Grounding and Bonding of Service Equipment

3/27/2018 | NW Electrical Meter School | Track D – Grounding and Bonding of Meters | Chuck Matsen, Seattle City Light

1. **Grounding** means: “attached to an earth ground”.
2. **Bonding** means: “physically connected to insure electrical continuity”.

» **NEC 250.4**

- **1. Grounding:**
  - Electrical Systems that are grounded shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines and that will stabilized the voltage to earth during normal operation.

- **2. Grounding:**
  - **Non-current carrying** conductive materials enclosing electrical conductors or equipment, or forming part of such equipment shall be connected to earth so as to limit the voltage to ground on these materials.

- **3. Bonding:**
  - **Non-current carrying** conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault current path.
NEC 250.4 (continued)

- 4. Bonding:
  - Electrical conductive materials that are likely to become energized shall be connected together and to the electrical supply in a manner that establishes an effective ground-fault path.

- 5. Effective Path:
  - Electrical equipment and wiring and other electrically conductive material likely to become energized shall be installed in a manner that creates a permanent, low-impedance circuit capable of safely carrying the maximum ground-fault current likely to be imposed on it from any point on the wiring system where a ground fault may occur to the electrical supply source. The earth shall not be used as the sole equipment grounding conductor or effective ground-fault current path.

- 6. Objectionable Currents:
  - The grounding of electrical systems, circuit conductors, surge arresters, and conductive non-current carrying materials and equipment shall be installed and arranged in a manner that will prevent objectionable current over the grounding conductors or grounding path.

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NEC 250.4 (continued)

- 6. Objectionable Currents: (cont.)
  - 1. Alterations to stop objectionable current: If the use of multiple grounding connections results in objectionable current, one or more of the following alterations shall be permitted to be made, provided that the other requirements are met:
    - A. Discontinue one or more, but not all of such grounding connections
    - B. Change the locations of the grounding connections
    - C. Interrupt the continuity of the conductor or conductive path interconnecting the grounding connections
    - D. Take other suitable remedial and approved action

  - 2. Limitations: The provisions of this section shall not be considered as permitting equipment from being operated on systems or branch circuits that are not grounded as required by this section. Currents that introduce noise or data error in electronic equipment shall not be considered the objectionable currents addressed in this section.
1. **Grounding** **means:** “attached to an earth ground”.
2. **Bonding** **means:** “physically connected to insure electrical continuity”.

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### NEC 250.24

1. **System Grounding Connections:**
   - A premise wiring system supplied by a grounded AC service shall have a grounding electrode conductor connected to the grounded service conductor, at each service.

2. **General:**
   - The connection shall be made at any accessible point from the load end of the service drop or lateral to and including the terminal or bus to which the grounded service conductor is connected at the service disconnecting means.

3. **Bus:**
   - Where the main bonding jumper is a wire or bus-bar and is installed from the neutral bar or bus to the equipment grounding terminal bar or bus in the service equipment, the grounding electrode conductor shall be permitted to be connected to the equipment grounding terminal or bus to which the main bonding jumper is connected.

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4. **Load Side Grounding Connections:**
   - A grounding connection shall not be made to any grounded circuit conductor on the load side of the service disconnecting means.

5. **Grounded Conductor Brought to Service Equipment:**
   - Where an AC system operating at less than 1000 volts is grounded at any point, the grounded conductor shall be run to each service disconnecting means and shall be bonded to each disconnecting means enclosure.
5. **Grounded Conductor Brought to Service Equipment**: (continued)
   - Bonding
     1. **General**: Bonding shall be provided where necessary to ensure electrical continuity and the capacity to conduct safely any fault current likely to be imposed.
     2. **Bonding of Services**: The non-current carrying metal parts of equipment shall be effectively bonded together
        - A. The service raceways, cable trays, cable bus framework, auxiliary gutters or service cable armor or sheath.
        - B. All service enclosures containing service conductors, including meter fittings and boxes interposed in the service raceway or armor.
        - C. Any metallic raceway of armor enclosing a grounding electrode conductor. Bonding shall apply at each end and to all intervening raceways, boxes, and enclosures between the service equipment and the grounding electrode.

1. **Instrument Transformer Circuits**: (continued)
   - Secondary circuits of current and potential instrument transformers shall be grounded where the primary windings are connected to circuits of 300 volts or more to ground and where on switchboards shall be grounded irrespective of voltage. **SEPARATELY DERIVED SYSTEM**

2. **Instrument Transformer Cases**: (continued)
   - Cases of frames of instrument transformers shall be grounded where accessible to other than qualified persons.
NEC 250.170 (Continued)

3. Cases of Instruments, Meters, and Relays operating at less than 1000 volts:
   - Instruments, meters, and relays operating with winding or working parts at less than 1000 volts shall be grounded.

4. Instrument Grounding Conductor:
   - The grounding conductor for secondary circuits of instrument transformers and for instrument cases shall not be smaller than #12 copper or #10 aluminum. Cases of instrument transformers, instruments, meters, and relays that are mounted directly on grounded metal surfaces of enclosures or grounded metal switchboard panels shall be considered to be grounded and no additional grounding conductor shall be required.
**Typical Self Contained Installation**

**Typical CT Installation Grounding and Bonding Points**

SCL NO LONGER ALLOWS THIS

Some utilities still do
We will see why this is a bad idea later
Ground Loops

6/13/2016
What is the name of the “grounded conductor” in an electrical circuit?

What color is it?

What is it’s function?
A ground loop exists when an electrical system is connected with multiple paths to ground.

When two or more devices are connected to a common ground through different paths a ground loop occurs.
Currents flow through these multiple paths and develop voltages that can damage sensitive equipment, cause noise, and affect meter readings which offset from actual values.
They can cause indicating meters to “peg up” or “peg down” and/or lock up

They can cause sensitive electronic equipment to be inaccurate or even fail

NEC defines a ground as a conducting connection between an electrical circuit and earth

A ground loop can be defined as objectionable current flowing in that ground or return path
The simplest ground loop involves a connection between two different earth grounds.
Even though NEC requires grounding electrodes and metal parts to be bonded together, there will still be differences in ground potentials in most systems.

One common cause of ground loops is double bonding of the “grounded conductor”

NEC requires the neutral to be bonded to ground at only one place, at the source entrance or first disconnect.
When the neutral is double bonded, returning neutral current will split per Kirchhoff's law and flow in the ground circuit.

This current can cause varying voltage references to equipment in the circuit such as metering.
The addition of another ground compounds the problem
Solving ground loop problems is a two-fold process

#1 Remove multiple paths to ground
#2 Remove multiple neutral to ground bonds

With these two easy steps, ground loops will be eliminated
Metering circuits that contain ground loops can have measurement errors

The measurement errors will be proportional to the voltage drop in the metering potential circuit caused by current in the neutral conductor

The measurement error will always be a net loss for the utility

• AC Calculation for Ground Loop Loss
  • Voltage: 120 V
  • Load: 1200 Amps (300/5 CT’s)
  • Load Circuit: 3-PH, 4-W Wye
  • Power Factor: 1 (for this example)
  • Insulation Temp: 75°C/167°F
  • Conductor: Copper
  • Conductors per Phase: 1
  • Conduit: Aluminum
  • Cable Length: 75 Feet
  • Conductor Gauge: 12

• Observed in field:
  • 1.20 Volts Line-to-Neutral voltage drop = 118.8 Volts at the 9S meter socket
With this ground loop, the voltage at the bus is 120 volts, but the voltage at the meter is 118.8

The correct metering would be:
\[ E \times I \times 3 \times PF(1) \text{ or } \]
\[ 120 \times 1200 \times 3 \times 1 = 432.0 \text{ Kw} \]

The metering with the ground loop is:
\[ 118.8 \times 1200 \times 3 \times 1 = 427.7 \text{ Kw} \]

The difference is 4.3 Kw or 1%

If this building has a duty cycle of 432 Kw for 12 hours, and 216 Kw for nights and weekends, the lost revenue could be calculated as below for a 30 day billing period:

4.3 Kwh’s for 12 x 5 x 4 = 1,032 Kwh’s  M-F Day
2.2 Kwh’s for 12 x 5 x 4 = 528 Kwh’s  M-F Night
2.2 Kwh’s for 24 x 2 x 4 = 422 Kwh’s  Sat - Sun
Total: 1,982 Kwh’s

Assuming $0.06 per Kwh:
For the month = 1,982 x $0.06 = $119
For the year = 23,784 x $0.06 = $1,427
Our Utility has 420,000 accounts with 43,000 CT services

Each CT service is undergoing an electrical Audit to insure the integrity of our metering systems

Our Utility has instituted steps to eliminate all ground loops from new and existing service installations
How can you determine if you have a ground loop condition on your metering system?

1. Measure for current on the neutral at the test switch

2. Measure for a difference in potential between the bus and the test switch

If either of these conditions is true, you probably have a ground loop.

If you find either of these conditions, you will find a ground loop.

Clear your ground loop and retake your measurements.

Once your ground loop is cleared, your measurements will return to normal levels.

(very small current - and - bus voltage will match test switch voltage)
VM1 and VM2 are unequal

JUMPER AT TEST SWITCH CAUSING A GROUND LOOP
JUMPER AT TEST SWITCH CAUSING A GROUND LOOP

High reading using Clamp on Ammeter

Bonded to Ground
Neutral

GROUND CURRENT
NEUTRAL CURRENT

C1 - C1 C2 - C2 C3 - C3 + + + + + +
Most desirable Means
Less desirable means
But OK
Less desirable means
But OK

Most desirable means
The End