Substation Grounding

Presented by: **Bruce Kayser, PE**

785-633-5756

Assisted by Danny Seele

Introduction

- Bruce Kayser, PE
  - BSEE from KSU in 1989
  - Licensed Professional Engineer in KS
  - Employed by ElectriComm, Inc.
    - Kansas Electric Power Cooperative, Inc.
    - Wolf Creek Nuclear Operating Corp
    - Kansas Power and Light (Westar Energy)

Substation Grounding

ElectriComm

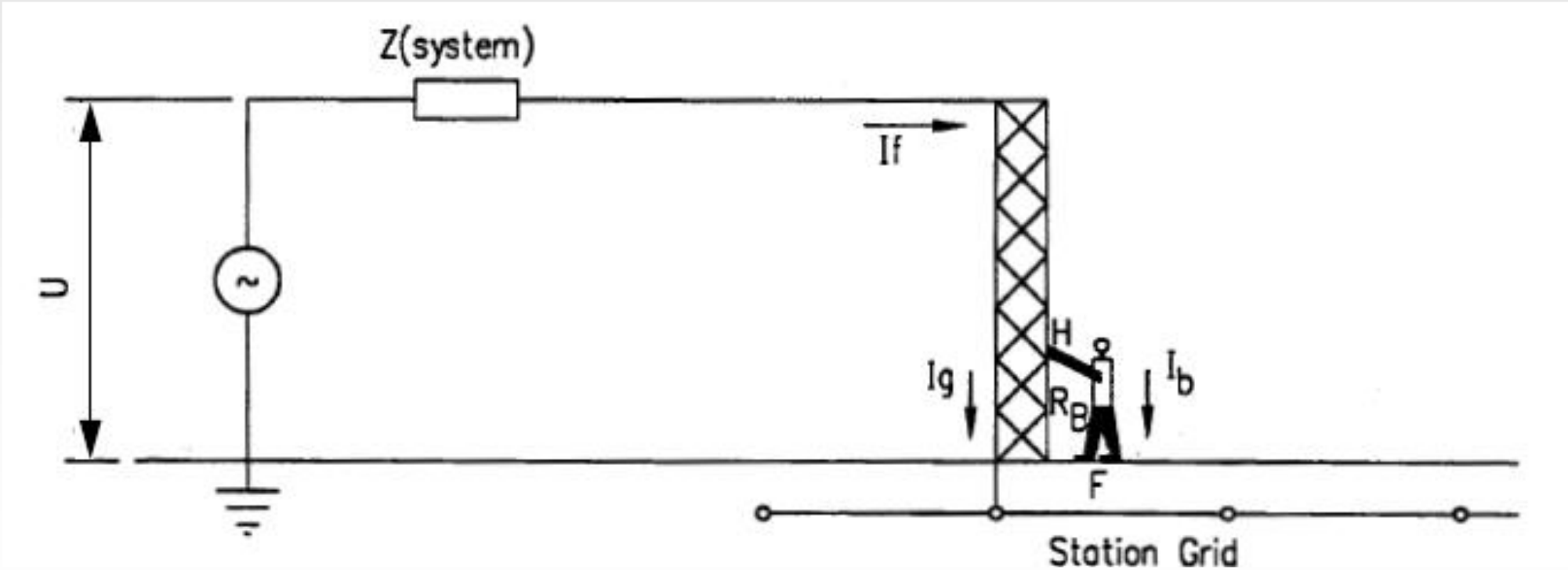
Substation Grounding

AGENDA

- Why use Grounding System?
- Design of Grounding System
- Grounding Installation - Design thru Test
- In Service Testing and Inspection
- Questions, Discussions, War Stories, etc.

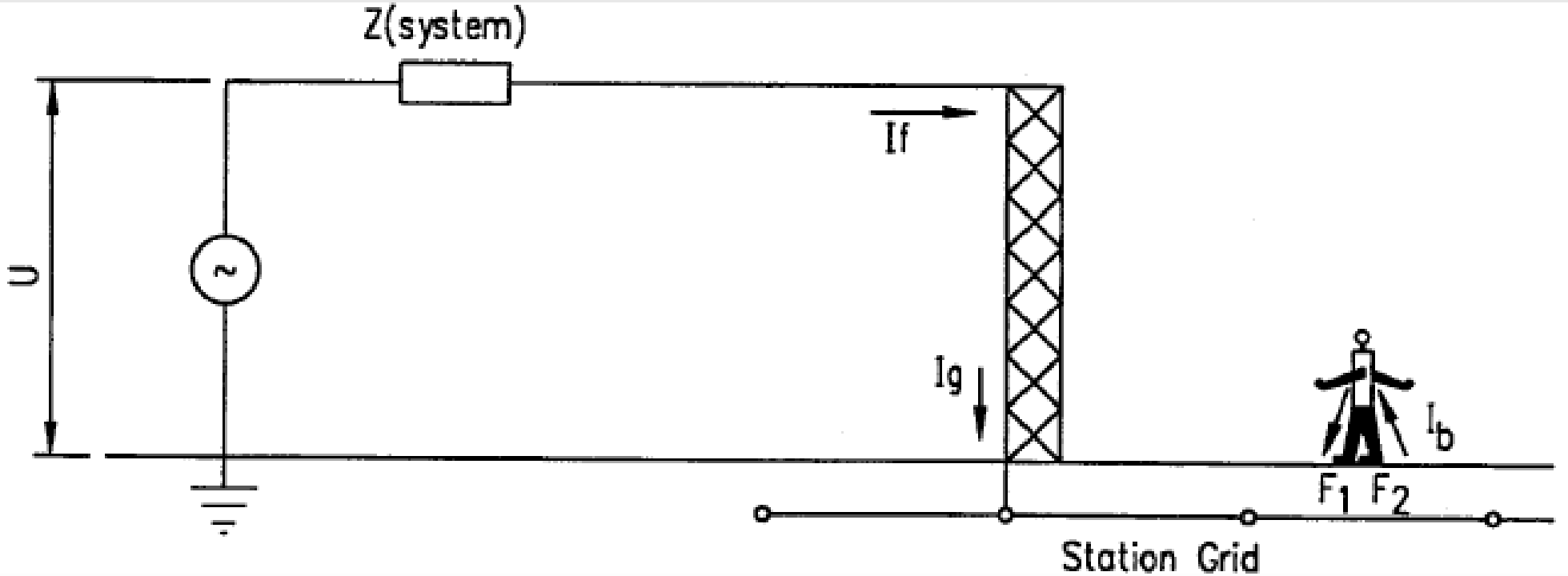
Why Use Grounding System

- Protection of Substation Workers
  - Touch Potential



Why Use Grounding System

- Protection of Substation Workers
  - Step Potential



Why Use Grounding System

- Protection of General Public
  - Step Potential (walking near sub)
  - Touch Potential (touching sub fence)
- Proper Operation of System Protection
  - Sufficient Current Ph-G Fault to Trip Relay

Design of Grounding System

- IEEE Standard 80
  - Design Considerations
    - Human Body Resistance (defined IEEE 80)
    - Soil Resistance (Measured)
    - System Impedance (Calculated)
    - Size of Grid Conductor (Determined)
    - Size of Equipment Ground Conductor (Determined)
    - Grid Pattern (Determined)
    - Seasonal Wet/Dry Conditions (Affects Design)

Design of Grounding System

- Human Body
  - Current Through Body
    - 1mA – Threshold of Detection
    - 1-6mA – Let Go Range – Unpleasant but able to control muscles.
    - 9-25mA – Painful and may be unable to Let Go due to loss of muscle control.
    - 60-100mA – Ventricular Fibrillation (heart stoppage).

Design of Grounding System

- Human Body
  - Body Resistance is 1000 Ohms for IEEE 80 Assumptions. (H-H, H-F, F-F)
  - At 60-100mA, using V=IR, the voltage to stop the heart can be 60 to 100 volts.

Design of Grounding System

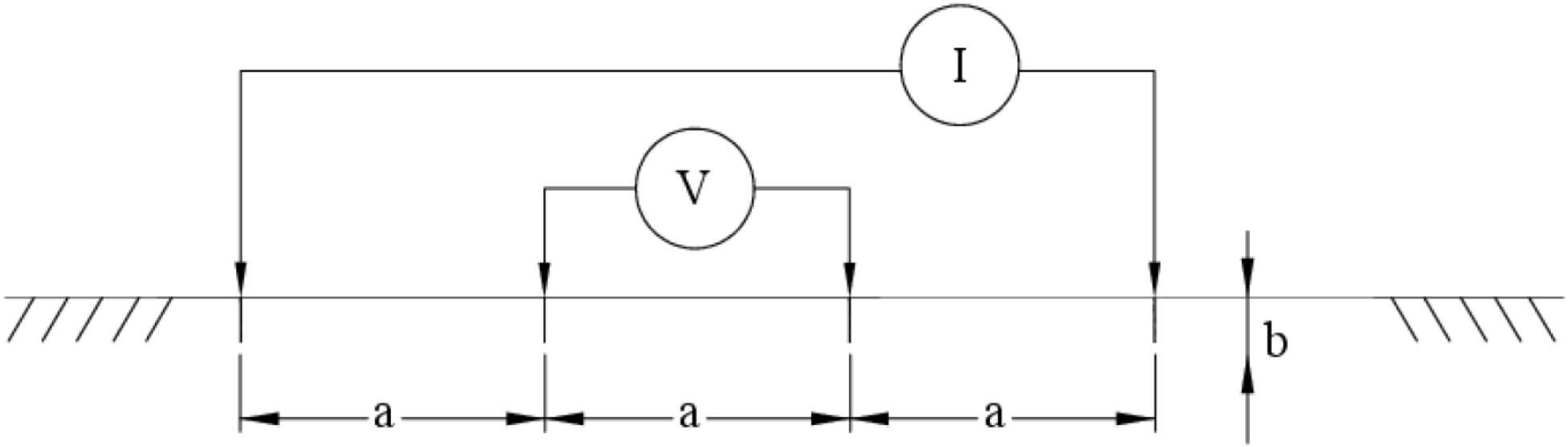
- Soil Resistance
  - Before the Ground Grid Design is started, the soil resistance needs to be measured. This is typically done during the Geotechnical Survey.
  - This soil resistivity is an important input to determining step and touch potential. This will affect ground grid spacing and depth of the grid.

Design of Grounding System

- Soil Resistance
  - This is measured by installing 4 probes in the substation area all in a straight line. A current source is used to inject current on the outer two probes and the voltage is measured on the inner two probes. The Ohms-meters can then be calculated.

Design of Grounding System

- Soil Resistance



Design of Grounding System

- System Impedance
  - What is upstream serving the site?
  - The system impedance is used to determine the maximum available fault current and also the X/R ratio to determine the asymmetrical fault current and decay rate.

Design of Grounding System

- Detailed Design
  - The aforementioned items are used to determine proper conductor size for ground grid, equipment ground tails, ground grid spacing, ground rod locations, and ground grid depth.
  - This is typically analyzed using software. The details of the design are outside of this presentation.

Design of Grounding System

- Gravel is an important design consideration for step potentials.
- Gravel acts somewhat like an insulator.
- It is recommended to use a larger diameter rock without fines. Fines will hold moisture longer after a rain.
- Some utilities will not energize substation until rock is placed.

Grounding Installation

- SEQUENCE
  - Determination of Site Area
  - Soil Resistivity Measurement (Geotech)
  - Determine System Impedance
  - Detailed Ground Grid Design
  - Install the Ground Grid (after foundations,conduit)
  - Measure Ground Grid Resistance to Earth prior to any outside connection to ground grid area. *Static or Shields can not connect to station steel.*
  - Complete Substation Construction
  - Measure point to point resistance

Grounding Installation

- IEEE Standard 81 – Testing Methods
- Two Tests Associated with Ground Grid after Design:
  - Measure Ground Grid Resistance to Earth prior to any outside connection to ground grid area.
  - Measure point to point resistance

Grounding Installation

- Measure Ground Grid Resistance to Earth prior to any outside connection to ground grid area.

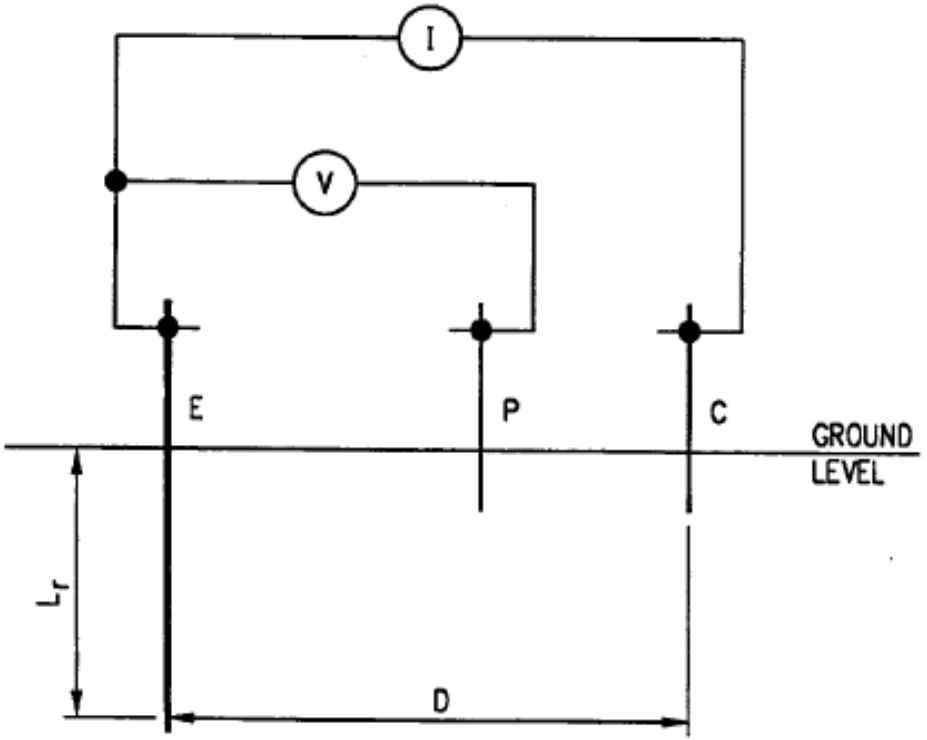
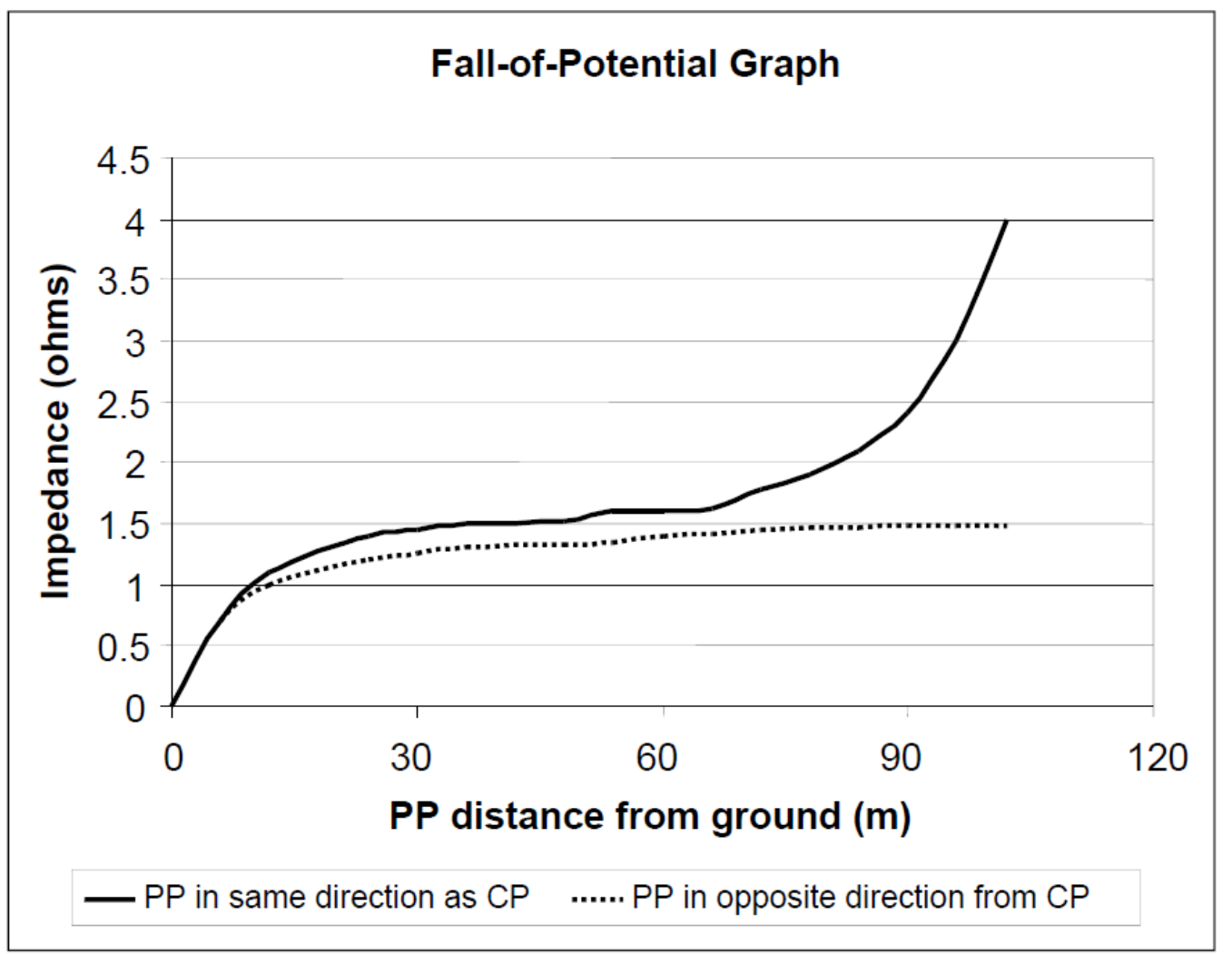


Figure 20—Circuit diagram for three-pin or driven-ground rod method

Grounding Installation

- 

Grounding Installation

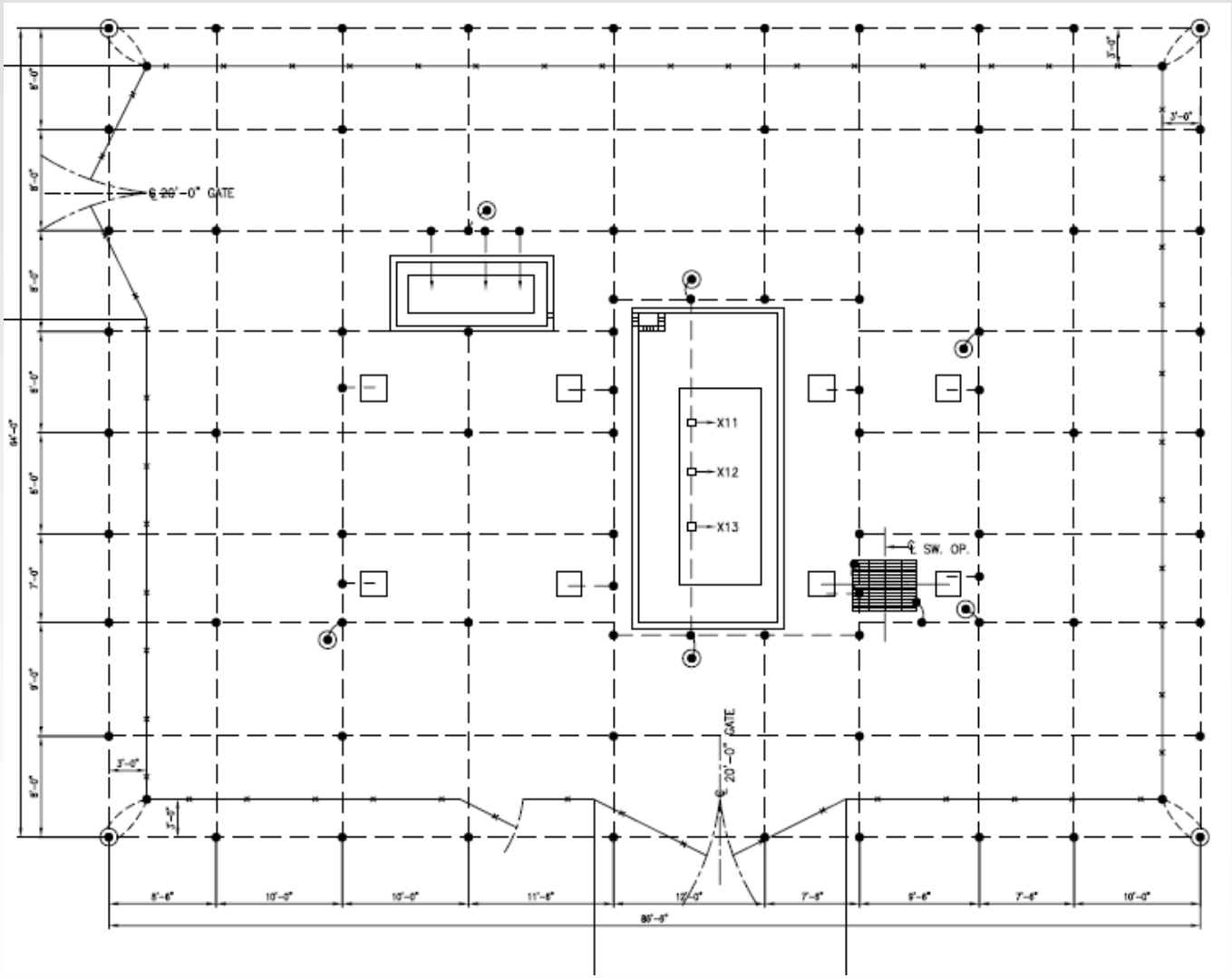
- The fall of potential test can only be performed prior to external connections to the substation.
- Items such as powerlines, railroad tracks, UG tanks, buried piping can affect the measurements.
- Switch Station and Large Substations <1 Ohm, Small Substations <5 Ohms

Grounding Installation

- Measure point to point resistance
  - Use a 100 amp Ductor or DLRO to measure resistance starting with two equipment tails and always measure relative to a measured tail. So, you only move one probe at a time.
  - An internal threshold developed from many years of testing experience – reading should be less than 3000 microOhms for normal tails and 5000 microOhms for fence grounding tails.

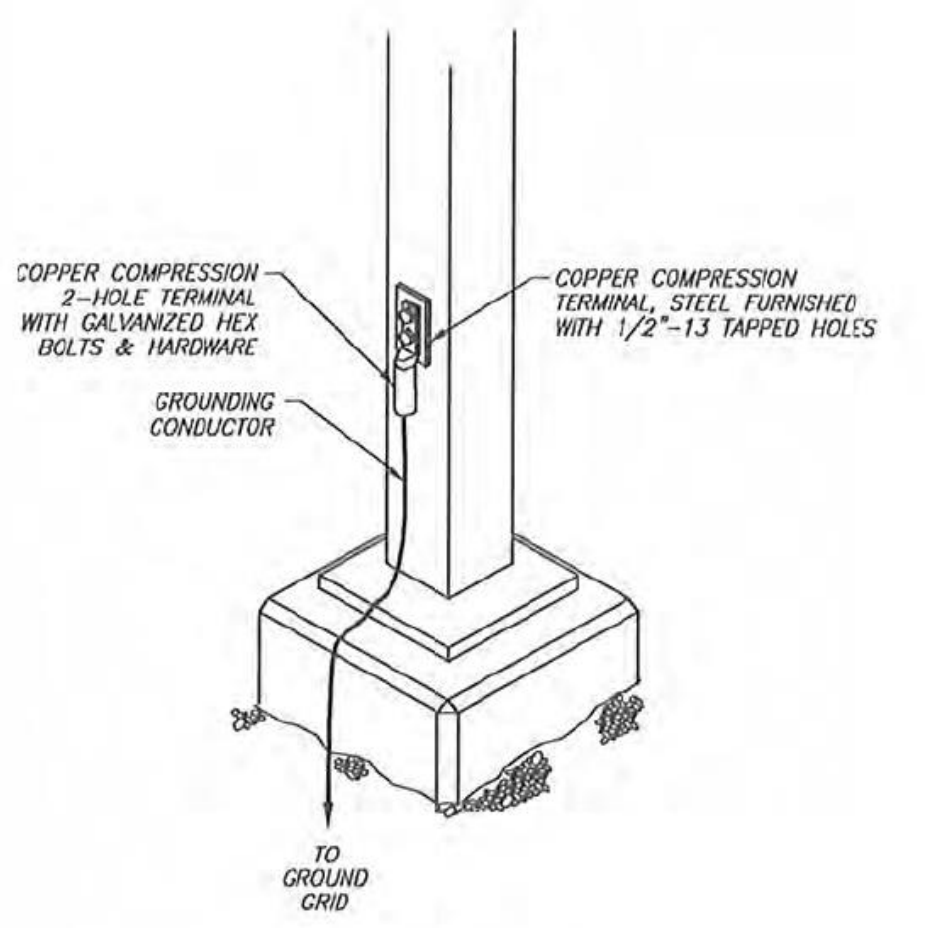
Grounding Installation

- Gnd Grid



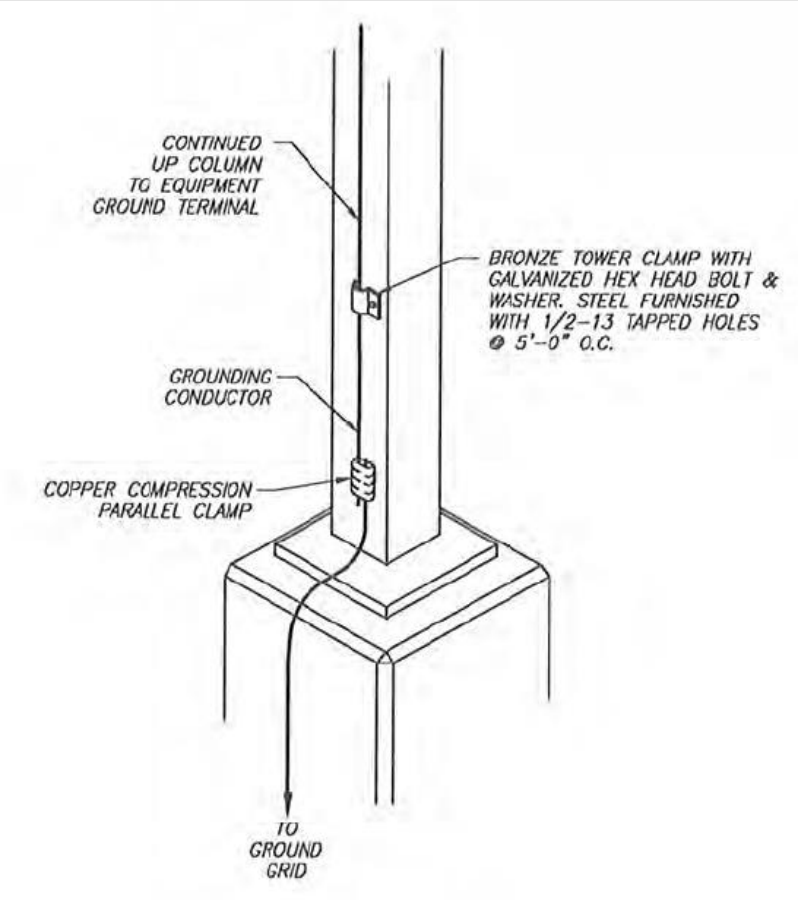
Grounding Installation

- Grounding Examples



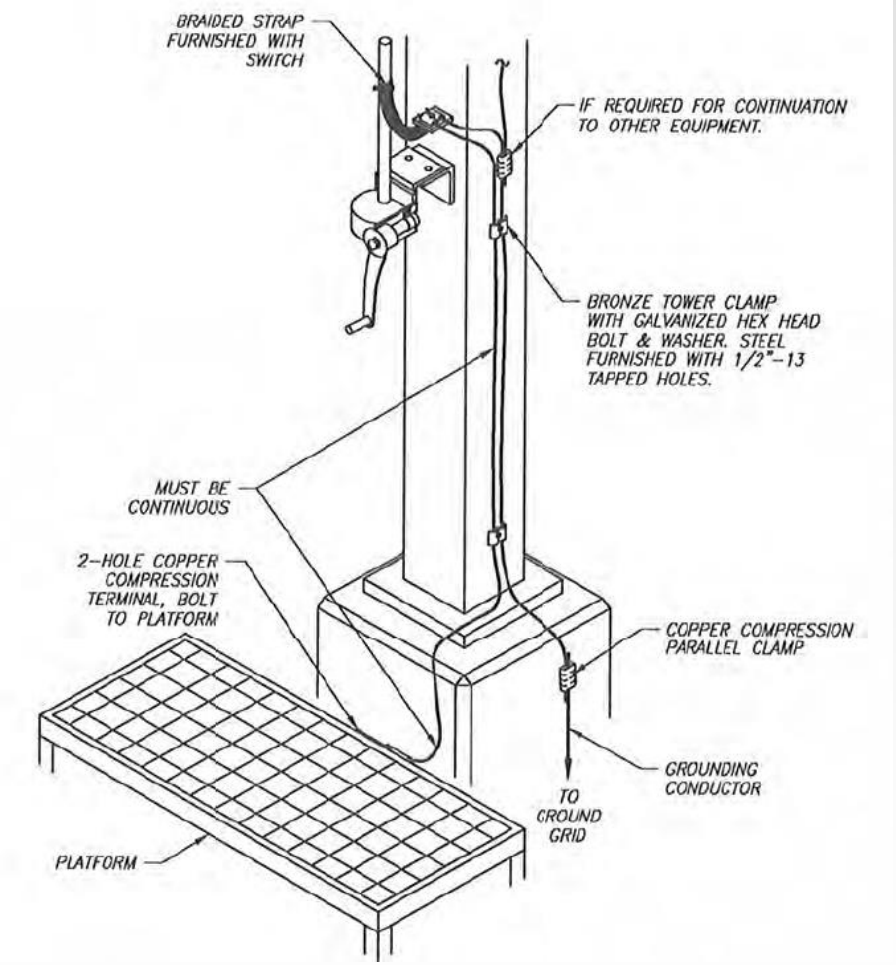
Grounding Installation

- Grounding Examples



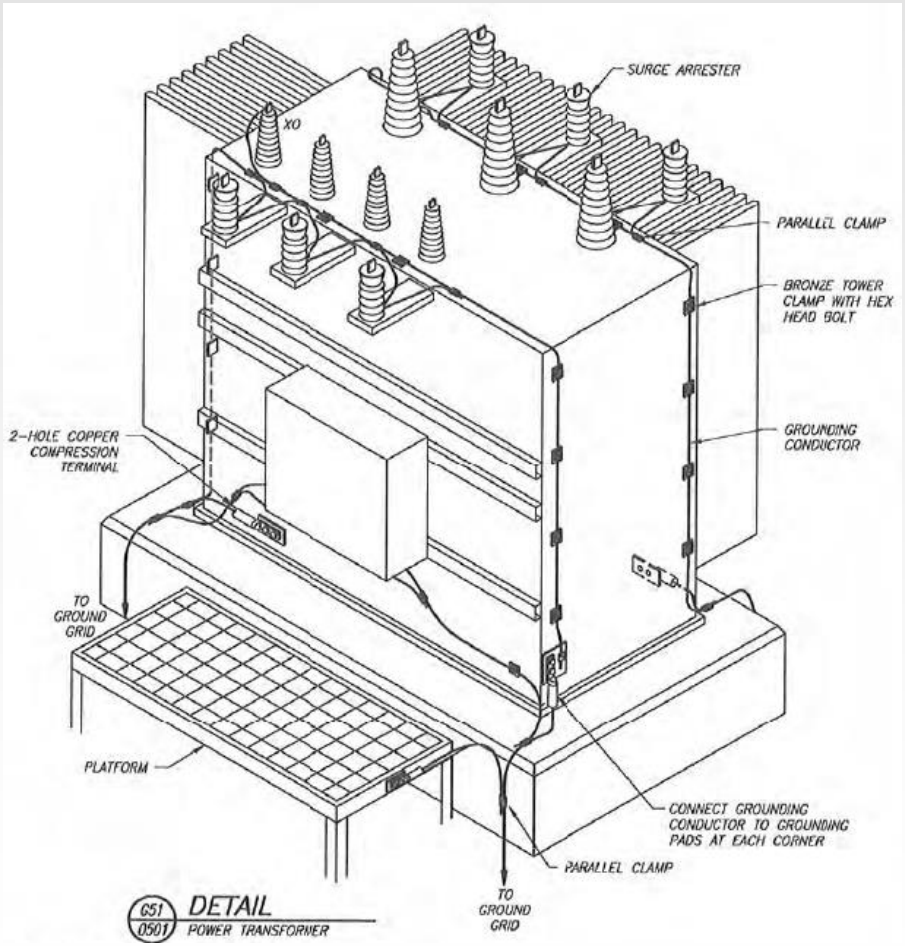
Grounding Installation

- Grounding Examples



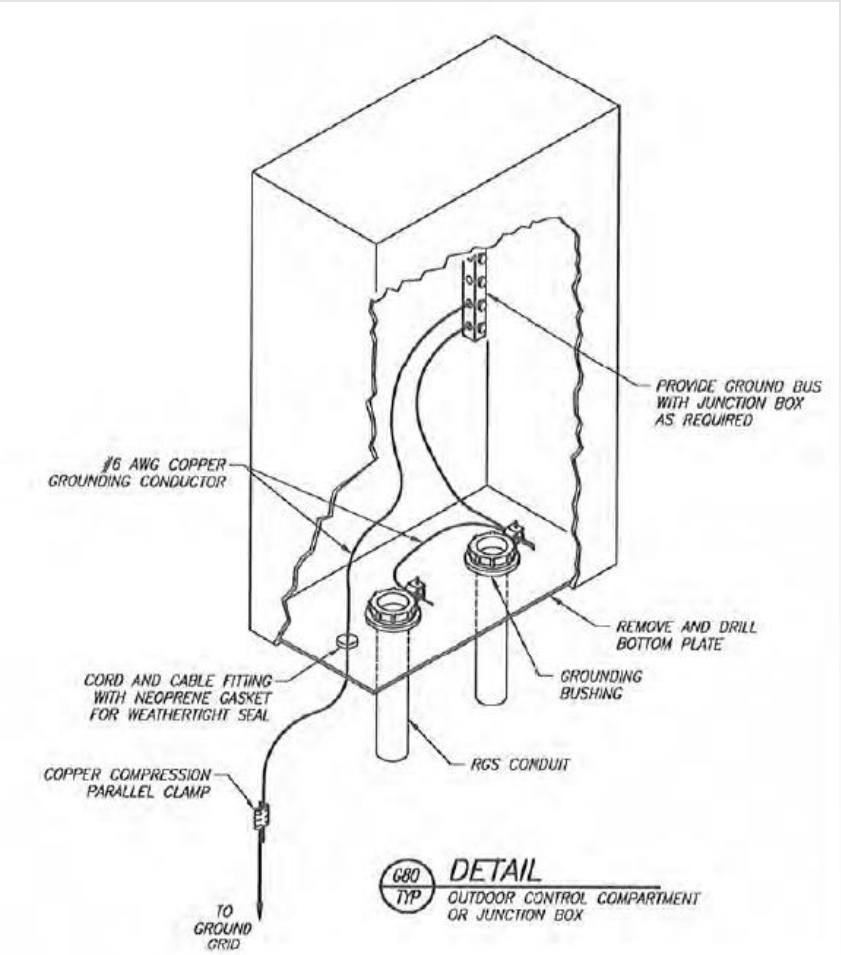
Grounding Installation

- Grounding Examples



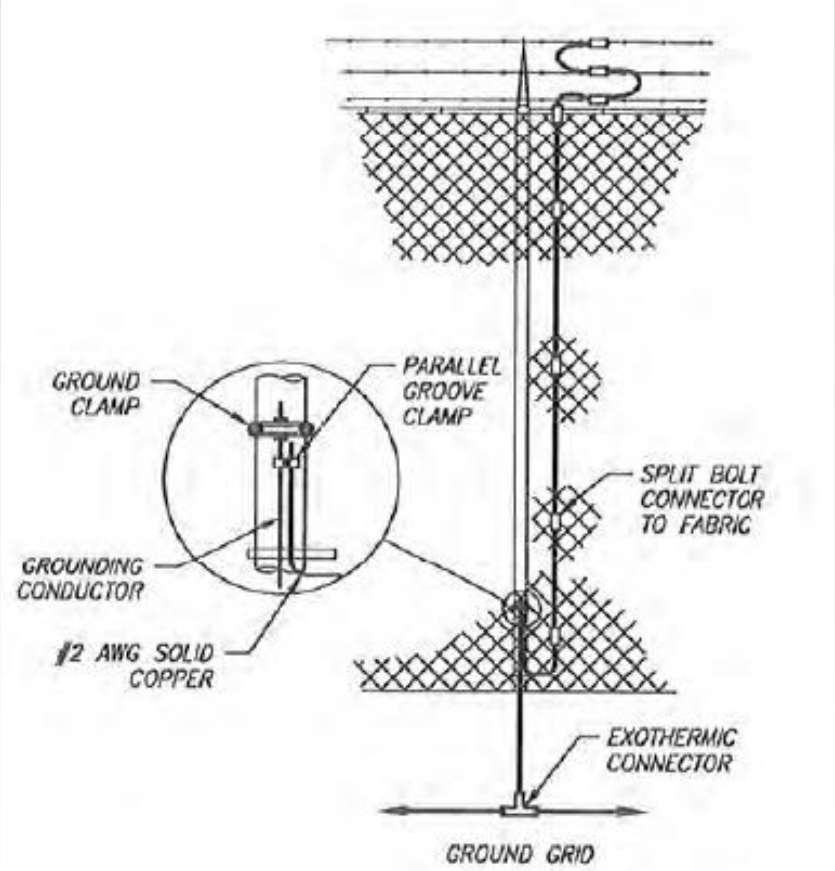
Grounding Installation

- Grounding Examples



Grounding Installation

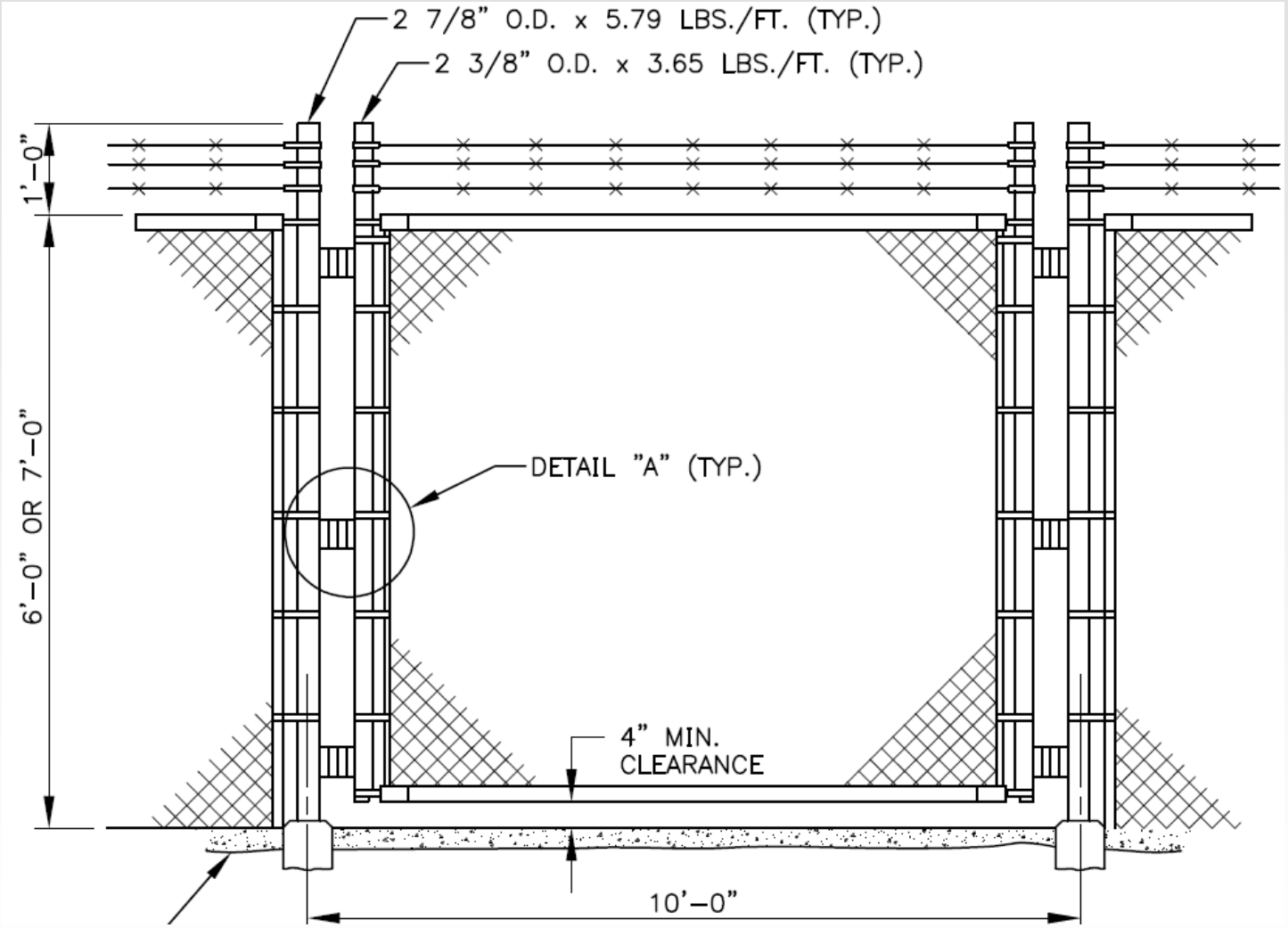
- Grounding Examples



Grounding Installation

- Ground System Extensions…
  - Do not extend a substation fence or connect to a substation fence and extend outside of the ground grid. This extends the need for touch potential grounding.
  - If you need to attach a fence to the substation fence, then use an insulated section between the fences.

Grounding Installation



Inservice Testing

- Can’t perform Fall Potential Test due to power lines and shield wires exiting substation.
- Measure point to point resistance

In-Service Testing and Maint.

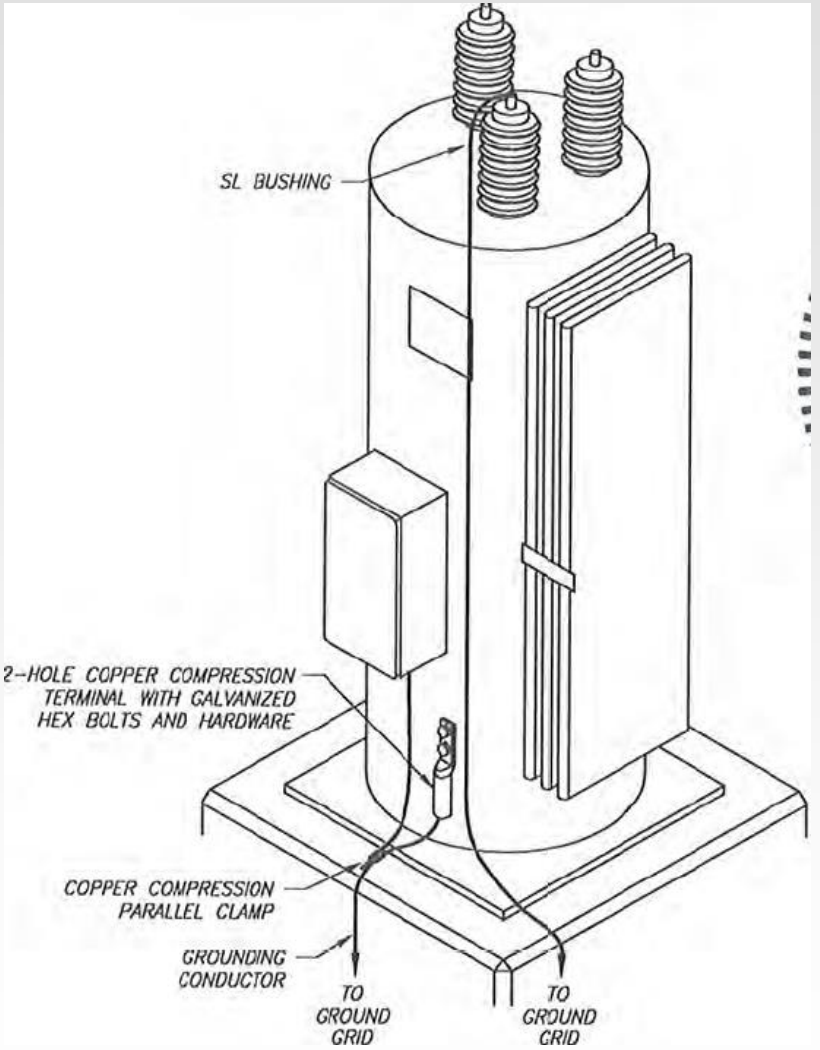
- Can’t perform Fall Potential Test due to power lines and shield wires exiting substation.
- Measure point to point resistance
  - Poor or Loose connections
  - Broken or cut wires

In-Service Testing and Maint.

- IF Ground Grid is Unknown
  - Use cable locator to locate ground grid.
  - Dig at sample of intersections and make sure below grade connections are used.
  - Measure point to point resistance.
  - Document wire sizes of grid and tails.
  - Consider having an engineer reverse engineer to make sure adequate.

Operation Issues

- Regulator issues
  - Steps a lot
  - Unstable
  - Might be a bad connection below grade.



Operation Issues

- If you need to cut a grid wire, install a jumper around the area you plan to cut. If the conductor is a tap to the XO bushing on a transformer or to the SL bushing on a regulator, dangerous voltage will occur when cut unless a jumper is installed first.

Operation Issues

- Connection outside substation. Be very cautious of extending the ground grid outside the substation (including a 120 or 240 volt circuit) due to Transferred Potential.
- This can create a remote touch potential hazard.
- Wind Farm server room on remote office.

Questions ?

- My Questions:
  - Has anyone found any ground grid issues?
  - Has anyone experienced step or touch potential voltages?
- Questions, Discussions, War Stories, etc.
- THANK YOU!!