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GROUNDING VERSUS BONDING

Many individuals confuse "grounding" and "bonding" of a traffic signal system. The purpose of this article is to clarify the difference and to discuss important aspects of both grounding and bonding systems.

Making sure that all of the metallic components of a traffic signal system are well-grounded (properly connected to a suitable number of rods driven into the ground) helps protect electronic equipment from damage due to unanticipated voltage transients, such as those caused by nearby lightning strikes. Without a good grounding system a much greater potential exists for harmful electric current to travel a path that goes through an expensive piece of equipment (such as a controller). Good **grounding** helps protect equipment.

When a separate copper wire is connected between the metallic components of a traffic signal system and the ground bus of the controller cabinet, the signal system is said to be "bonded". Bonding together the metallic components of a traffic signal system helps protect signal technicians and the public from injury due to short circuits. Good **bonding** helps protect people.

BONDING:

Proper bonding of a traffic signal provides the same protection that the ground wire in a household electrical system does. In modern homes, the frame of your refrigerator is connected to the neutral buss bar back at the circuit breaker box via a green wire that is attached to the refrigerator through the "third prong" of a household plug. If the black power wire somehow makes contact with the frame of the refrigerator, a short circuit is established and the resulting high current causes the circuit breaker to trip. Without this third wire, the frame of the refrigerator would remain energized and anyone touching it could get a nasty shock.

The same operational principals apply in a signal system. If a "high voltage" (120V AC) signal wire sustains a break in the insulation and makes contact with a metallic surface (such as a signal head or mast arm pole), the surface will become energized. Without a bonding conductor to close the circuit and activate the circuit breaker, the metallic surface will remain energized. The potential then exists for harmful electric current to travel through the next person to come in contact with the metallic surface.

The size of the bonding conductor is usually specified in the plans and specifications. If not, the National Electrical Code (NEC) provides guidance on sizing.

So we see that bonding is very important for the safety of both the public and repair personnel.

GROUNDING:

The primary reference document for traffic signal grounding appears to be NCHRP Report 317, "Transient Protection, Grounding, and Shielding of Electronic Traffic Control Equipment". This document has a lot of good information relative to grounding and other forms of transient protection.

The 25 ohm grounding requirement used by most agencies is taken from Section 250-84 of the National Electrical Code (NEC) which states that:

> *"A single electrode consisting of a rod, pipe, or plate that does not have a resistance to ground of 25 ohms or less shall be augmented by one additional electrode of any of the types specified in Section 250-81 or 250-83. Where multiple rod, pipe, or plate electrodes are installed to meet the requirements of this section, they shall not be less than 6 feet apart."*

Section 96B of The National Electrical Safety Code (NESC) has a similar requirement:

> *"Individual made electrodes shall, where practical, have a resistance to ground not exceeding 25 ohms. If a single electrode resistance exceeds 25 ohms, two electrodes connected in parallel shall be used."*

Neither the NEC nor the NESC offer justification for use of the 25 ohm value. It appears that this value has simply become established over time as a relatively low resistance value that is obtainable by driving a reasonable number of ground rods into common soil conditions. Note that the NEC and NESC do not require the continued addition of ground rod until the 25 ohm requirement is met, but merely require the addition of a second ground rod.

The resistance of a given portion of soil depends primarily on 3 items: moisture content, salt content, and porosity. Dense, moist soils with high salt contents have low resistivity. The resistivity of a portion of soil can vary widely over time and there is no guarantee that the resistance measurement of a ground rod installation taken under one set of conditions will remain the same as the seasons and the weather change. A 24 ohm reading in March under wet conditions might turn to a 32 ohm reading in August under dry conditions.

It is clear from a simple review of ohm's law (E = IR) that ground rod installation to 25 ohms will not provide suitable ground-fault protection. 120 Volts/25 Ohms = 4.8 Amps, which is not enough to trigger even a small 15 Amp circuit breaker. This conclusion is supported by NCHRP Report 317 (page 25). Consequently, if a "hot" wire touches a steel mast arm pole, the pole could easily remain energized and shock repair personnel or pedestrians, even if it is connected to a ground rod with a 25 ohm resistance. The same problem exists with metallic pull box lids, metallic ped poles, ped buttons, and the metallic components of a span wire assembly; if a hot wire makes contact (and bonding is not provided) someone could get hurt! This is not a problem with the cabinet since the components within the cabinet are all tied-together; if a hot wire touches the cabinet then a low-resistance path will be created, a large current will flow, and the circuit breaker will trigger. Consequently, adequate bonding is very important to ensure that poles and ped buttons do not remain energized.

Although grounding to 25 ohms does not provide adequate protection against the ground-fault situation just discussed (that is the role of bonding), it does help in the dissipation of voltage transients so that sensitive and expensive electronic equipment is protected. Transients can be caused by a number of items, including: motor start-ups or switch closures from industrial plants; a short in the power distribution system; or strong radio frequency transmissions (TV, radar, CB radios). However, the most frequent cause is a nearby lightning strike.

Lightning-spawned transients can enter the controller cabinet through the signal cables, the pedestrian detection or signal head wires, or the loop wires. But the path of highest probability is that of either communication cables or the power service (or telephone service if the cabinet has it). This is true because the network for communication and power service wires is very extensive so that even somewhat distant lightning activity can produce harmful voltage transients in these lines. It should be noted that the lightning does not even have to make contact with a wire to cause a problem; a lightning bolt that simply runs parallel to the wire for some distance can <u>induce</u> a large transient voltage into the system.

It is emphasized that a ground of less than 25 ohms does not guarantee protection against voltage transients. A large voltage transient can cause damage, even with an excellent ground, as the tremendous amount of energy that is released follows all potential paths. However, the lower the resistance of the ground, the greater the probability that enough energy will be drawn to ground to protect the equipment. A good ground <u>reduces the probability</u> of equipment damage due to voltage transients, but by no means eliminates it.

At certain locations, a point of diminishing benefit is obtained from ground rod installation. The following is a typical example:

10 feet of ground rod installed --->	reading of 150 ohms
10 more feet installed ------------->	reading of 89 ohms
10 more feet installed ------------->	reading of 68 ohms
10 more feet installed ------------->	reading of 56 ohms
10 more feet installed ------------->	reading of 52 ohms
10 more feet installed ------------->	reading of 52 ohms

In this example, the resistance does not change much after 40 feet of ground rod has been added and it is pointless to keep adding ground rods. Adding Epsom salt (magnesium sulphate) to the ground and letting it settle in over time can substantially decrease the resistance of a given section of soil. Placing the ground rod in a drainage ditch or in a pond is another good strategy for reducing resistance (as long as this ditch or pond is nearby).

If I were "king of signals", all grounding would be tested for adherence to the 25 ohm criteria. If this criteria is not met with the amount of ground rod specified in the plans or specifications, then additional ground rods (cost of about $30 per 10 feet) would be added until the change in resistance is less than 5 ohms or until the 25 ohm criterion is met. In no case would a final resistance-to-ground reading of greater than 100 ohms be permitted. If the final reading were greater than 25 ohms, a 2-pound bag of Epsom salt (cost of about $5) would then be trenched into the soil. This would be a reasonable and cost-effective approach that meets both NEC and NESC requirements. The current practice (in some states) of continuing to add ground rod, ad nauseam, until the 25 ohm criteria is reached (and sometimes it just can't be reached) makes little sense once one realizes the nature of the "voltage transient probability game" that surrounds the use of this criterion.

Even if an excellent grounding system is installed, it is also prudent to use surge suppression devices on all circuits entering the cabinet in order to further reduce the probability of damage caused by voltage transients. It is especially important to protect communication, power, and telephone circuits.