GROUNDING AND BONDING
NATIONAL ELECTRICAL CODE
ARTICLE 250

By Jim Biesterveld

Some of the material is taken from Mike Holt and Soars presentations
NEC 250.1 Scope

(1) Systems, circuits, and equipment require, permitted, or not permitted to be grounded

(2) Circuits conductors to be grounded on grounded systems
(3) Location of grounding connections

(4) Type and size of grounding and bonding conductors and electrodes

(5) Methods of grounding and bonding
(6) Conditions under which guards, isolation, or insulation maybe substituted for grounding

The code has it’s definitions and these need to be understood to properly understand and interpret the code requirements of the NEC and Wisconsin Comm 16
Reproduction of NEC Figure 250.1
Grounding and Bonding

Part I General

Part II Circuit and system grounding
Part VIII Direct current systems
Part X Grounding of systems and circuits of 1 kV and over

Part III Grounding electrode system and grounding electrode conductor
Part IV Enclosure, raceway, and service cable grounding
Part VI Equipment grounding and equipment grounding conductors
Part VII Methods of equipment grounding

Part V Bonding

Part IX Instruments, meters, and relays
Severity of Electric Shock

The severity of electric shock is related to three elements.

If the combination of these three elements is just right, the shock can be severe or lead to electrocution.

1. Amount of current
2. Length of time current is present
3. Path of current through the body
4. Frequency of the current (Hz)

Amount of time current is allowed to pass through the body

Voltage source

Resistance

200 milliamps
fatal
Effects of Electricity on Humans

1000 milliamperes or 1 ampere

- Will light a 100-watt bulb
- Severe burns
- Breathing stops
- Heart stops beating
- Suffocation possible
- Muscle contraction
- Cannot let go
- GFCI will trip
- Mild shock
- Threshold of sensation

It doesn't take much current to cause injury or to cause death.
Series and Parallel Paths for Current

Current will always try to return to the source

Current will return in as many paths that are available to it

Amount of current on a particular path depends on the impedance of that path
Grounded Conductor: A system or circuit conductor that is intentionally grounded. For these systems, it is also the neutral conductor.
**Grounded (Grounding) Article 100 Definition**

*Grounded*: Connected to ground or some conductive body that extends the ground connection.

Structural steel that is connected to the grounding electrode system is an example of a conductive body that extends the ground connection.

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The following grounding electrodes that are present must be connected together to form the grounding electrode system:

1. Metal underground water pipe
2. Metal frame of building or structure
3. Concrete-encased electrode (Ufer)
4. Ground ring
5. Ground rod
6. Other listed electrode
The conductive path installed to connect normally noncurrent-carrying metal parts of equipment together and to the system neutral conductor or to the grounding electrode conductor, or both.

The equipment grounding conductor also performs bonding [FPN No. 1].

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Effective Ground-Fault Current Path To Open Overcurrent Device
Section 250.118 FPN

100A Device

583 Amps

200 ft 3 AWG 0.05Ω

200 ft 8 AWG 0.156Ω

Effective Ground-Fault Current Path [250.2]

Fault-Current Amps = \( \frac{E}{Z} \) = \( \frac{120V}{0.206Ω} \) = 583A

The 100A overcurrent device quickly opens and removes dangerous voltage from metal parts.

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The higher the current, the faster the fault clears.
250.4 General Requirements for Grounding and Bonding

- EARTH IS NOT AN EFFECTIVE GROUND-FAULT CURRENT PATH
250.4 General Requirements for Grounding and Bonding

- BONDING CONDUCTIVE MATERIALS
- To quickly remove ground-fault voltage by the opening of the circuit protection device, metal parts of the building structure must be connected to the source via the equipment grounding conductor.
Objectionable Current
Improper Neutral Connection
Section 250.6(A)

Parallel path for neutral current.

VIOLATION
Neutral-to-case connection on the load side of the service equipment.

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250.24 Service Equipment

- Service equipment supplied from a grounded system must have the neutral conductor grounded.
Neutral Point: A neutral point is the:
A - Common point of a wye 3-ph, 4-wire system
B - Midpoint of a 1-ph, 3-wire system
C - Midpoint of one phase of a delta 3-ph, 4-wire system
Service Equipment - Multiple Disconnect
Neutral Conductor Required
Section 250.24(C)

Service neutral conductor at each service disconnect.

Neutral-to-case connection required in each disconnect.

The neutral conductor must be run to, and connected to, each service disconnect via a main bonding jumper.
A grounding electrode conductor must connect the neutral conductor to a grounding electrode at the:

1. Service drop,
2. Meter enclosure, or
3. Service disconnect
The following grounding electrodes that are present must be connected together to form the grounding electrode system:

1. Metal underground water pipe
2. Metal frame of building or structure
3. Concrete-encased electrode (Ufer)
4. Ground ring
5. Ground rod
6. Other listed electrode
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.
Resistance of Rod, Pipe, and Plate Electrodes

Rod, pipe, or plate electrode that exceeds 25 ohms must be augmented by an additional electrode of a type specified in 250.52(A)(4) through (A)(8)

Minimum 6 feet apart or follow manufacturer's instructions

COMM 16 2-rods
Generator - Not Separately Derived System

Service

Feeder with neutral and equipment ground

Generator bonding jumper removed

Neutral not switched

To load
Grounding Method 1 [250.32(B)]

Grounding at separate building or structure using equipment grounding conductor [250.32(B)]

Isolate grounded conductor [250.24(A)(5)]

Service

Building 1

Building 2

Equipment grounding conductor

Required grounding electrode(s)
Grounding Metal Well Casings

Generally required to comply with the requirements of Article 250

A copper equipment grounding conductor is required

Metal well casing required to be bonded to the equipment grounding conductor supplying the pump circuit

250.112(L) and (M)
Equipment Grounding Conductor Insulated

Feeder may be overhead or underground

Distribution point

Equipment grounding conductor required to be insulated or covered copper if installed underground

547.9(D)
547.10 Equipotential Planes and Bonding of Equipotential Planes

- An equipotential plane must be installed at indoor and outdoor concrete confinement areas where metallic equipment is located that may become energized and is accessible to livestock.
Bonding & Grounding at Agricultural Buildings

• Specific requirements regarding grounding and bonding

• Two major concerns:
  – Integrity of grounding path due to corrosive conditions that exist in these locations
  – Neutral to earth stray voltages, if excessive, can cause behavior responses and can lead to loss of production and health problems in livestock

• Equipment grounding conductor run underground to these locations must be insulated or covered copper

• See Article 547 for specific Code sections.
Equipotential Bonding Planes

Panelboard

- Rebar, mesh, stanchions, etc.
- Copper bonding conductor not smaller than 8 AWG (typical)
Equipotential bonding plane is required in animal confinement areas with concrete floors or slabs in indoor and outdoor locations.
**Equipotential Plane:** An area where conductive elements in or under concrete are bonded to metal structures, fixed nonelectrical equipment, and the electrical grounding system to prevent a voltage difference from developing within the plane.
An equipotential plane must be installed in concrete floor confinement areas containing metallic equipment accessible to livestock.
An equipotential plane must be installed in outdoor **concrete** confinement areas containing metallic equipment accessible to livestock.
547.10 Equipotential Planes and Bonding of Equipotential Planes

- The equipotential plane must be connected to the building or structure’s electrical grounding system with a copper conductor not smaller than 8 AWG.
Agricultural Building – Voltage Gradient Ramp
Section 547.10(B) FPN 1

A voltage gradient ramp may be installed at entrances and exits that are traversed daily by livestock.
Agricultural Building – Voltage Gradient Ramp

Section 547.10(B) FPN 1

A voltage gradient ramp may be installed at entrances and exits that are traversed daily by livestock.
<table>
<thead>
<tr>
<th>Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)</th>
<th>Size (AWG or kcmil)</th>
<th>Aluminum or Copper-Clad Aluminum*</th>
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<tbody>
<tr>
<td>15</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>20</td>
<td>12</td>
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<td>2</td>
<td>1/0</td>
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<tr>
<td>600</td>
<td>1</td>
<td>2/0</td>
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<td>1/0</td>
<td>3/0</td>
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<tr>
<td>6000</td>
<td>800</td>
<td>1200</td>
</tr>
</tbody>
</table>

*Note: When aluminum is used, with 250 kcmil or 2/0 kcmil, the aluminum shall be of a design having a copper conductor core.
# Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems

<table>
<thead>
<tr>
<th>Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors&lt;sup&gt;a&lt;/sup&gt; (AWG/kcmil)</th>
<th>Size of Grounding Electrode Conductor (AWG/kcmil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>Aluminum or Copper-Clad Aluminum</td>
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<tr>
<td>2 or smaller</td>
<td>1/0 or smaller</td>
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<tr>
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<td>2/0 or 3/0</td>
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<tr>
<td>2/0 or 3/0</td>
<td>4/0 or 250</td>
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<tr>
<td>Over 3/0 through 350</td>
<td>Over 250 through 500</td>
</tr>
<tr>
<td>Over 350 through 600</td>
<td>Over 500 through 900</td>
</tr>
<tr>
<td>Over 600 through 1100</td>
<td>Over 900 through 1750</td>
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<tr>
<td>Over 1100</td>
<td>Over 1750</td>
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</table>