Considerations and Pitfalls of External Ethernet and PoE Protection Devices

Mick Maytum

mjmaytum@gmail.com
https://pes-spdc.org/content/low-voltage-tutorials
https://ict-surge-protection-essays.co.uk

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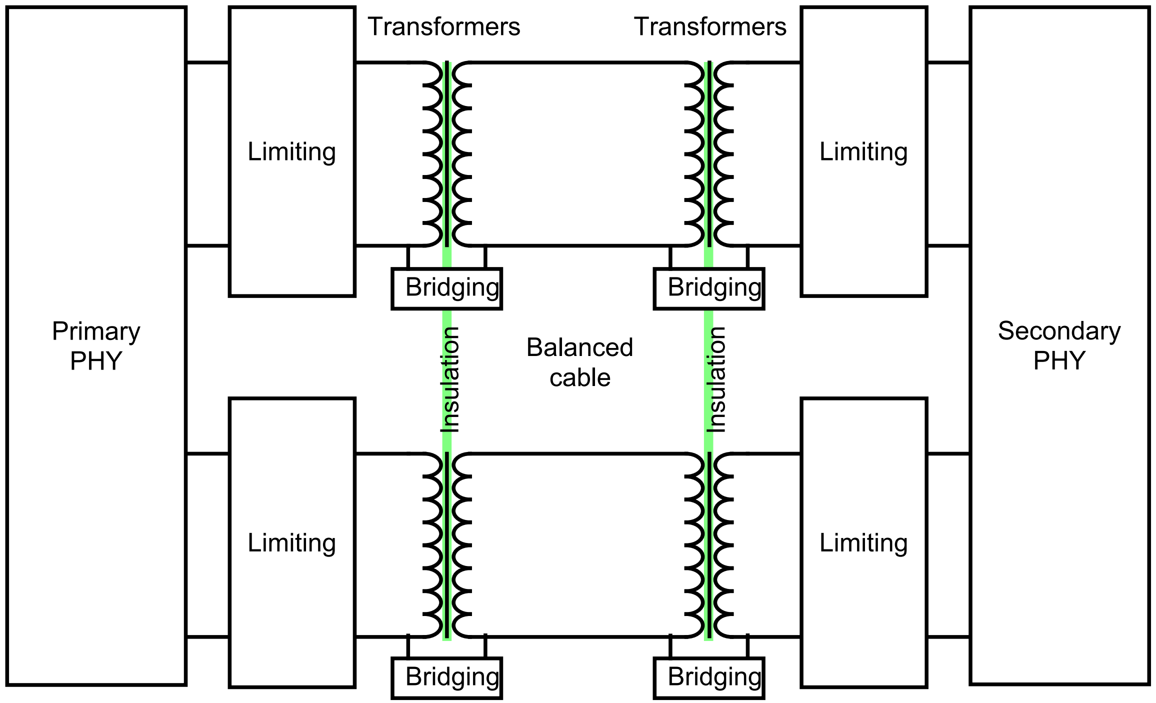
Contents

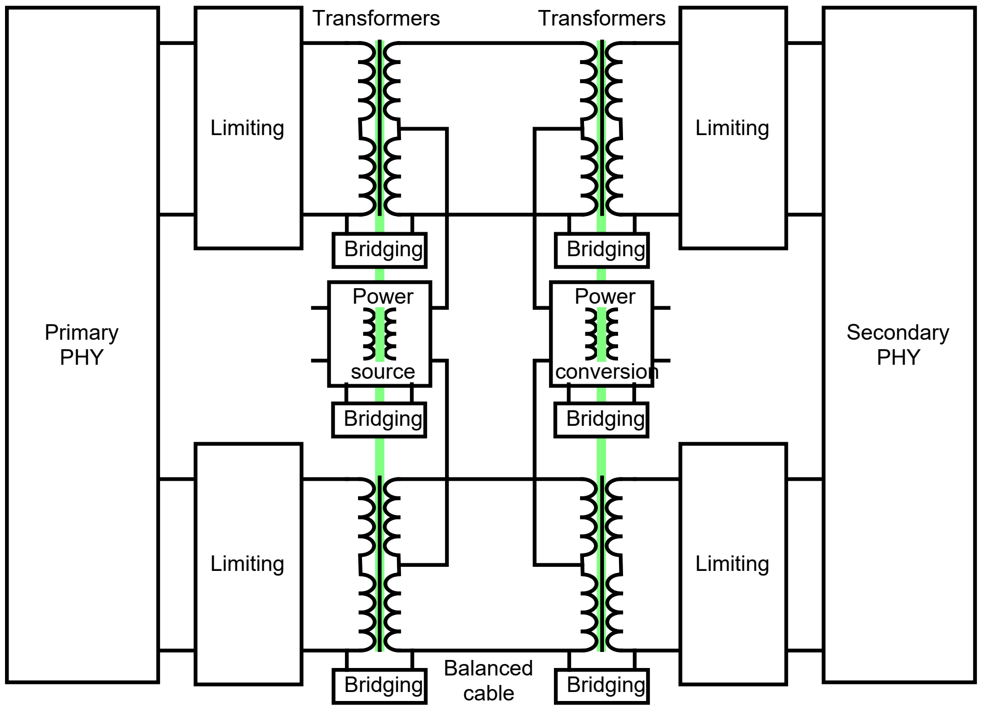
- Ethernet interface configurations (floating and grounded)
- What are the overvoltage threats
- What are the Ethernet interface withstands
- Surge mitigation functions
- Protection design mishaps
- Protection design rules

Floating Ethernet interface configurations

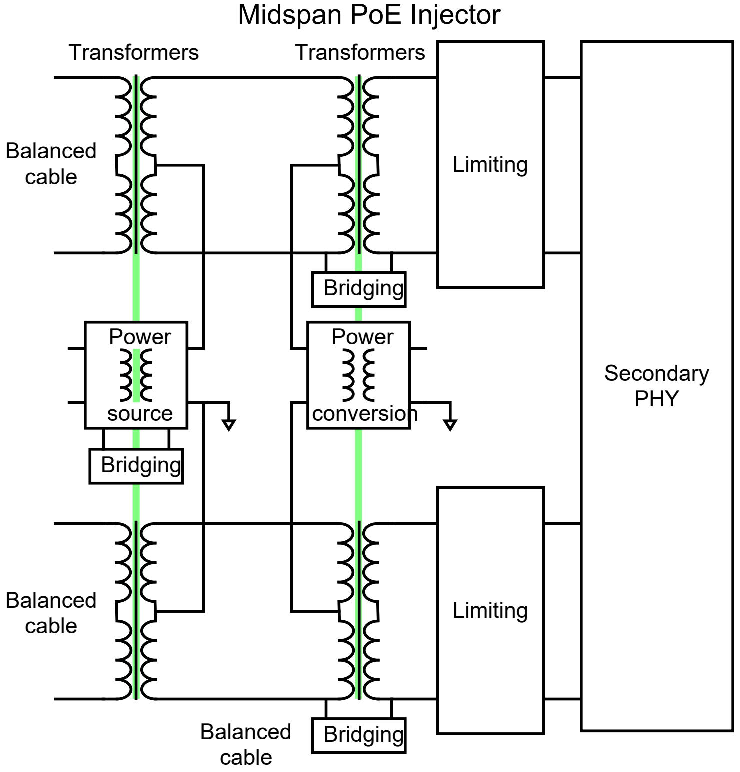
Standard



PoE



Locally grounded Ethernet interface Midspan



What are the overvoltage threats

ITU-T Recommendation K.39 *Risk assessment of damages to telecommunication sites due to lightning discharges* states there are four main coupling mechanisms for surges to couple into networks and equipment

- Direct coupling (permanent or transient, such as SPD operation due to ground potential rise)
- Magnetic coupling
- Electric coupling
- Electromagnetic coupling

In addition power frequency overvoltages can be caused by induction from and direct contact to the power distribution network.

More details are given in ITU-T Recommendation K.147 *Ethernet port resistibility testing for overvoltages and overcurrents* and Series K Supplement 23 *Ethernet port surge voltages and currents.*

Overvoltage threat examples — Surge propagation

.model 100ohm2LTRA LTRA(len=500 R=67m L=525n C=2p)

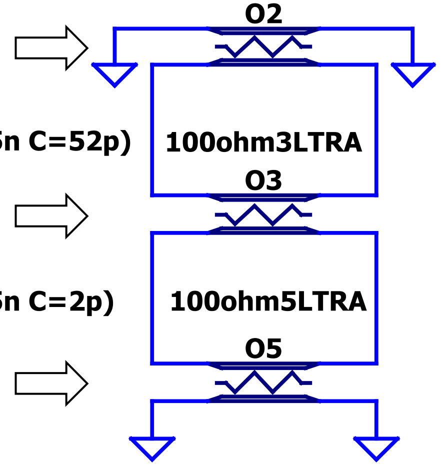
Common-mode surge

.model 100ohm3LTRA LTRA(len=500 R=67m L=525n C=52p)

Differential-mode surge

.model 100ohm5LTRA LTRA(len=500 R=67m L=525n C=2p)

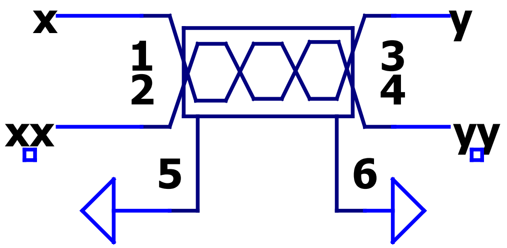
Common-mode surge



- To model surge propagation three transmission lines are required:
  - One (O3) for the twisted pair differential
  - Two (O2 and O5) for each conductor to screen/ground common-mode

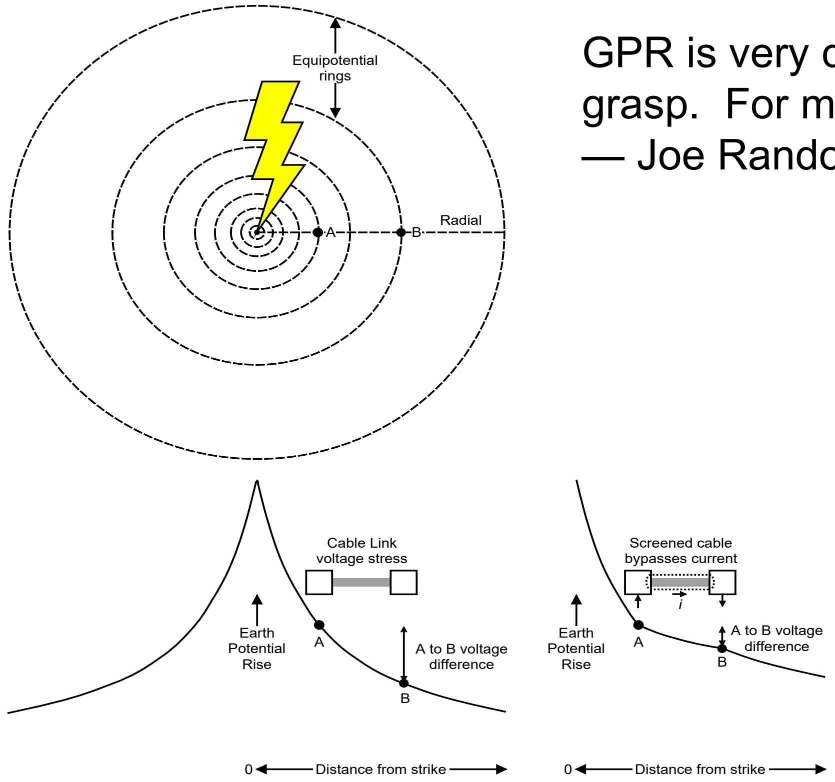
Len=2 R=53m C=70p Cws=118p L=629n Rs=R/10

X1



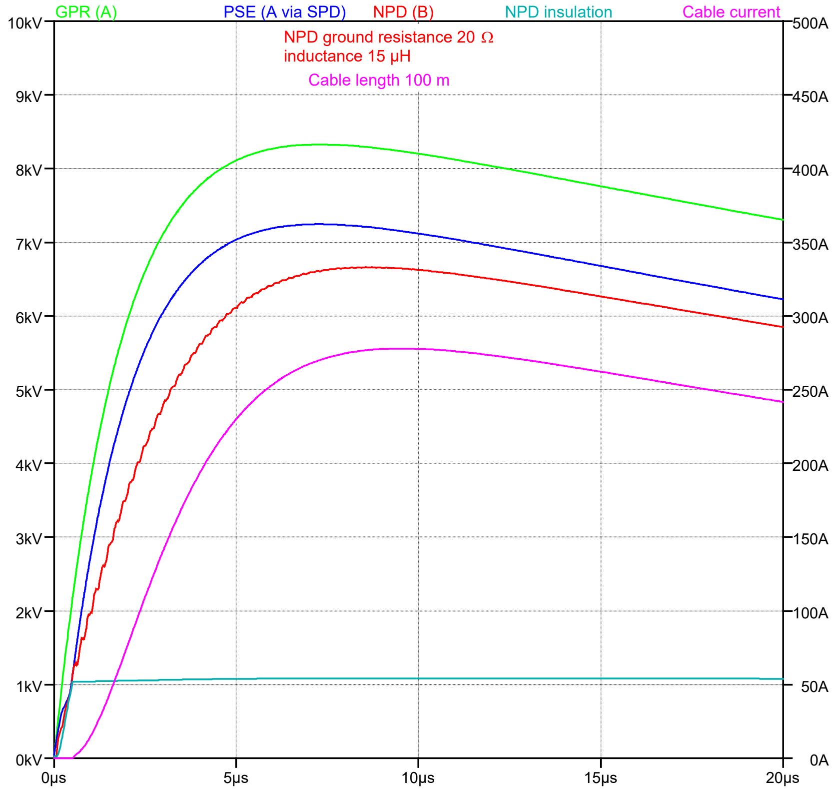
- Bordodynov integrated the three transmission lines into a single array of up to 1024 lumped elements:
  - Len is the cable length m
  - R, C and L are the resistance, capacitance and inductance per m
  - Cws is the conductor to screen/ground capacitance per m

Overvoltage threat examples — Ground Potential Rise

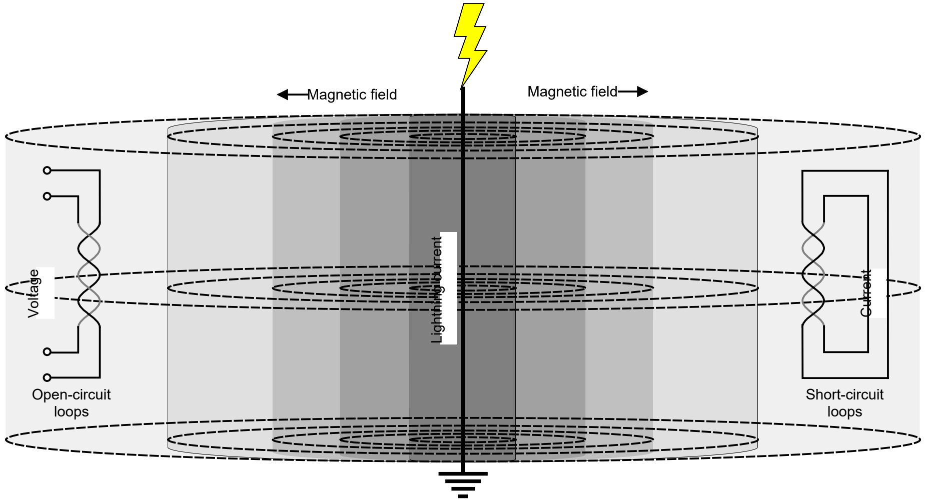


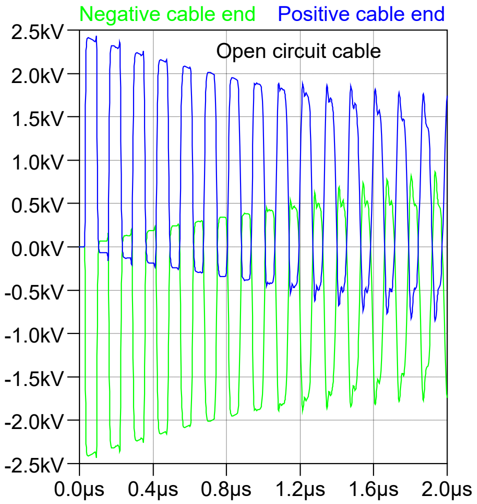
GPR is very difficult for ordinary engineers to grasp. For most engineers, "ground is ground."
— Joe Randolph, Telecom Design Consultant

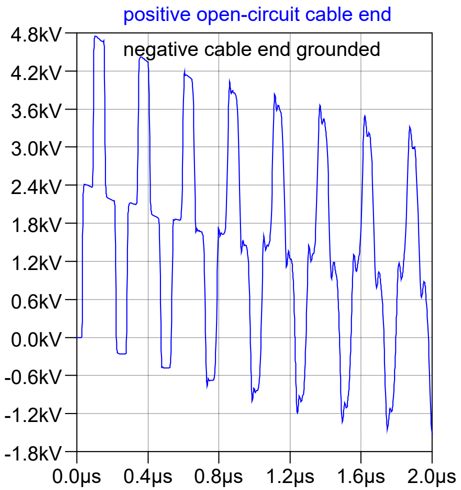
The A to B voltage difference enters the cabling through ground referencing or SPD operation.
The right traces show the remote to ground voltages of the GPR surge and the cable ends. The actual network powered device (NPD) insulation voltage is limited to about 1 kV.

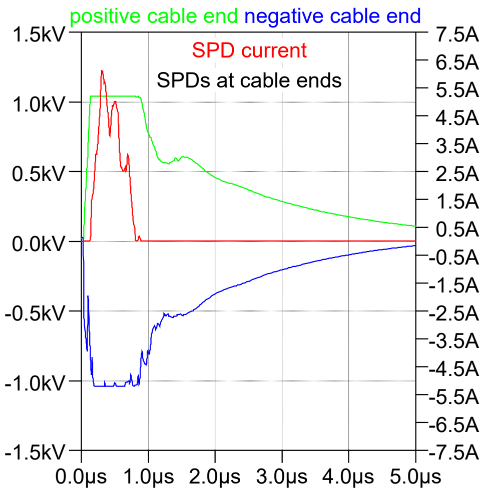


Overvoltage threat examples — Magnetic induction









- Magnetically induced voltage surges are dependent on the lightning di/dt
- Magnetically induced surges are high in voltage amplitude but low in current amplitude
- SPDs needed at both cable ends to prevent double voltage
- GPR surges are usually more severe

What are the Ethernet interface withstands

- Differential-mode signal surge protectors are generally in the 10 V to 15 V range. Diode clamping to the PHY supply rails is also used
- Differential-mode powering surge protectors will typically have 60 V thresholds and maximum limiting voltages of 100 V
- Common-mode insulation surge protectors should have 500 V thresholds and maximum limiting voltages below the insulation breakdown voltage.

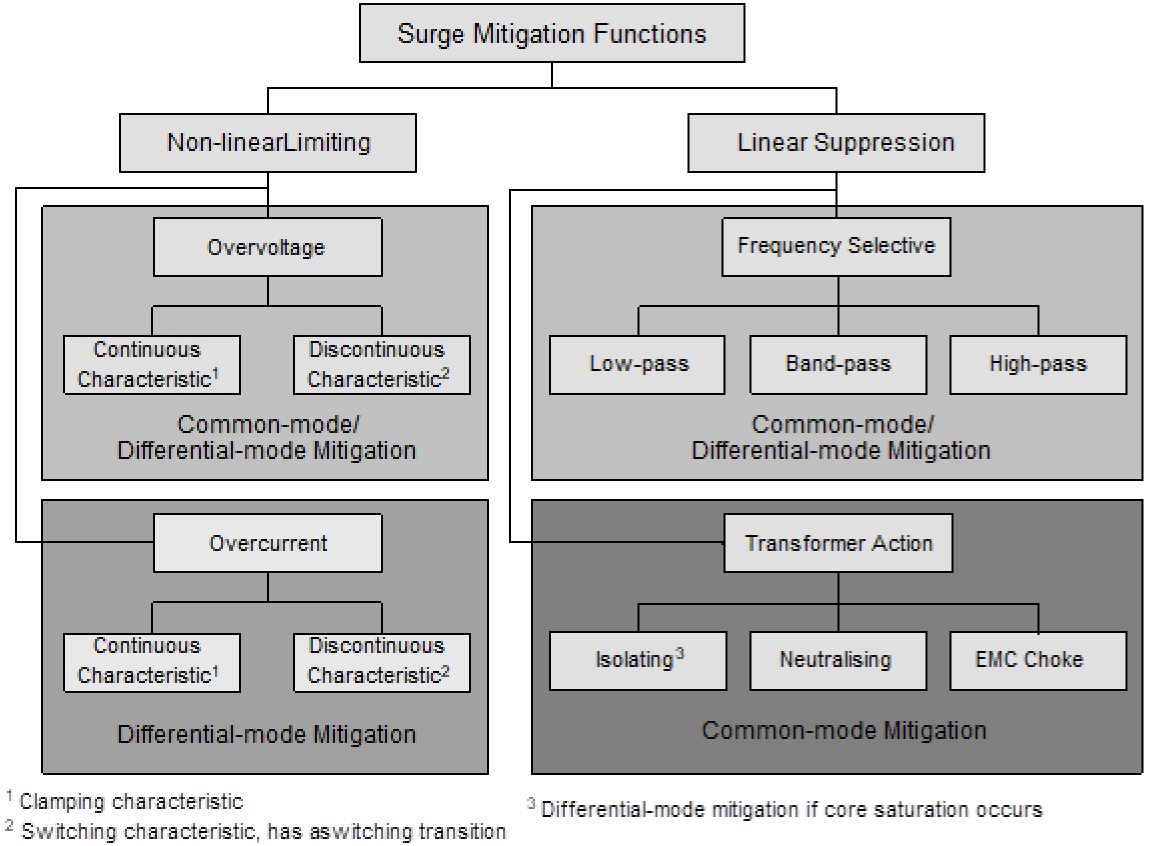
Surge mitigation functions

Surge mitigation functions figure from ITU-T Recommendation K.96: *Surge protective components: Overview of surge mitigation functions and technologies.*

Overvoltage characteristic technologies are continuous: metal oxide varistor and PN junction diode and switching: gas discharge tube and thyristor. Often switching functions can cause additional threats.

Overcurrent characteristic technologies are continuous and self-restoring: thermistor and current limiting/current reducing electronic current limiters and breaking: fuses and current operated switches.

EMC chokes often mean common-mode chokes

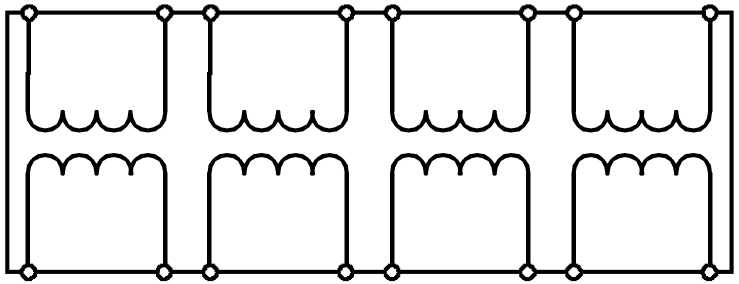


Protection design mishaps —Home Networks, Geneva, 2011

This meeting discussed the failure of optical network terminals with papers on:

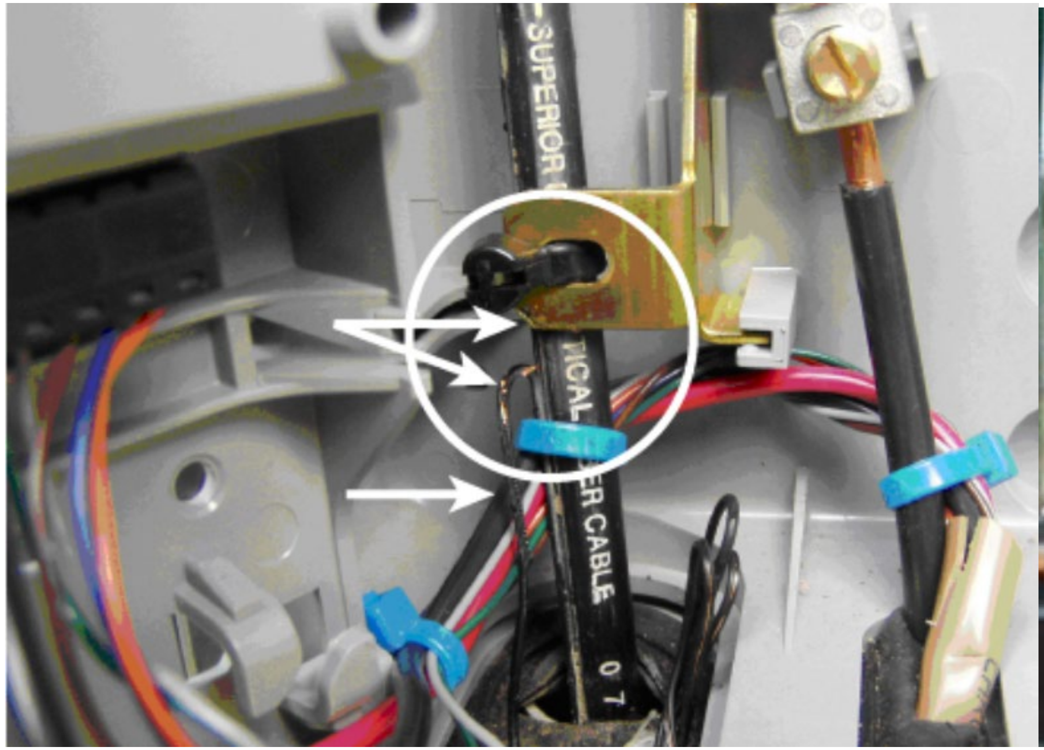
- Damage to equipment in Japan and the US
- Model testing and simulations
- Need for special requirements
- Protection against lightning

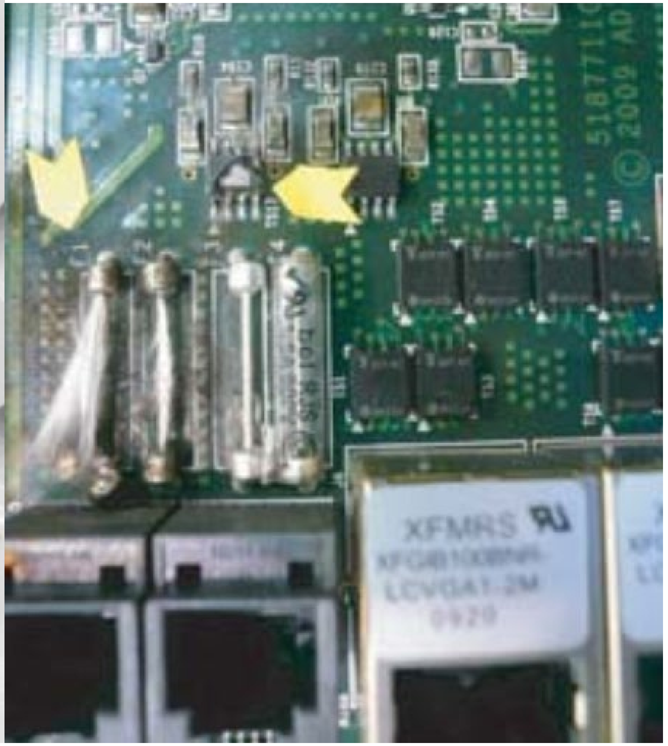
Evidence of inter-port surge paths between AC mains, Ethernet and POTs ports
Subsequently Japan deployed 7 kV isolating transformer dongles to harden Ethernet ports



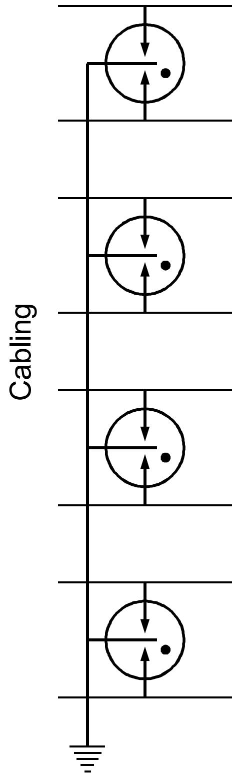
Protection design mishaps — Fibre locate wire

ADTRAN White paper: *Customer Premises Optical Network Terminal Equipment Installation Practices* by Jim Wiese.
Left picture shows Fibre locate wire to lug arcing (probably occurred about 30 kV).
Right picture shows board damage

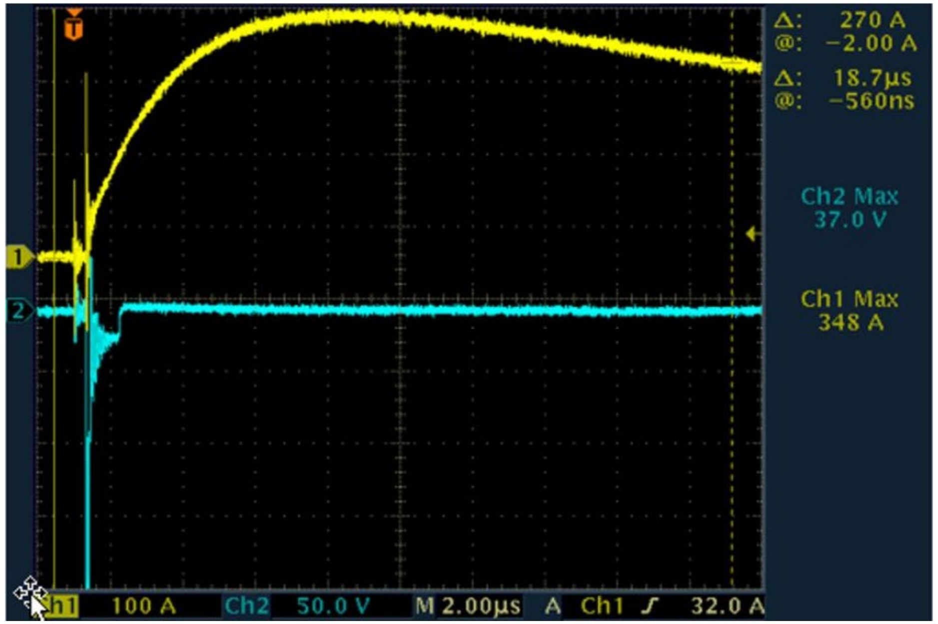




Protection design mishaps – Overvoltage protectors

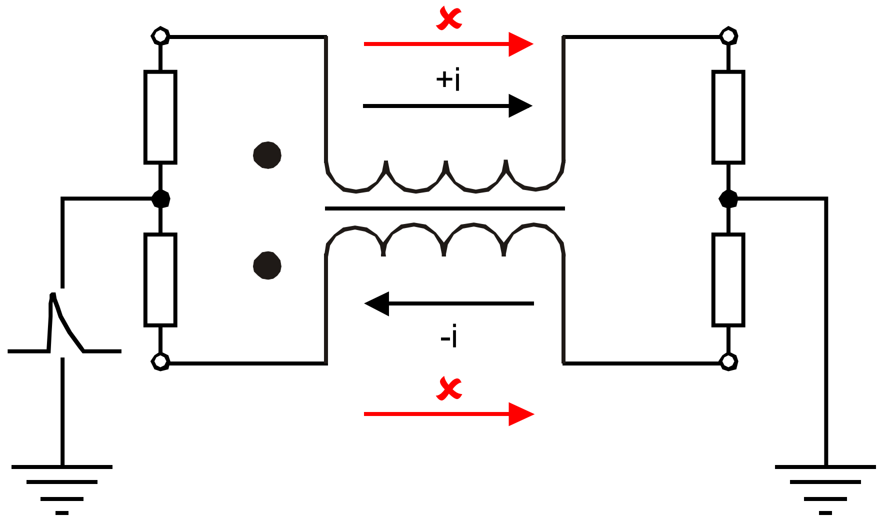


NO
3-electrode gas discharge tubes are likely not to sparkover at the same instant, causing common-mode to differential-mode surge conversion



NO
3-electrode gas discharge tubes are expected to simultaneously conduct when a surged. But this is for two independently applied surges. The low impedance Ethernet transformer effectively joins the outer electrodes together which delays full conduction. Differential voltages of 100 V for 1 μs (cyan trace example) can occur

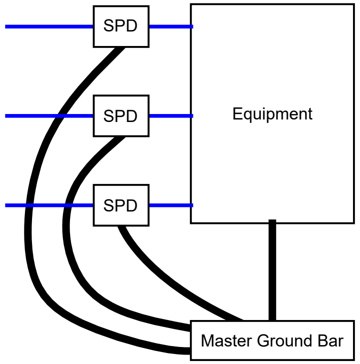
Protection design mishaps – Common-mode chokes

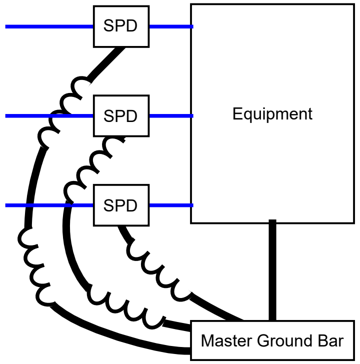


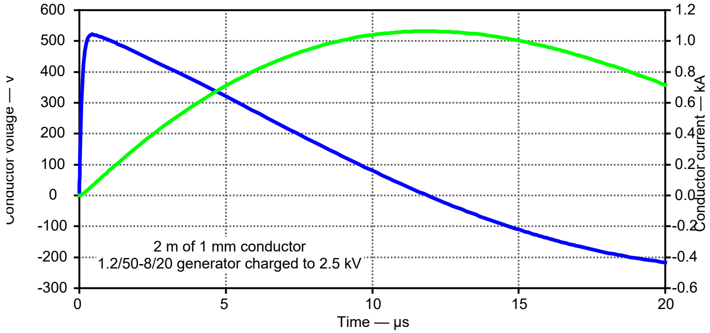
Common-mode chokes will offer a high impedance to common-mode surges and a low impedance to differential signals.
Common-mode chokes can tolerate DC provide that plus current flows on one winding and negative current in the other winding, thereby cancelling.
If the currents in the windings are the same polarity (shown red), as in PoE, then the choke core will be biased towards, if not in, saturation making the choke ineffective. A solution to this is to have all the choke windings on a single core

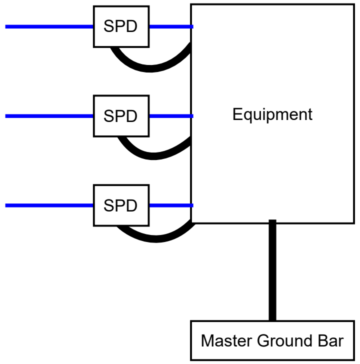
Protection design mishaps – Installation grounding cable length

- Although cables making single point grounding to the master ground bar is a safe practice, these long cables are inductive (1.5 μH/m) and increase the common-mode protection voltage.
- A 1.2/50-8/20 generator set to 2.5 kV generates over 500 V across 2 m of wire. The field current surges rise much faster than 8/20 and could easily generate 2 kV across the 2 m conductor.
- To realise the SPD common-mode protective level a direct connection should be made to the equipment port, possibly using screened cable.









SPD design rules

- **Common-mode protection**
  - Only bridge the insulation barrier with a single voltage limiter as this avoids common-mode surge to differential -mode surge conversion
  - Make the common-mode voltage limiter threshold voltage higher than the peak AC power distribution voltage, e.g. DC 500 V, to avoid the flow of damaging AC due to power cross.
  - Clamping voltage limiters produce less subsequent disturbance than switching voltage limiters
  - A two port SPD will force surges to flow through the SPD
  - Large differences in the terminal local (GPR) bonding potentials can be blocked by a common-mode choke. Due to DC core saturation special chokes are required for PoE systems
  - Any screen connections should have sufficient surge current capability
  - Testing should check for current hogging and common-mode surge to differential-mode surge conversion

- **Differential-mode protection**
  - Signal path overvoltage limiter
    - capacitance should be sufficiently low for the signal frequencies concerned
    - capacitance should be reasonably independent of signal voltage to minimize distortion
    - Testing should be at high dv/dt rates
  - DC powering overvoltage limiter
    - Maximum limiting voltage 100 V or less to protect the typical power source and power conversion integrated circuits from exceeding their voltage ratings
- **Installation**
  - SPD to equipment bonding lead length should be as short as possible to minimize inductive voltages adding to the inherent SPD common-mode protection voltage
  - SPDs, if used, should be fitted at both cable ends