diagram.
3. These designations shall be followed by a dash number(s) or letter(s) to indicate to what terminal, connector, pigtail, lead, etc., they are to be connected. If the item description nomenclature is too long, it may be abbreviated.
4. One end of each wire or cable shall specify the wire size and type and be placed, preferably, above one of the spur lines, unless better indicated by note.
5. One end of each wire shall include its color code in the terms specified by Section 1910.3 and be placed above the spur line unless it may be better indicated by note.
6. If the wires for mating between item connections are furnished with items, they shall be labeled "PGT" (pigtails). In such cases the wire size and type may be omitted.

SECTION 2211 - FUNCTION DESIGNATIONS
2211.1 Definitions: Functional designations are words, abbreviations, or meaningful number or letter combinations, usually derived from the function of an item, and used on drawings, equipment, and instructional material to identify items of a complete control system or equipment in terms of function.

2211.2 General Requirements: Switchgear and control device designations shall be applied as outlined under definitions. In general, on one complete drawing or set of drawings, only one system of designations shall be used. When using functional designations on individual equipment, supplementary letters or numbers shall have one meaning only and the meaning shall be clearly designated in a device list on the drawing.

2211.3 Switchgear Designations: Switchgear designations are numbers that describe the functions performed by electric devices in switching circuits used in the generation, transmission, and distribution of electric power. Supplementary letters and numbers are used with the basic designation to permit positive identification of an item.

A device function number, with appropriate suffix letter or letters where necessary, shall be used to identify the function of each device in all types of partial automatic and automatic, and in many types of manual, switchgear. These numbers shall be used on drawings, in publications, and in specifications. In addition, for automatic switchgear, the number shall be placed on or adjacent to each device in the assembled equipment so that the device may be readily identified. Designations shall be in accordance with designations for Electric Power Switchgear Devices and Industrial Control Devices.

2211.4 Control Device Designations: Control device designations are letters used to identify the function of electric control devices on power utilization equipment. Suitable prefix numbers and letters are added to the basic designation to distinguish between devices performing similar functions.

The assignment of designations to devices on a specific equipment is governed solely by the function or functions performed by each device on a particular equipment and not by the type or nature of the device or its possible use for other functions in other equipment. Thus, the same type of device may perform different functions in different equipment or even in the same equipment. It may, therefore, be identified by different designations. Designations shall be in accordance with ANSI/IEEE C37.2 -1979, Electrical Power System Device Function.

SECTION 2212 - SYMBOLS FOR ELECTRICAL DRAWINGS

2212.1 Diagram Symbols: Electrical and Electronic Symbols for Diagrams are graphical symbols providing coverage for electrical and electronic diagrams. Correlation of symbols with parts lists, descriptions, or instructions may be established by means of reference and functional designations. Symbols shall be in accordance with American National Standards Institute ANSI – Y32.2, Graphical Symbols for Electrical and Electronics Diagrams. Notify the Project Manager of any inconsistency between the CSU Design Standard Symbols and the ANSI Standards.

2212.2 Plan Symbols: Symbols for Electrical Plans are graphical symbols that provide coverage for architectural and electrical layout drawings. Functional electrical and electronic symbols should be used to provide full coverage for these drawings. Symbols shall be in accordance with American National Standards Institute ANSI – Y32.9, Graphic Symbols for Electrical Wiring and Layout Diagrams used in Architecture and Building Construction.

2212.3 Labels: Labels for panelboards and electrical equipment shall designate the source location (“Fed from .”) and voltage. Panel names shall comply with the following conventions:

\[ X - Y - # - Z \]
SECTION 2213 – ELECTRICAL DESIGN

2213.1 General: Prior to commencing design, the Consultant shall study and be familiar with the CSU Construction Standards, Part III, Divisions 25 Electrical, 26 Telecommunications and 33 Utilities, along with all other parts of the CSU Construction Standards (Administrative, Design and Construction Standards), current edition, as posted on the Facilities Management website.

2213.2 Space and Clearance Responsibility: By submitting the documents for Bid, the Consultant certifies that space allocations for equipment specified is adequate and compliant with all code requirements, including clearance requirements and free of conflicting space requirements of all other trades.

2213.3 Load Data: The Electrical Engineer shall provide NEC load calculation and complete load data for use by Facilities Management as it becomes apparent during the design stage. Data shall include all connected and demand loads.

2213.4 Short Circuit Calculations and Coordination Study

1. The Electrical Engineer shall submit calculations of available fault current at all points within the electrical distribution system. Fault current calculations shall be based on the assumption of an infinite utility source at the primary side of the building transformer. Interrupt or withstand ratings that exceed the values determined in these calculations are required for all electrical equipment specified in the design. Minimum impedance values which correspond to those used in the calculations shall be included in the specifications for all transformers.

2. On service sizes larger than 600 amperes, provide service feeder device coordination studies for overcurrent and ground fault protective systems to assure selective tripping.

3. Series rating breakers are not permitted without prior approval from CSU Electrical Engineer.

4. Short circuit calculation and Coordination study shall be performed using the latest version of SKM Power Tools.

   a. The comprehensive method for short circuit calculation shall be used for systems 600V and below. A-fault shall be used for medium voltage systems.


5. Both the electronic .prj file and a hard copy shall be provided to CSU.

2213.5 Arc Flash Study

1. The Electrical Engineer shall submit calculations of available flash hazard energy in calories per centimeter squared at each piece of equipment in the electrical system down to branch panels. This study shall be done after the short circuit calculations and protective devices coordination study have been completed.

2. The arc flash study shall be performed using the latest version of SKM Power Tools.
a. The Arc Flash Study Options (Standard and Unit) shall be as follows:

1) The arc flash hazard analysis shall be performed according to the IEEE 1584 equations that are presented in NFPA70E, 2015 Annex D.4.

2) The flash boundary calculation adjustment shall be Use Incident Energy Equation to Calculate Boundary for Equipment Below 1kV.

3) Equipment Below 240V: Report Calculated values from Equations.

b. The Arc Flash Study Options (Fault Current) shall be as follows:

1) Use a Global Max Arcing Time of 2 sec for all voltages

2) Arcing Tolerances shall be:
   a. Low Voltage Open Air Low Tolerance: -15%
   b. Low Voltage in Box Low Tolerance: -15%

3) Pre Fault voltage shall be: No Load with Tap

4) Utility and Impedance Tolerances: Regular

5) Check: Transformer Tap and Transformer Phase Shift

6) Define Grounded as SLG/3P Fault>= 5%

7) Reduce Generator/Synch motor fault contribution to 300% of Rated current after 10 cycles
   a. Check: Apply to Generators
   b. Check: Recalculate Trip time using reduced current

8) Induction Motor Fault Contribution: Include for 5 cycles

9) Treat Fuses as: Specified in Library


c. The Arc Flash Study Options (Report Options) shall be as follows:

1) Report Option: Bus

2) Color One-Line: Bus

3) Device to Report in Labels and Summary View: Main Device

4) Report Options when Equipment Evaluation Failed: Report IE/PPE

5) Upstream Mis-Coordination Options:
   a. Check: Check Upstream devices for mis-coordination
b. Upstream Levels to check: 2

6) Cleared Fault Threshold: 80% of Total

7) Check: Auto update Arc Flash Results

8) Check Report PPE Others 1,2,3,4,5

9) Check: Report PPE Level

3. Arc Flash calculations shall be based on actual overcurrent protective device clearing time. Maximum clearing time will be capped at 2 seconds based on IEEE 1584-2002 section B.1.2. Where it is not physically possible to move outside of the flash protection boundary in less than 2 seconds during an arc flash event, a maximum clearing time based on the specific location shall be utilized.

4. Arc flash labels
   a. Provide a 4.75 in. x 7.75 in. thermal transfer type label of high adhesion material for each work location analyzed.
      i. Label material shall be gloss film (2.6 mil white polypropylene film with extreme water resistant gloss top coating)
      ii. Label laminate shall be UV resistant (1.42 mil clear polyester film with UV protection, providing resistance to moisture, chemicals, acids, weather and aging.
      iii. Label shall be printed by Leaping Lizards of Fort Collins, or equal.
   b. Label shall be “SKM Sample 05- Avery 6876- Portrait” template.
   c. Labels shall be installed on all new equipment with appropriate hazard and PPE levels identified.

END OF CHAPTER 22