Grounding & Bonding

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ERICO, Inc.

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Learning Objectives

At the end of this presentation you will be able to:

- Discuss the basics of electrical grounding and bonding.
- Discuss electrical engineering principles and relevant specifications.
- Discuss the basic design criteria for grounding systems.

Outline

- **Basic Electricity and Materials**
- **Utility Grounding**
- **C & I – Residential Grounding**
- **Telecommunications Systems Considerations**

Purpose of System Grounding

System Grounding: The intentional connection of a phase or neutral conductor to EARTH for the propose of controlling the voltage to EARTH or GROUND within predictable limits. It also provides for a flow of current that will allow detection of an unwanted connection between system conductors and ground which may instigate operation of automatic devices to remove the source of voltage. The control of voltage also allows reduction of shock hazard to person who might come in contact with live conductors.

IEEE 142-1991 (Green Book)

Purpose of Grounding

- Limit potential difference of neutral for system stability
- Allow for operation of relays and system protections devices
- Personnel safety

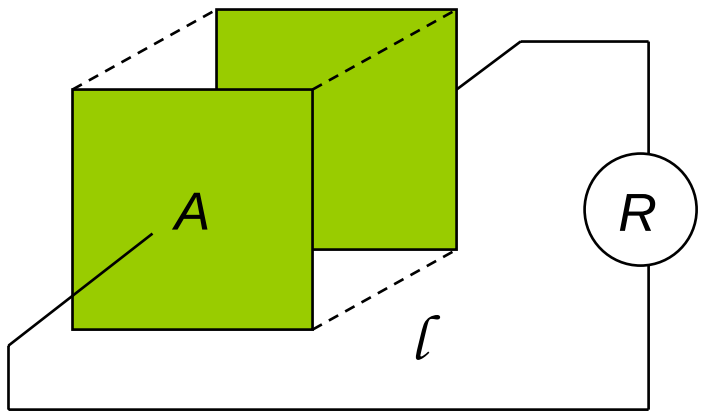
This is different from most grounding presentations; if you do the first two, you will get **safety** for free.

Basic Electrical Theory
Resistivity

Resistivity is the intrinsic property of a material to impede the flow of electrical current. It is the resistance factored by the length and cross sectional area. It is also referred to as volume resistivity.

$$\rho = \frac{RA}{l}$$

$$\rho = \frac{\Omega m^2}{m} = \quad \Omega m$$



Volume Resistivity of Materials

10^{-8} 10^{-2} 10^{2} 10^{4} 10^{12}

Metals Soils Wood Insulators

All in Ωm

SOIL RESISTIVITY

Loam	1 to 50 ohm-m
Clay	20 to 100 ohm-m
Sand & Gravel	50 to 1000 ohm-m
Surface Limestone	100 to 10,000 ohm-m
Shale	5 to 100 ohm-m
Sandstone	20 to 2000 ohm-m
Granites, Basalt	10,000 ohm-m
Slates	10 to 100 ohm-m

IMPEDENCE

Impedence：is the sum (and much more complex mathematical operations) of a circuit resistance elements and the REACTANCE which is caused by inductors and capacitive elements in the circuit. IT IS AFFECTED BY FREQUENCY *f* in Hz. Transients or faults in electrical systems look like very high frequency events, not 60 hz.

Inductive Reactance

$$X_L = L\omega$$

$$\omega = 2\pi f$$

Capacitive Reactance

$$X_C = \frac{1}{C\omega}$$

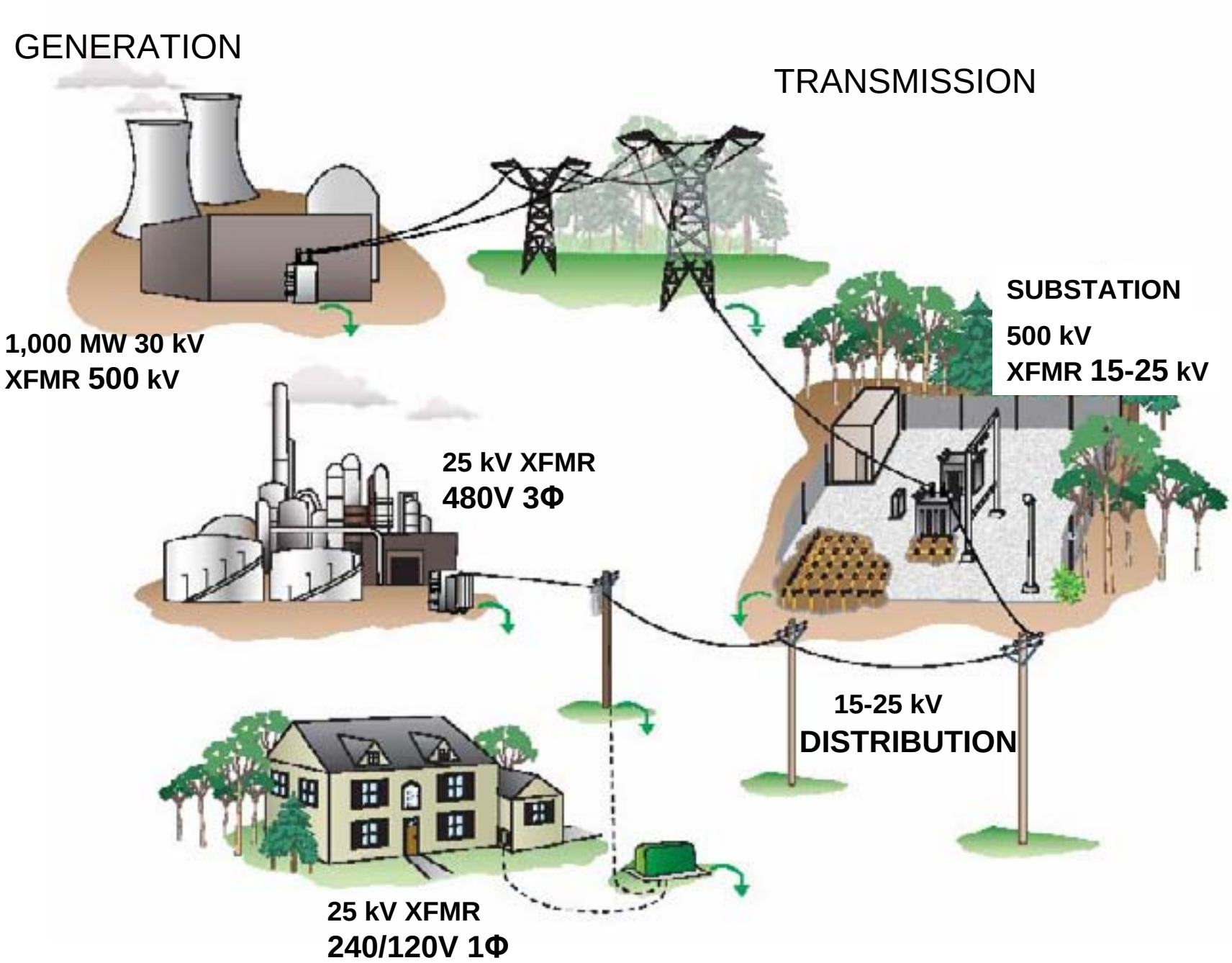
ELECTRICAL SYSTEMS - TRANSIENTS

- **ELECTRICAL SYSTEM**
  - Generators, Transformers, and Utilization devices
  - Use the earth as a REFERENCE for system stability
  - The **EARTH is not a destination** of currents
  - The System Neutral is the destination for currents
  - Earth is sometimes a conductor during transients

- **NON SYSTEM TRANSIENTS**
  - Lightning is a Non System Transient
  - The **EARTH IS a destination** for currents and they are LARGE MAGNITUDE currents.

UTILITY ELECTRICAL SYSTEM

- **GENERATION**
  - Transforms mechanical energy to electricity
    P = 1,300MW @ 30 kV
- **TRANSMISSION**
  - P= V x I
  - Losses are proportional to I so V is increased, Iis decreased for efficient transmission. V >130kV
- **DISTRIBUTION**
  - Requires lower voltage for practical handling of components. Substations transform voltage to 15-25kV and then to 480 or 240/120V

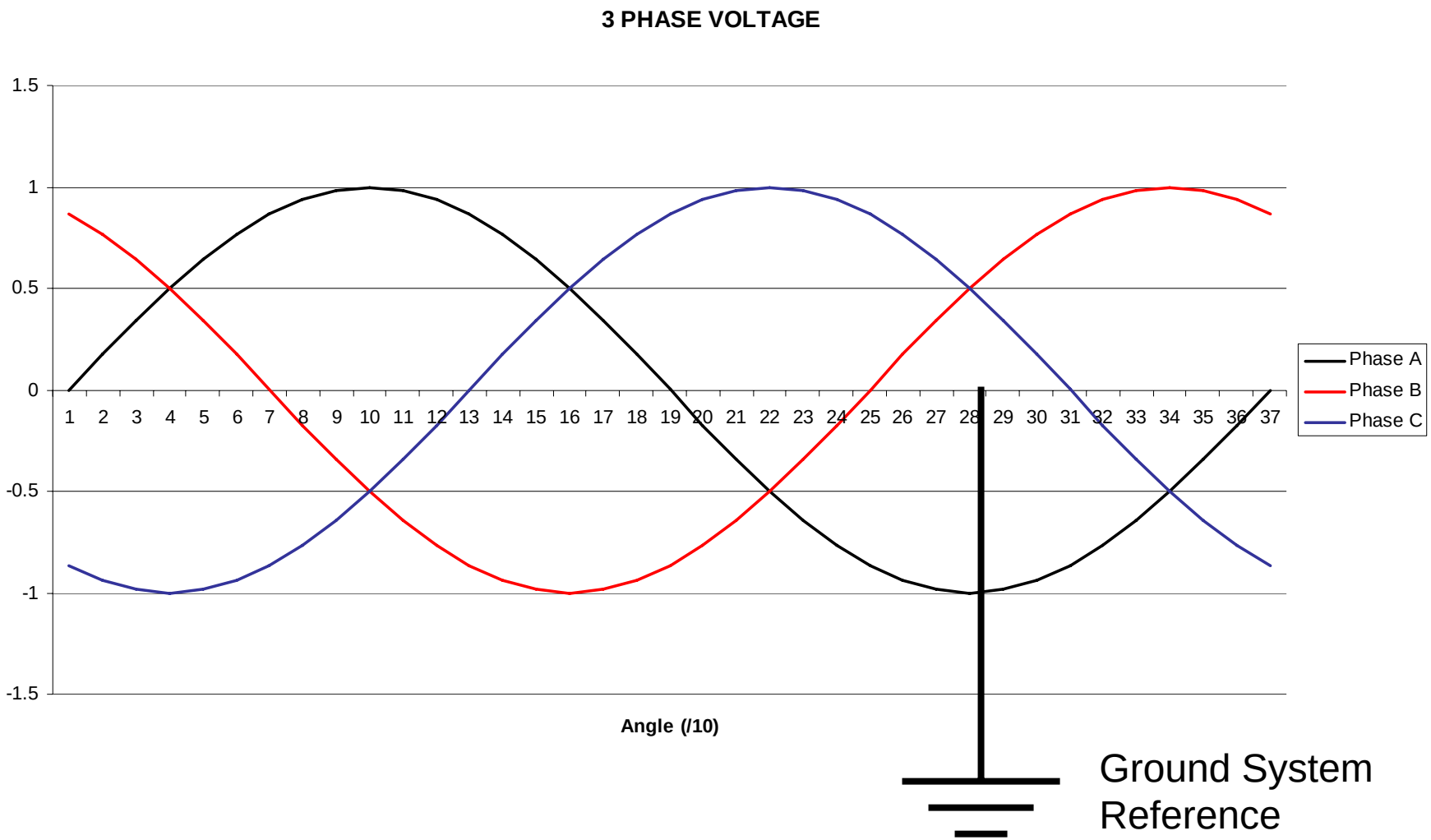

GENERATION
TRANSMISSION
1,000 MW 30 kV
XFMR 500 kV
SUBSTATION
500 kV
XFMR 15-25 kV
25 kV XFMR
480V 3Φ
15-25 kV
DISTRIBUTION
25 kV XFMR
240/120V 1Φ

Typical Utility System

UTILITY GROUNDING SUMMARY

- **ESTABLISH REFERENCE TO EARTH**
  - **Allows for Protection devices to operate**
  - **Keeps metallic and structures at the potential of the earth**
- **CREATES EQUIPOTENTIAL PLANE**
  - **Significantly reduces risk of step and touch potential**
- **PROVIDES LOW IMPEDENCE PATH**
  - **Especially for SYSTEM and NON SYSTEM transients**

AC Three Phase



Utility Substation Grounding

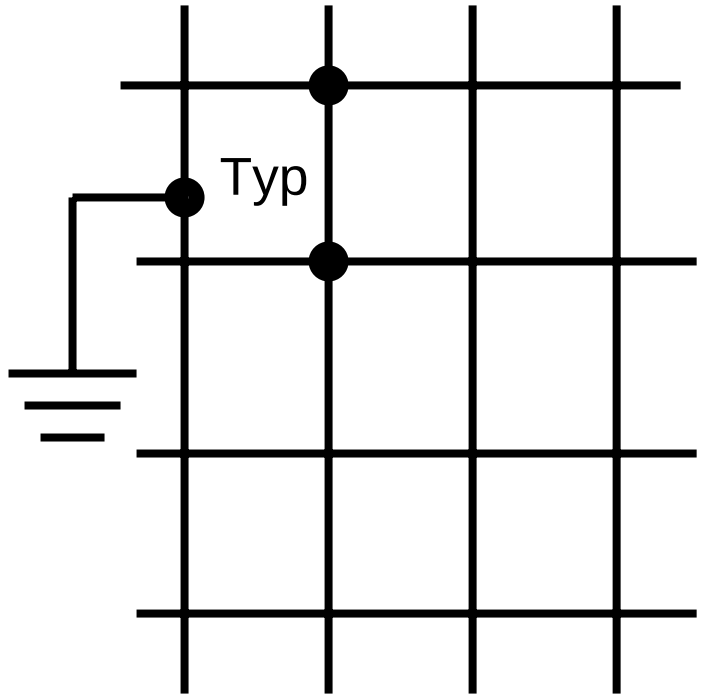
Substations have high fault currents and potential for voltages caused by that current. Fault Currents > 50kA

$$V = I * R$$

SAFTEY – At 50-60 Hz 60-100mA can cause ventricular fibrillation. Threshold voltage can be as low as 50 V

TYPICAL SUBSTATION GROUDNING

- 4/0 Cu buried at 18”
- 10-20’ grid, welded
- Ground Rods every 20’ typical.
- Extremely low R
- IEEE 80



Exothermic Welding for Connections

- Provides a Molecular Bond Between Conductors
  - Current Carrying Capacity Equal to that of the Conductor
  - Permanent - Cannot Loosen or Corrode to Cause a High-Resistance Connection
  - Requires No External Source of Power or Heat
  - Can be Visually Checked for Quality

Exothermic Welding Process

Aluminum Reduces Copper Oxide, Forming Super Heated Copper and Aluminum Oxide (Slag)

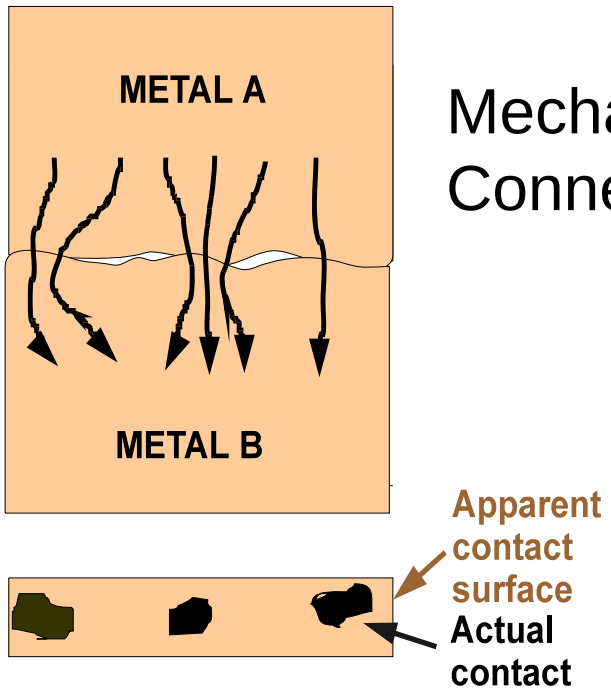
$3Cu_2O + 2Al \rightarrow 6Cu + Al_2O_3 + HEAT$

Mechanical / Compression Connections

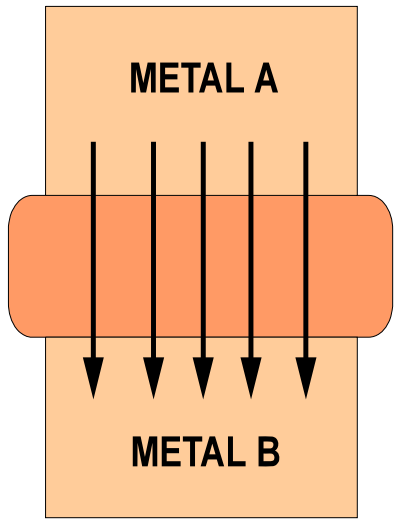
- Joint Resistance (R_J)
  - Contact or Interface Resistance ($R_{c)}$
    - Surface is Actually Consists of Many Points of Contact
    - Actual Area or Contact of Joint is Much Less than Surface Area Brought Together
    - Dependent on Applied Pressure
  - Spreading Resistance (R_s)
    - Diversion of Current Flow (Current Path is Not Uniform)

$$R_j = R_c + R_s$$

Comparison of Mechanical and Exothermic Connections



Mechanical Connection



Molecular Bond

Molecular Bonds Guarantee Conductivity Across the Entire Section
Contact and Spreading Resistance (R_s) Portion of Connection is Zero

C & I Grounding

- Generally C & I and Residential grounding methods establish a good earth reference
- Also grounding elements provide a path for fault currents
- All metal parts associated with the electrical system shall be connected to the ground reference for safety.

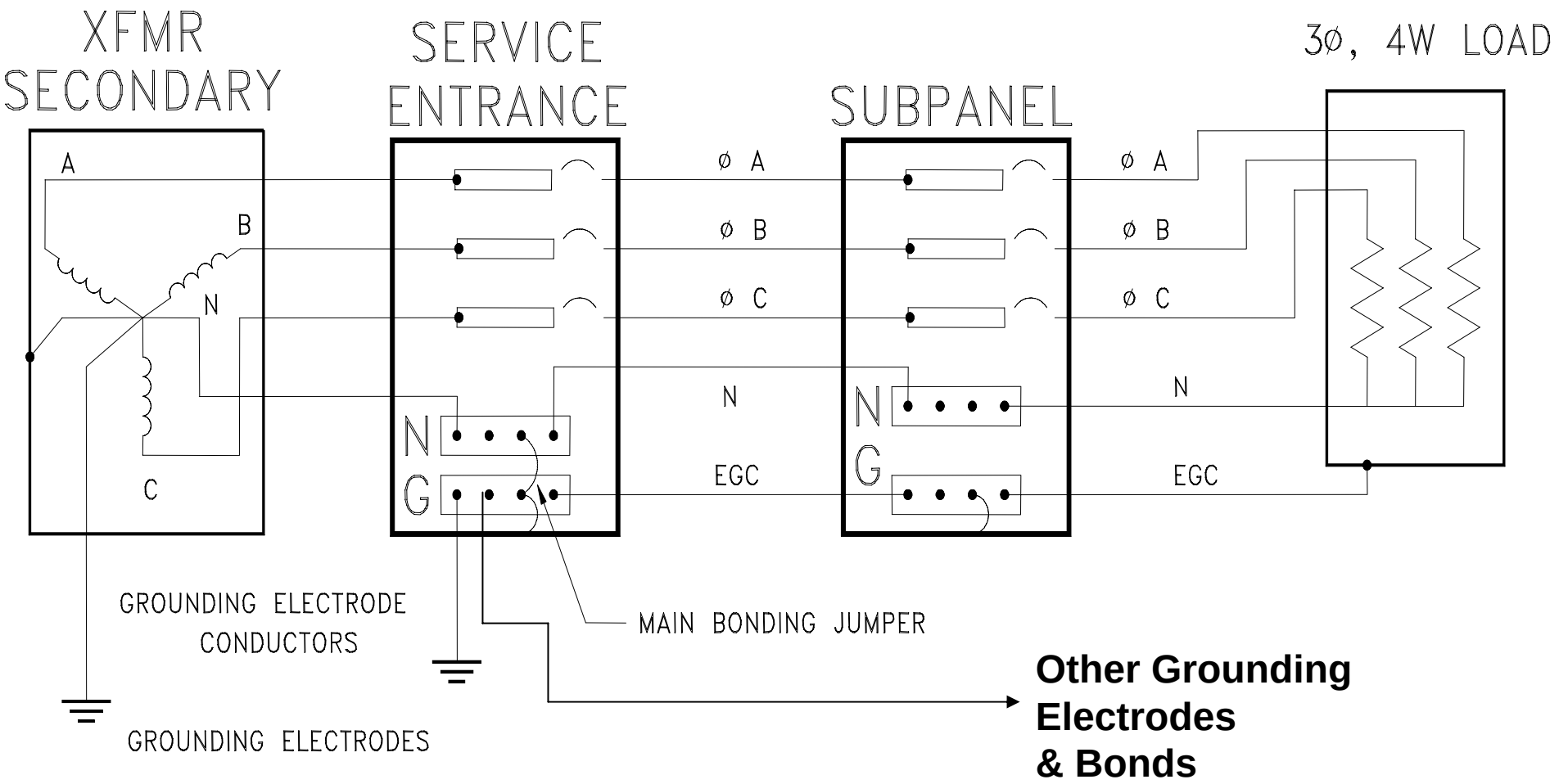
NEC 250 Definition of Grounding

- Intentional permanent low impedance Path to carry fault current
- Capacity to carry ground fault current
- Returns fault current to SOURCE, NOT EARTH
- Is connected to EARTH for system REFERENCE
- Used to allow operation of protection devices

C & I and Residential System Grounding Elements

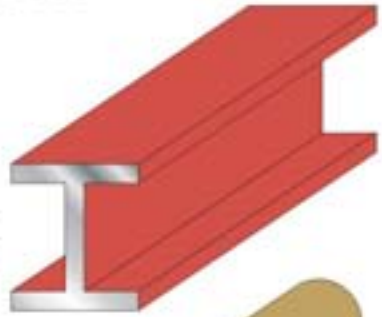
- **GROUNDED CONDUCTOR -NEUTRAL**
- **GROUNDING ELECTRODE -SEVERAL**
- **GROUNDING ELECTRODE CONDUCTOR**
- **SERVICE BONDING JUMPER**
- **EQUIPMENT GROUNDING CONDUCTOR**

Solidly Grounded 3 Phase Electrical System

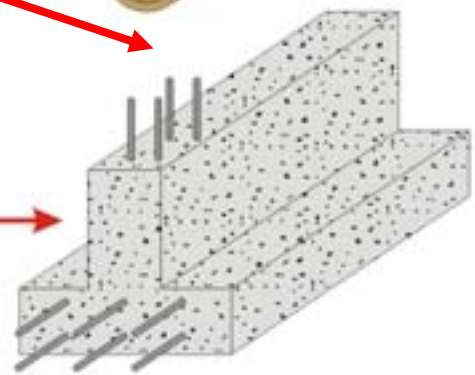


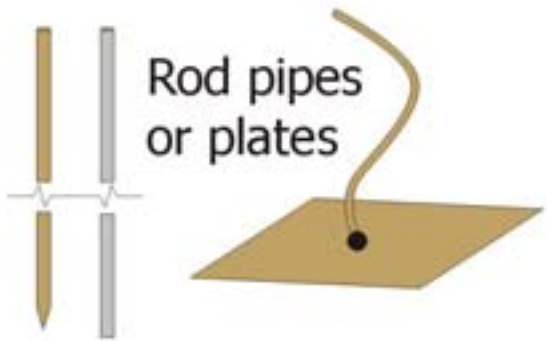
250.50 Grounding Electrode System

- Grounding electrodes required to be used to form the grounding electrode system where present
- Includes electrodes that are an inherent component of the building construction
- By exception, concrete-encased electrodes not required to be used where doing so involves disturbing concrete footings of existing structures or buildings

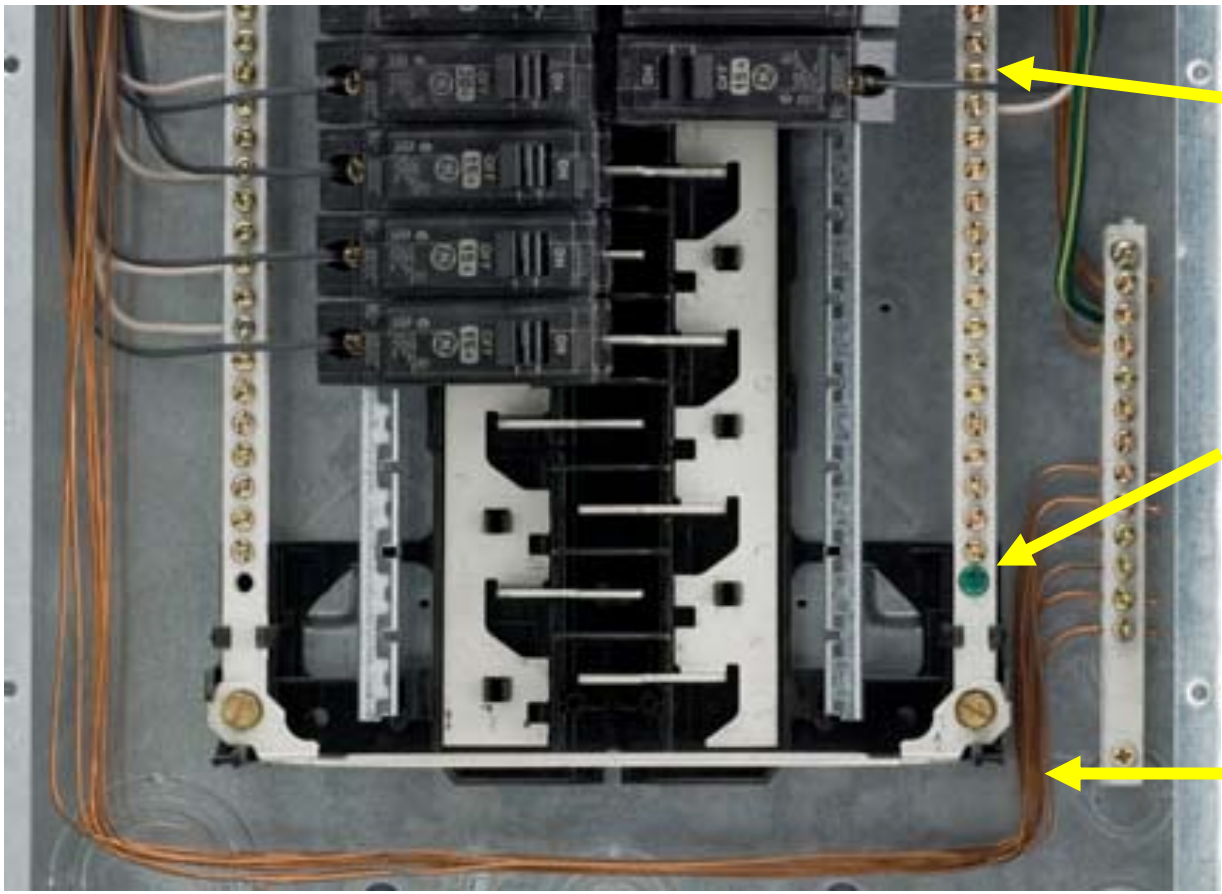


NEW – MUST Be Bonded into GEC System





Typical Grounding Connections in small Main Service Panel

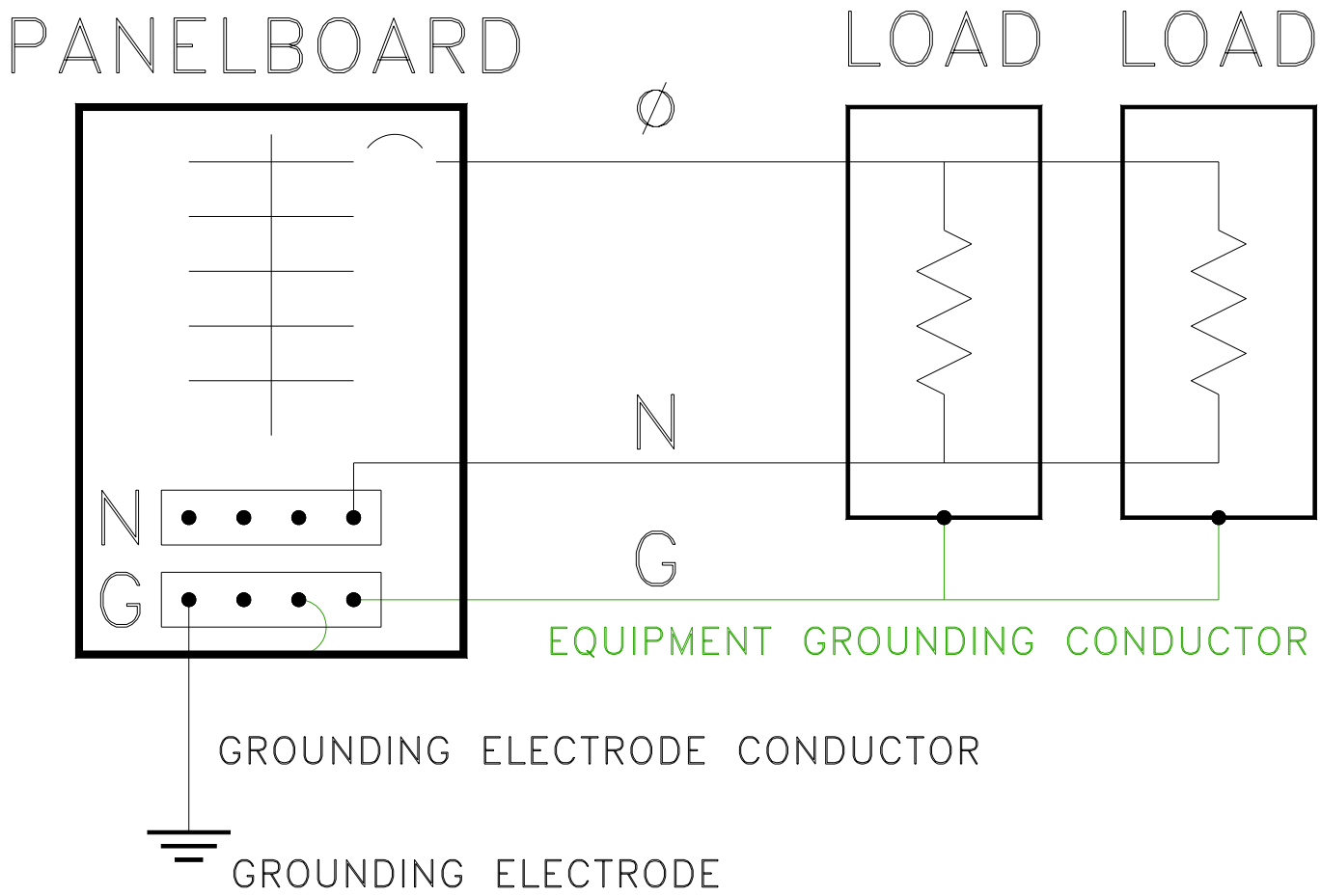


Neutral – Grounded Conductor

Main Bonding Jumper

Equipment Grounding Conductors

Difference between Neutral (Grounded) and Grounding Conductor



NEC 250 Resistance Requirement

- Section 250.56 requires < 25 Ω resistance for pipe, rod or plate electrodes OR
- Add another electrode > 6’ away from the first, WITHOUT FURTHER MEASUREMENT

Using this formula for resistance (from MIL Handbook 419)

$$R_O = \frac{\rho}{2\pi l}\ln\left(\frac{4l}{d}\right)$$

R_O = Resistance of rod
d = Rod diameter
l = rod length
ρ = Soil Volume Resistivity

A ¾” by 10’ in 500 Ω M soil would have a resistance of over 160 Ω

Source : http://www.mikeholt.com/newsletters.php?action=display&letterID=407

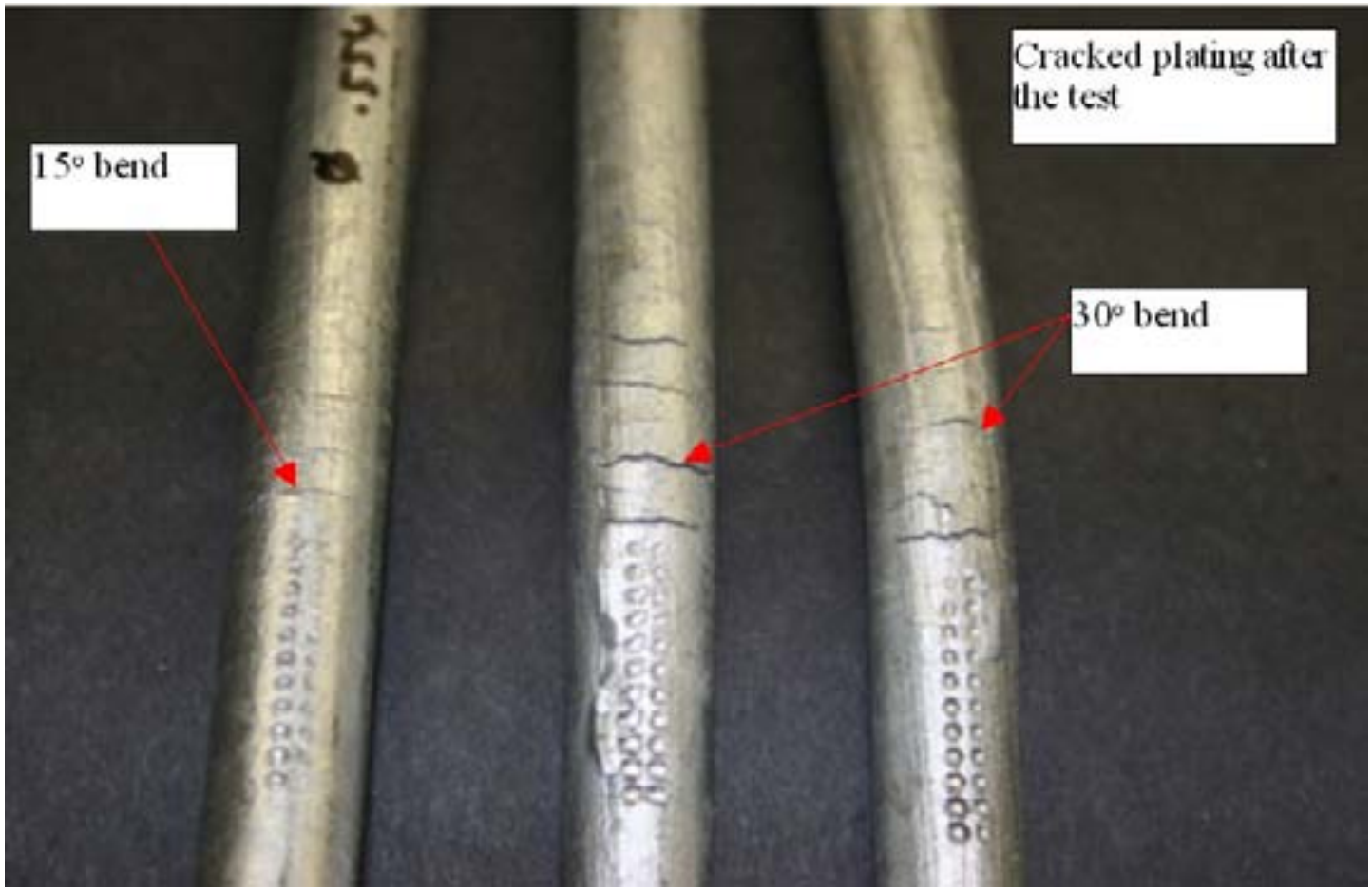
Practical Ground Resistance

- Most rods have much less than 160 Ω
- Typical rod resistances will be less than 25 Ω in most soils because of the existence of proximate utility ground references.

Low ground resistance (< 10 Ω) can be achieved with

- Multiple Rods bonded together
- Counterpoise system
- Coupled rods
- Conductive Enhancement Materials
- Chemical Rods

Beware of False Claims



UL 467 Bend Test Results Galvanize Rod

Copper Electroplated Rod

UL 467 Bend Test Results - Cu Rod

BONDING

- **Interconnecting of all Ground Electrode Systems**
  - Electrical Power Grounding System
  - Lightning Grounding System
  - Telecommunications Grounding System
  - Cable Grounding System
- Connect all conductive objects together both internal and external to the facility
- **Provides near zero voltage difference** during ground potential rise

Other Grounding and Bonding Applications

- Signal Reference Grids
- Grounding Bus Bars
- Equipotential Mesh
- Rebar Clamps
- Swimming Pool Grounding
- Wind Mill Grounding

SRG for low impedance ground

- Stops noise from interfering with low voltage digital signals.
- Provides a lower impedance ground reference than signal conductors and shields.
- Minimizes voltage potential difference between interconnected equipment.

SRG Impedance vs. Freq

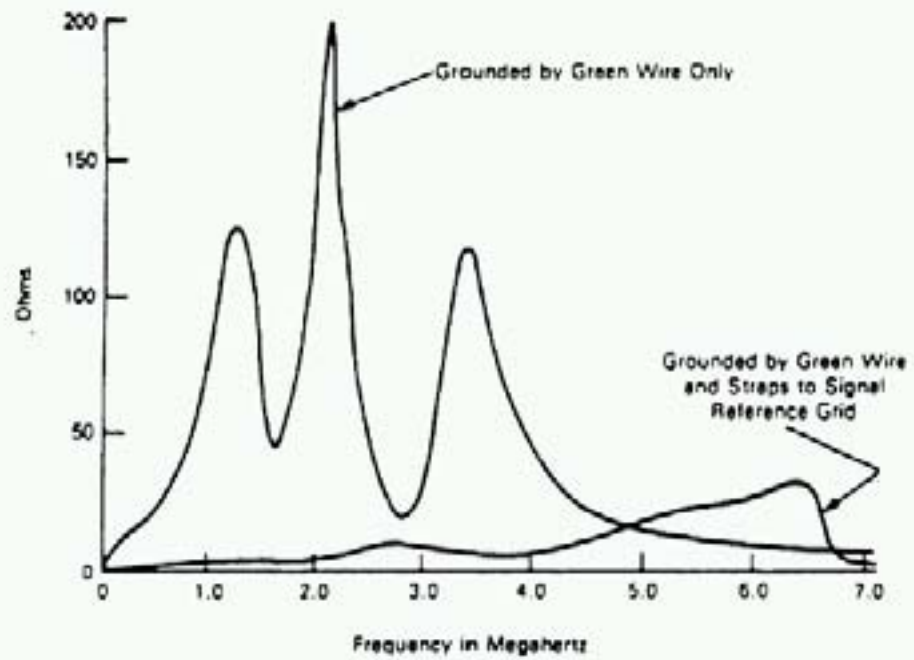
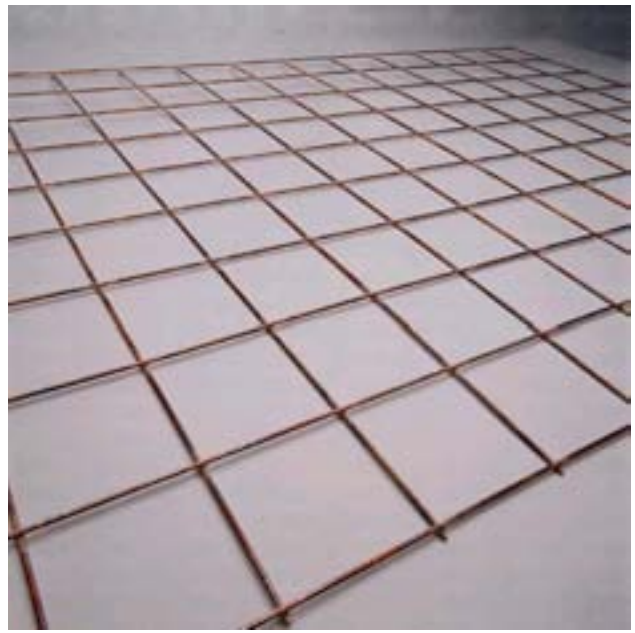


Figure 4-66—Impedance of grounding conductors for a computer system

Signal Reference Grids
Sensitive Electronics Grounding

PREFABRICATED WIRE MESH



- Applications:
  - Reduce step & touch potential
  - Signal Reference Grid
  - Antenna ground screen
  - Electronic shielding
- Configuration:
  - Wire: #6 to #12 - 30 %CW, 40% CW, Cu
  - Mesh size: 2” x 2” up to 48” x 24”
  - 20’ maximum width - 500 lb maximum weight
  - Wire overhang for field splicing using PG style connection.

EIA/TIA Ground Bars and Ground Plates

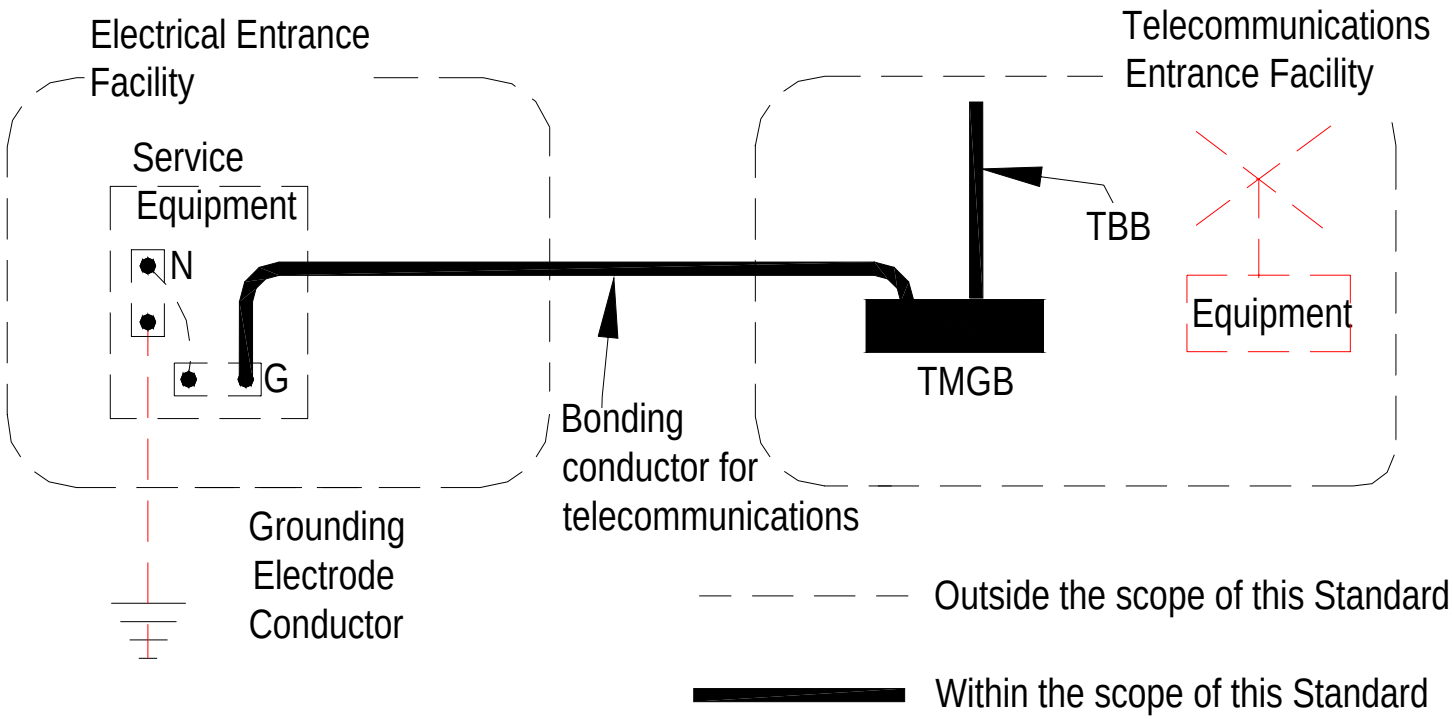
TGB and TMGB Grounding Bus Bars

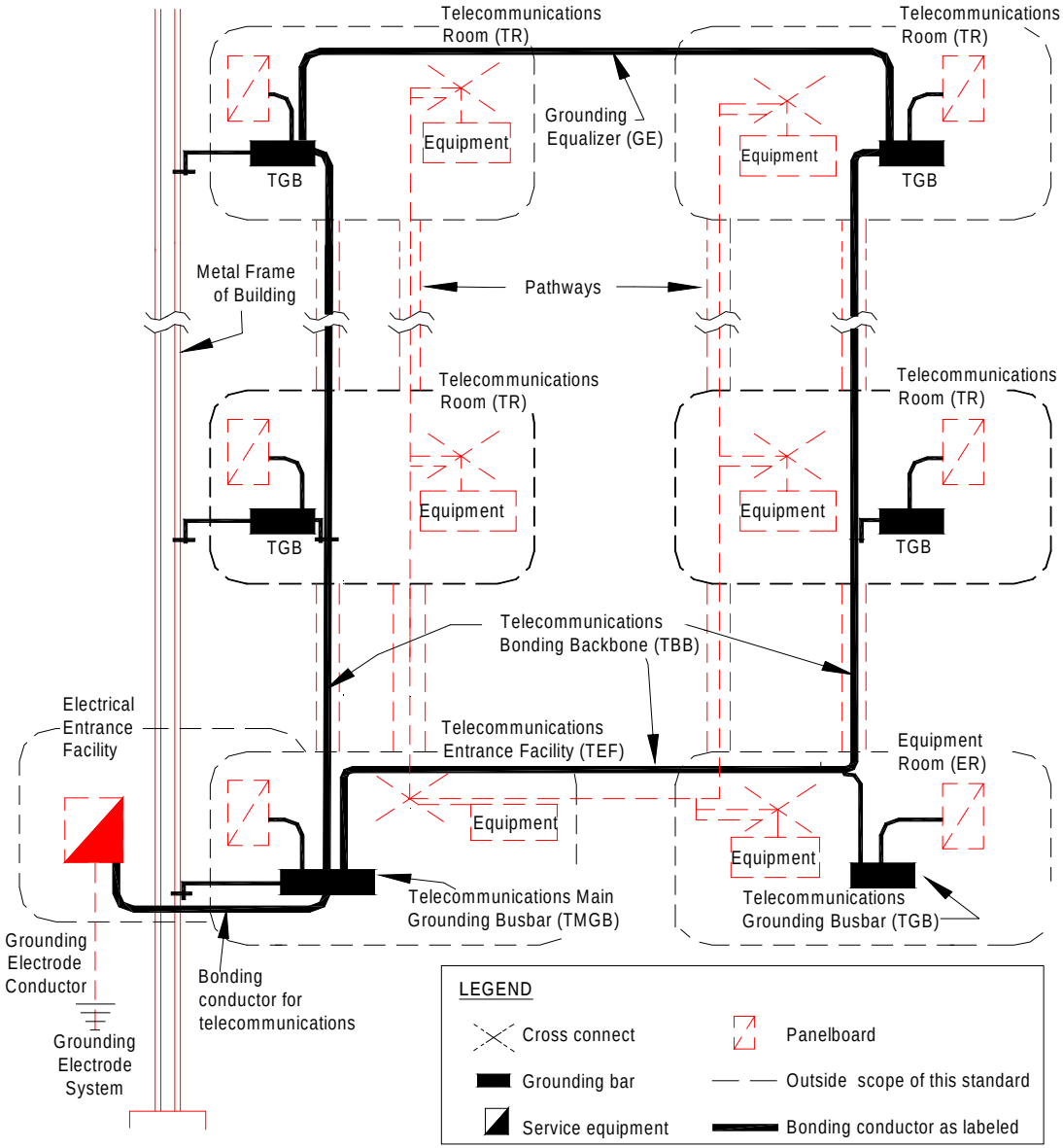
Main Elements of Telecom Grounding and Bonding Equipment

- Bonding Conductor for Telecommunications
- Telecom Main Grounding Busbar (TMGB)

- Telecomm Bonding Backbone (TBB)
- Telecomm Grounding Busbar (TGB)
- Telecomm Bonding Backbone Interconnecting

Bonding Conductor for Telecommunications




Telecommunications Room (TR)
Telecommunications Room (TR)
Grounding Equalizer (GE)
Equipment
Equipment
TGB
TGB
Metal Frame of Building
Pathways
Telecommunications Room (TR)
Telecommunications Room (TR)
Equipment
Equipment
TGB
TGB
Telecommunications Bonding Backbone (TBB)
Electrical Entrance Facility
Telecommunications Entrance Facility (TEF)
Equipment Room (ER)
Equipment
Equipment
Telecommunications Main Grounding Busbar (TMGB)
Telecommunications Grounding Busbar (TGB)
Grounding Electrode Conductor
Bonding conductor for telecommunications
Grounding Electrode System
LEGEND
Cross connect
Panelboard
Grounding bar
Outside scope of this standard
Service equipment
Bonding conductor as labeled

Grounding and Bonding SUMMARY

- Discussed Basic Electricity
- Understand Resistivity
- Should know why Utilities Ground their systems
- Should know elements of commercial – industrial- residential grounding
- Telecom Bonding and Grounding