GOOD GROUNDING PRACTICES

A Brief Introduction to the Basics of Electrical Grounding for Power Systems

Introduction to Grounding

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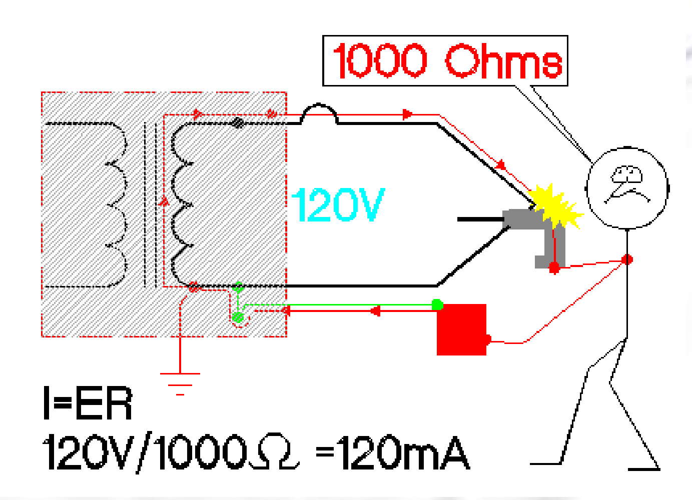
Introduction to Grounding

- The primary goal of the grounding system throughout any facility is SAFETY. Secondary are effective lightning protection, diminishing electromagnetic coupling (EMC), and the protection against electromagnetic pulses (EMP).
- Grounding is implemented to ensure rapid clearing of faults and to prevent hazardous voltage, which in turn reduce the risks of fires and personnel injuries. Grounding serves the primary functions of referencing the AC systems and providing a means to ensure fault clearing.
- 99.5% survival threshold –
  - 116 mA for one (1) second.
  - 367 mA for zero point one (0.1) second.



Introduction to Grounding

- A frequently quoted criteria is the establishment of a one (1) ohm resistance to earth. A large number of equipment manufacturers have this in their installation guides. The NEC requires only twenty-five (25) ohms of resistance for made electrodes, while the ANSI/IEEE Standard 141 (Red Book) and ANSI/IEEE 142 (Green Book) specifies a ground resistance of one (1) to five (5) ohms.
- External changes in the grounding system (environment) may effect the ultimate functionality of the entire electrical system.
- Frequency matters in very complex grounding systems. Leakage currents of equipment do not return to the earth; high frequency leakage currents return to the equipment which generated them, while power frequency leakage currents return to the derived source.
- The impedance of the system is viewed from the perspective of power frequencies and immediate harmonics (i.e., 60Hz and its associated harmonics).

Introduction to Grounding

- Generally accepted electrical wiring practices are not good ground system wiring practices (i.e. no sharp bends or turns).
- Grounding systems are not meant to last for ever. The best grounding systems need to most attention paid to them as they will corrode the quickest.

NDING SYS

There are basically six (6) grounding systems in use. The six (6) systems are the equipment grounds, static grounds, systems grounds, maintenance grounds, electronic grounds and lightning grounds.

- Equipment grounds: An equipment ground is the physical connection to earth of non-current carrying metal parts. This type grounding is done so that all metal part of equipment that personnel can come into contact with are always at or near zero (0) volts with respect to ground. All metal parts must be interconnected and grounded by a conductor in such away as to ensure a path of lowest impedance for flow of ground fault current. Typical items (equipment) to be grounded are; electrical motor frames, outlet boxes, breaker panels, metal conduit, support structures, cable tray, to name a few.
- Static grounds: A static ground is a connection made between a piece of equipment and the earth for the purpose of draining off static electricity charges before a flash over potential is reached. This type grounding system is utilized in dry materials handling, flammable liquid pumps and delivery equipment, plastic piping, and explosive storage facilities.

Standard Industrial System Grounding Methods

Methods of System Grounding

Characteristics	Ungrounded	Solid Ground	Low Resistance Ground	High Resistances Ground
Susceptible to Transient overvoltages	WORST	GOOD	GOOD	BEST
Under fault conditions (line-to-ground) increase of voltage stress	POOR	BEST	GOOD	POOR
Arc Fault Damage	WORST	POOR	GOOD	BEST
Personnel Safety	WORST	POOR	GOOD	BEST
Reliability	WORST	GOOD	BETTER	BEST
Economics' (Maintenance costs)	WORST	POOR	POOR	BEST
Plant continues to operates under single line-to-ground fault	FAIR	POOR	POOR	BEST
Ease of locating ground faults (time)	WORST	GOOD	BETTER	BEST
System coordination	NOT POSSIBLE	GOOD	BETTER	BEST
Upgrade of ground system	WORST	GOOD	BETTER	BEST
Two voltage levels on same system	NOT POSSIBLE	POSSIBLE	NOT POSSIBLE	NOT POSSIBLE
Reduction in number of faults	WORST	BETTER	GOOD	BEST
Initial fault current Into ground system	BEST	WORST	GOOD	BETTER
Potential flashover to ground	POOR	WORST	GOOD	BEST

TYPES OF GROUNDING SYSTEMS

- Ungrounded System:

  The ungrounded system is one that has no intentional connection between the neutral or any phase and ground. Please note that an ungrounded system is grounded through the concept of capacitively coupling. The neutral potential of an ungrounded system, with balanced loading will be close to ground potential due to the capacitance between each phase conductor and ground.

  - Low ground fault current.
  - Very high voltages to ground potential on unfaulted phases.
  - Sustained faults lead to system line-to-line voltages on unfaulted line.
  - Insulation failure.
  - Failure due to restrike ground faults.
  - Continued operation of facility.

TYPES OF GROUNDING SYSTEMS

- Solidly Grounded System:

  The solidly grounded system is one that has the neutral connected to ground without an intentional impedance. In contrast to the ungrounded system the solidly grounded system will result in a large magnitude of current to flow (Aids in coordination), but has no increase in voltage on unfaulted phases.

    Low initial cost to install and implement, but stray currents then become a possible consequence.

    Common in low voltage distribution systems, such as overhead lines.

    typically feeds to transformer primary with high side fuse protection.

    Not the preferred grounding scheme for industrial or commercial facilities due to high magnitude fault currents.

TYPES OF GROUNDING SYSTEMS

- Low Resistance Grounded System:

  The low resistance grounded system is one that has the neutral connected to ground through a small resistance that limits the fault current. The size of the grounding resistor is selected to detect and clear the faulted circuit..

  The resistor can limit ground currents to a desired level based on coordination requirement or relay limitations.

  Limits transient overvoltages during ground faults.

  Low resistance grounding is not recommended for low voltage systems due to the limited ground fault current. This reduced fault current can be insufficient to positively operate fuses and/or series trip units.

  Ground fault current typically in the 100 – 600 Amp range.

TYPES OF GROUNDING SYSTEMS

- High Resistance Grounded System:

  The high resistance grounded system is one that has the neutral connected to ground through a resistive impedance whose resistance is selected to allow a ground fault current through the resistor equal to or slightly more that the capacitive charging current of the system.

  - The resistor can limit ground currents to a desired level based on coordination requirement or relay limitations.
  - Limits transient overvoltages during ground faults.
  - Physically large resistor banks.
  - Very low ground fault current, typically under 10 Amps.
  - Special relaying methods utilized to detect and remove ground faults.
  - High resistance grounding is typically applied to situations where it is essential to prevent unplanned outages.
  - Recent trend has been to utilize high resistance grounding methods on 600 volt systems and lower.

GROUNDING SYSTEMS

- System grounds: A system ground refers to the point in an electrical circuit that is connected to earth. This connection point is typically at the electrical neutral. The sole purpose of the system ground is to protect equipment. This type ground also provides a low impedance path for fault currents improving ground fault coordination. This ensures longer insulation life of motors, transformers and other system components.
- Maintenance grounds: This type ground is utilized for safe work practices, and is a temporary ground.
- Electronic and computer grounds: Grounding for electronic equipment is a special case in which the equipment ground and the system ground are combined and applied in unity. Electronic equipment grounding systems must not only provide a means of stabilizing input voltage levels, but also act as the zero (0) voltage reference point. Grounding systems for the modern electronics installation must be able to provide effective grounding and bonding functions well into the high frequency megahertz range.
- Lightning protection: Lightning protection grounding requirements are dependent upon the structure, equipment to be protected, and the level of lightning protection required of desired.

GROUNDING SYSTEMS

- Several factures should be considered in the initial design of the grounding system.
  - The area available for installation of the grounding system. This could lead to the requirement and utilization of chemical rods, or wells.
  - Water table and seasonal changes to it.
  - Soil condition and resistivity, Please see chart of typical results. Also elevation above sea level and hard rocky soil are concerns that would need to be addressed.
  - Available fault currents (i.e., three (3) phase, line-to-ground, and line-to-line-to ground, etc.).
  - NEC and ANSI/IEEE requirements. Also include here the requirements of the process equipment to be installed.
  - Consideration to the number of lightning strikes and thunder storm days per year.
  - Utility ties and/or service entrance voltage levels.
  - Utilization of area were ground system is to be installed, (i.e., do not install under paved parking lot).

GROUNDING SYSTEMS

SOIL RESISTIVITIES

(Approximate Ohm-Meters)

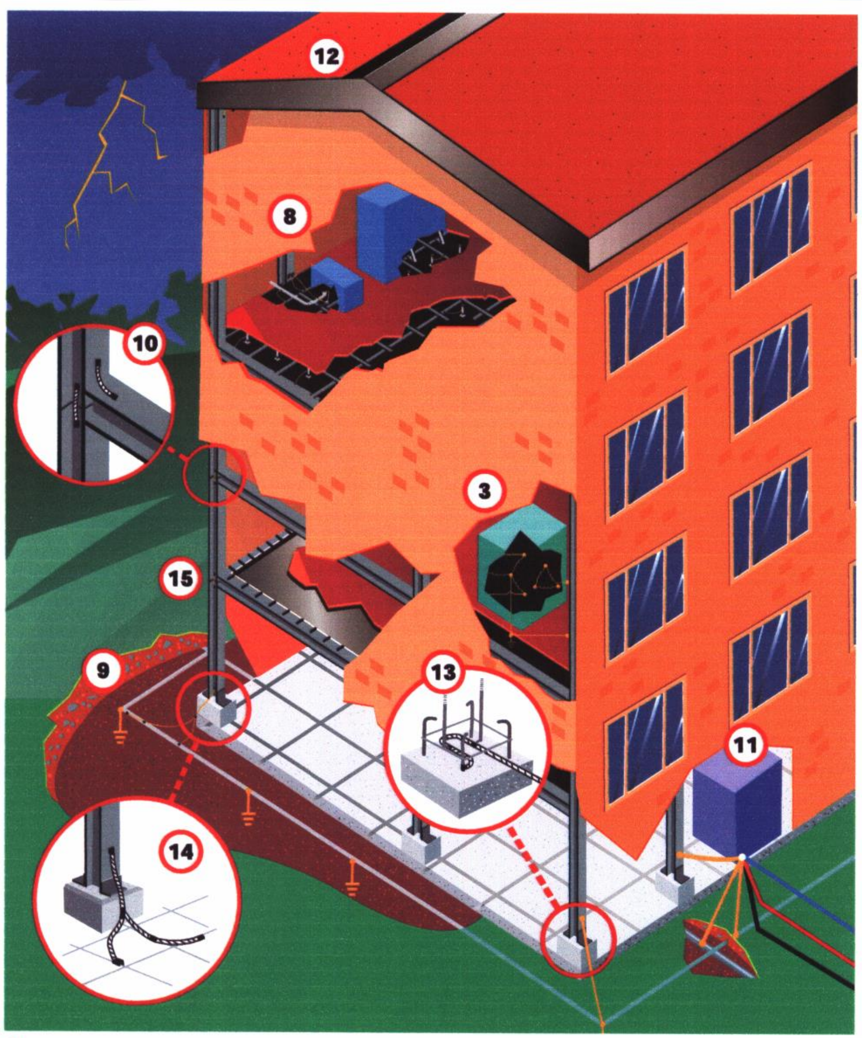
Description[1,2]	Median	Min.	Max.
Topsoil's, loams	26	1	50
Inorganic clays of high plasticity	33	10	55
Fills-ashes, cinders, brine wastes	38	6	70
Silty or clayey fine sands with slight plasticity	55	30	80
Porous limestone, chalk	65	30	100
Clayey sands, poorly graded sand-clay mixtures	125	50	200
Fine sandy or silty clays, silty clays, lean clays	140	80	200
Clay-sand-gravel mixtures	145	40	250
Marls[3]	155	10	300
Decomposed granites, gneisses[4], etc.	300	100	500
Clayey gravel, poorly graded gravel	300	200	400
Silty sands, poorly graded sand-silt mixtures	300	100	500
Sands, sandstone	510	20	1,000
Gravel, gravel-sand mixtures	800	600	1,000
Slates, schists[5], gneiss, igneous rocks, shales, granites, basalts	1,500	1,000	2,000
Quartzite's, crystalline limestone, marble, crystalline rocks	5,500	1,000	10,000

Notes: 1. Low resistivity soils are highly influenced by the presence of moisture.
2. Low resistivity soils are more corrosive than high resistivity soils.
3. Crumbly soil composed mostly of clay with a high limestone content.
4. Metamorphic rock formed by recrystallization of granite, separated into bands.
5. Metamorphic rock much coarser than gneiss.

This chart compiled from data published in:

IEEE Standard 142-1991, Recommended Grounding Practices
British Standard Code of Practice, CP-1013: 1965, Earthing
Megger: A Simple Guide to Earth Testing
Biddle: Getting Down to Earth

GROUNDING SYSTEMS



1. Parity sized grounding conductors.
2. Grounding symmetry in all parallel feeders.
3. Zones of equipment with localized transformers to isolate the equipment and control leakage current.
4. Limiting the quantity of devices grounded by any single conductor.
5. Utilizing specialty transformers to limit ground interference.
6. Faraday cage design concepts.
7. Use different networks throughout the facility as opposed to a single ended data network.
8. Reference grids in all computer, data processing and information technology rooms.
9. Perimeter ground ring bonded to the service entrance.
10. Intentional continuity of structural steel.
11. Bonding of all communication cables to structural steel.
12. Architectural steel treatment for lightning protection.
13. Ufer ground treatment per NEC for all main vertical steel footers.
14. Grounding grid below moisture barrier.
15. Bonding horizontal steel pans to structural steel.

GROUNDING SYSTEMS

- Several factures can degrade initially good grounding systems. These factors indicate the importance of continuous periodic testing (Typically once per calendar year unless problems arise). A change (lower) in the water table across the USA would lead to a degrade in the grounding system. Another consideration in the ground system would be in facility growth and the addition of non-metallic piping and conduit which do not provide low resistance ground connections. Along with the these concerns are the increase load and associated increase in available fault currents. The better the ground system, the more attention should be paid to corroded electrodes. All these could result in the need for a decrease in the grounding resistance.
  - Testing: Periodic testing should be done to assure grounding system effectiveness.

GROUNDING SYSTEMS

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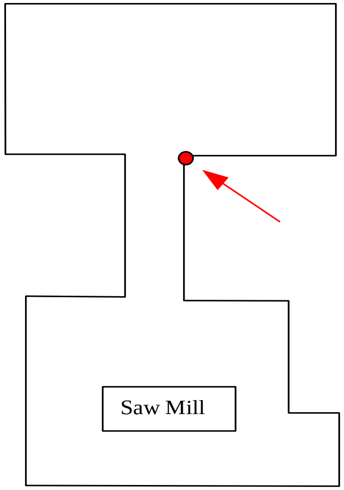
Earth Ground Test Report
Project : 302xxxx Test Page 1

Earth Ground Test Data	
Engineer	Bill Engel, P.E. & Harry Tittel, E.E.
Client / Facility	Client Name
Location	Saw Mill Area
Date	January 8, 2001
Time	9:30 AM
Ambient Conditions	83 °F, Humid, Dry Ground

Analysis & Problem Classification	
Test Method	Clamp on Ground Tester
Photograph No.	0
Amperage Reading	0 mA
Test Results	46.2 Ω
Notes:	Ground Tested High. Perform
	Maintenance on Ground or
	Replace.

Test Point Digital Image

Test Point Location Representation



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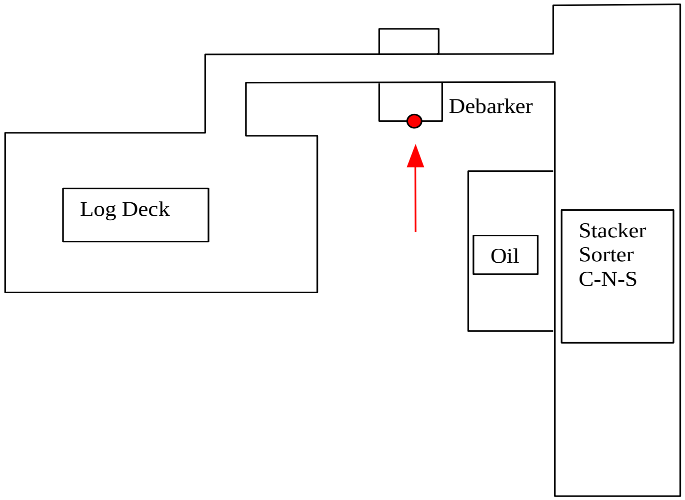
Earth Ground Test Report
Project : 302xxxx Test Page 2

Earth Ground Test Data	
Engineer	Harry Tittel, E.E.
Client / Facility	Client Name
Location	Stacker, Sorter, C-N-S Area
	Debarker Area
Date	January 8, 2001
Time	11:35 AM
Ambient Conditions	93 °F, Humid, Dry Ground

Analysis & Problem Classification	
Test Method	Clamp on Ground Tester
Photograph No.	7
Amperage Reading	34 mA
Test Results	1.5 Ω
Notes:	Ground Tested Within
	Parameters.

Test Point Digital Image

Test Point Location Representation



- Open question and Answer session.