IEEE-IAS Atlanta Section

CH2MHILL

# Electrical Drawing Preparation
# Single Lines and Grounding Plans



*Mark A. Sorrells, PE*

*May 20, 2013*

*msorrells.ee85@ieee.org*



# Electrical Drawing Preparation
# Single Lines

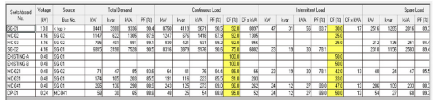
## Electrical Drawing Preparation
## Single Lines

- INPUTS:
  - P&ID's
  - Load List
  - Distribution Philosophy
  - Basis of Design
  - Layout Drawings



## Electrical Drawing Preparation
## Single Lines

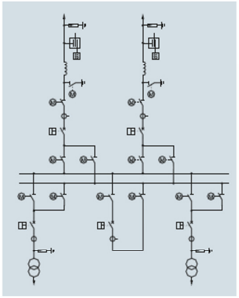
- P&ID's
  - Process Motor Loads
  - Process Heater Loads
  - Heat Tracing
- Load List
  - Non- Process Motors
    - HVAC
    - Air Compressors / Vacuum Pumps
  - Lighting
    - Indoor
    - Outdoor
  - UPS for Communications / Security / Fire Alarm



Heaters for Safety Showers

## Electrical Drawing Preparation
## Single Lines

- Distribution Philosophy
  - Voltage Level(s)
  - Distribution Scheme
  - Protection Scheme / Philosophy
  - Selectivity
- Basis of Design
  - Motor HP / Voltage Ranges
  - Motor Protection Philosophy
  - Lighting Voltage
- Layout Drawings
  - Location of Electrical Rooms & Transformers
  - Load Concentration(s)



Voltages: 13.8 (4.16) kV; 600V or 480V
NEMA C84.1-2011, IEC 60038

Distribution Scheme: Radial, Loop, Double-Ending

Protection: Fuses, Circuit Breakers, Resistance or Solid Ground
Standard Current ratings: NEC 240.6 Standard Ampere Ratings, IEC 60059 (logarithmic progression)

Motor Voltage Ranges: ½Hp single phase, 200 Hp maximum LV, >200 Hp MV (IEC HV)
Motor Protection: Fuses / MCP's / MCCB's. Overload Class 10, 20, 30
480V – 480/277 V or 480-208/120 for lighting and receptacle loads

Transformer Secondary: Bus Duct, Cable in tray, Cables underground



## Electrical Drawing Preparation
## Single Lines

- Use the proper ABBREVIATIONS.
- Follow the LEGEND sheet.
- Don't mix ANSI and IEC symbols for the same item type.
- Proper TERMINOLOGY (Ratings, Equipment)
- Indicate FUTURE expansion capability.
- Indicate normal operational mode (OPEN/ CLOSE) for all switching devices
- Provide a front VIEW.

## Electrical Drawing Preparation Single Lines (IEEE 141-1993 )

Include the following:

- Utility Supply System
  - Available SC current (including X/R ratio)
  - Line supply voltage
  - High-voltage protective devices and switches
  - Show the normal operating mode
  - Type(s) of relays



## Electrical Drawing Preparation Single Lines (IEEE 141-1993 )

- Transformers
  - Nameplate rating(s) (kVA and kV) and temperature rise
  - Cooling Method (ONAN, ONAF {AA, FA})
  - High-voltage winding voltage taps and winding connection (delta/wye)
  - Low-voltage winding voltage taps and winding connection (delta/wye)
  - Impedance and kVA base
  - Grounding scheme and ohmic value of neutral resistor(s) if used; show connections
  - Surge arrestors and capacitors (show switching if switched), and connections
  - Metering of utility supply, primary protective devices

IEEE C57.12.00-2010 - IEEE Standard for General Requirements for Liquid-Immersed Transformers
IEEE C57.12.01-2005 - Standard General Requirements for Dry-Type Distribution and Power Transformers

## Electrical Drawing Preparation
## Single Lines (IEEE 141-1993 )

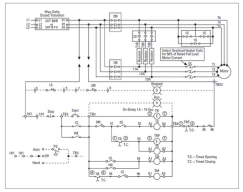
- Switchgear
  - Manufacturer(s), type, model, current rating, MVA class
  - Symmetrical interrupting current rating, and asymmetrical momentary/closing-and-latching current rating for main, tie, and feeder devices
  - Phase arrangement, voltage, ampacity, bracing of bus

When listing the AIC rating of switchboards and panelboards, show the minimum rating acceptable, do not round up to what is perceived as the next industry standard rating. Engineers often round up to one particular manufacturer's standards giving that manufacturer a competitive advantage during the biding phase.



## Electrical Drawing Preparation
## Single Lines (IEEE 141-1993 )

- Motor loads
  - List individual medium-voltage motors including HP/KW, RPM, and type (induction, synchronous)
  - Include powerhouse motors (chillers, compressors, etc.)
  - LV motors on MCC's: Categorize load by size(s) at a minimum
  - Indicate all VFD motors, RV starters



NEMA MG1-2011 Motors and Generators
IEC 60034 Series Rotating electrical machinery

## Electrical Drawing Preparation
## Single Lines (IEEE 141-1993 )

- Feeder cables
  - Number of feeders
  - Cable insulation and type
  - Installation design (conduit, IAC in tray, size of tray, number of cables in tray, etc.)
  - Nominal maximum current rating and basis
  - Cable callouts are consistent



No cable schedule on smaller jobs

Schedules (tabular format) where possible for ease of takeoff

3 #4AWG: Is it 3 – 1/c #4 or 1 – 3/c #4? Call out ground where used.



## Electrical Drawing Preparation
## Single Lines (IEEE 141-1993 )

- Other
  - Dedicated lighting loads
  - Special purpose loads, such as data processing and computer applications
  - Capacitor banks, including switching
  - Relay coordination and protective-device settings (on separate documentation)
  - Standby Generators

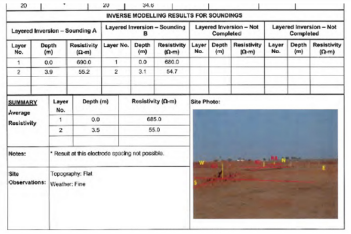
ANSI C37.2 Device #'s correct

# Electrical Drawing Preparation
# Grounding Plans



## Electrical Drawing Preparation
## Grounding Plans

- INPUTS:
  - Basis of Design
  - Ground Resistance Data
  - Grounding Calculations
  - Layout Drawings
    - Process Equipment (Large Motors, Tanks)
    - Electrical Rooms
  - Structural Drawings
    - Foundations
    - Columns



INVERSE MODELLING RESULTS FOR SOUNDINGS

| Layered Inversion – Sounding A | | | Layered Inversion – Sounding B | | | Layered Inversion – Not Completed | | | Layered Inversion – Not Completed | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Layer No. | Depth (m) | Resistivity (Ω-m) | Layer No. | Depth (m) | Resistivity (Ω-m) | Layer No. | Depth (m) | Resistivity (Ω-m) | Layer No. | Depth (m) | Resistivity (Ω-m) |
| 1 | 0.0 | 690.6 | 1 | 0.9 | 680.0 | | | | | | |
| 2 | 3.9 | 55.2 | 2 | 3.1 | 54.7 | | | | | | |

| SUMMARY | Layer No. | Depth (m) | Resistivity (Ω-m) |
|---|---|---|---|
| Average Resistivity | 1 | 0.0 | 685.9 |
| | 2 | 3.5 | 55.9 |

Notes: * Result at this electrode spacing not possible.

Site Observations: Topography: Flat; Weather: Fine

Site Photo:



Ground Grid Summary Report

| Rg Ground Resistance ohm | GPR Ground Potential Rise Volts | Maximum Touch Potential | | | | | Maximum Step Potential | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tolerable Volts | Calculated Volts | Calculated % | Coordinates (m) X | Coordinates (m) Y | Tolerable Volts | Calculated Volts | Calculated % | Coordinates (m) X | Coordinates (m) Y |
| 0.636 | 631.9 | 326.2 | 436.8 | 133.1 | 23.6 | 62.5 | 841.8 | 127.7 | 15.2 | 230.10 | 10.77 |

| | | | |
|---|---|---|---|
| Total Fault Current | 1.800 kA | Reflection Factor (K): | 0.322 |
| Maximum Grid Current: | 0.994 kA | Surface Layer Derating Factor (Cs): | 1.231 |
| | | Decrement Factor (Df): | 1.001 |

Grounding vs Earthing

## Electrical Drawing Preparation
## Plan Drawings

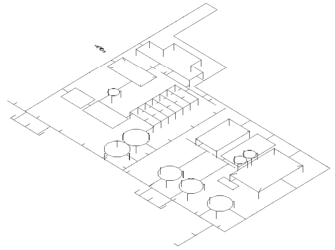
- Overall Plan 
  - North ARROW
  - SCALE: Consistent, include graphic bar 
  - Match lines
  - Reference drawings
  - TITLE Block
  - Follow LEGEND Sheet
  - General notes: Generic to Specific
  - COLUMN line numbers 
  - General arrangement of process equipment

Drawing number, title block name match the master drawing list



## Electrical Drawing Preparation
## Grounding Plans

- Facility Ground System
  - Primary
    - Earth Electrode Subsystem
    - Fault Protection Subsystem
    - Lightning Protection Subsystem
    - Signal Reference Subsystem
  - Secondary
    - Static Protection
    - Cathodic Protection
    - Safety (Maintenance) Grounding



## Grounding Plans
## Facility Ground System

- Primary
  - Earth Electrode Subsystem

    network of interconnected rods, wires, pipes, or other configuration of metals which establishes electrical contact between the elements of the facility and the earth[1]

  - Fault Protection Subsystem

    ensures that personnel are protected from shock hazard and equipment is protected from damage or destruction resulting from faults that may develop in the electrical system[1]



## Grounding Plans
## Facility Ground System

- Primary
  - Lightning Protection Subsystem

    provides a nondestructive path to ground for lightning energy contacting or induced in facility structures[1]

  - Signal Reference Subsystem

    The purpose of a signal reference ground is to provide a low impedance signal reference system for electronic equipment to minimize noise-induced voltages and thereby reduce equipment malfunctions[2]

## Grounding Plans
## Facility Ground System

- Secondary
  - Static Protection
    static ground is a connection between a piece of equipment and earth to drain off static electricity charges before they reach a sparking potential[2]
  - Cathodic Protection
    Cathodic protection is a method to reduce corrosion by minimizing the difference in potential between anode and cathode.[3]
  - Safety (Maintenance) Grounding
    Temporary grounding is provided to protect workers engaged in deenergized electric line maintenance.[4]

Safety Grounding – Step & Touch Potential



## Electrical Drawing Preparation
## Grounding Plans

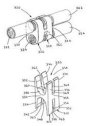
- Facility Ground System
  - Primary
    - Earth Electrode Subsystem IEEE 142-2007 (Green Book)
    - Fault Protection Subsystem NFPA 70 (NEC®)
    - Lightning Protection Subsystem NFPA 780
    - Signal Reference Subsystem IEEE 1100-2005 (Emerald Book)
  - Secondary
    - Static Protection NFPA 77
    - Cathodic Protection NACE SP9999
    - Safety (Maintenance) Grounding NFPA 70E, IEEE C2

Extra precaution in Hazardous Areas

## Electrical Drawing Preparation
## Grounding Plans - Earth Electrodes

- IEEE 142-2007 (Green Book)
  - Chapter 4 Connection to earth
    - 4.1 Resistance to earth (Table 4-5—Formulas for the calculation of resistances to ground)
    - 4.2.3 Concrete encased electrodes
    - 4.3.1 Choice of rods
    - 4.3.3 Connecting to electrodes
    - 4.4 Measurement of resistance to earth
  - Chapter 1 System grounding
  - Chapter 2 Equipment grounding
  - Chapter 3 Static and lightning protection grounding
  - Chapter 5 Electronic equipment grounding

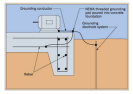




## Electrical Drawing Preparation
## Grounding Plans - Fault Protection

- NFPA 70 (NEC®) ARTICLE 250 Grounding and Bonding
  - II. System Grounding
    - 250.20 Alternating-Current Systems to Be Grounded
    - 250.24 Grounding Service-Supplied Alternating-Current Systems
    - 250.30 Grounding Separately Derived Alternating-Current Systems
  - III. Grounding Electrode System and Grounding Electrode Conductor
    - 250.50 Grounding Electrode System
    - 250.52 Grounding Electrodes
    - 250.66 Size of Alternating-Current Grounding Electrode Conductor
  - V. Bonding
    - 250.106 Lightning Protection Systems

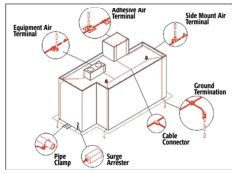
(B) Alternating-Current Systems of 50 Volts to 1000 Volts.
Alternating-current systems of 50 volts to less than 1000 volts that supply premises wiring and premises wiring systems shall be grounded under any of the following conditions:
(1) Where the system can be grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts
(2) Where the system is 3-phase, 4-wire, wye connected in which the neutral conductor is used as a circuit conductor
(3) Where the system is 3-phase, 4-wire, delta connected in which the midpoint of one phase winding is used as a circuit conductor

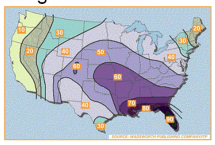
All grounding electrodes as described in 250.52(A)(1) through (A)(7) that are present at each building or structure served shall be bonded together to form the grounding electrode system.

(1) Metal Underground Water Pipe
(2) Metal Frame of the Building or Structure
(3) Concrete-Encased Electrode
(4) Ground Ring
(5) Rod and Pipe Electrodes
(6) Other Listed Electrodes
(7) Plate Electrodes

## Electrical Drawing Preparation
## Grounding Plans – Lightning Protection

- NFPA 780 Standard for the Installation of Lightning Protection Systems
  - Chapter 4 Protection for Ordinary Structures
    - 4.2 Materials
    - 4.7.4 Rolling Sphere Method
    - 4.9.10 Number of Down Conductors
    - 4.13 Grounding Electrodes
    - 4.14 Common Grounding
    - 4.16.4 (Structural Metallic Systems) Grounding Electrodes
  - Annex L Lightning Risk Assessment



Structures exceeding 76 m (250 ft) in perimeter shall have a down conductor for every 30 m (100 ft) of perimeter or fraction thereof.

Ground rods shall be not less than 12.7 mm (1⁄2 in.) in diameter and 2.4 m (8 ft) long

This interconnection shall include lightning protection, electric service, communications, and antenna system grounds, as well as underground metallic piping systems.

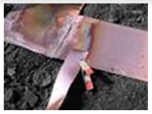
Grounding electrodes shall be connected to steel columns around the perimeter of the structure at intervals averaging not more than 18 m (60 ft).

5.4 Metal Towers and Tanks. Metal towers and tanks constructed so as to receive a stroke of lightning without damage shall require only bonding to grounding electrodes as required in Chapter 4, except as provided in Chapter 7. pi(R)^2 > 250 for 17.84 ft diameter



## Electrical Drawing Preparation
## Grounding Plans – Signal Reference

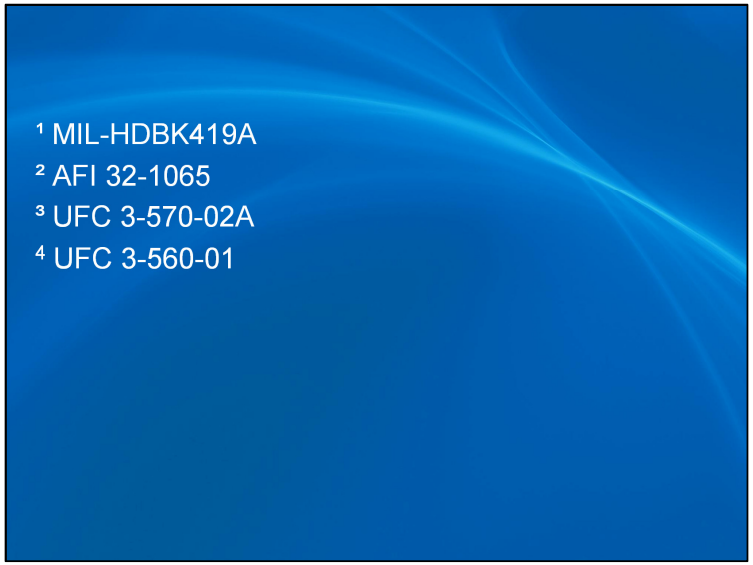
- IEEE 1100-2005 (Emerald Book)
  - Chapter 3 General needs guidelines
    - 3.3 Grounding considerations
  - Chapter 8 Recommended design/installation practices
    - 8.2 Equipment room wiring and grounding
    - 8.5 Grounding considerations
    - 8.6 Lightning/surge protection considerations
  - Chapter 9 Telecommunications, information technology, and distributed computing
    - 9.9 Grounding and bonding



Recommended practice is that all grounding and bonding connections for metal piping systems be noted on the appropriate mechanical and electrical drawings.

UL 96, the Standard for Safety of Lightning Protection Components
UL 96A, the Standard for Installation Requirements for Lightning Protection Systems

NFPA 75-2013 Standard for the Fire Protection of Information Technology Equipment
UL 1950 – 60950 3RD Edition UL Standard for Safety Safety on Information Technology Equipment


[1] MIL-HDBK419A
[2] AFI 32-1065
[3] UFC 3-570-02A
[4] UFC 3-560-01