PROTECTION ENGINEERS GROUP

HUNTSVILLE, AL - MARCH 13-15, 2018

Achieving Network Reliably with Proper Application of Bonding and SPDs

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SPD Grounding and Bonding Principles via IEEE Std. C62.72-2016

Clause 11 - Grounding (earthing) and bonding

IEEE Std C62.72-2016 - IEEE Guide for the Application of Surge-Protective Devices for Use on the Load Side of Service Equipment in Low-Voltage (1000 V or Less, 50 Hz or 60 Hz) AC Power Circuits

C62.72-2016 available here: https://standards.ieee.org/findstds/standard/C62.72-2016.html

About IEEE Std. C62.72:

Society:
Power and Energy Society (PES)
https://www.ieee-pes.org/

Technical Committee:
Surge Protective Devices Committee (SPDC)
https://pes-spdc.org/Home

Working Group:
WG 3.6.6 - Low Voltage AC Power System SPDs — Load Side of the Service Equipment
https://pes-spdc.org/lv_spd

IEEE STANDARDS ASSOCIATION IEEE

IEEE Guide for the Application of Surge-Protective Devices for Use on the Load Side of Service Equipment in Low-Voltage (1000 V or Less, 50 Hz or 60 Hz) AC Power Circuits

IEEE Power and Energy Society

Sponsored by the
Surge Protective Devices Committee

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IEEE Std C62.72™-2016
(Revision of
IEEE Std C62.72-2007)

About IEEE Std. C62.72-2016

1.1 Scope
This guide covers the application of surge-protective devices (SPDs) for installation on the load side of the service equipment for 50 Hz or 60 Hz, ac power circuits rated 1000 Vrms or less.

1.2 Purpose
The purpose of this guide is to provide users, specifiers, installers and manufacturers with guidance on the use, selection, application and installation of SPDs for installation on the load side of the service equipment for 50 Hz or 60 Hz, ac power circuits rated 1000 Vrms or less.

Topics covered

- **SPD grounding lead and related considerations**
- **Loop area**
- **SPD connections**
- **Common bonding network (CBN)**
- **Grounding**
- **Ground potential rise**
- **Practical applications**

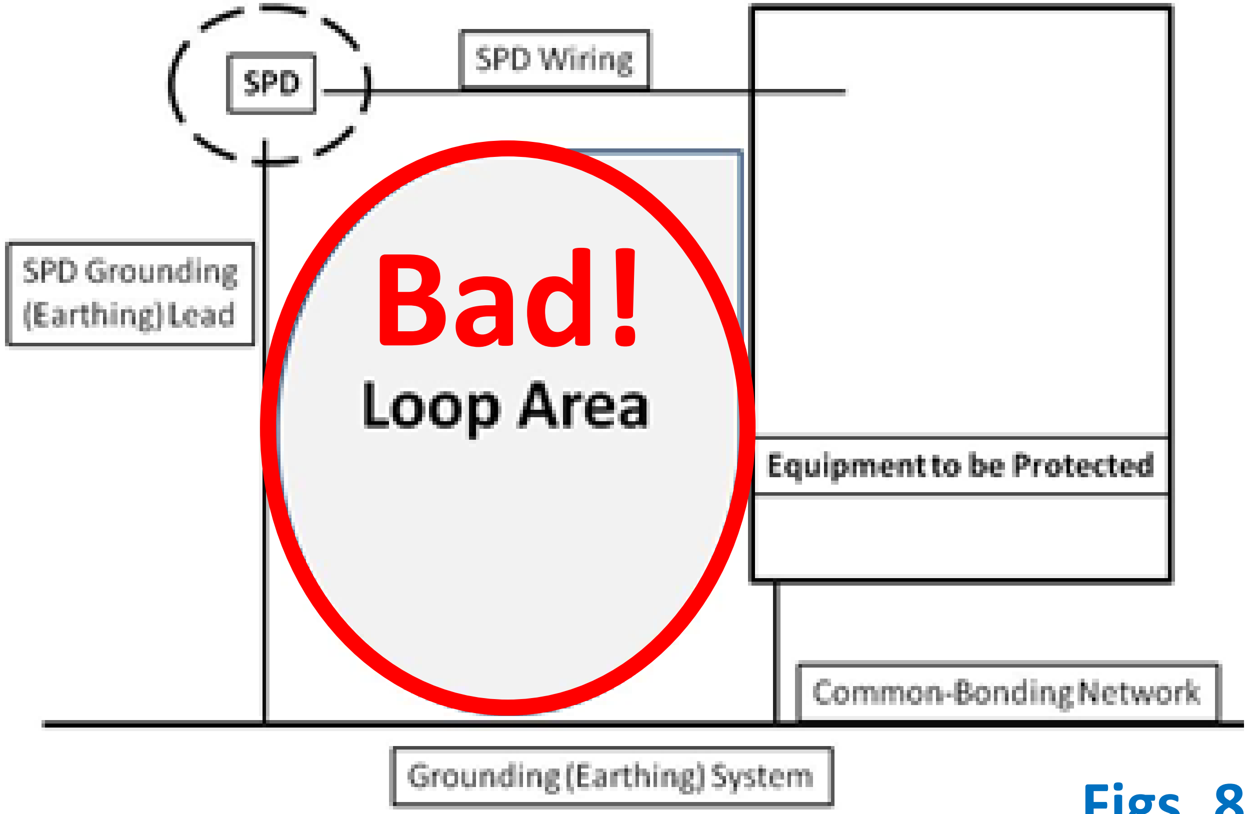
Grounding and Bonding for SPDs

- SPD grounding lead and related considerations
  - The SPD grounding lead should be as short as practical
  - Installed in a straight and as direct manner as feasible
  - Partial self-inductance of this lead will be the dominant impedance factor during a surge event due to the relatively short rise time
- Greatly influenced by the loop area of the total circuit
  - Minimize loop area (see next slide - “Loop area”)

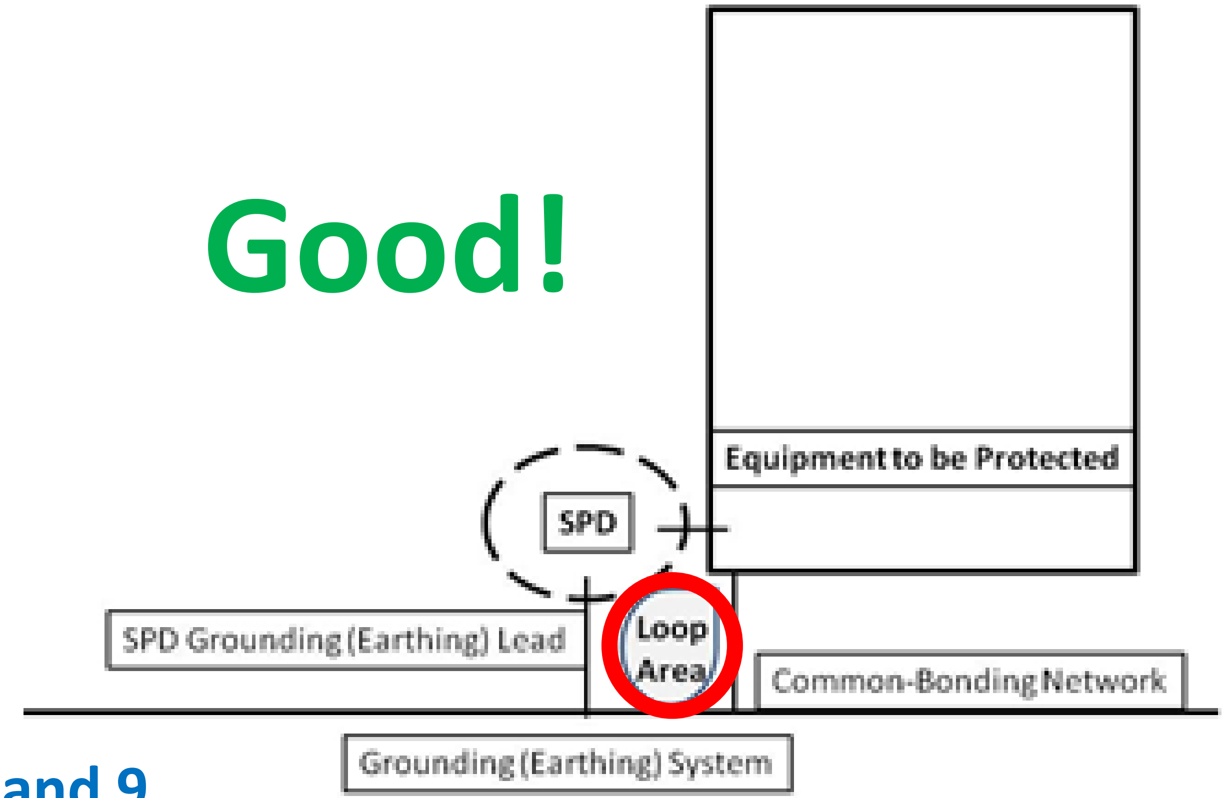
Grounding and Bonding for SPDs

- Loop area
  - The loop area is formed by the SPD and its grounding lead and the equipment to which it is connected
  - The loop area captures the electromagnetic field from a lightning event
    - Fields are usually higher at Category C locations and building exterior
    - Concern diminishes toward center of building and shielded areas
  - Voltage induced into the loop adds to SPD let-through voltage
    - A small loop area reduces this additive voltage

Grounding and Bonding for SPDs



Large Loop Area

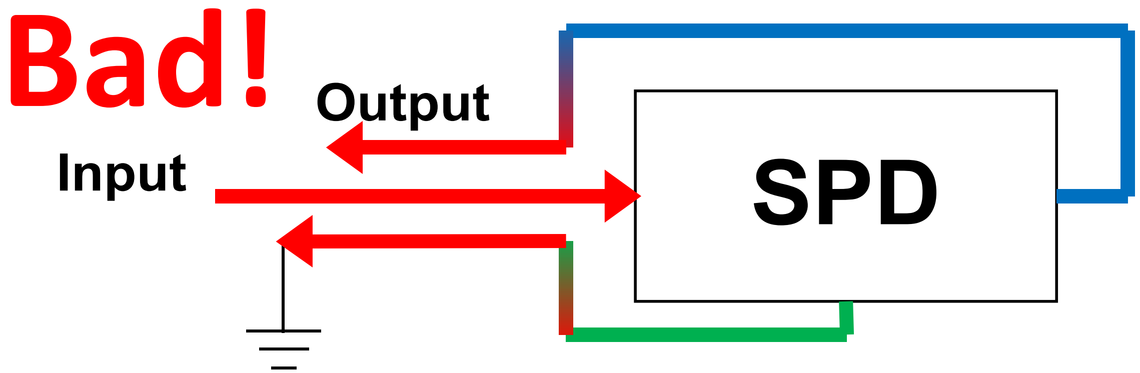


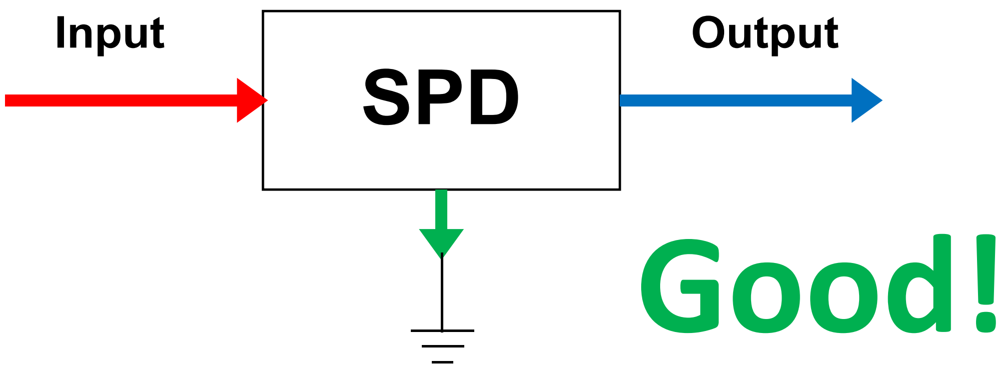
Minimized Loop Area

Figs. 8 and 9
From C62.72-2016

Grounding and Bonding for SPDs

- Other considerations – Input and output connections
  - For two port SPDs (like many communication SPDs), protected and unprotected connections should be separated and routed in different directions
  - To avoid coupling of the transient, route the wiring at 90 degree angles





Grounding and Bonding for SPDs

- Other considerations – SPD connections
  - Leads enclosed in non-metallic bodies should be twisted together (to aid in reducing inductive coupling)
  - A ground plane can be utilized to reduce the loop areas
    - Route the SPD wiring within continuous metal conduit (sections bonded)
    - Use separate conduit for the input and output wiring
    - SPD ground lead can be routed close along the surface of the metal enclosure of the protected equipment

Grounding and Bonding for SPDs

- Common bonding network
  - Physical bonding of all metallic infrastructure, equipment cases, and grounding conductors within the facility perimeter in order to create a holistic bonding network
  - C62.72-2016 references and reiterates content from these IEEE Standards
    - IEEE Std. 1100 - IEEE Recommended Practice for Powering and Grounding Electronic Equipment
    - IEEE Std. 142 - IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems

Grounding and Bonding for SPDs

- Common bonding network
  - Designed to promote relative equipotential across the bonding network
  - Includes both intentional and unintentional entities
  - Intentional entities utilize “approved” bonding and grounding hardware as required by the applicable local electrical code

Grounding and Bonding for SPDs

- Common bonding network
  - The equipotential is realized only during static to quasi-steady-state condition
  - Tends to degrade with current waveforms of higher magnitudes and faster rise/fall times
    - (Such as during a transient or surge event)

Grounding and Bonding for SPDs

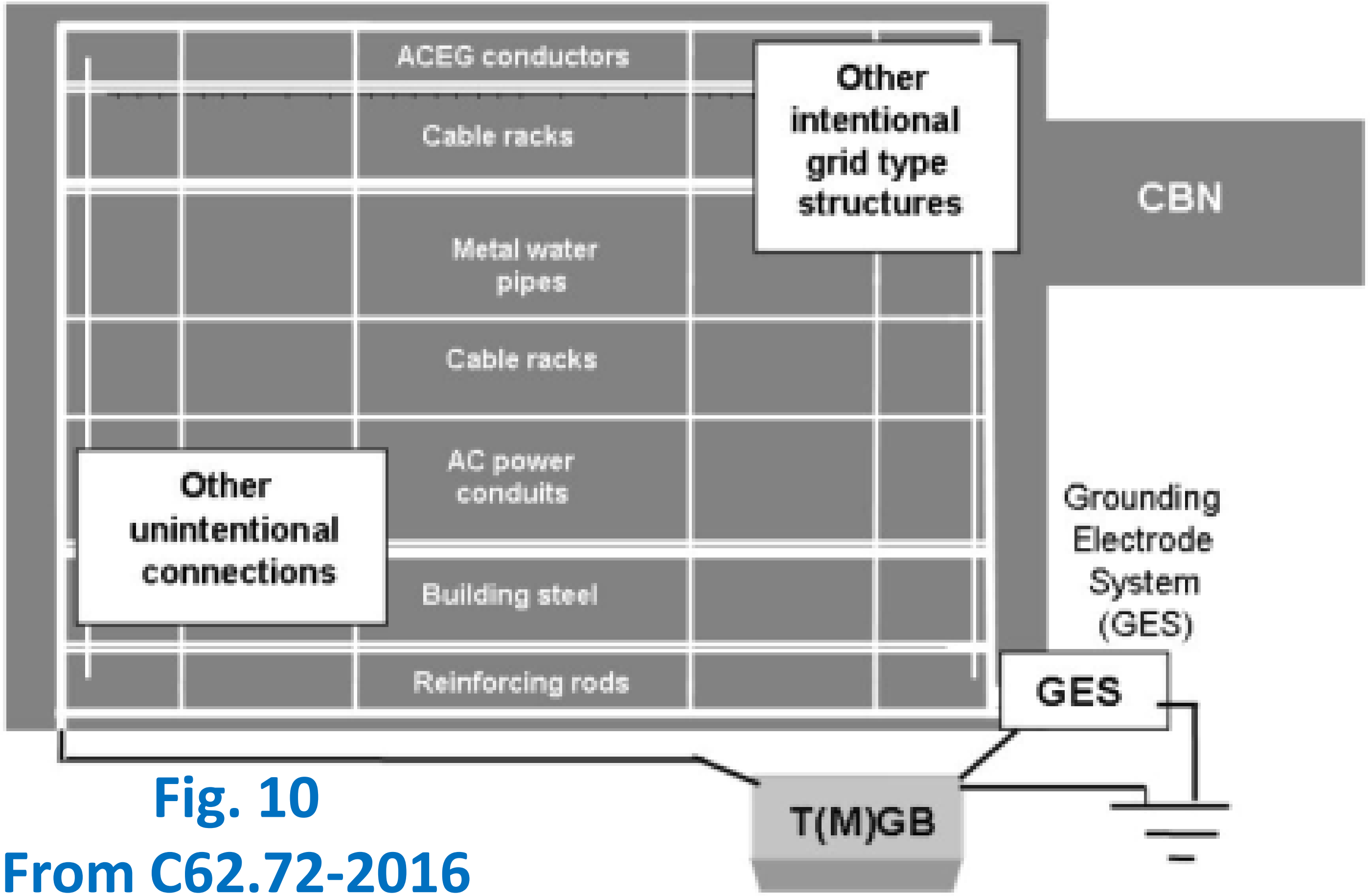


Fig. 10
From C62.72-2016

T(M)GB: telecommunications (main) ground bar

ACEG: ac equipment grounding conductor

CBN: common bonding network

GES: grounding electrode system

Grounding and Bonding for SPDs

- Common bonding network
  - Figure 10 illustrates the complex and ubiquitous interconnections that make up the CBN
  - Generally, SPDs are grounded (earthed) by bonding into the CBN
  - CBN is grounded via the grounding electrode system

Grounding and Bonding for SPDs

- Common bonding network
  - The relative equipotential is dependent upon the impulse (surge) current waveform parameters—mainly magnitude and rise/fall times
  - This arrangement will reduce (but not eliminate) the buildup of undue potentials across the ends of the bonding connections
  - Lightning and both ac and dc power faults are the energy sources that cause the greatest concern

Grounding and Bonding for SPDs

- Common bonding network
  - The CBN should be inspected to aid in complying with:
    - Local electric codes
    - The requirements of lightning protection systems
      - See NFPA 780/UL 96A
  - The best bond occurs when there is a metal-to-metal connection (direct bond)
  - Examples include NRTL listed mechanical, compression and welded connectors/connections

Grounding and Bonding for SPDs

- CBN grounding impedance
  - Attempts to reduce the net impedance value of the connection of the common-bonding network to the grounding system are unnecessary
  - Such a reduction does not improve the protective performance of the SPDs inside the facility
  - The equipotential bonding of the common bonding network exceeds the importance of a low ground resistance at the installation point of the ground rod or other grounding electrodes

Grounding and Bonding for SPDs

- CBN equipotential
  - It is far more important that all the equipment in the facility is referenced to the common bonding network vs. the absolute value of the CBN grounding resistance or impedance
  - Local/regional areas within the CBN will rise and fall to the same relative potential during a surge event

Grounding and Bonding for SPDs

- **Additional grounding electrodes**
  - **An auxiliary (or supplementary) grounding electrode can be also be connected to the SPD's ground (earth) terminal**
  - **However, the auxiliary grounding electrode *must* be bonded to the facility grounding/earthing electrode**

Grounding and Bonding for SPDs

- Ground Potential Rise (GPR)
  - When surge current exits from the SPD into the grounding system, the voltage at the current injection point to the earth rises relative to remote earth (GPR!)
  - Can impact equipment and metallic objects near the SPD
  - Where there is metallic interconnection (such as a communications link) to other equipment, GPR can force surge currents into the other connected equipment

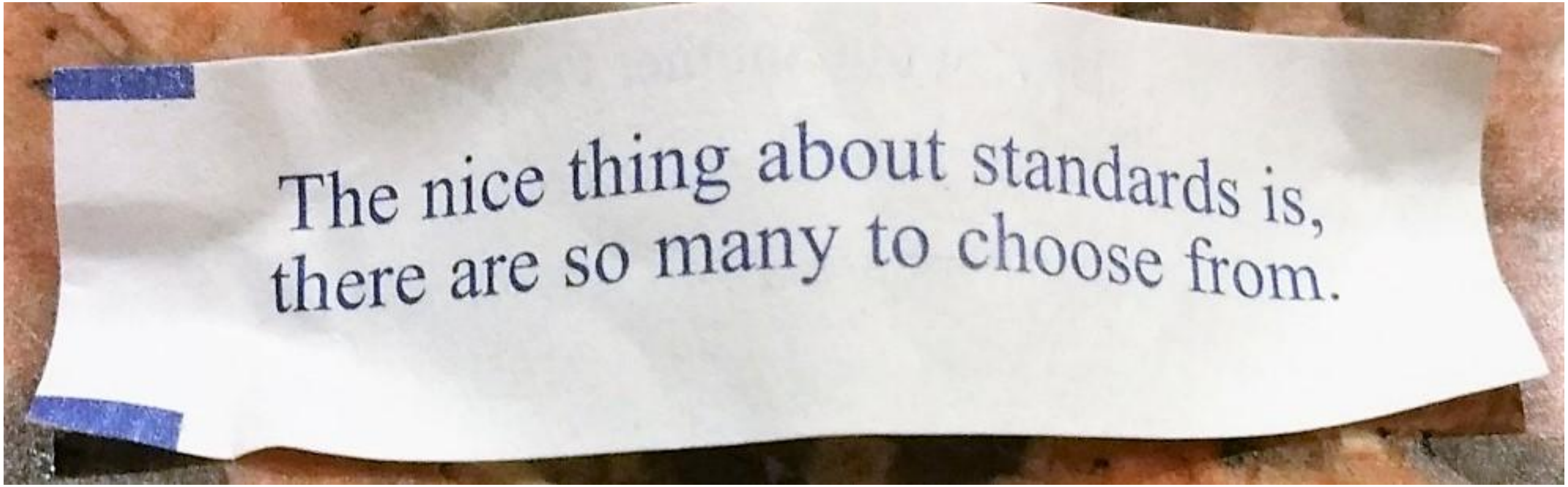
Grounding and Bonding for SPDs

- Ground Potential Rise (GPR)
  - This difference in voltage can result in equipment upset as well as permanent damage
  - Equalizing these voltages can be achieved by proper routing of the input/output wiring through a single device, termed a multiservice (multiport) SPD (ports include ac power, coaxial, twisted pair, etc.)
    - See IEEE Std. 1100 and IEEE Std. C62.50-2012

Grounding and Bonding for SPDs

- Ground Potential Rise (GPR)
  - Equalization is often achieved via a surge reference equalizer (SRE)
  - The SRE adds a local “approved” inter-port bond during surge (transient) events (via an SPD function) at the affected equipment
  - The SRE provides a low impedance path around (rather than through) the affected ports
  - To prevent damage, SPDs should be utilized at the ac service panel and properly coordinated with downstream SPDs, including those at the SRE’s

Grounding and Bonding for SPDs

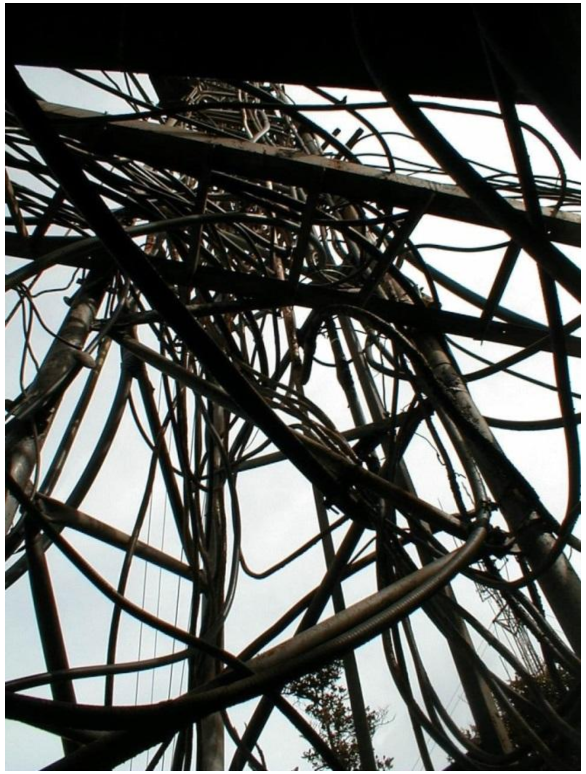


Practical Applications of SPD Grounding and Bonding Principles

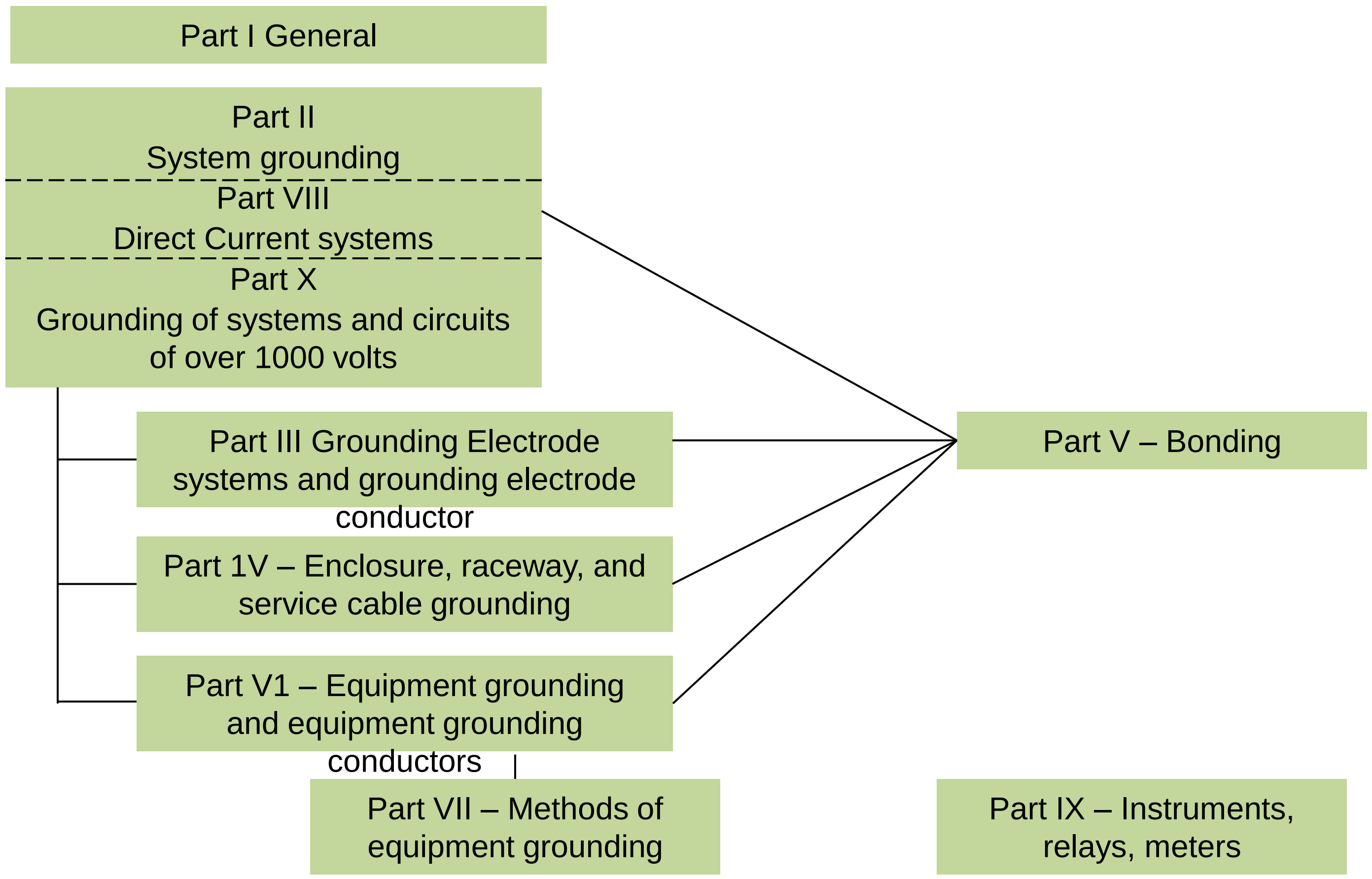
About Quality Power, Inc.

QPI Before

QPI After



Reproduction of NEC Figure 2 Grounding and Bonding



NEC Article 285 (250.64(E)(1)) and C.62.72.2016:11.3

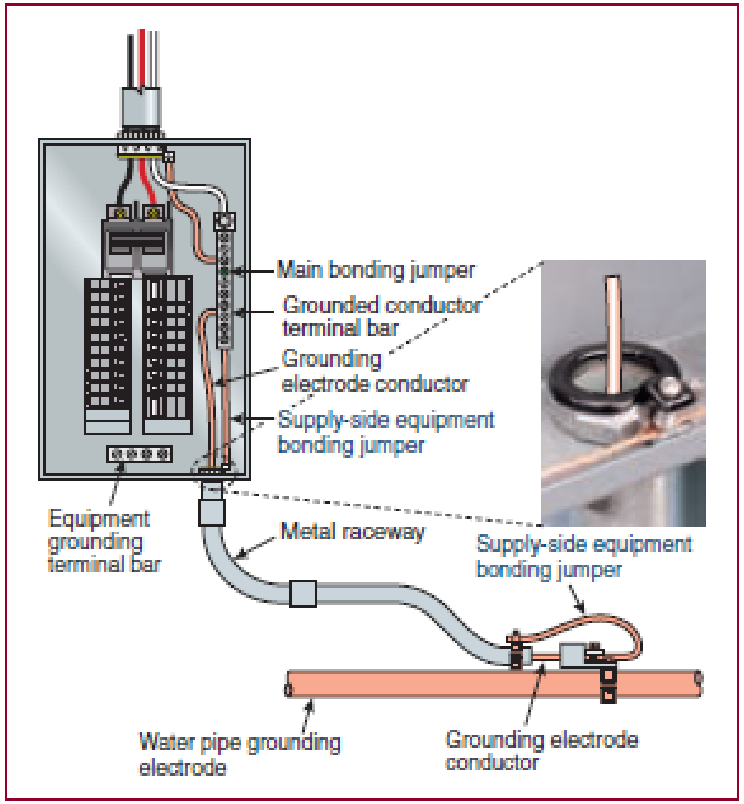
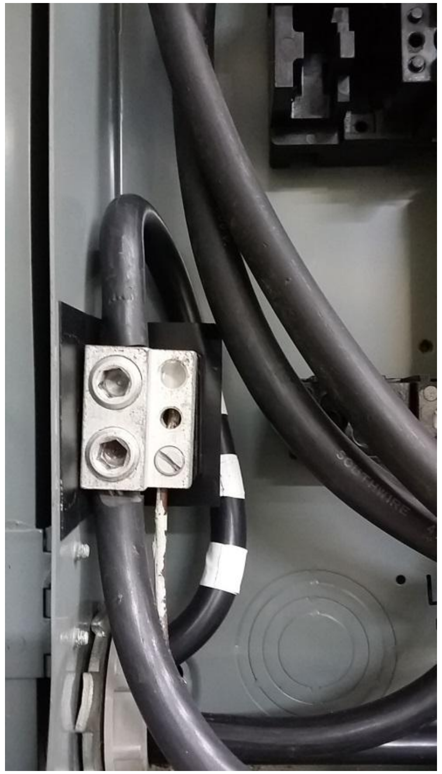
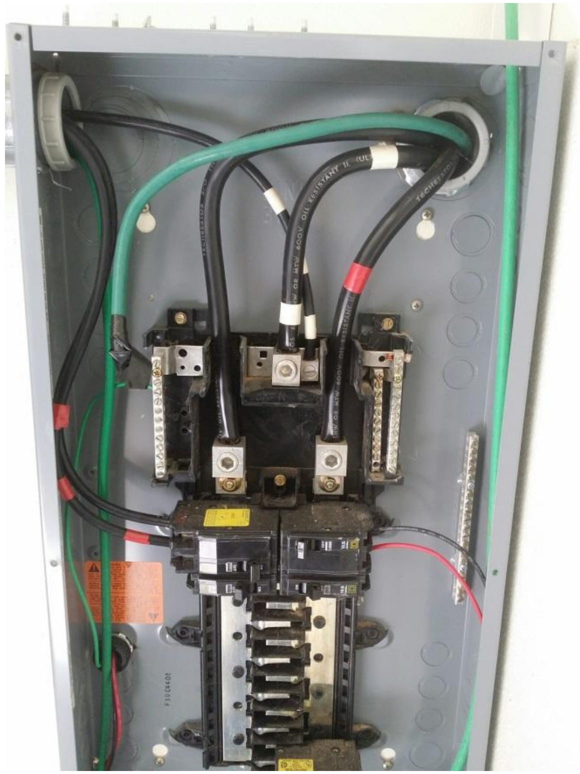


EXHIBIT 250.28 Bonding of a metal raceway that contains a grounding electrode conductor to the conductor at both ends.

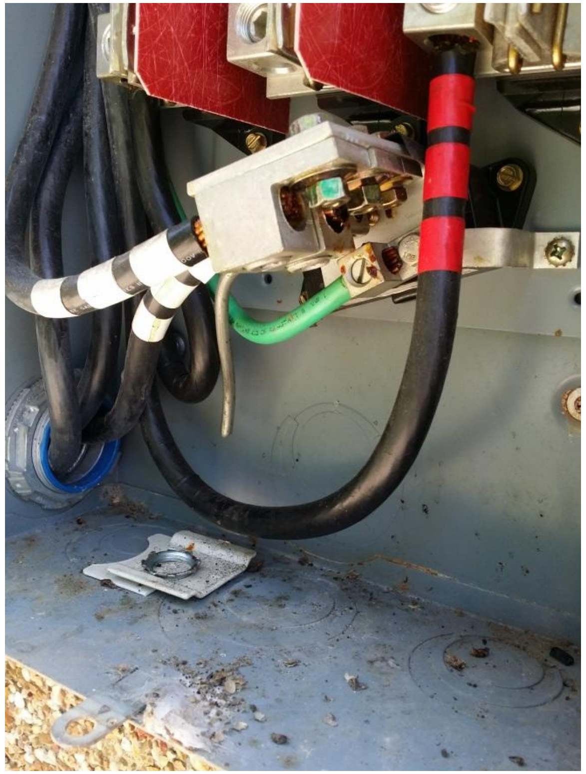
Where SPDs are installed on exterior building or facility equipment that is also powered by the facility's ac power service, an auxiliary (or supplementary) grounding electrode can be also be connected to the SPD's ground (earth) terminal. This arrangement provides for a more direct path to keep the lightning current external to the building or facility. The electrode can be rods, plates, rings, etc. The electrode cannot replace the requirement for the SPD's ground (earth) lead to be connected to the serving ac power circuit's equipment grounding conductor. The additional grounding path is required by (NFPA 70 [B54]) to be bonded to the facility grounding/earthing electrode.

Service Bonding (MBJ, EGC)

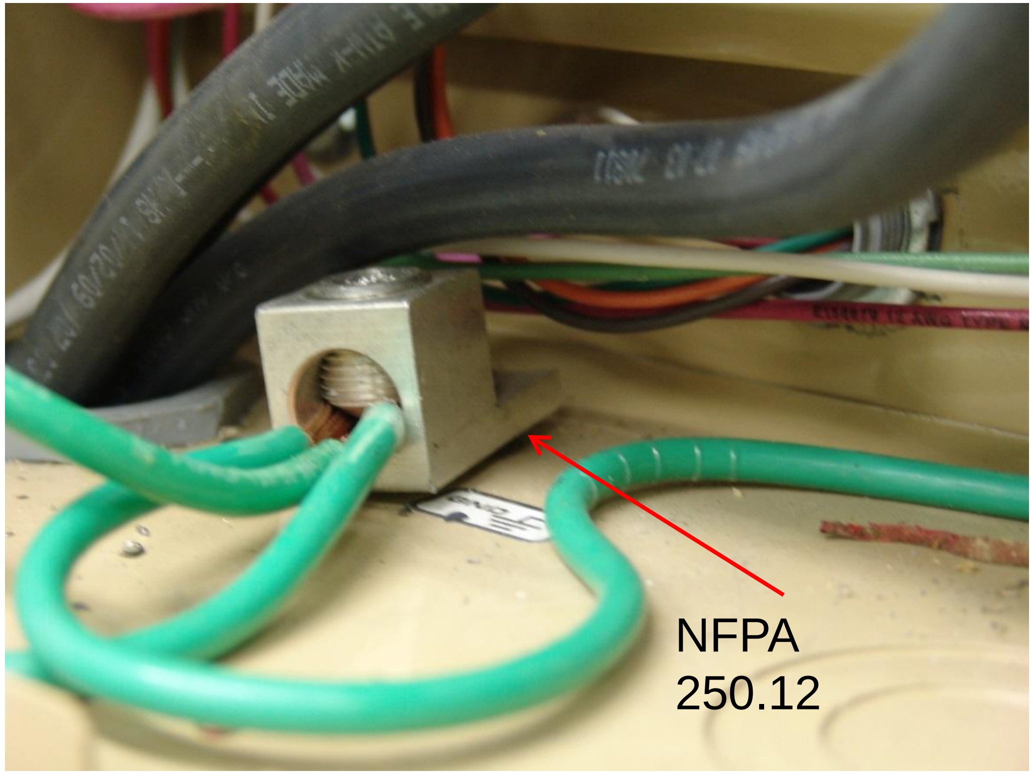




Service GEC

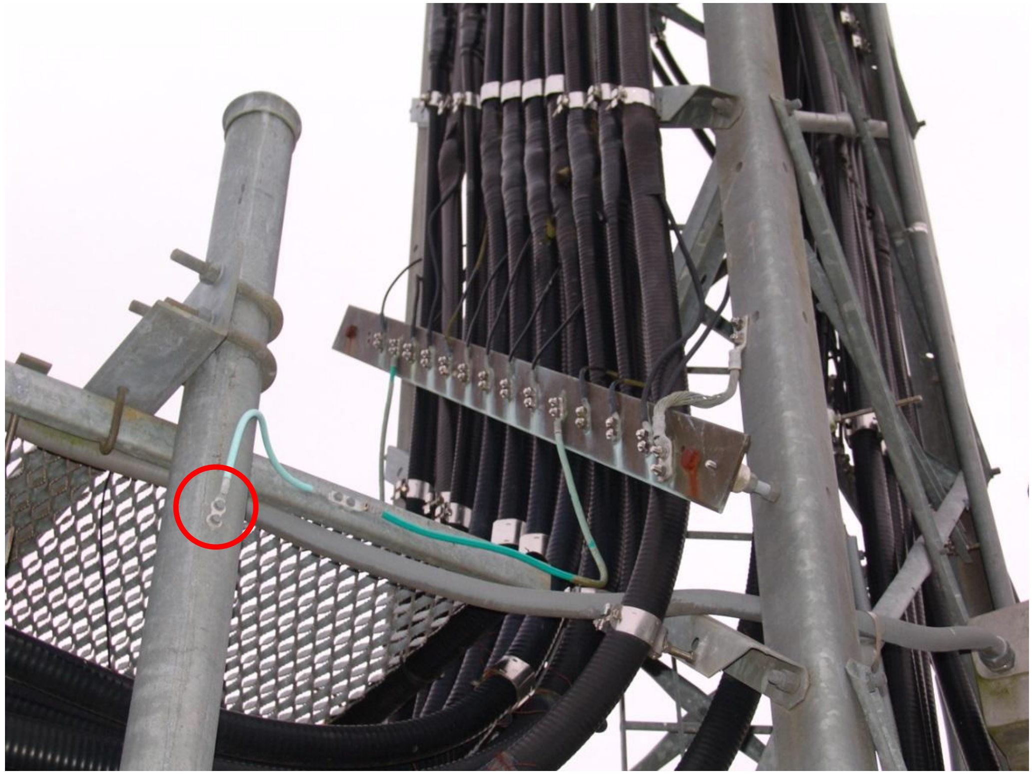


Bonding and Grounding



Relative to the installation of SPDs, the condition of the common-bonding network should be inspected to aid in complying with local electric codes and approved low-impedance bonding techniques. The best bond occurs when there is a metal-to-metal connection (direct bond). The connection can be achieved by methods approved by the authority having jurisdiction. Such methods mainly include those listed by the NRTL. Examples include mechanical, compression and welded connections. Direct bonds must be made by following the proper installation instructions, including NRTL listing instructions.

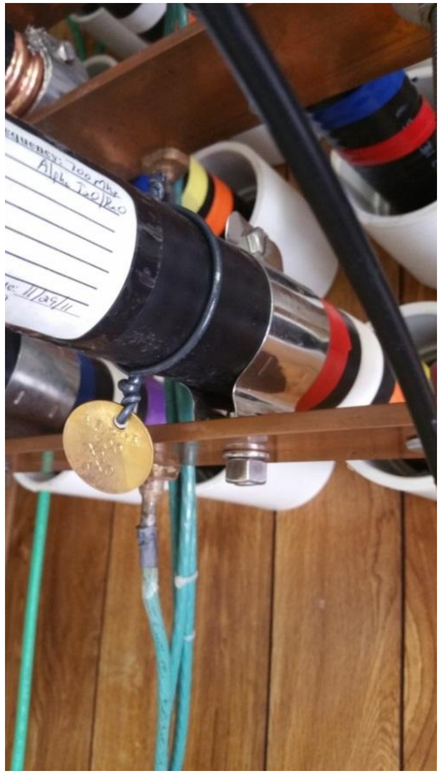
Bonding of Tower RF Ground Bar



Bonding of Tower RF Ground Kits

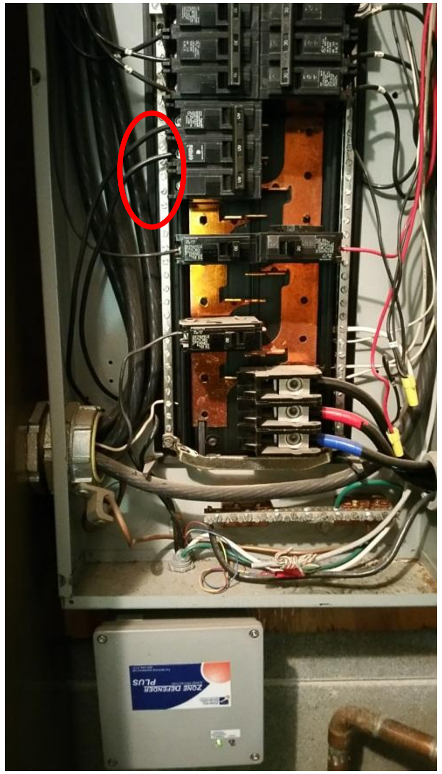
- Leads come down and turn back up to ground bar.

RF Bonding



- Coax insulation was not stripped reducing effectiveness of downstream RF SPD.

SPD Installation Failure

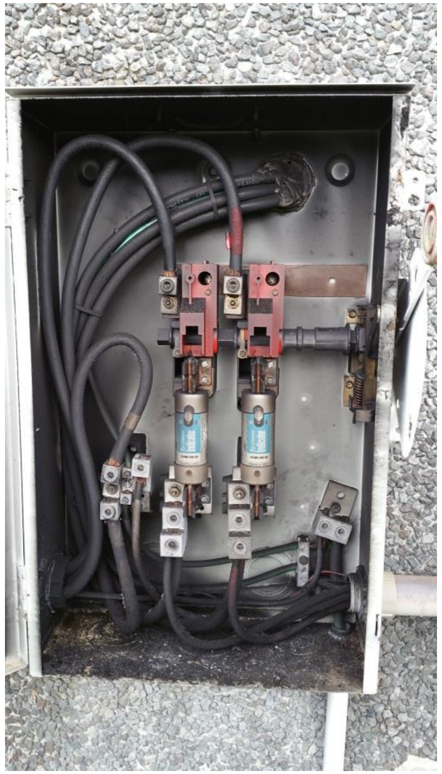


- 3 phase 120/240 Delta System
- Installed 1 phase SPD

NEC Article 250 Violation

- Site was not a Separately Derived System as required By NFPA 70 Article 250.30

Installation Failure



NEC Article 250 Violation

- EGC Cut and shoved in conduit

Winterboro-LTE Failure

- Site lost LTE cabinet after lightning storm.
- With all +24 leads removed, input # 2 resistance was < 2Ω

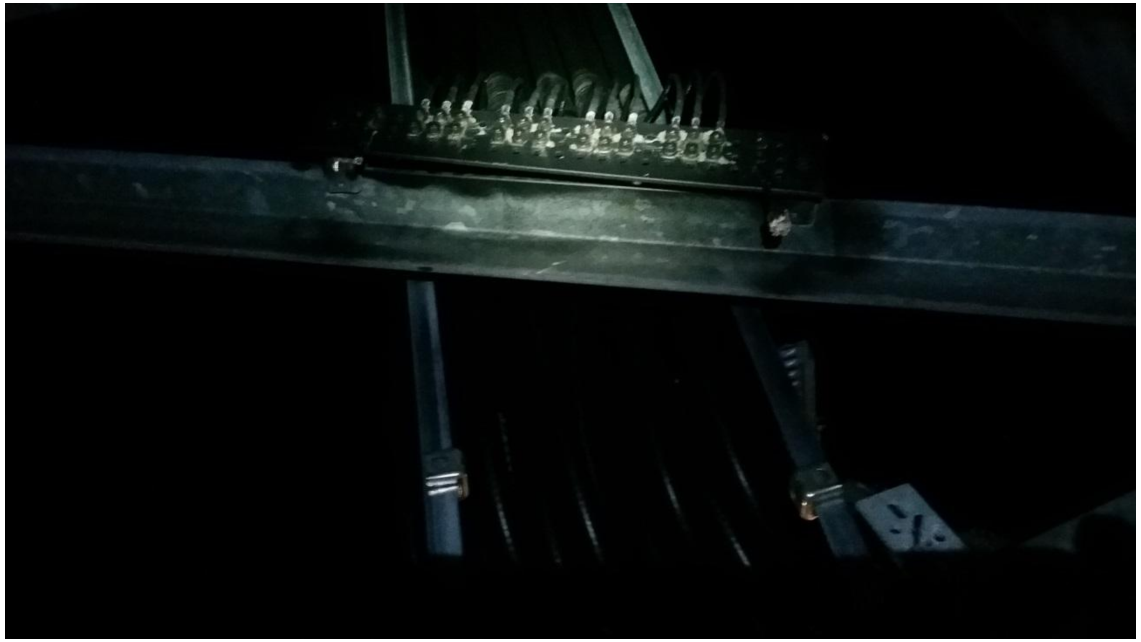
Winterboro-LTE Failure-Copper Theft

- Thieves cut AC GEC

Winterboro-LTE Failure-Copper Theft

- Thieves cut tower leg grounds

Winterboro-LTE Failure-Copper Theft



- Thieves cut RF Tower Ground Bar Down Leads

Winterboro-LTE Failure

- Arcing visible at Power Utility Meter H-Frame

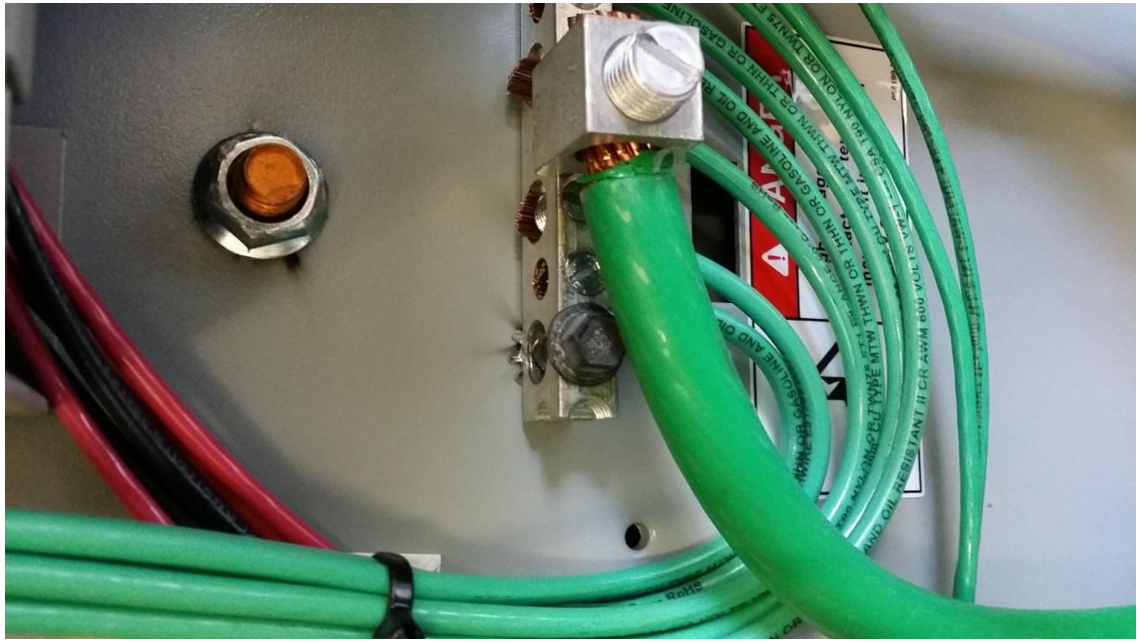
Winterboro-LTE Failure

- Arcing visible at conduit inside Shelter disconnect.
- This feeds the ILCA directly inside of the site.

Winterboro-LTE Failure

- ILCA Interior

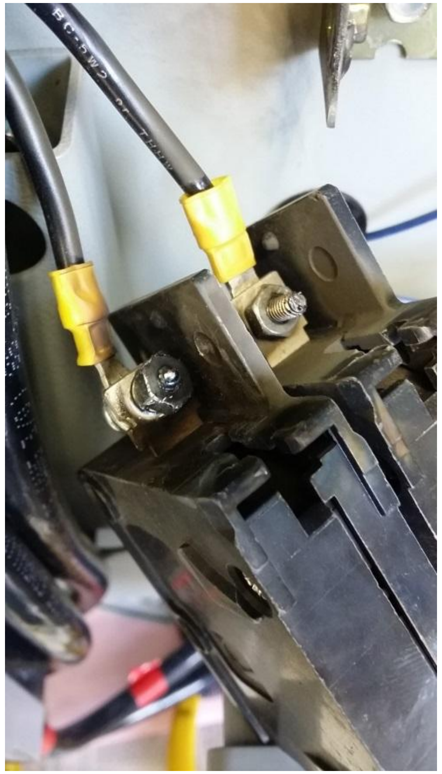
Winterboro-LTE Failure



- Arcing on ground bar and panel bolts

Winterboro-LTE Failure

Winterboro-LTE Failure



- Installation from manufacturer
- Lead was not tightened
- High Z may have allowed surge currents to continue onto rectifier circuits?

Winterboro-LTE Failure

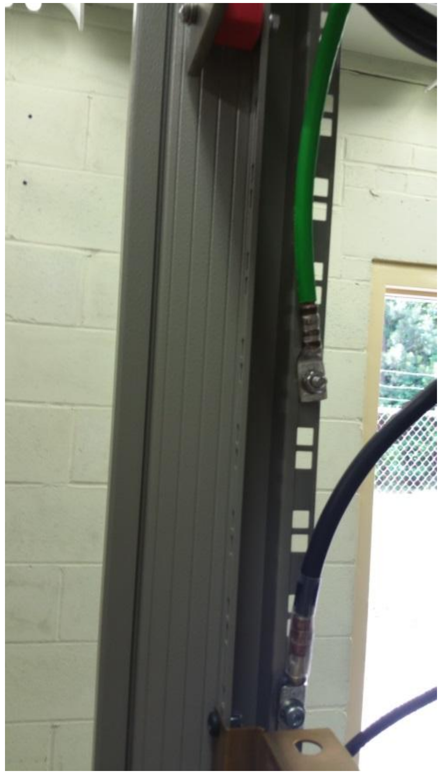
Winterboro-LTE Failure

- Back side of LTE control card

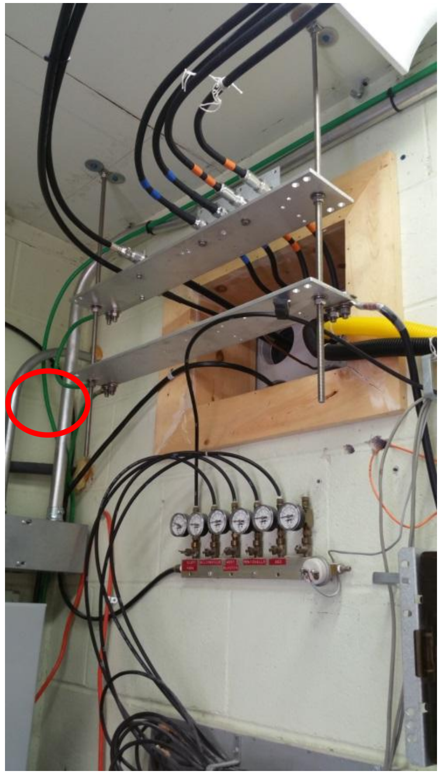
Winterboro-LTE Failure: Addition of DC SPD

Maylene

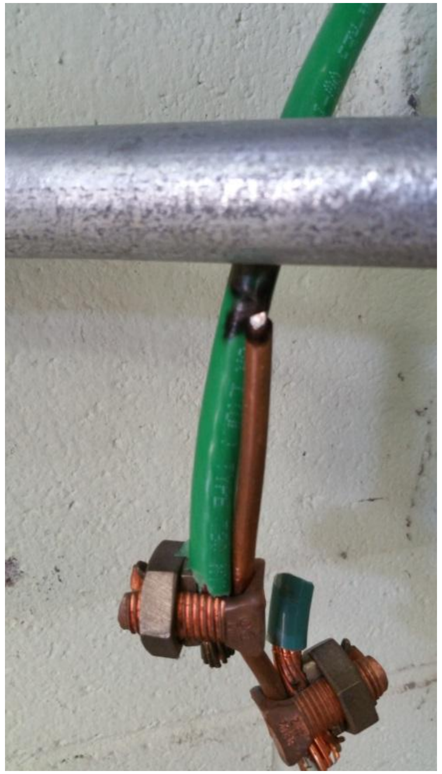
Maylene – Cabinet and Gutter Bonding



Maylene – Interior RF and Frame Bonding

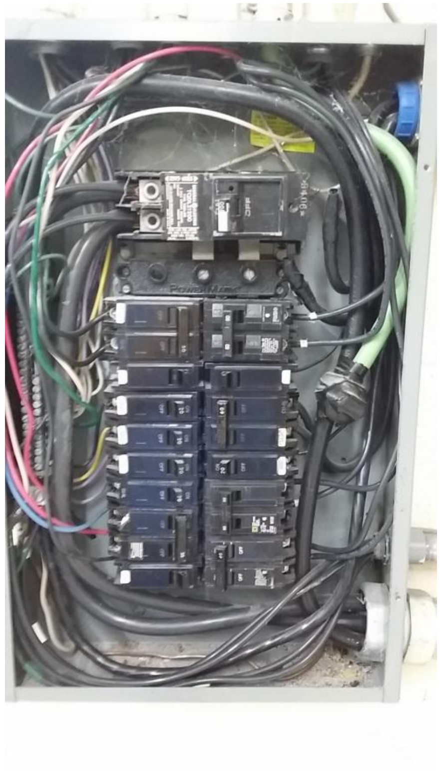


Maylene – Interior RF and Frame Bonding



Waters Road – Bonding Issues

Waters Road – Bonding Issues

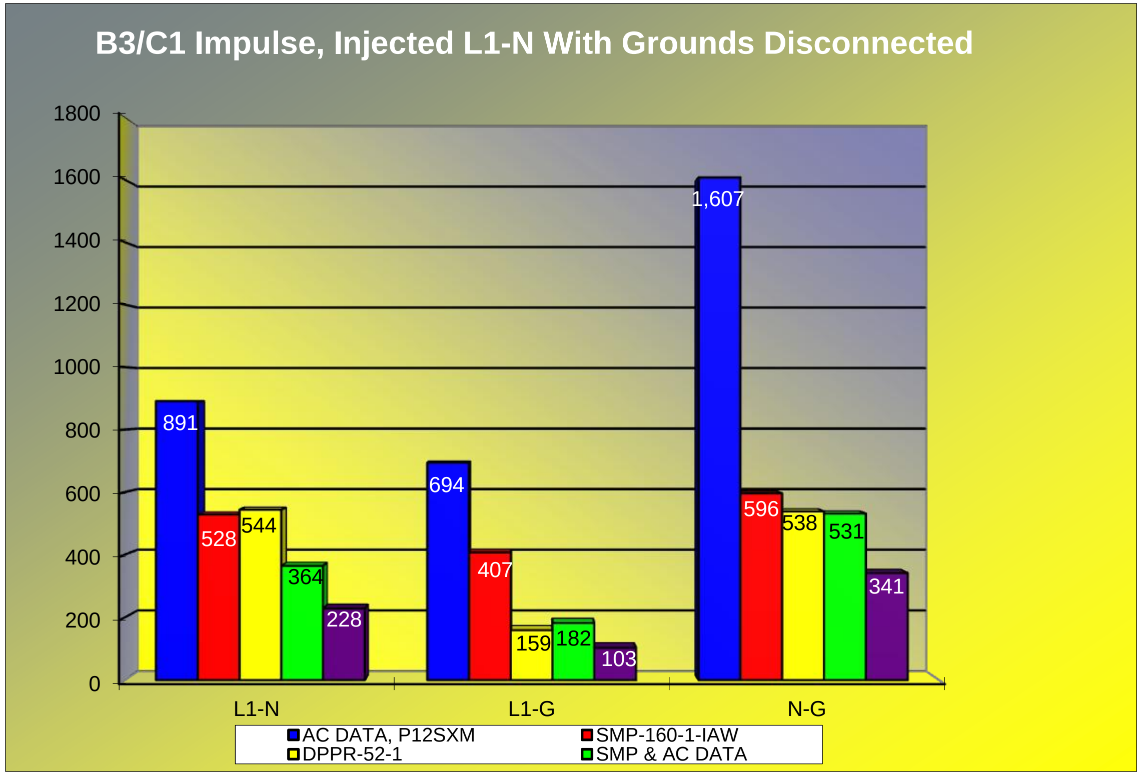


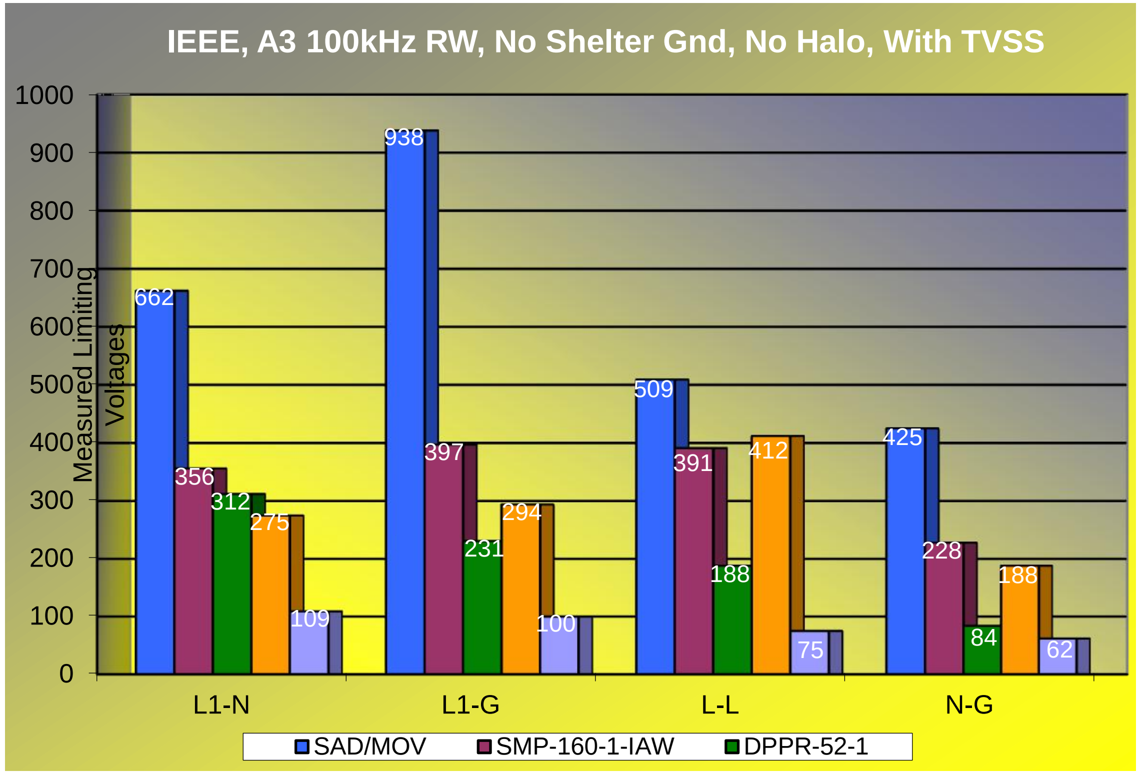
Waters Road – Bonding Issues

Unr-Rohn Testing

- Testing performed with shelter sitting on timbers.
  - Shelter was fully manufactured waiting for truck transport and was sitting on large wooden timbers, isolated from earth
- BMI and ROHN personnel were present during testing.
- Surges were injected at shelter/Service disconnect on shelter exterior.
- MLV recorded on buss of DP-1
- Halo leads floating.
- Every time a surge was generated, the conduits buzzed and fluorescent fixtures illuminated momentarily.

MLV Recorded at DP-1





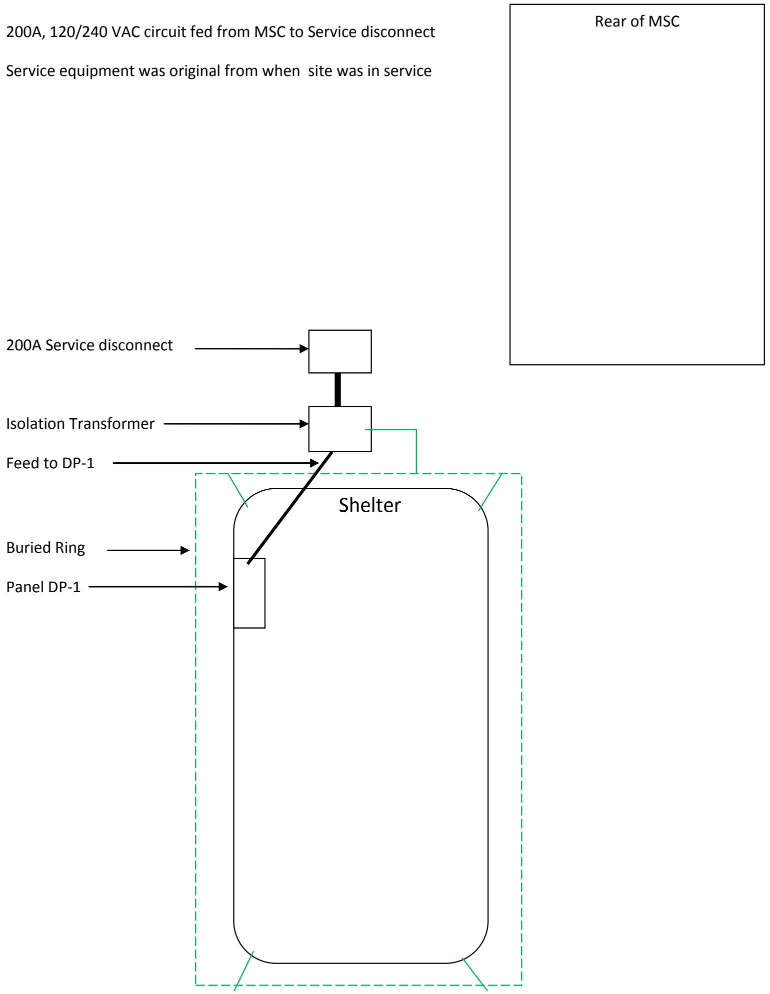
Pine Mountain MSC

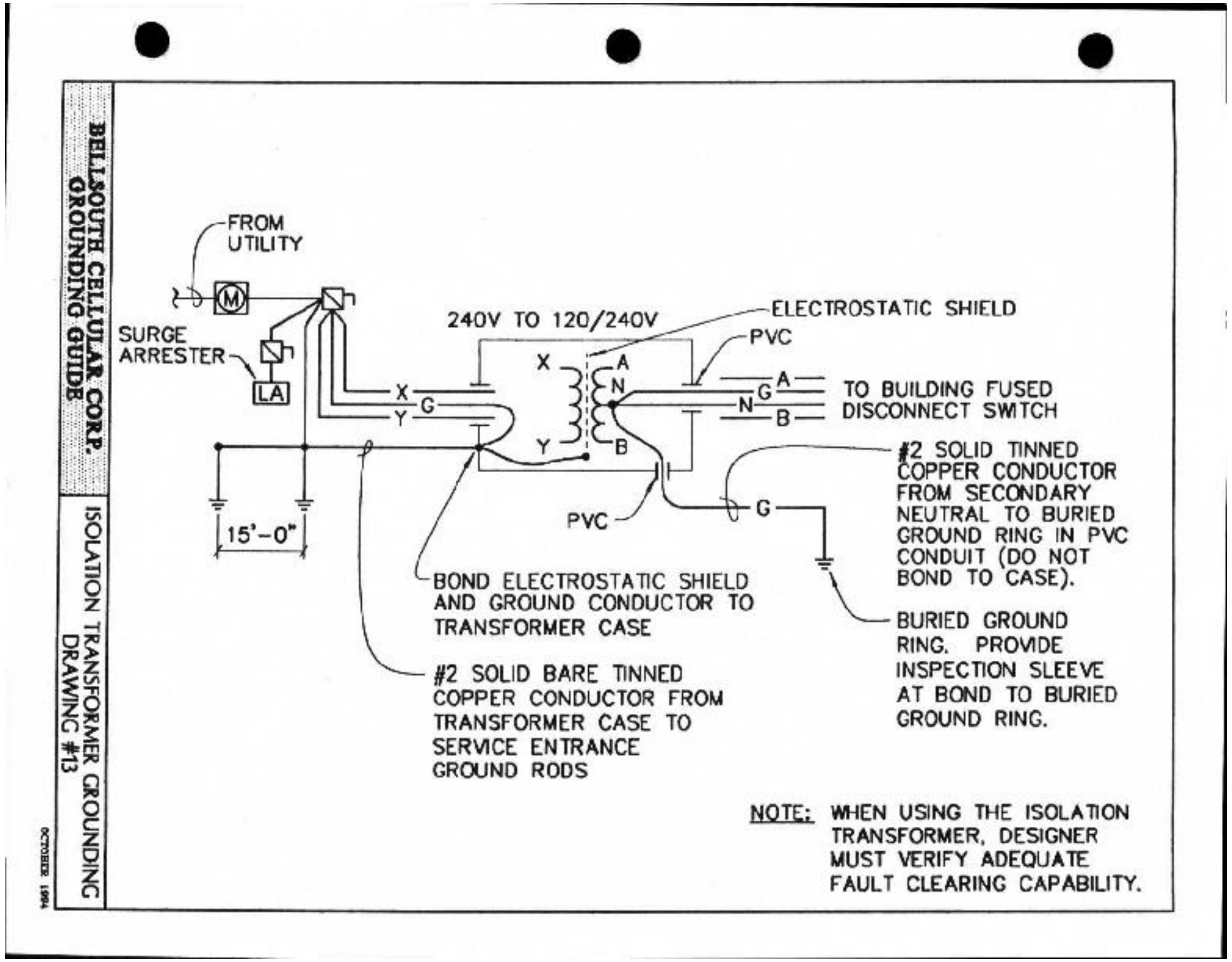
- Output of Velonex wired to Service disconnect: 120/240V, 200A Fused Disconnect fed from a circuit in the MSC.
  - Static testing. All conductors of MSC feeder were removed and isolated.
- Buried ring around shelter 2 AWG SBTC was also bonded to transformer enclosure
- Primary and secondary grounds bonded together
- "Transformer Bypassed" means primary and secondary conductors were removed from transformer and tapped together as if no transformer was installed
- "Transformer Isolated" means the primary and secondary grounds were isolated from each other
- Transients injected at Disconnect, Measurements recorded at buss of DP-1 inside

Pine Mountain Test Layout-NTS

200A, 120/240 VAC circuit fed from MSC to Service disconnect

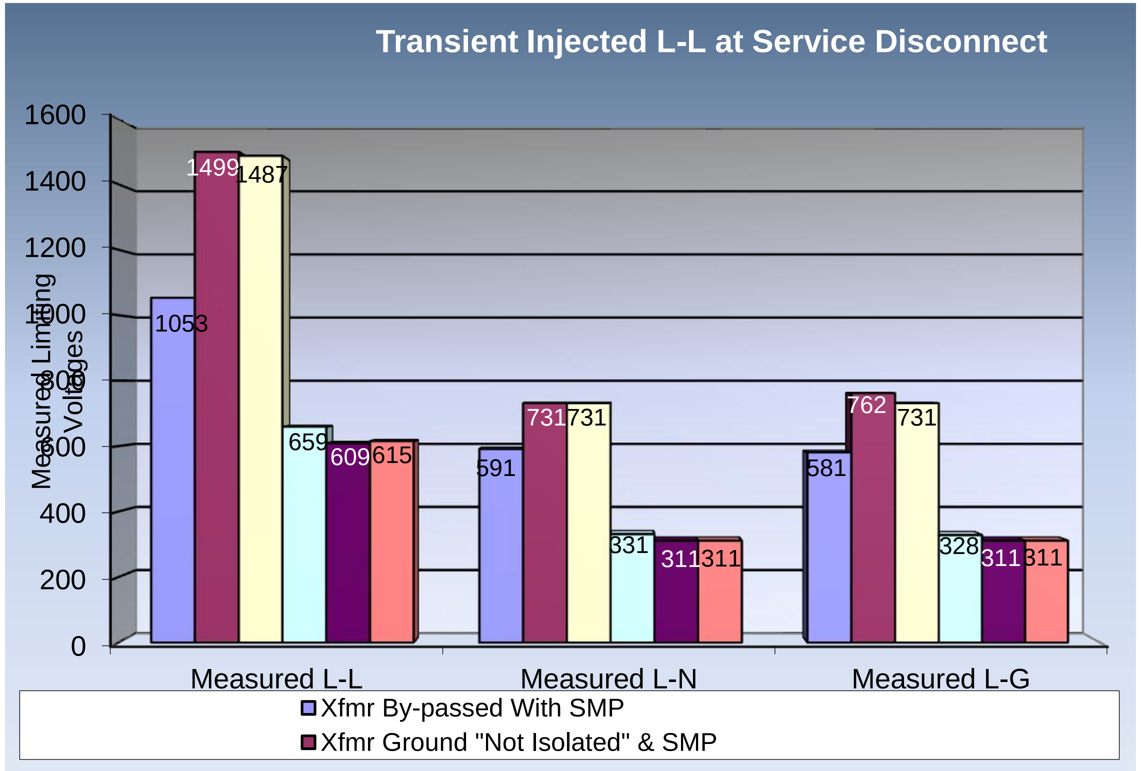
Service equipment was original from when site was in service

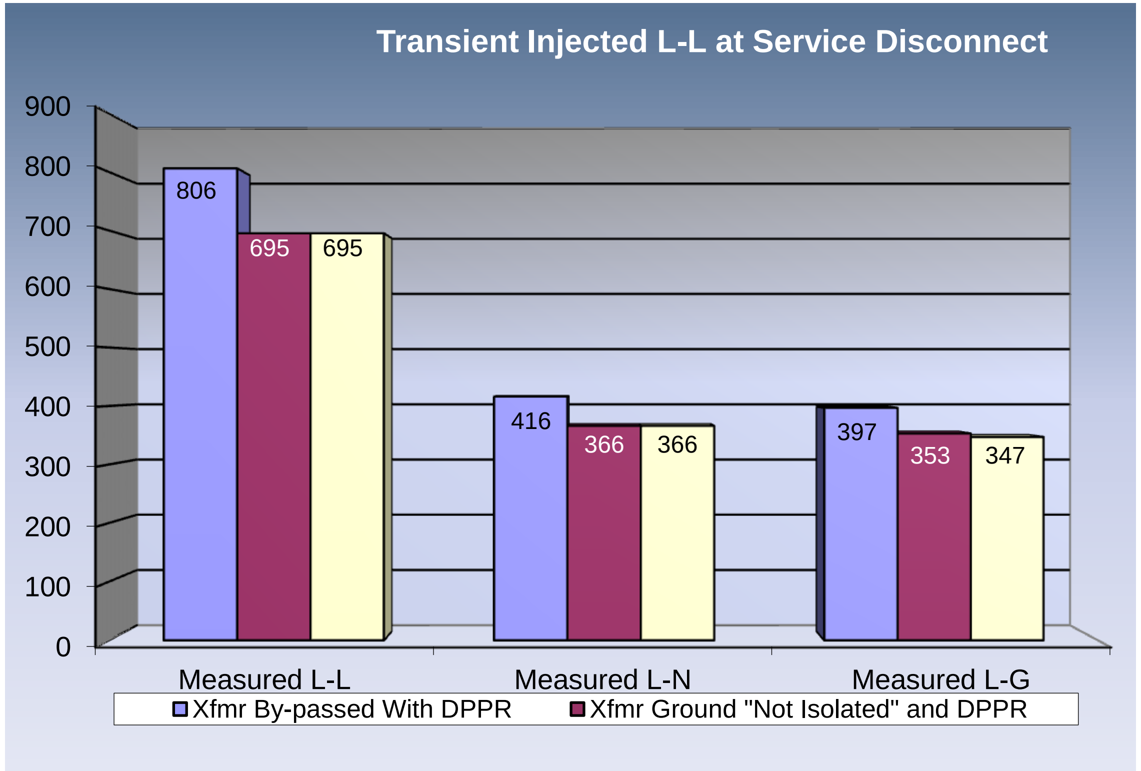




PROTECTION ENGINEERS GROUP

IMPROVING NETWORK INFRASTRUCTURE RELIABILITY AND SUSTAINABILITY





Thank you!