Safety Issues Caused by High Earth Resistance and Identifying Them Using Instruments

Thomas Szollossy
Senior Technical Support Engineer
Power Quality Thailand

Power Quality Thailand LTD.

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Introduction

- High Earth Resistance results in inadequate grounding
- A good ground protects against dangerous voltages
  - Safety for humans
  - Protection of equipment
- Inadequate grounding can cause a fire hazard
  - Faults not cleared resulting in high currents
- Inadequate grounding effects Power Quality
  - Noise on protective earth

Introduction

- An Earth Resistance meter is used to measure the quality of grounding
- Earth resistance meters are available from most Power Quality Instrument manufacturers
  - Various sizes, features, and prices

Power Quality Thailand is a distributor of Sonel® Earth Resistance Meters

Purpose of Grounding

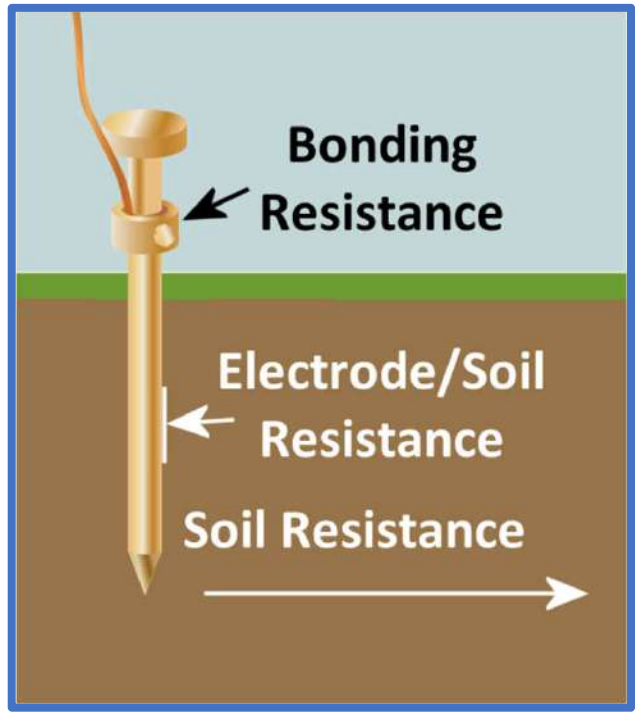
- The purpose of grounding is to provide safety for people and to protect electronic and electrical equipment
- Grounding provides a safe low impedance path for fault currents, lightning strikes, static discharges, EMI and RFI signals to be dissipated into the earth.

Grounding and Power Quality

- Nearly 80% of reported Power Quality Problems are due to deficiencies in the wiring and more specifically in grounding (earthing)
- Power Quality Problem is defined as power supply causing equipment to not operate as intended

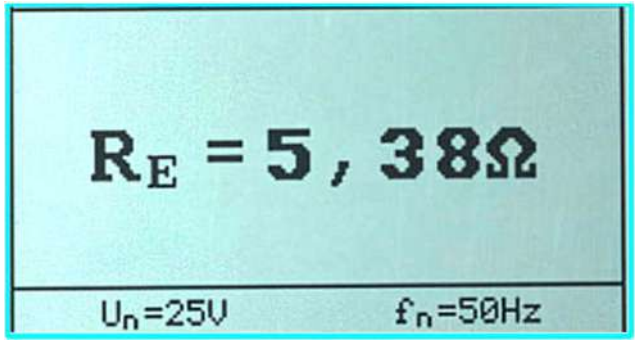
What is Earth Resistance?

- It is the resistance to the passage of current from the equipment ground connection to the soil outside
- It is the sum of the following resistances:
  - Grounding system of the building
  - Bonding resistance of wire to ground electrodes
  - Resistance between electrode and soil
  - Soil Resistance



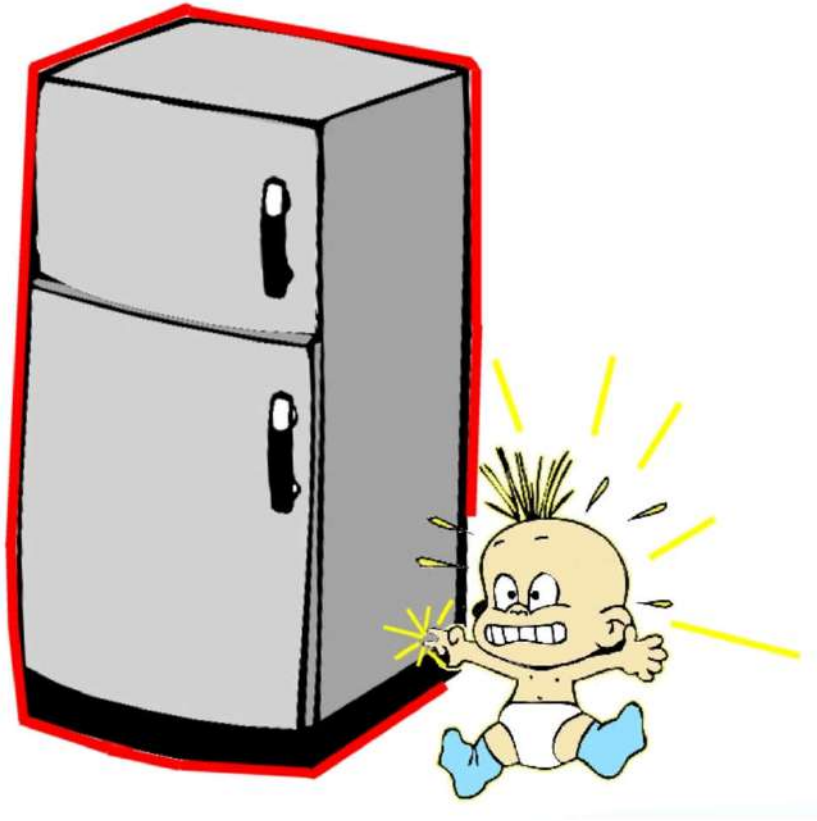
Earth Resistance Measurement

Earth Resistance Measurement is a direct measurement of the ability of the grounding system to dissipate current into the soil



Low Earth Resistance: Prevent Electric Shock

Low earth resistance prevents electric shock by keeping the voltage of grounded objects near the earth potential in the event of a fault



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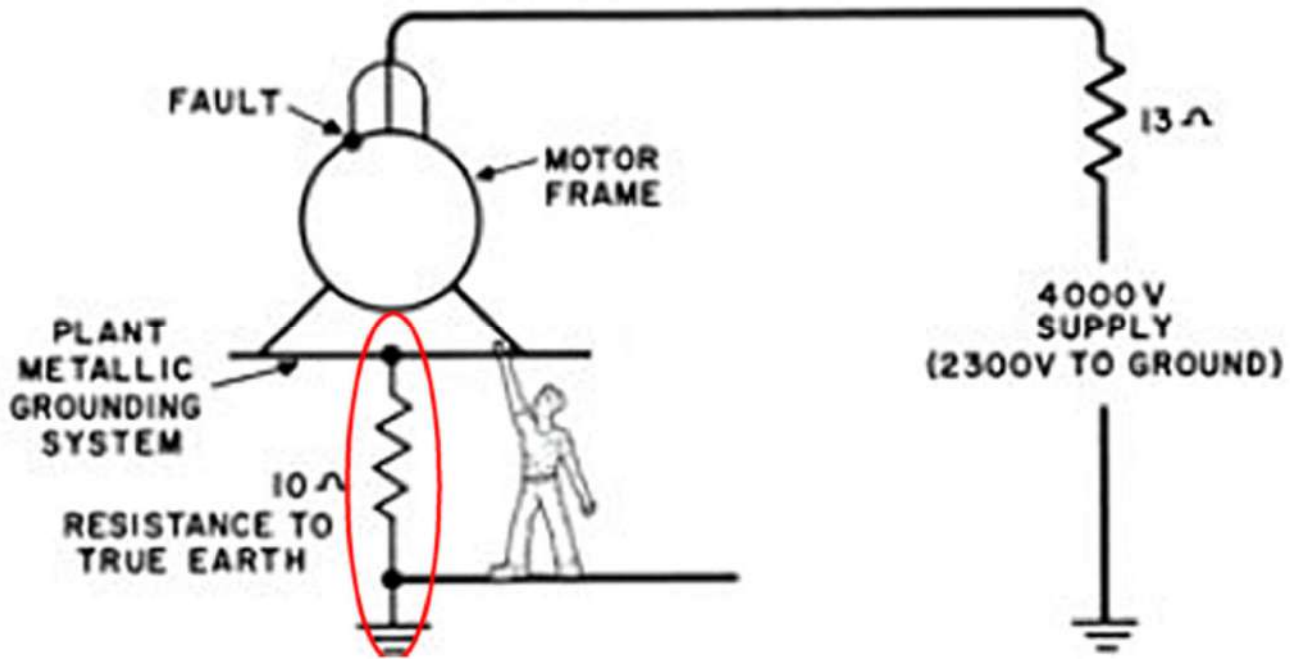
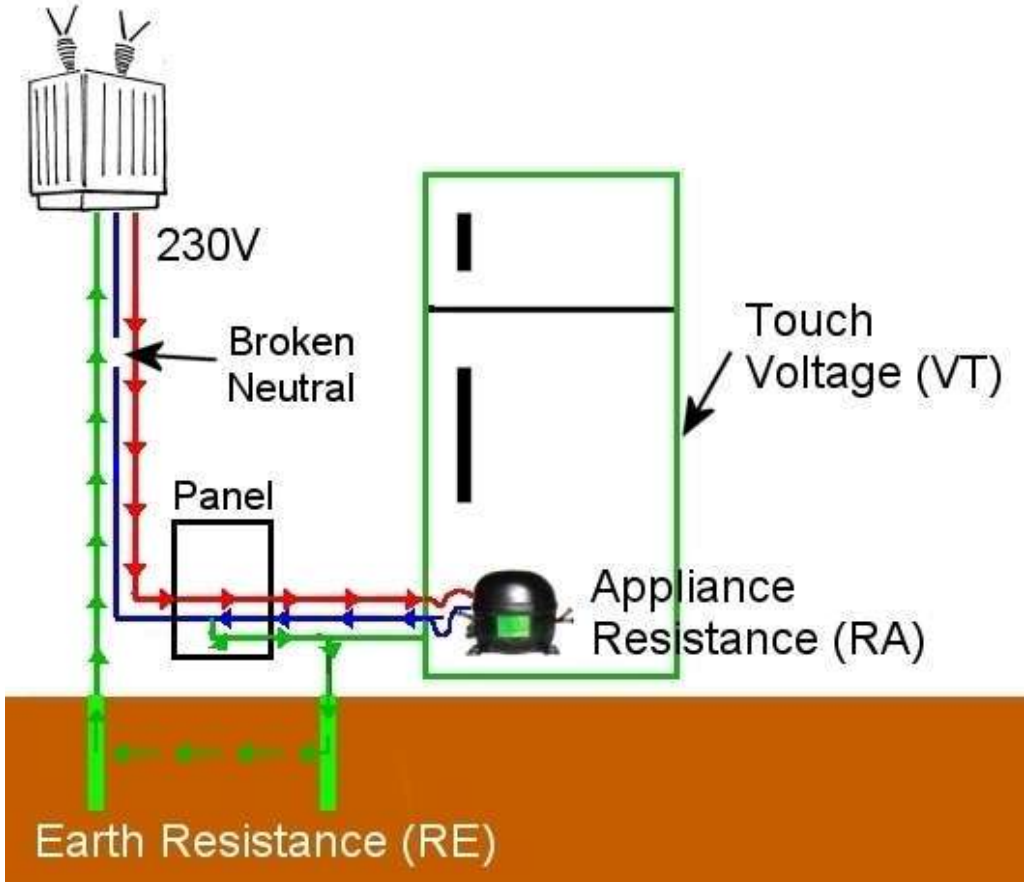


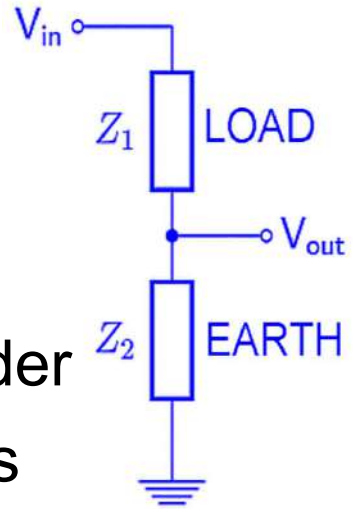
- Example 1: Fault causes voltage on motor frame
  - Voltage on motor frame transferred to plant's grounding system.
  - Low earth resistance keeps voltage at safe level

Low Earth Resistance: Prevent Electric Shock



Example 2: Broken neutral in TN-C and TN-S grounding systems

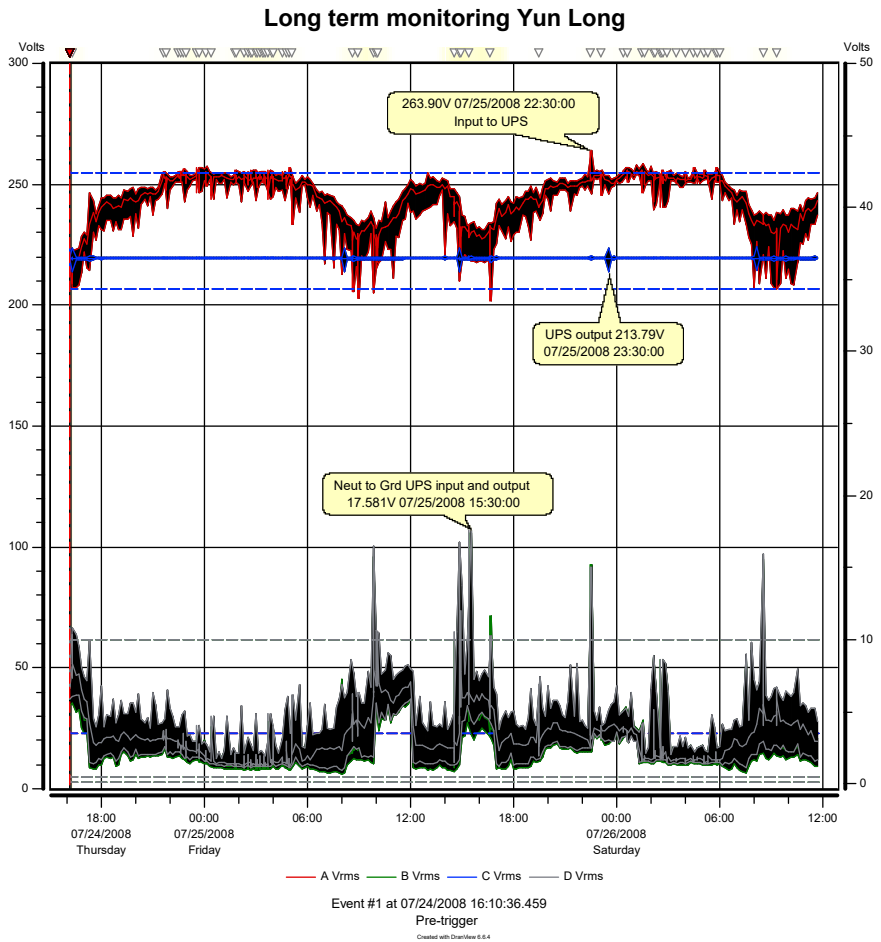
- Return path to transformer through ground
- Earth resistance in series with load resistance → voltage divider
- Current through load generates voltage across Z_2



Low Earth Resistance: Over-Voltage Protection

- Low earth resistance required for:
  - Lightning protection systems to work properly
  - Protection devices to channel power surges to ground
  - Keeping neutral voltage from rising in event of fault

Low Earth Resistance: Voltage Stabilization



← Neutral to Ground not stabilized by UPS!!!

Low Earth Resistance: Voltage Stabilization

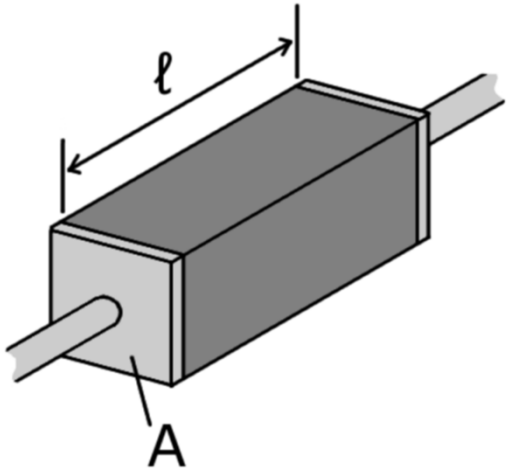
- Grounding system provides a common reference potential for power supply system, building structure, plant steelwork, electrical conduits, cable ladders & trays, and the instrumentation system
- Provides a common voltage reference for independent systems, such as electrical service, phone network, cable TV, etc.
- Minimizes electrical noise by conducting it to ground

Soil Resistivity: Largest Effect on Earth Resistance

- Soil Resistivity is the resistance of soil to passage of current through it
- It refers only to the resistivity of the soil. Ground spikes, wires, bonding are not included
- Use to decide the type of ground electrodes to install for the soil condition
- In a properly functioning grounding system, the soil contributes the most to *total* earth resistance

What is “Resistivity”?

- Measured in ohm-meters [Ω·m]
- It is the resistance of a material taking its volume into consideration
- Also takes into consideration that material is not uniform material
- This is why Resistivity is used to measure the he soil’s opposition to current flow



$$\rho = R\frac{A}{l}$$

P is the resistivity
R is the resistance
A is cross section area
l is length

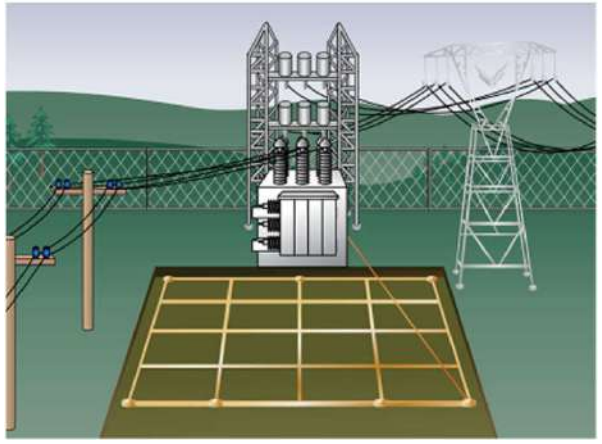
Causes of High Soil Resistivity

- Soil dry
- Soil that contains a lot of sand and rocks
- Low mineral content of soil

Measuring Soil Resistivity to Decide What Kind of Ground Electrodes to Install

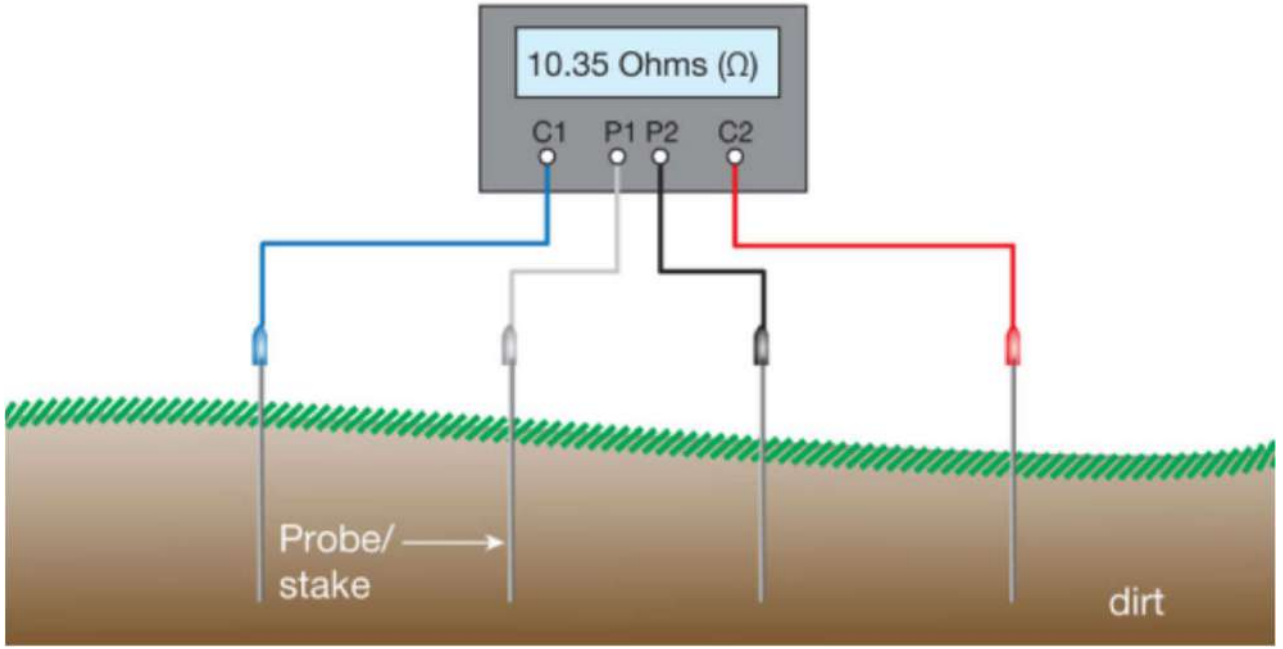
Especially important for:

- New building construction
- Electric utility & distribution stations
- Grounding of communications towers



Measuring Soil Resistivity Using Wenner Method

- 4 stakes, equally spaced, in a straight line
- Distance between them large compared to depth



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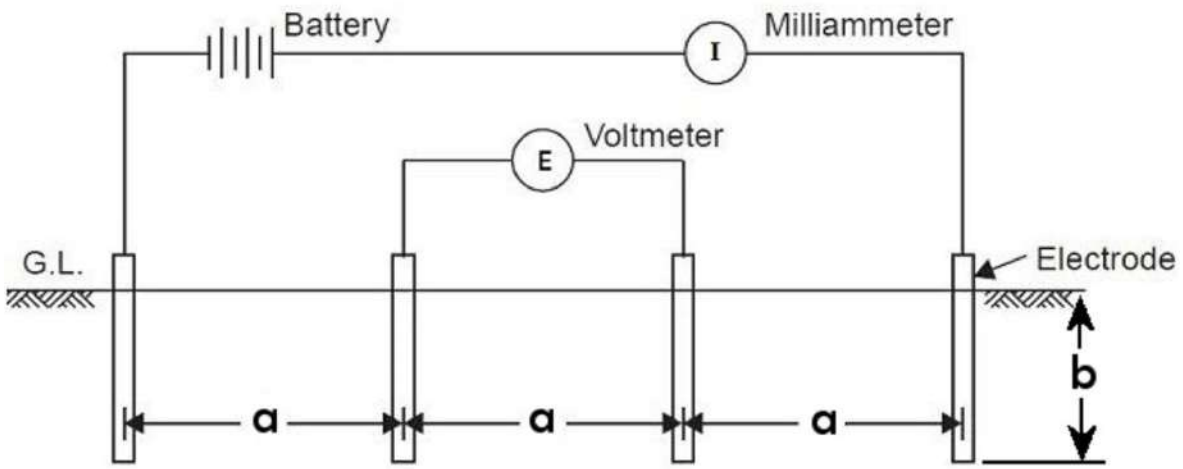


Stakes equal distance apart (*a*) and depth (*b*)

- Kelvin connection to soil
- If (a) much larger than (b), then Soil Resistivity (ρ_E) is given by:

$$\boldsymbol{\rho_E = 2\pi a \cdot \frac{E}{I}}$$

- Meter calculates ρ_E internally and displays result

Effect of Soil Resistivity on Earth Resistance

- Table shows that soil resistivity has a very big effect on earth resistance
- For high resistivity soils, electrodes must be put deeper, and more than one electrode should be used

Type of soil	Soil resistivity R_E	Earthing resistance					
		Ground electrode depth (meters)			Earthing strip (meters)		
	ΩM	3	6	10	5	10	20
Very moist soil, swamplike	30	10	5	3	12	6	3
Farming soil loamy and clay soils	100	33	17	10	40	20	10
Sandy clay soil	150	50	25	15	60	30	15
Moist sandy soil	300	66	33	20	80	40	20
Concrete 1:5	400	-	-	-	160	80	40
Moist gravel	500	160	80	48	200	100	50
Dry sandy soil	1000	330	165	100	400	200	100
Dry gravel	1000	330	165	100	400	200	100
Stoney soil	30,000	1000	500	300	1200	600	300
Rock	10^7	-	-	-	-	-	-

Back to Topic of Earth Resistance

- Just finished discussing Soil Resistivity, which is the largest contributor to high Earth Resistance
- Looked at Wenner method to measure Soil Resistivity
- Next, we will talk about other contributors to high Earth Resistance

Connections to Soil are Very Important!

Choose the correct method to connect into the soil, based on measured resistivity of the soil

Most common connection to soil problems

- Ground rods not deep enough (40% decrease in resistance if length doubled)
- Not enough grounding rods for soil conditions (ground rods in parallel)
- Not using proper grounding electrodes for high-resistivity soil:
  - Ground mesh
  - Ground plate
  - Radial conductors

High Earth Resistance: Connections Within System

Every bad connection in the grounding system adds to earth resistance

High Earth Resistance: Connections Within System

- Loose, corroded, or improper connections to the grounding system in the soil
- Ground rods located outside
  - Weather causes corrosion
  - Damage caused by vehicles/people/etc.
- Connections at junction boxes, wall receptacles, bus bars, and bonding connections together increase total ground resistance

Ground wire cut at Hospital in China

High Earth Resistance: Damaged Conductors

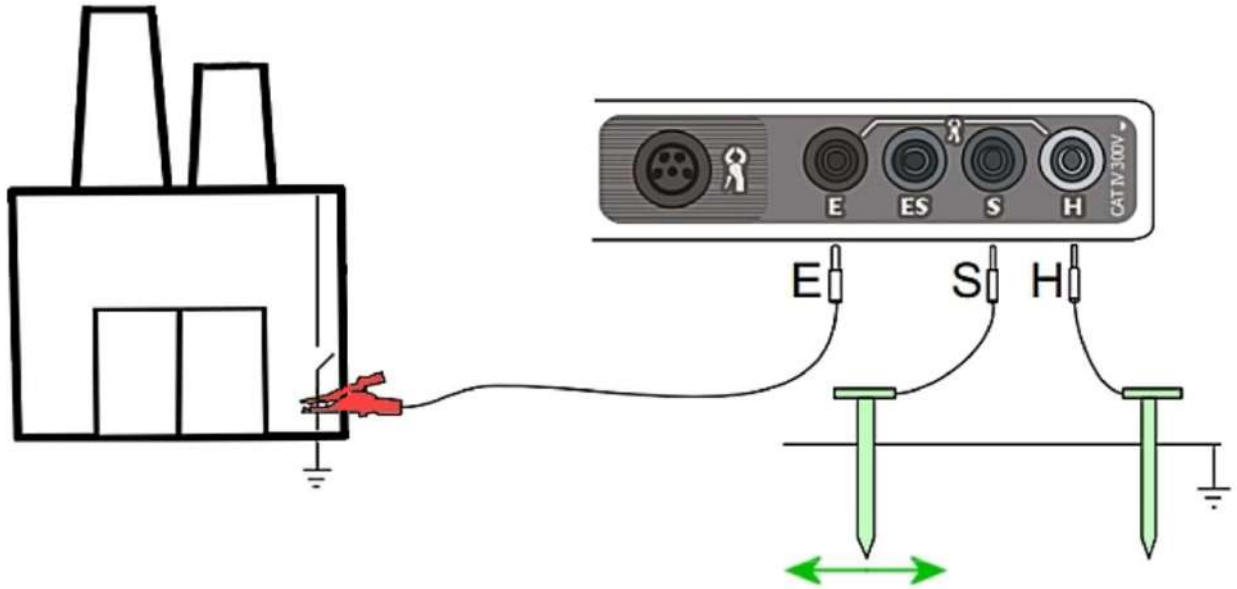
Wire damaged by drilling

Wire damaged during construction/maintenance

Measuring Earth Resistance: Fall of Potential Method (3-pole) Description

- Also known as 62% Method
- Measurement of the entire grounding system including rod, bonding, and soil
- Referenced in all the electrical installation testing standards and measures the earth resistance both accurately and safely.
- **This is the earth resistance measurement of reference**

Measuring Earth Resistance: Fall of Potential Method (3-pole) Process



- Cut power and disconnect system at earth electrode
- Current travels form red clip to last stake
- Meter measures voltage at middle stake
- Make several measurements with middle stake different locations
- If big difference, then move “H” electrode farther away and repeat

Measuring Earth Resistance of Transmission Towers

- Very important to have good grounding of metal towers due to extreme high voltages
- High Earth Resistance will result in deadly voltages on the tower and the soil nearby if live wire touches tower

Other Earth Resistance Measurements

MEASUREMENT	APPLICATION
2-Pole (Earth & Equipotential Bonding)	Internal grounding system
4-Pole Method	High accuracy
3-Pole + Clamp	No need to disconnect ground
2-Clamp	No need for stakes in ground
Impulse Method	For lighting safety systems
Current	Earth leakage current

Acceptable Earth Resistances

Factory	**5 Ω**
Mobile Phone Tower.....	**5 Ω**
Major power station	**0.5 Ω**
Major Sub-station	**1.0 Ω**
Minor Sub-station	**2 Ω**
Service connection	**4 Ω**
Med. Voltage Network	**2 Ω**
Lightening Arrestor	**4 Ω**
Low Tension Pole	**5 Ω**
High Tension Pole	**10 Ω**
Transmission Tower	**20-30 Ω**

Conclusion

- Earth resistance is very important to safety of people and equipment
- It is tempting to check the ground connections in the building, but not think to check the actual connection into the earth
- Also not think to check soil resistivity
- Entire grounding system health can be checked quickly and easily using the correct tools
- Earth resistance check should be part of the regular electrical system testing and maintenance plan

The End