Grounding and Bonding

An Online Continuing Education Course for Engineers

Course Number: E-1033

Credit: 1 Hour / 1 PDH / 1 CPD

Grounding and Bonding

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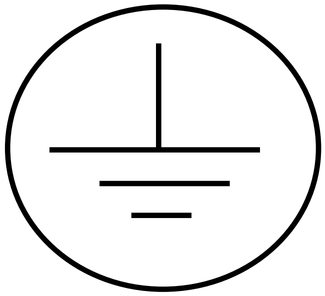


Introduction

In this course, we will examine why we ground and why we bond, and the difference between them. The reasons for grounding include:

1. Protect people from electric shock and possible death
2. Protect buildings and other manmade structures, including communication towers
3. Protect equipment from electrical damage
4. Provide for a return path to ensure the proper operation of overcurrent protection devices
5. Reduces or eliminates noise from electromagnetic interference
6. Provides a polarity reference for systems that use DC powered equipment

This course will review each of these fundamental reasons for grounding.

The practicality of using electrical grounding to protect structures originated around 1750 with Benjamin Franklin's lightning rod. Lightning has a potential difference of between 10^8 and 10^9 volts between the clouds and the ground. (1) According to the National Weather Service, the typical lightning flash is about 30,000 Amps and 300 X 10^6 Volts. (2) Figure 1.1 is a simplified equivalent circuit of what can happen when a building is struck by lightning. In this example, the building has no lightning protection. The voltage drop across the building can be minimized by minimizing the impedance across the building, Z_B.

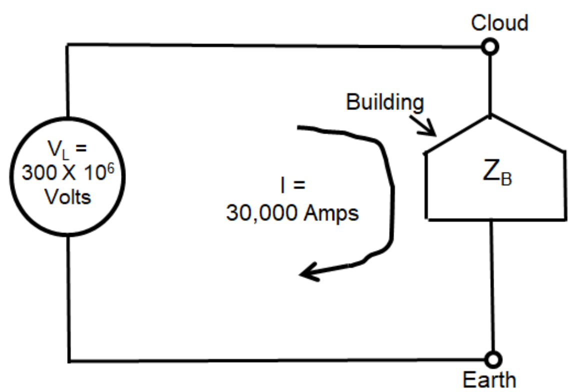


Figure 1.1: Building struck by lightning.

Without lightning protection, the building is exposed to 30,000 Amps. If Z_B is equal to 100Ωs, the voltage across the building would be 3 million volts. People in the building would be subject to injury and possibly death. Equipment may be damaged or destroyed. The building itself may be destroyed. To avert these consequences, buildings now use lightning rods.

The Franklin Lightning Rod was made of iron [3] and was fastened at the highest point of a church steeple, a barn, or other tall structure. The lightning rod system is made up of the lightning rod, a wire, and a ground electrode. Figure 1.2 is an equivalent circuit drawing of lightning striking a building that is equipped with a lightning rod. A copper lightning rod is bonded to a copper wire which runs down on the outside of the building and is bonded to a ground rod that terminates in the soil. The lightning rod, the wire, and the ground rod provide a low impedance path to ground for the 30,000 AMPS. Instead of the lightning current traveling through the building, it now travels on the copper wire, which is outside of the building.

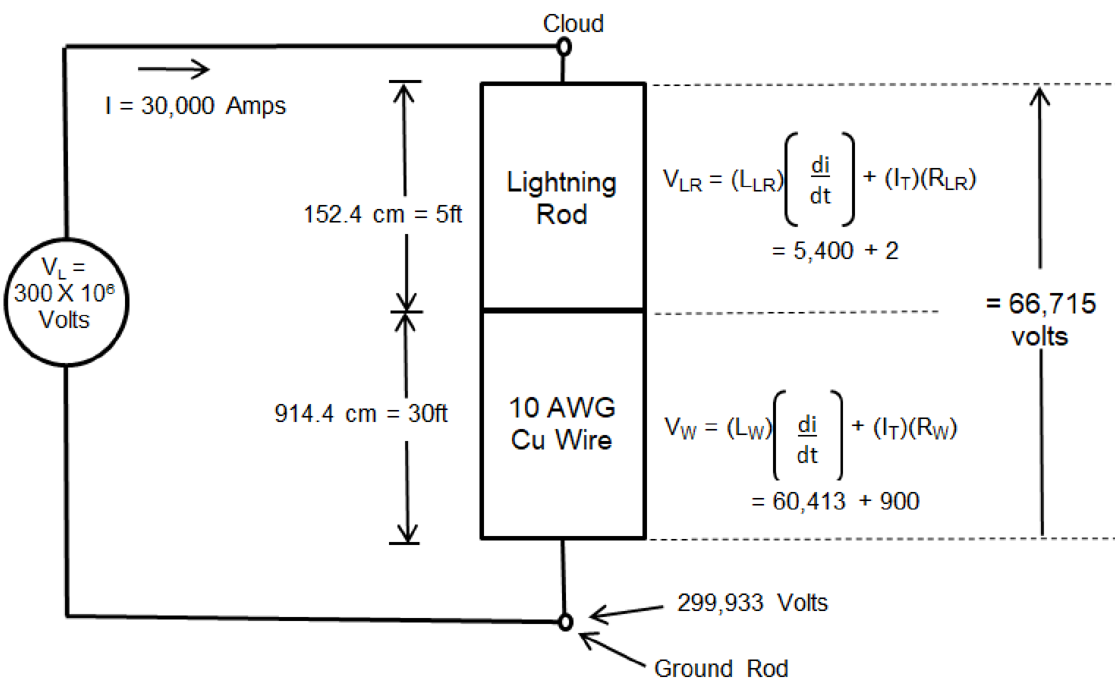


Figure 1.2: Lightning Rod at top of building struck by lightning.

Now that we have the current flowing outside of the building, we should look at the impact the system has on the voltage. For Figure 1.2, to calculate the voltage drops across the lightning rod and the 10 AWG wire, we first must calculate the inductance of each.

$$L = 2l \left\{ 2.303 \operatorname{Log}\left(\frac{(4)(l)}{D}\right) - 1 + \frac{\mu}{4} + \left(\frac{D}{(2)(l)}\right) \right\}^{(4)}$$

L_{LR} and L_W are inductances in Henries X 10^{-9}
l = length in centimeters
D = diameter in centimeters (2.54cm, for the lightning rod; 0.259cm i.e. 0.102 inch, for 10AWG wire)
μ = permeability of the material (= 0.9999906 ≈ 1 for copper [5])
L_{LR} = Inductance of the lightning rod
L_W = Inductance of the 10AWG Wire
I = 30,000Amps

$L_{LR} = 1.44 \times 10^{-6}$ Henries
$L_W = 16.11 \times 10^{-6}$ Henries

Next, we need to calculate the resistance of the lightning rod and wire.

$$R = \frac{(\rho)(\text{length in cm})}{\text{Area in cm}^2}$$

ρ = Resistivity of copper = 1.73×10^{-6} Ω cm @ 20°C [6]
D = diameter (2.54cm for lightning rod, 0.259cm for 10AWG wire)

$R_{LR} = 52.0 \times 10^{-6}$ Ω
$R_W = 30.0 \times 10^{-3}$ Ω

dt - assume lightning amperage rises to a peak in 8 X 10^{-6} seconds [7]

$$V_{LR} = L_{LR}\left(\frac{di}{dt}\right) + (I)(R_{LR})$$

$$V_{LR} = 1.44 \text{ X } 10^{-6}\left(\frac{30{,}000}{8 \text{ X } 10^{-6}}\right) + (30{,}000)(52.0 \text{ X } 10^{-6})$$

V_{LR} = 5,400.00 volts + 1.56 volts = 5,401.56 Volts

$$V_{w} = 16.11 \text{ X } 10^{-6}\left(\frac{30{,}000}{8 \text{ X } 10^{-6}}\right) + (30{,}000)(30\text{X}10^{-3})$$

V_{w} = 60,412.50 volts + 900.00 volts = 61,312.50 Volts

$V_{LR} + V_{w}$ = 5,402 + 61,313 = 66,715 Volts

The lightning in Figure 1.2 strikes the lightning rod with 300 X 10^{6} volts. The voltage drop across the lightning rod and the wire connecting the lightning rod to the ground rod is 5,402 and 61,313 volts, respectively, for a total of 66,715 volts. The inductive component of the wire accounts for most of this voltage drop, i.e., 60,412.5 volts. Most notably, the remaining component of the voltage, 299,933 volts, is dissipated to the earth via the ground rod. This voltage drops as you walk away from the ground rod. You don't want to be standing close to a building's ground rod in a lightning storm.

The wire connecting the lightning rod to the ground rod should not make contact with building steel or some alternative path within the building that would provide an alternate route to ground. Lightning will find it. Since the mid-1700s, the lightning rod has been used to provide a measure of safety for people, the protection of buildings, and the protection of equipment.

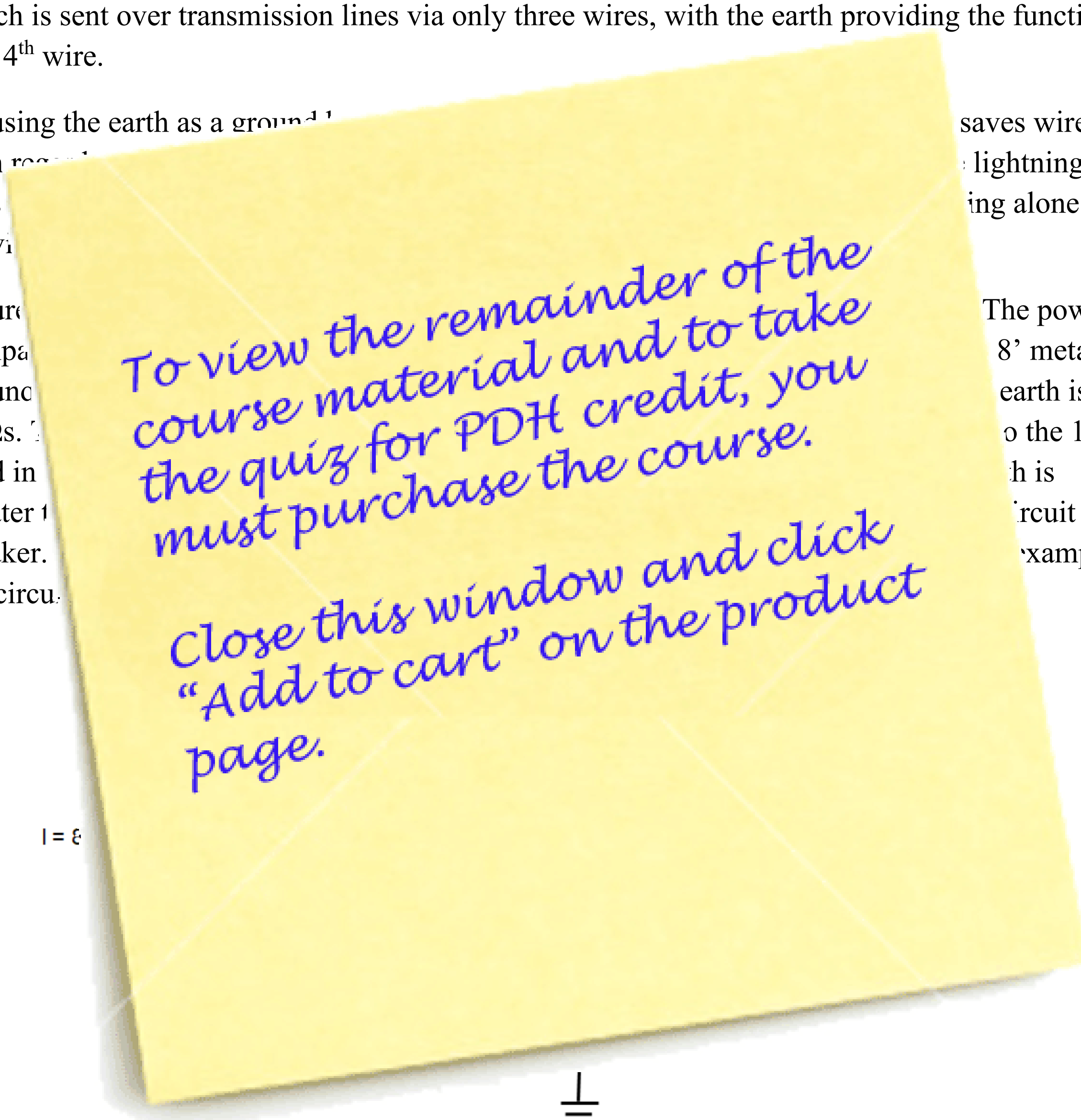
Earth and Electricity

Another use of the earth (the ground) with regard to electricity was the telegraph in the 1800s. The early versions of the telegraph used two wires, a signal wire, and a return wire. In 1838, Carl von Steinheil discovered that the earth could be used in place of the return wire. [8]

Power companies also use the earth as a return. Power companies generate three-phase power, which is sent over transmission lines via only three wires, with the earth providing the function of a 4th wire.

So using the earth as a ground ... saves wire with re... lightning rods ... ing alone provi...

Figur... The power compa... 8’ metal ground... earth is 15Ωs. ... o the 15Ωs used in ... h is greater ... rcuit breaker. ... xample, the circu...



I = 8...

Figure 2.1: House with Short Circuit to a Grounding Electrode (no main bonding jumper)