Reference material

Signalling Surge Protection Installation Guidelines

This legacy document is published as historical reference material. The content described might be of assistance to individuals and organisations performing work on Transport for NSW Rail Assets.

This document refers to organisational and positional roles and responsibilities in place prior to 1 July 2013 and may have been superseded by other documents.

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SIGNALLING SURGE PROTECTION

INSTALLATION GUIDELINES

15 June 2005

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1. Introduction

The RailCorp's Signalling Construction Specifications, "Lightning and Surge Protection Requirements" SC 00 17 00 00 SP details RailCorp's performance specification for Lightning and Surge Protection requirements.

This document details installation practices to achieve the requirements.

2. Lightning and related surges

Typical surges due to lightning last for about 1/10,000 Seconds with a peak current flow of about 20,000 Amps.

Due to the speed of a lightning surge event, with fast rise time and short duration, lightning surges behave like high-frequency signals. The impedance of connections to earth, and wiring separation has a large impact on the effectiveness of the surge protection equipment.

The typical surge can develop 10,000 volts across a 1 metre length of 16 mm^2 earth cable due to its inductance. It is therefore very important to keep earth wires as short and direct as possible.

10,000 volts can flash over an air gap of a centimetre, so separation of wiring is also important.

3. Entry of surges

- Lightning surges look for the easiest way to earth.
- Power surges typically are an increase or decrease in supply voltage.
- Power faults to earth look for a path to the source power supply location and last for 100 to 600mS.

3.1. Galvanic coupling

A surge can be coupled into electrical equipment due to differences in the impedance to earth. This can be addressed by having very low impedance to earth or by having common connections that ensures all paths to earth rise to the same potential.

3.2. Electrostatic coupling

A surge can be coupled between two wires due to the capacitance between the wires. Although the capacitance is extremely small, a surge is coupled into the other wire because of the high rate of change of the surge voltage. Physical separation of the wiring and limiting any parallelism of the wires limits this coupling method.

3.3. Electromagnetic coupling

A surge can be coupled into another circuit due to the high rate of change of the surge current. Physical separation of the wiring and limiting any parallelism of the wires limits this coupling method.

4. Zones

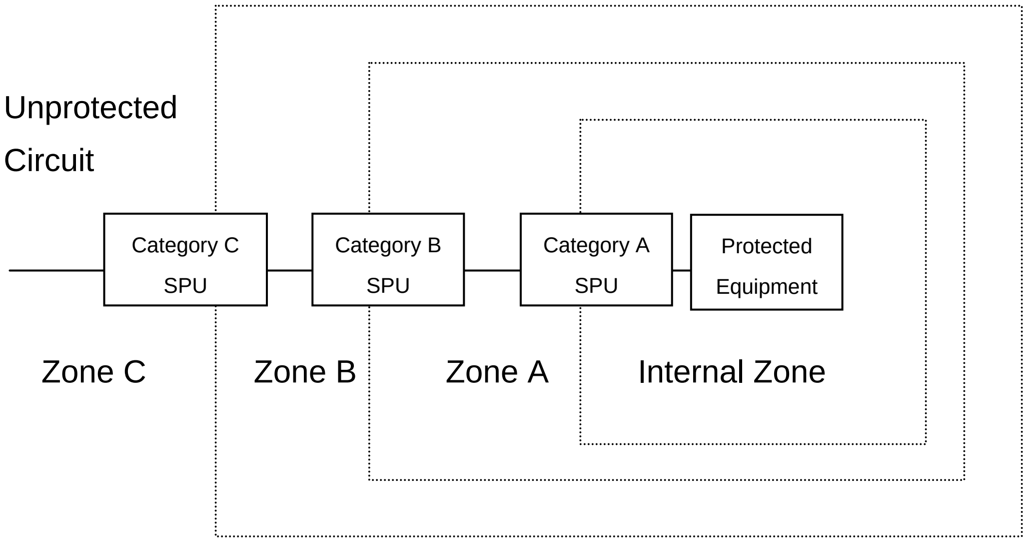
Typical surge protection schemes are based on dividing the equipment installations into zones. Each zone defining the possible level of surge that could occur in the zone from a protected zone by using surge protection filters on the entry to the zone, and physical separation of the zones.

The surge protection zones defined in the Australian Standards are targeted towards physical protection of buildings. Surge protection equipment supplier defined zones vary from one supplier to another. As a result this document defines a set of surge protection zones based on the Australian Standard Surge Categories to illustrate the concept in a more relavent manner. The zones are defined as:

- Internal: Protected wiring with-in the location.
- Zone A: External wiring that originates in another equipment room.
- Zone B: External wiring that originates at a ground level source.
- Zone C: External wiring that originates from an above ground source.

Zone C has the highest exposure to surges, and internal zone has the least exposure to surges.

Surge protection devices are rated as Category A, B, or C with the appropriate category device fitted on the zone boundary.



SPU - Surge Protection Unit

Figure 1 ZONE CONCEPT

Wiring between the zones needs to pass through a surge protector to limit the possible magnitude of surges to that of the new zone.

Wiring in each of the zones needs to be physically separated from adjacent zones.

Separation of the wiring in the different zones becomes important to make sure that surges do not couple around the surge protectors.

5. Earthing

5.1. Earth Mat/Main earth stake

The signalling earth is an earth mat with, at some locations, a main earth stake.

The signalling earth mat must be low impedance to limit Earth Potential Rise at the location.

The signalling earth is installed in an environment where most items in contact with the soil are made of ferrous material. As a result the signalling earth uses ferrous materials in contact with the soil, eg stainless steel earth stakes, and stainless steel earth wire between the earth stakes.

The earth mat is the required number of earth stakes equally spaced around the main earth bar, and connected to the main earth bar by at least 16 mm^2 insulated Green/Yellow copper cable. The earth stakes are also directly connected together via bare 2 mm stainless steel wire in direct connection to the soil.

Earth mat and main earth

Location	Required Earth Resistance	Main Earth stake required	Minimum number of earth stakes (excluding main earth stake).	Maximum number of earth Stakes (excluding main earth stake).
Track-side equipment	75 ohms	No	Use Post	1 x 4 m
Standard	10 ohms	No	2 x 2 m	4 x 2 m
Location with CBI or Telemetry equipment.	5 ohms	Yes	4 x 2 m	4 x 4 m
Power supply distribution locations	5 ohms	Yes	4 x 2 m	6 x 4 m

Earth stakes are 14 mm diameter Stainless Steel Earth stake.

A main earth stake is one 2 meter earth stake in the cable pit, as close as possible to the main earth bar. It is provided to minimise the impedance of the signalling earth.

Earth stakes need to be physically separated so that earth stake will act independently. The separation between each pair of stakes must be at least equal to the length of the two stakes added together

Earth conductors are bonded to earth stakes by exothermic welding, which is referred to as "Cadweld Bonds" or alternatively a cast copper clamp connection may be used.

Earth stake connections are not buried but are installed with an inspection cover so as to be readily accessible for inspection purposes. The strength of the inspection cover is to suit the physical position (i.e. truck axle loads in access roads).

If additional earth stakes are required they must be connected via $16mm^2$ wire directly to the main earth bar.

Track-side equipment earth stakes may be connected via $2mm^2$ stainless steel wire to the equipment earth.

The use of approved Earth Enhancing compounds is accepted to reduce earth resistance.

5.2. Bonding between earth bars

Subsidiary earth bars should be directly connected to the main earth bar although Subsidiary earth bars can be connected in series to the main earth bar provided that the connection between earth bars is less than 1 meter. If this cannot be achieved then the subsidiary bars must be connected directly to the main earth bar.

The wiring between earth bars should be two $16mm^2$ or larger earth braids although 2 separated $16mm^2$ wires are acceptable if the distance is less than 1 metre.

5.3. Earth bonding of location metalwork.

All exposed metalwork for locations that do not have 240VAC power must be bonded to the signalling earth.

Mounting rails that are used as earth connections for surge protection equipment must be bonded to the signalling earth.

For locations with 240VAC power, metalwork containing 240 volt mains wiring must be bonded to the mains earth and metalwork not containing 240 volt power circuits must be bonded to the signalling earth.

This may require separation/isolation of 240 volt power earth bonded metalwork and signalling earth bonded metal work.

5.4. Stainless steel earth wire to protect buried cables.

Stainless steel wire is used in buried non re-enterable cable routes as a grading wire to protect the cables from damage. The stainless steel wire is run above the cables. Its function is dependant on it having good electrical contact with the surrounding earth.

The stainless steel earth wire when installed must be:

- Run a minimum of 300mm above the top cable and 300mm below the surface.
- Terminated on the location main earth bar to allow for disconnection when testing the location earth.

- Insulated until it has passed the location earth mat by more than 1 m so that it does not influence the location earth when disconnected for location earth testing.
- Jointed by using a stainless steel U clamp.
- Broken at the mid-point between locations to prevent the transfer of earth potential rises between locations. The break must be 4 metres. The ends do not need to be terminated on earth stakes as per previous practice.
- Broken for 20m either side of High Voltage earths to prevent fault current being collected and directed along the signalling cable route to the signalling location. High Voltage earths are the earths found at 11kV or higher power poles, AC sub-stations, and traction sub-stations. If the cable route is run alongside a High Voltage Pole line with an overhead earth wire then the stainless steel is not to be installed.

The stainless steel earth wire along the cable route is not required in GST, GLT, or re-enterable cable routes because:

- GST provides good protection of the cables as it is continuous, metallic, has many earth connections, and fully encloses the cables.
- In GLT route the stainless steel wire is not physically separated from the cables, nor is it in intimate contact with earth, and therefore will not provide effective protection.
- Re-enterable cable route provides protection to the cables by the use of PVC pipe as extra insulation.

Stainless Steel earth wire is installed as per Drawings 112000/5/1, 112000/5/2, 112000/5/3, and 112000/5/5 from Specification Construction of Cable route and Associated Civil Works SC 112000 00 SP. Drawing 112000/5/4 shows the stainless steel earth wire as required but it is not necessary where all cables are in PVC pipe.

5.5. Selection of Earth connection

The housings of some sensitive equipment may need to be insulated from the mounting rack so that significant Earth Potential Rises that occur during a lightning surge event due to the impedance of earth connections do not cause a insulation breakdown to the equipment case. In these situations, although the physical housing is insulated to prevent it from being earthed via the rack, the housing would be earthed via a direct connection to the earth point of the applicable surge protector.

This issue needs to be evaluated as part of the surge protection scheme for each equipment type.

5.6. Separation from or Bonding to other earths

a) Communications earths

Communications earths must be direct bonded to the low voltage power earth as per ACA rules. Therefore the installation of signalling earths only needs to consider the low voltage and high voltage power earths.

b) High voltage earths

RailCorp's Electrical Systems Requirements document "Co-ordination of Signalling and Power Systems - Earth Potential Rise" EP 90 10 00 04 SP details the requirements for the management of the High Voltage and Signalling earths.

Fundamentally, the aim is to achieve as great a separation as practicable between signalling and high voltage earths. Depending on the distance achievable between the signalling earth and the high voltage earth then different design and installation practices are used.

Criteria	Typical Distance between earths*	Installation requirement
Signalling earth inside the 800 volt Earth Potential Rise (EPR) gradient of High voltage earth	<5 metres.	Use isolation transformers rated for 2500v isolation to ensure galvanic isolation for paths to remote earths.
Signalling earth outside the 800 volt Earth Potential Rise (EPR) gradient of High voltage earth.	>5 metres	Use surge protection equipment that can handle 800v EPR. *The new IVAP surge panels (also called PRF, from 2001 on) are rated for 800 volt EPR and therefore need a separation distance of >5 metres.*
Signalling earth outside the 430 volt Earth Potential Rise (EPR) gradient of High voltage earth.	>15 metres	Use surge protection equipment that can handle 430v EPR. *The original IVAP, VAP, and IDP surge panels (pre 2001) are only rated to 400 volt EPR and therefore need a separation distance of >17 metres.*

** The actual distances can vary greatly from the typical distance due to variations in soil resistivity.*

Earth separation distance measurements are made between the closest two earth stakes, or between the closest edges of the earth mats.

c) Low voltage power earths

If the signalling equipment uses both 240VAC equipment powered from the railway power supply and 120VAC equipment powered from the signalling power supply then the signalling earth is bonded to the low voltage power earth via a Transient Earth Clamp.

If a Transient Earth Clamp is used to bond the signalling earth to another earth system then the device is to be installed inside the equipment room so that these devices can be tested.

If the signalling installation only uses 120VAC powered equipment and does not interface to any communications equipment then the low voltage power earth and the signalling earth should be separated by more than 2 m. If the separation cannot be achieved then bond via a Transient Earth Clamp.

Earth separation distance measurements are made between the closest two earth stakes, or between the closest edges of the earth mats.

If the signalling location does not have any external power feeds, or circuits that could provide a galvanic path to a remote earth then it can have the signalling earth direct bonded to the power earth via a 16mm^2 cable.

5.7. Influence of remote earths

Faults from High voltage power equipment can cause EPRs (Earth Potential Rises) of over 3000 volts for up to 0.6 seconds in the vicinity of the High Voltage earth. Extensive damage can be caused by these types of faults.

If there is a signalling earth within the EPR zone and a path exists from the local signalling earth to a remote signalling earth then significant fault currents can flow between the earths causing damage to the surge protection equipment, and signalling equipment.

Section 5.6 details how the local signalling earth is dealt in regard to other earths.

The fundamental aim is to avoid direct paths between separate/remote earths, via signalling cables.

It is important to ensure that there is no galvanic path between the local signalling earth and the remote signalling earths that has a rated breakdown voltage less than required EPR voltage.

Cable Sheaths, screens and shields should only be earthed or arrested at one end. Typically this is either the location case end (for tail cables) or the end that is not at a Power supply location. Sheath arresters on multi-core cables may need to be removed at Power supply locations to prevent damage to the arresters and current flow along the sheaths due to power faults. Details are of the typical arrangements are discussed in Section 10.9.

5.8. Earth Leakage Detector Test earth

The Earth Leakage Detector Test earth is to be independent of the signalling earth. The Earth Leakage Detector Test earth is one 2 m stainless steel earth electrode separated from the other earths by more than 2 m and connected via a 4 mm^2 insulated cable to an insulated terminal in the location. The 4 mm^2 cable is preferred to allow easier identification of the purpose of the earth stake.

Where a 240 volt power earth is provided, with effective separation from the signalling earth, then the power earth may be used as the ELD Test Earth.

6. Earth wiring guidelines

The preferred method of earth wiring in the location is by use of the metal work of the mounting rails as earth conductors to reduce impedance of earth connections.

Surge protection equipment mounted on DIN mounting rail is earthed by a connection to the DIN mounting rail.

Steel TS32 mounting rail (G rail) is equivalent to 35mm^2 copper cable.

Steel TS35 mounting rail (Top hat rail) is equivalent to 16, or 35mm^2 copper cable depending on the type of rail used.

Mounting rails that are used for earthing are bonded to the location earth bar.

All metal work is bonded to the location earth bars.

Earth wiring must be stranded wire, braid to the equivalent size or flexible busbar. A minimum of 7 strands is required for the wires, with more strands preferred.

Earth wiring is Green/Yellow insulated copper. Bar or uninsulated earth is acceptable provided that there is no reasonable possibility of it causing an earth fault on other equipment, and it will improve the performance of the earthing.

Single 4 mm^2 earth wires for surge protection must not be more than 0.5 m long.

Single 16 mm^2 earth wires for surge protection must not be more than 0.5 m long.

Paired 16 mm^2 earth wires for surge protection within equipment locations must be separated from each other by 15mm, and must not be more than 1 m long when used in equipment locations. The use of conduits to provide separation is accepted practice.

Earth bars should be extended if earth wires will otherwise exceed the limits or braid wiring of equivalent size used.

Connections between the subsidiary earth bars and the main earth bar can exceed the distance limits.

7. Installation of Surge Protection equipment

Installation of surge protection equipment should be as close to the entry point of the surge as practical.

The installation should also consider:

- Minimising length of earth wires.
- Separation of unprotected and protected wiring.
- Power supply surge protection equipment should be mounted as close to the main earth bar as practical.
- Compliance with manufactures recommendations.
- Preventing surges from entering equipment locations and cable routes.

Wiring for surge diverters (or varistors) connected across a power supply bus is not to be run in ducting containing other wiring. Wire to be 7/0.85 blue & connected as close as practical to power cable connections. Each wire to the bus is to be typically less than 100mm, with a maximum acceptable length of 300mm.

8. Wiring separation guidelines

8.1. General

Surge protected wiring must be physically separated from non-surge protected wiring. Earth wires are considered as non-surge protected wiring.

The separation criteria are given in sections 8.2 and 8.3. If the separation cannot be achieved then a barrier consisting of an earthed piece of metal work is an acceptable solution to provide the separation.

If surge protected wiring must cross non-surge protected wiring then it must cross at right angles. Earth wires from surge protectors must be treated as unprotected wiring.

Most parallelism between cables or wires occurs in the cable routes and this needs to be taken into account when segregating wiring.

Figure 2 illustrates the concept of separation.

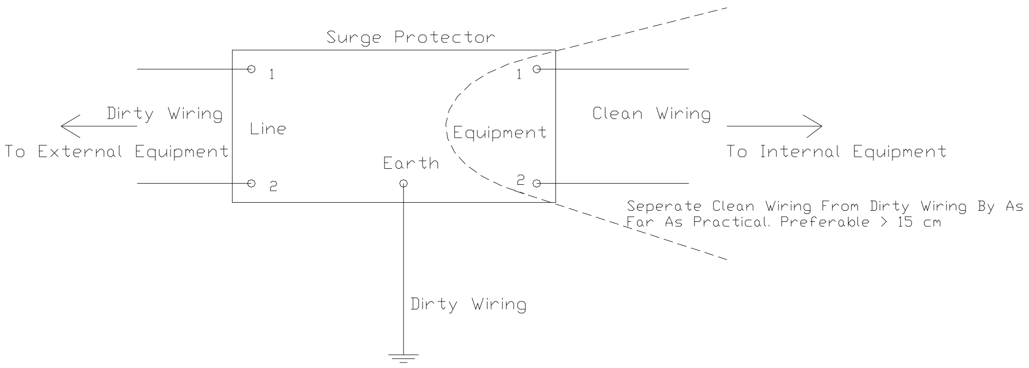


Figure 2

8.2. Absolute separation distance (includes wiring crossing at right angles)

To / From	Internal wiring	Zone A wiring	Zone B wiring	Zone C wiring
Internal wiring	0mm	5mm	15mm	30mm
Zone A wiring	5mm	0mm	5mm	15mm
Zone B wiring	15mm	5mm	0mm	15mm
Zone C wiring	30mm	15mm	15mm	0mm

8.3. Separation distance for more than 1 metre of parallelism

To / From	Internal wiring	Zone A wiring	Zone B wiring	Zone C wiring
Internal wiring	0mm	50mm	150mm	300mm
Zone A wiring	50mm	0mm	50mm	150mm
Zone B wiring	150mm	50mm	0mm	150mm
Zone C wiring	300mm	150mm	150mm	0mm

Zone A circuits from other equipment rooms.

Zone B circuits from external cables.

Zone C circuits from overhead power lines or pole route.

9. Examples of good and bad wiring practice

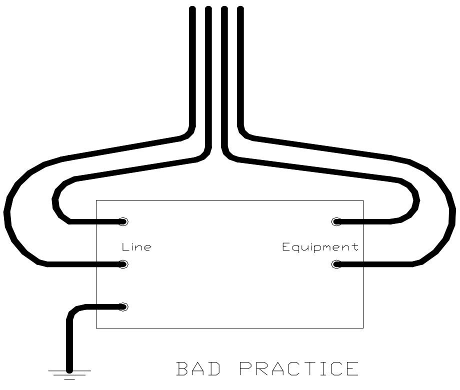


Figure 3

If the surge protector is installed as per figure 3 then the surge can couple between the wiring and bypass the surge protector. This is bad practice and needs to be avoided.

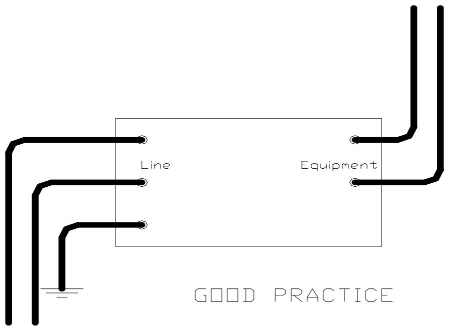


Figure 4.

If the surge protector is installed as per figure 4 then due to the separation of the wiring on the line and equipment side the surge is unable to bypass the surge protector. This is good practice.

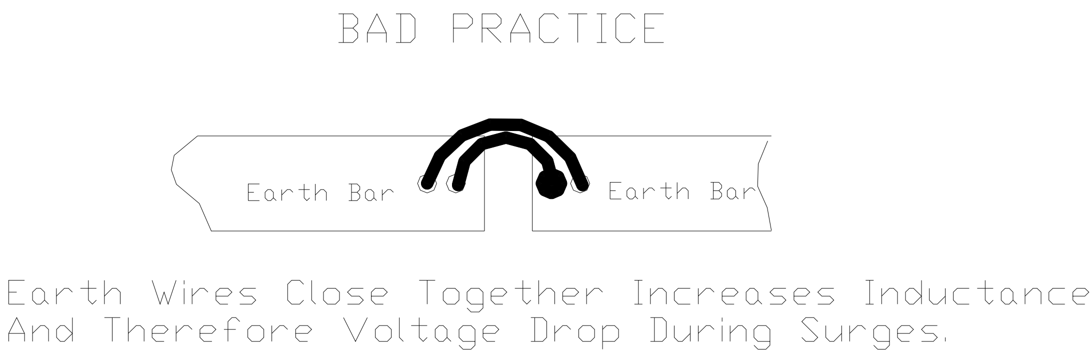


Figure 5

Very high currents flow through the earth wiring with very fast rates of change during surge events. As a result, currents in one wire affect the current flowing in other wires. Wires run in close proximity increases the effect between wires and as a result the surge current effectively treats the pair of wires as one wire. Bad practice puts the wires close together as per figure 5.

Figure 6

Very high currents flow through the earth wiring with very fast rates of change during surge events. As a result currents in one wire affects the current flowing in other wires. Separation of wires decreases the affect between wires and as a result the surge current effectively treats the pair of wires as individual wires. Good practice keeps the wires apart as per figure 6.

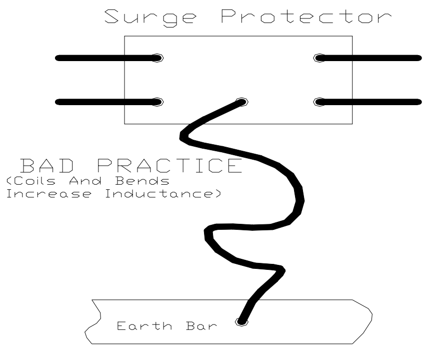


Figure 7

Coils and bends in the earth wire as per figure 7 increase its length and inductance and as a result reduce the effectiveness of the surge protector.

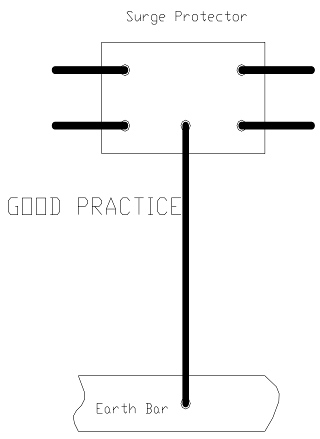


Figure 8

Minimum length on earth wire results in the best possible performance of the surge protector as per figure 8.

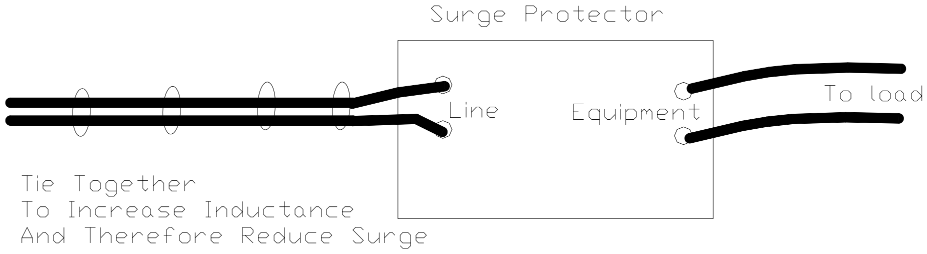


Figure 9

Wiring in close proximity will cause common mode surge currents to have a higher self inductance. Therefore it is best to make sure that power cables are kept in close proximity by binding them together prior to connection to the surge protector to increase their inductance to common mode surges. This practice is illustrated in figure 9.

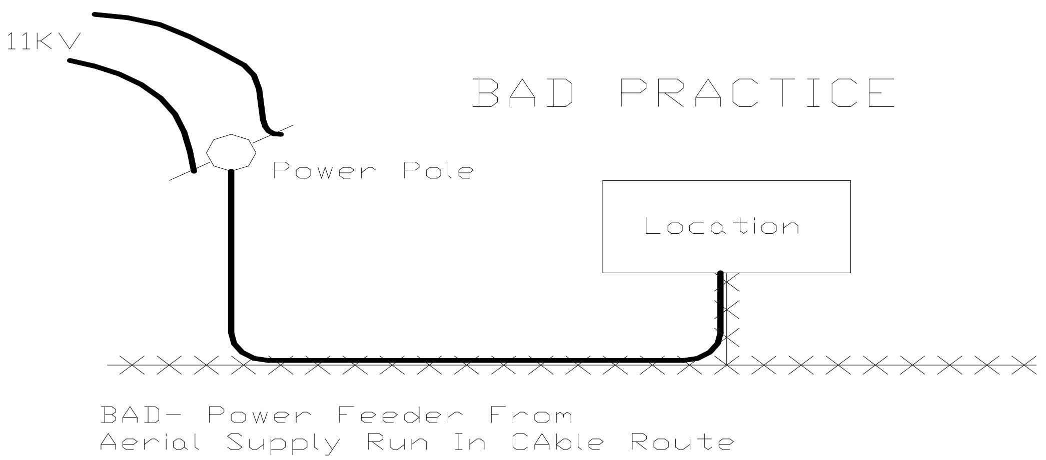


Figure 10 (11kv/120v Transformer on power pole)

Cabling that has not had proper surge protection should not be put in close proximity to the signalling cables as it can couple surges into other cables as would occur if installed as per figure 10. If placed in the same trench then it must have a physical separation of greater than 150 mm.

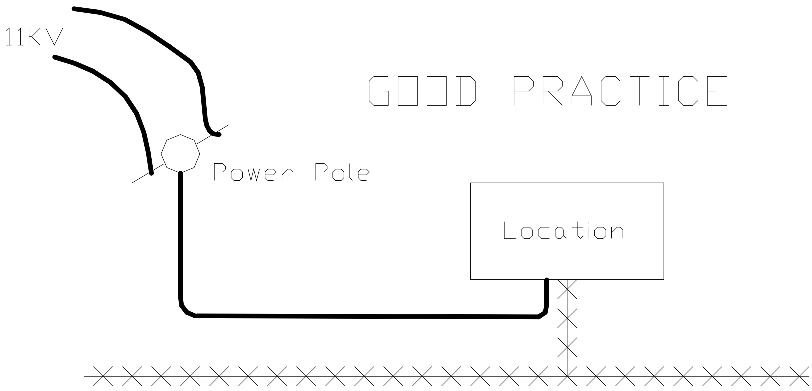


Figure 11 (transformer on pole)

Cables that do not have proper surge protection are run with a physical separation of more than 150mm to minimise coupling of surges into other cables as per figure 11.

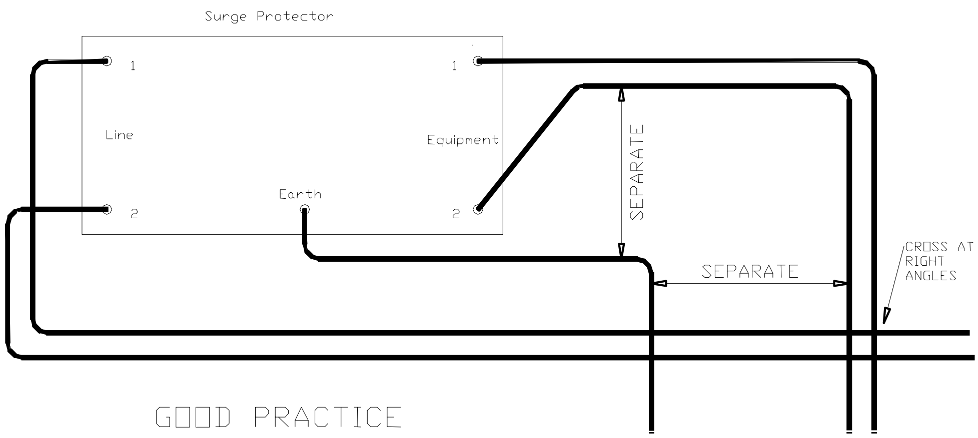


Figure 12

If wires have to cross, then it is acceptable practice to cross at right angles, with no parallelism as shown in figure 12. The wiring separation detailed in section 8.2 applies. If the wiring is from an above ground source then a piece of earthed metal or additional insulation must be placed between the crossing wires.

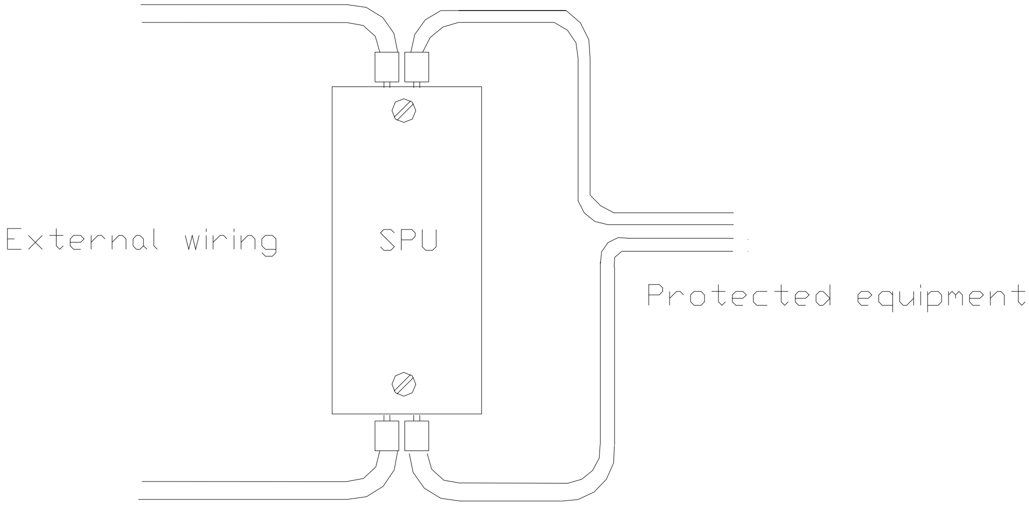


Figure 13

Figure 13 shows the preferred method of wiring a line-to-line MOV or surge diverter. The wiring on the protected equipment side should be close together to minimise any surge induced, by surge currents conducted by the surge protector.

10. Recommended practice

10.1. Wiring of Main surge protection panels

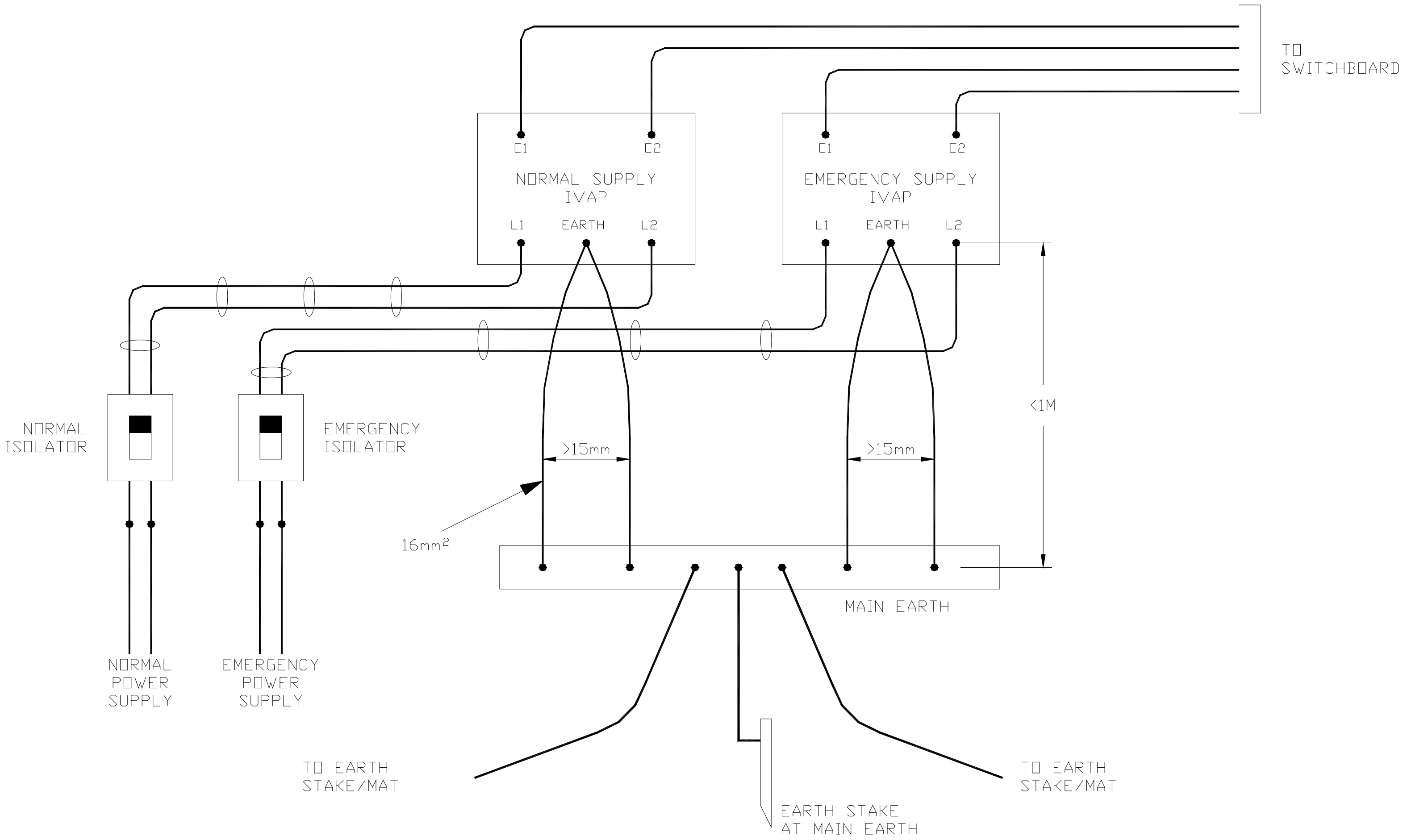


Figure 14 Showing the preferred method of wiring main surge protection panels.

10.2. Earthing of rail mounted equipment for existing locations

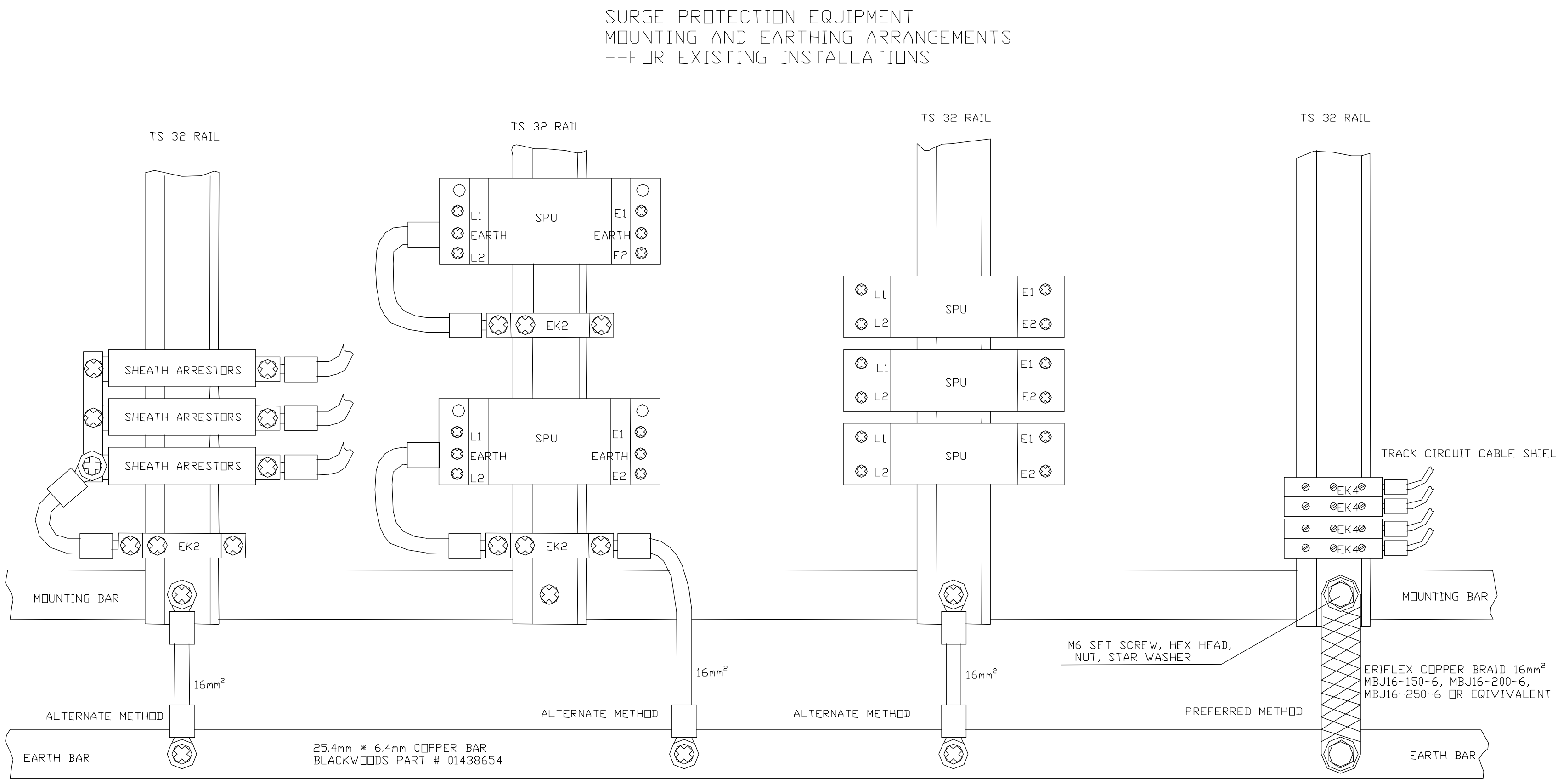


Figure 15 Showing the methods for retrofitting improved earthing practice into existing location cases.

10.3. Mounting and earthing of rail mounted equipment for new locations

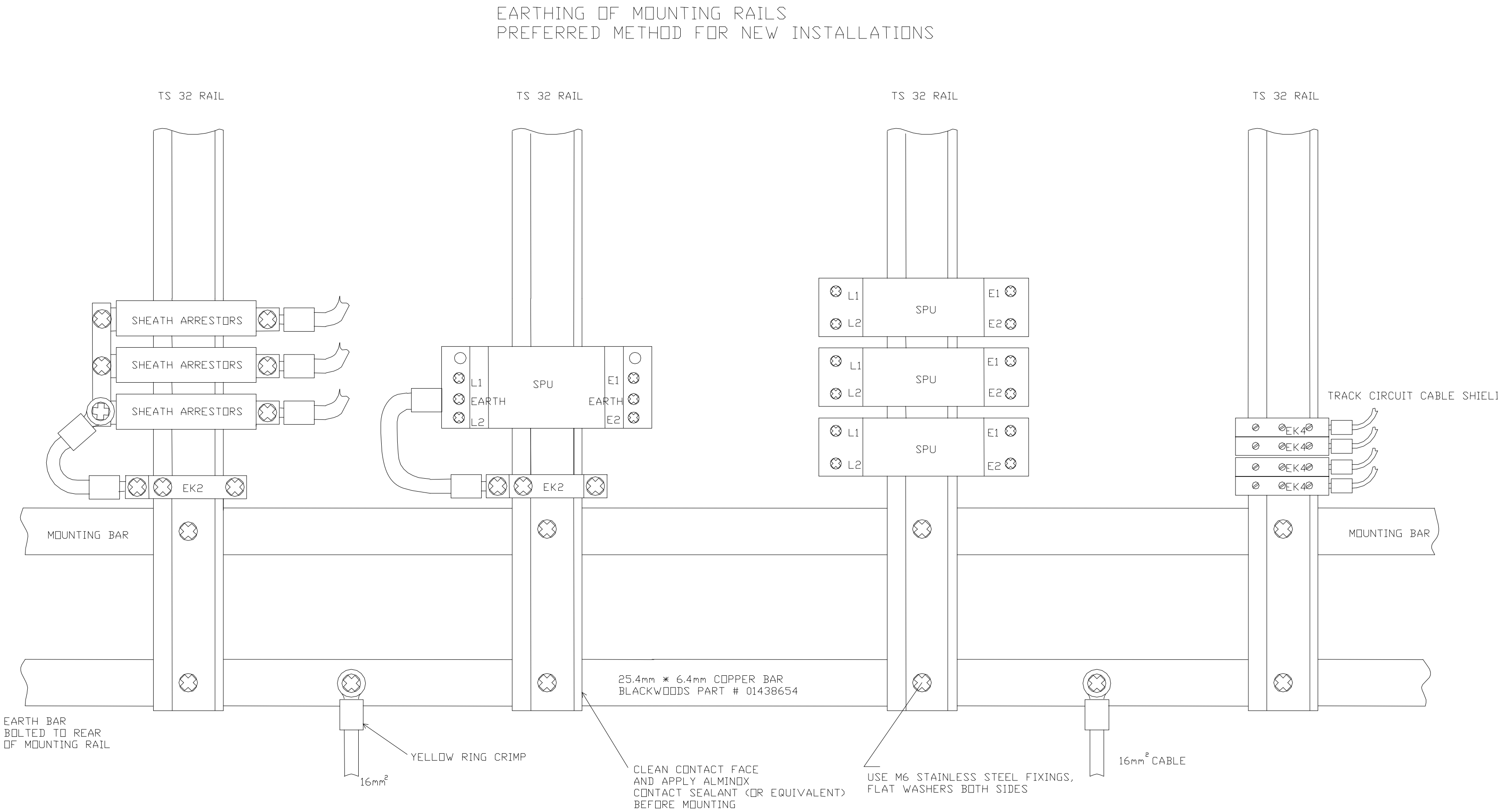


Figure 16 showing the preferred method for new installations.

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10.4. Separation of wiring ducts

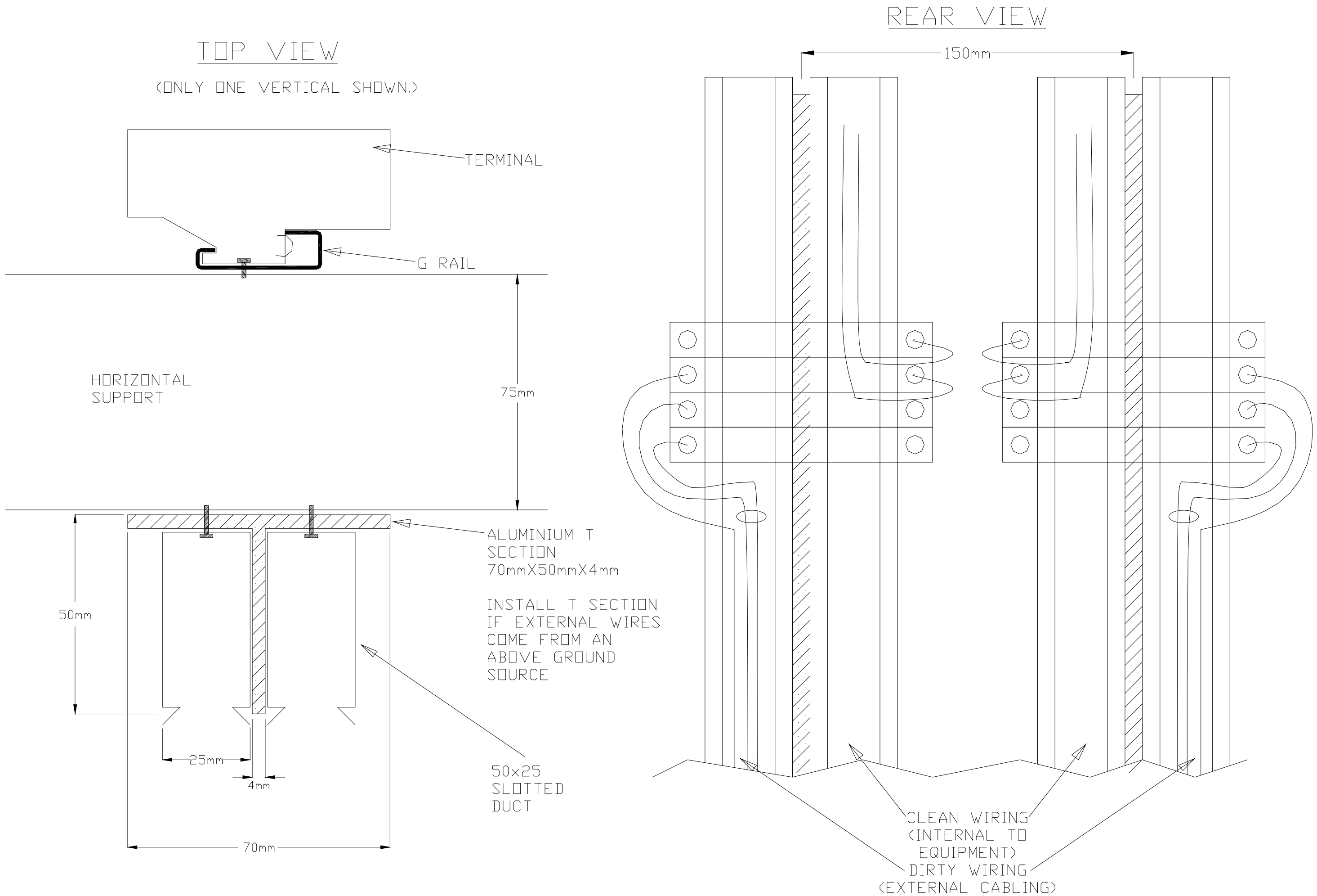


Figure 17 shows the preferred method to separate clean and dirty wiring by the use of separate wiring ducts.

10.5. SSI Data Link Isolation Transformer

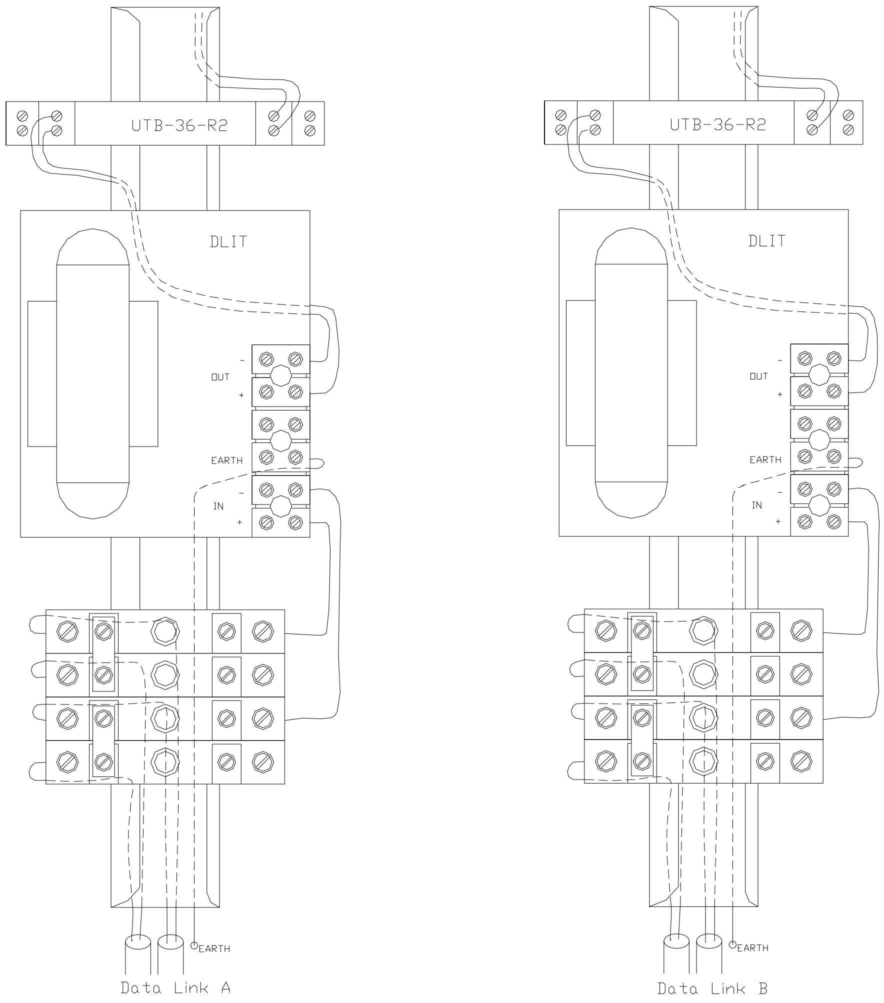


Figure 18 shows good installation practice for the pair of SSI Data link isolation transformers.

10.6. Earth bar connections

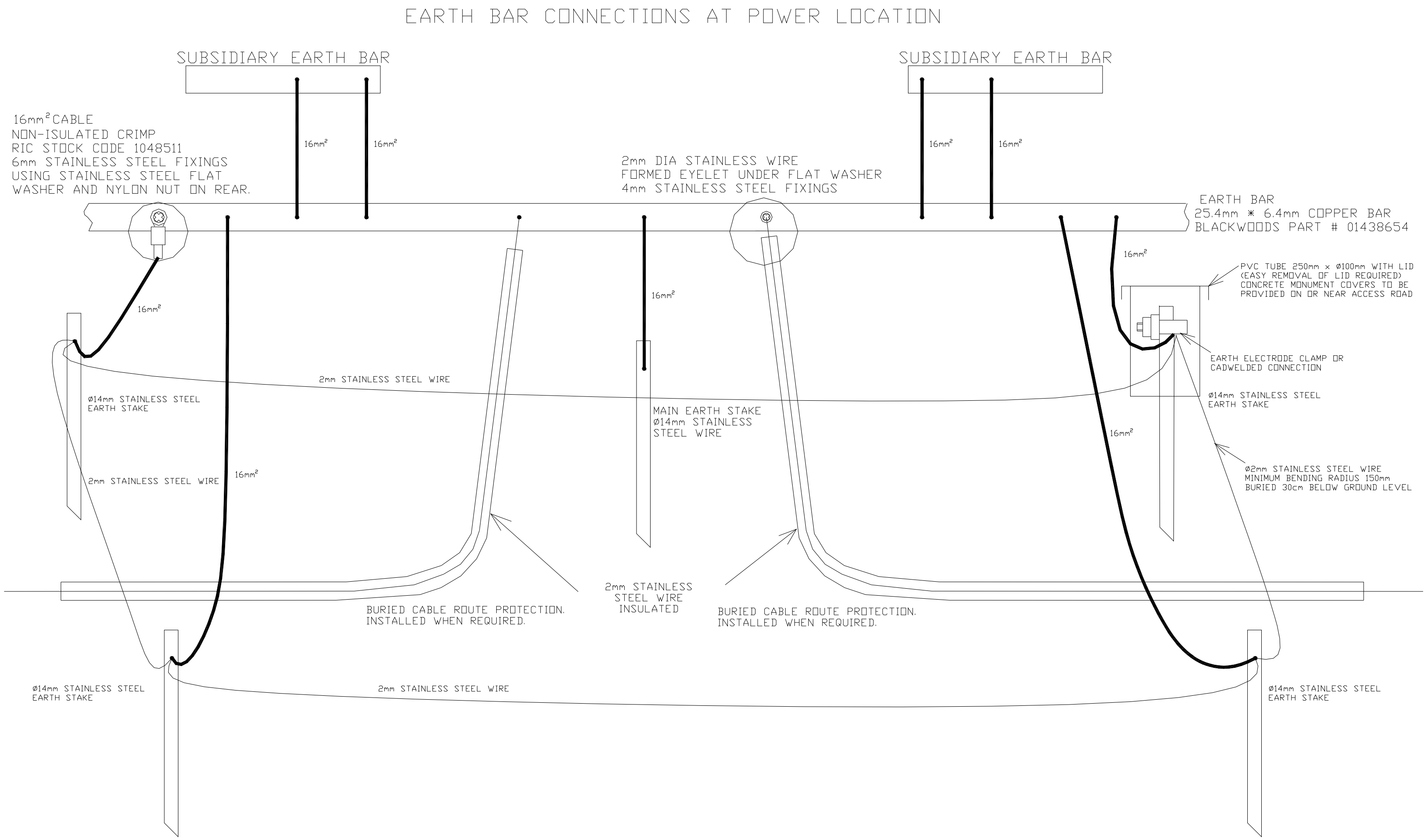


Figure 19 shows the preferred method for making connections to the earth bar.

10.7. Installation of VAPs

Figure 20 shows the preferred method of installing a Varistor Arrestor Panel (VAP) and the newer VAPL.

The earth wire must be as direct and short as practical. Therefore the VAP must be placed near to the earth bar.

The power wiring before and after the VAP needs to be segregated as much as practical, however the power wiring does not need to be short, or straight. The power wires on the internal side should be close run together.

Spare power feeder cable can be loosely coiled in the cable pit.

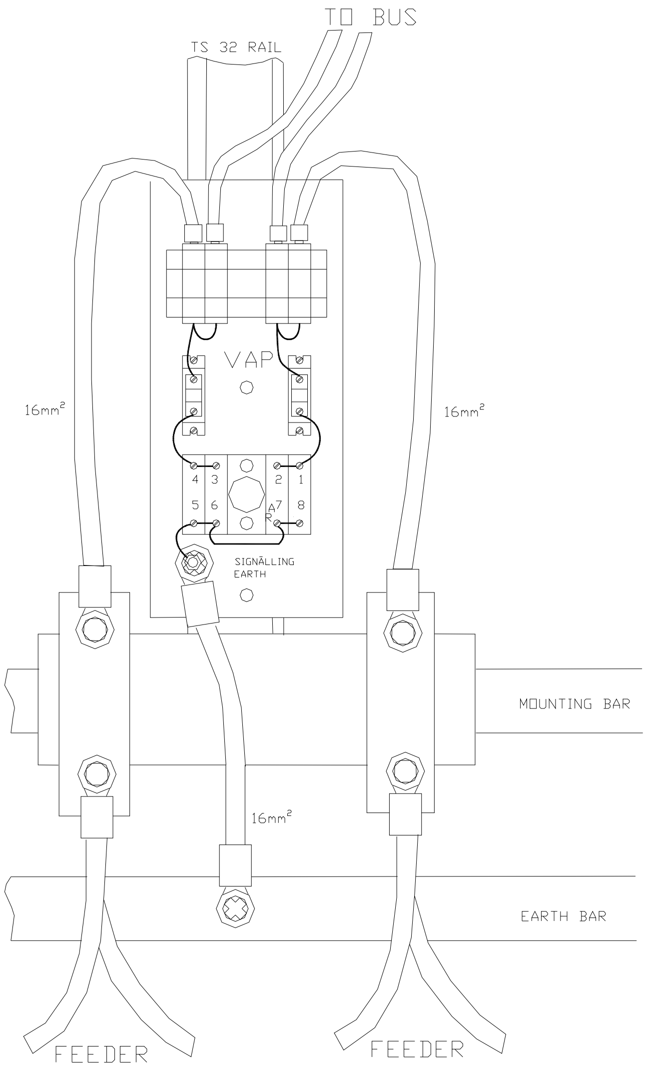


Figure 20 Mounting of VAP in location

10.8. Installation of MOV across power supply bus

Figure 21 shows the preferred method of installing a MOV across a power supply bus in existing installations. If the bus is on two adjacent rails then one wire is run directly across to the bus on the vertical that does not have the MOV.

New installations will be designed to include the MOV across the power supply bus as per figure 13 of the examples of good and bad wiring practice.

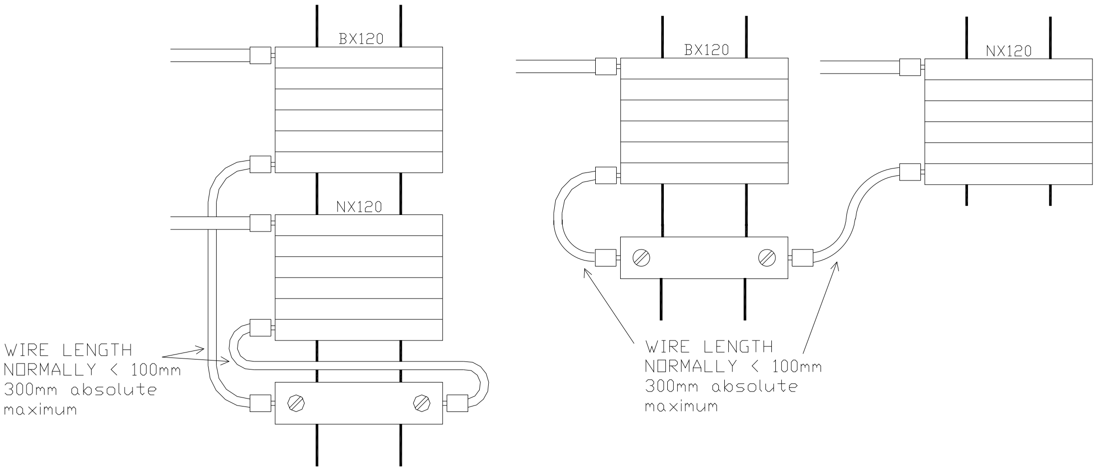


Figure 21 Mounting of MOV across Bus

10.9. Cable sheath termination

Traditional signalling multicore cables have copper sheaths for physical protection. Twisted pair cables have an aluminium foil shield and drain wire to limit interference from electrical noise.

The decision as to what to do with the metallic sheath, or shield of a cable is based on the needs for:

- Megger testing.
- Noise and surge protection.
- Transfer of earth potentials.
- Electrolysis.
- Cable locating.

In general the cable sheath, or shield is terminated so that:

- At one end it is connected via an arrestor to earth or directly connected to earth.
- At the other end it is insulated from earth and any other conductor but accessible for testing.

Figure 22 shows the treatment of sheaths for cables from locations to track-side equipment. The shield of the cable to track circuit equipment is earthed to provide shielding for electrical noise.

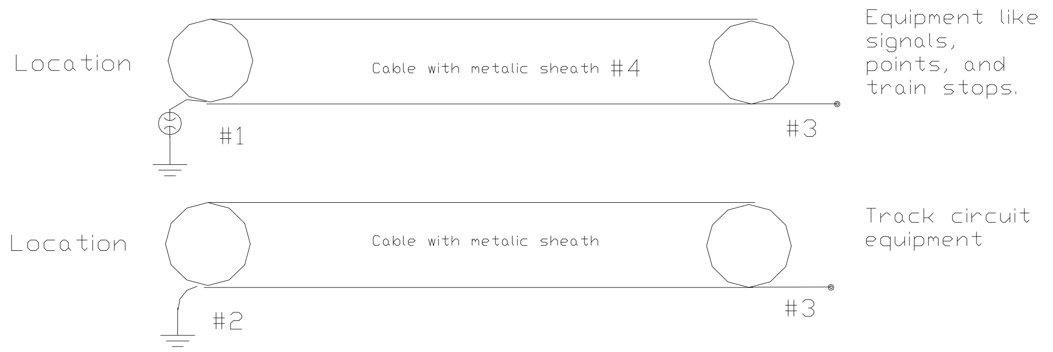


Figure 22 Cables to track-side equipment

Notes:

#1 The sheath is earthed via a Sankosha Y08JSZ-350D arrestor.

#2 The sheath is directly earthed at the location end only.

#3 Terminate the sheath on a terminal or a shrouded receptacle crimp.

#4 The twisted pair cable used in some newer installations has an orange test wire. The test wire is to be terminated at each end on a terminal or a shrouded receptacle crimp.

Figure 23 shows the treatment of sheaths for cables that run from location to location. Traditionally a sheath arrestor has been installed at both ends when a cable runs from location to location. This practice is no longer preferred as it requires site survey to confirm that no Earth Potential Rise hazards exist at or near either location.

The references to “location with power supply” and “location without power supply” in figure 23 refer to the location that gets the signalling power from the Electrical and/or Council grids. Locations with a power supply are more likely to have an Earth Potential Rise hazards as discussed in section 5.7 and therefore should not have the sheath arrestors installed.

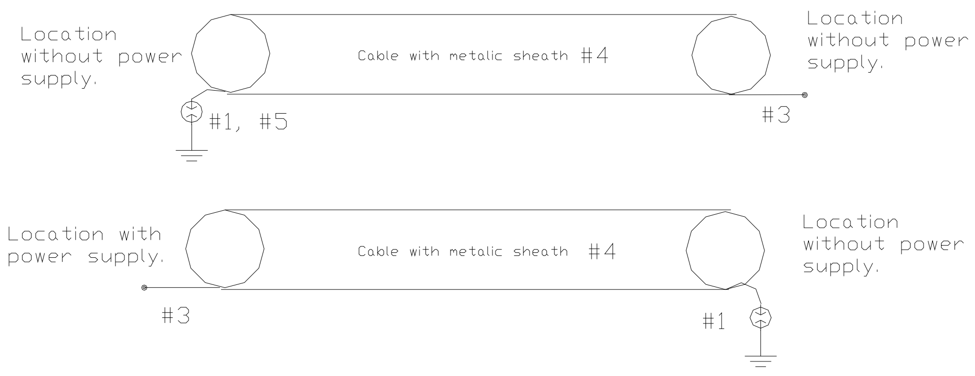


Figure 23 Cables between locations

Notes:

#1 The sheath or shield is earthed via a Sankosha Y08JSZ-350D arrestor.

#2 The shield is directly earthed at the location end only.

#3 Terminate the sheath on a terminal or a shrouded receptacle crimp.

#4 The twisted pair cable used in some newer installations has an orange test wire. The test wire is to be terminated at each end on a terminal or a shrouded receptacle crimp.

#5 The location of the arrestor may be at either end in this case.

10.10. Location Layout

Attached drawing SPG-01 shows an SSI location rack layout. Cable entry is from the bottom of the rack.

This drawing shows:

- Bonding of the mounting rails used for surge protection earth being directly connected to the earth bar.
- The earth bars being bonded in series because the length of the bond is short.
- The earth bars being bonded to the rack metalwork.
- An additional earth bar being run up the left hand side to reduce the length of the earth wires to the SSI modules.
- The SSI Data Link Isolation Transformers (DLIT) being mounted at the bottom of the rail to provide isolation at the entry point, and separation from the other location wiring. The dotted shading around the DLITs indicates the area that un-surged protected wiring must not be run in.
- Four of the mounting rails on the right hand side of the location are marked with a # symbol which is used to indicate that separated 'clean' and 'dirty' wiring ducts are to be installed on the rear of these mounting rails.
- The dotted shading between the mounting rails indicates the area where the non-surge protected wiring is to be run and surge protected wiring must not be run.
- Some of the rail mounted surge protection equipment will need to be mounted upside down to keep the un-protected wiring out of the protected area.

Attached drawing SPG-02 shows a Power Supply rack layout. Cable entry is from the bottom of the location.

This drawing shows:

- The earth bars being bonded in series because the length of the bond is short.
- The earth bars being bonded to the rack metalwork.
- The dotted shading area around the IVAP surge panels indicates the area where the non-surge protected wiring is to be run and surge protected wiring must not be run.
- The IVAP surge panels have been mounted low in the location to reduce the length earth wires to the earth bar.
- The IVAP surge panel 2 has been turned around to allow separation of the protected and un-protected wiring.

- The IVAP surge panel 3 is mounted higher in the location because of physical constraints and panels 1, and 2 are the primary power supply surge protection.

10.11. Earthing plan

Attached drawing SPG-03 Earth Connections example shows the earth connections for a Power supply location with SSI type CBI equipment.

A High voltage earth exists near the location but is separated from the signalling earth by more than 17 metres.

A Council MEN earth exists near the location but is separated from the signalling earth by more than 2 m.

These earths are not shown on the drawing because they meet the separation requirements. If they did not meet the separation requirements then they would be shown on the plan.

The drawing shows:

- The earth bars installed.
- How the earth bars are interconnected.
- Where the equipment earths are connected.
- The earth stakes installed, where they are located, and how they are connected.

10.12. AC Power supply circuit

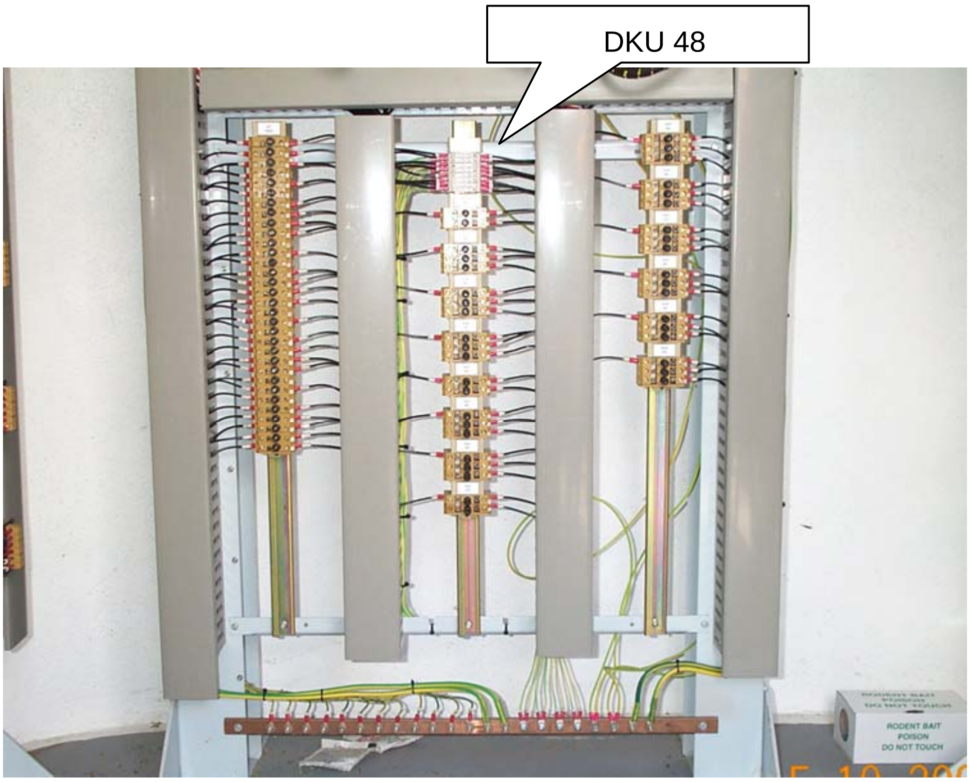
Attached drawing SPG-04 shows the circuit for wiring to the emergency Change-over contactor.

The drawing shows:

- Notes indicating the unprotected wiring that must be separated from surge protected wiring.
- Notes indicating the wiring the must be cable tied together to improve surge protection performance. The cable ties are not necessary if a twin or twisted pair cable is used.
- Notes detailing the limits for the length of the IVAP earth connections.
- A surge protector at Council supply meter box to limit surges in cabling to location.

11. Example Photographs

11.1. Typical example of poor earthing installation practice

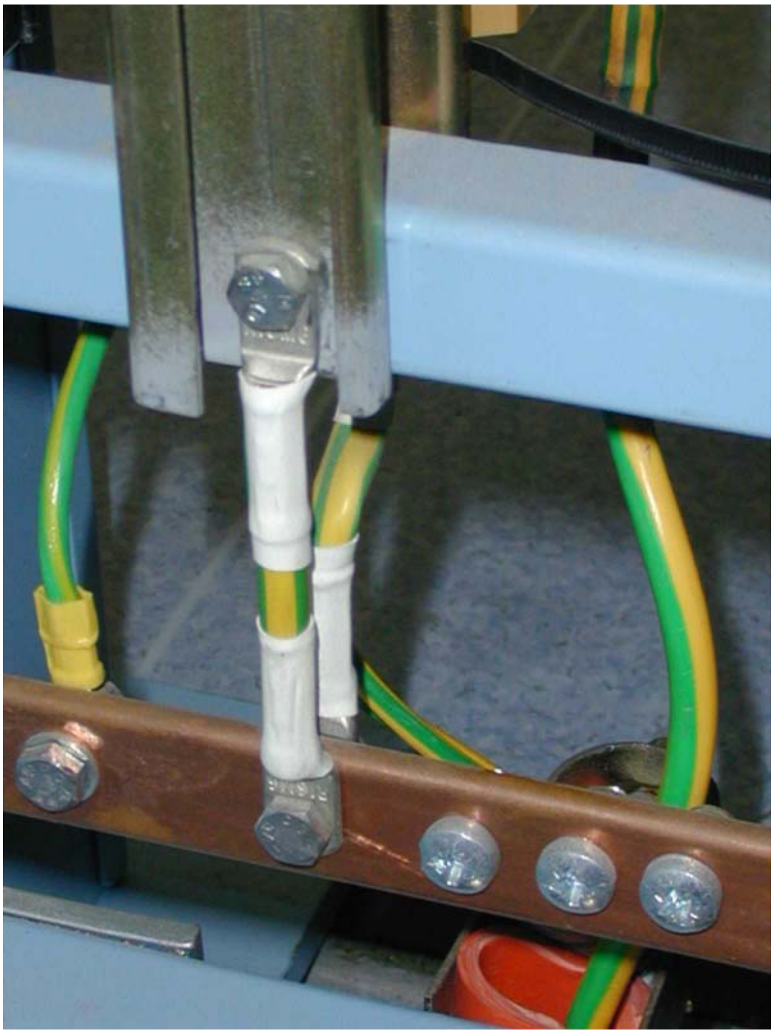


The photograph shows poor earth wiring practice because the wiring:

- is not as short as practical,
- has bends which are un-necessary,
- is mixed with surge protected wiring.

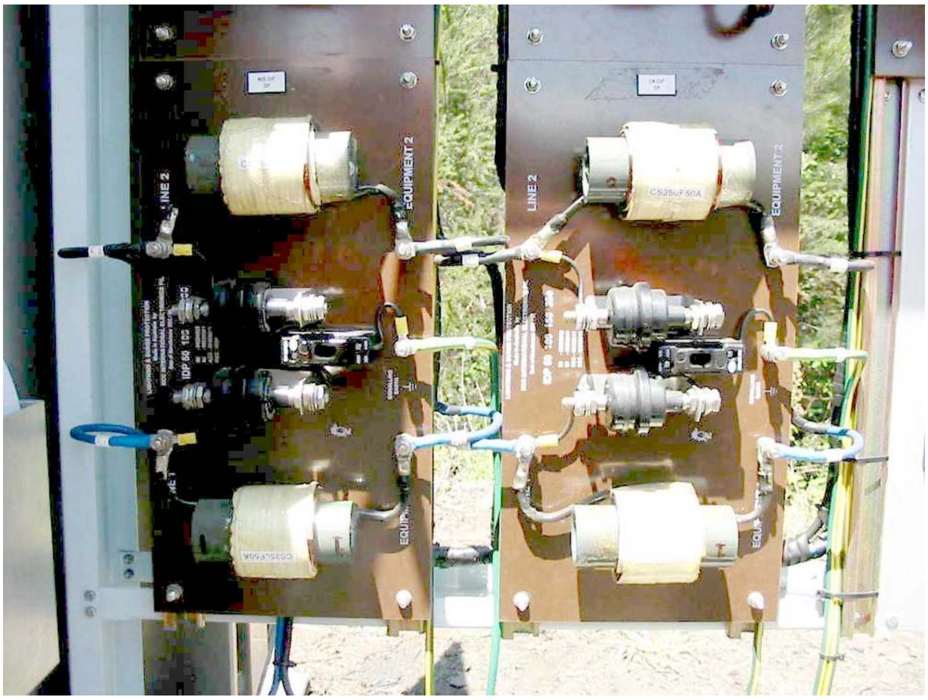
The DKU48 surge protectors are mounted at the top of the middle "G Rail" which maximises the length of the earth wires instead of minimising the length of earth wires.

11.2. Example of a good earth connection



The photograph shows good earth wiring practice, as the earth wire is as short and as direct as possible, with no bends, or coils, and separated from other wiring. The mounting rail is being used as part of the earth return circuit.

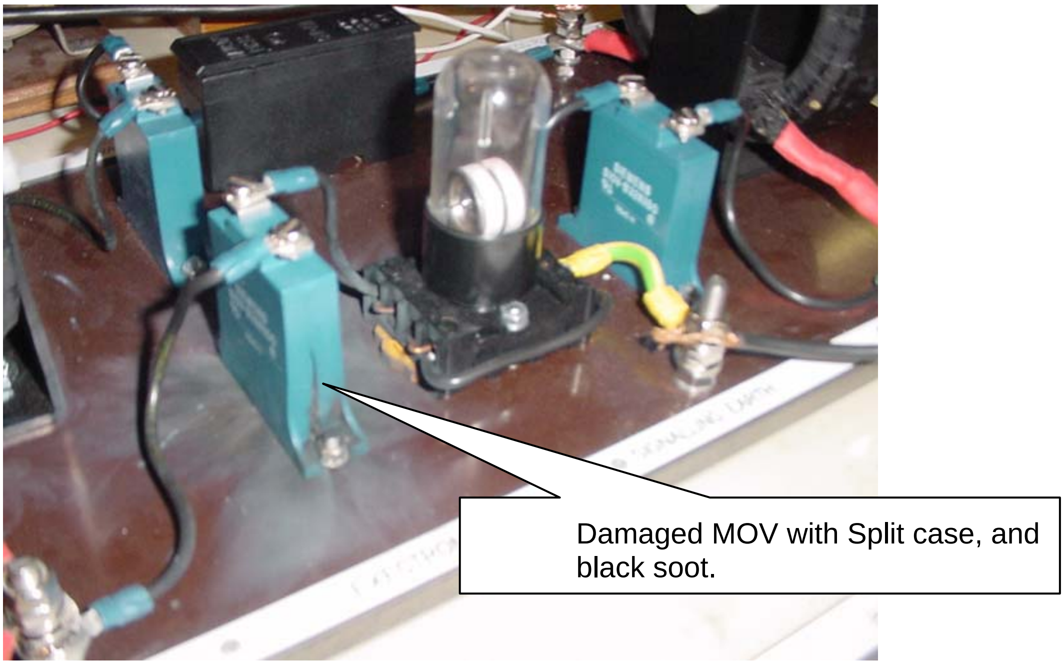
11.3. Example of poor installation of surge protection panel



The photograph show that the surge protected wiring from the surge panel on the right hand side is in close proximity to the unprotected wiring for the left hand surge protection panel. This is poor practice, as a lightning surge will be coupled into the protected wiring.

11.4. Examples of damage caused by 50Hz EPR faults

The photograph below shows a failed IVAP surge panel that has the left hand MOV failed due to a 50Hz EPR fault that exceeded 400V RMS. The failed MOVs typically have black burn marks.



The photograph below shows a Disk MOV that failed due to a 50Hz EPR fault, and resulted in a 20 ohm connection to earth.

12. Reference drawings

The following reference drawings are attached:

Location Layout example	SPG-01
Power Location Layout example	SPG-02
Earth Connections example	SPG-03
Power supply arrangement example.	SPG-04
Track Circuit Protection- Terminal & Arrestor layout	M08-818
Earthing Arrangement for Tuning Unit/Matching unit with earth stake	M08-824A
Earthing Arrangement for Tuning Unit/Matching unit without earth stake	M08-824B
Earthing Arrangement for track-side cupboards	M08-826
Typical layout of Equipment Room, Part A	M08-831/A
Typical layout of Equipment Room, Part B	M08-831/B
Layout of Level Crossing Equipment hut	M08-832
Preferred layout of Equipment room with Motor/Alternator set	M08-833
Preferred layout of Equipment room with dual transformer supplies 240/415/2KV/11KV	M08-834
Cable sheath arrangements	M08-890