1. SCOPE

This document defines the practices to be adopted in order to provide a low voltage supply from an external source to third party equipment that is metallically bonded to transmission line tower steelwork (e.g. mobile phone base stations with antennae mounted on the tower). The content of this document is based on EnergyNetworks policy EPS-01-005 and Engineering Recommendation G78-2.

2. ISSUE RECORD

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Issue Date	Issue No	Author	Amendment Details
May 2004	1	Bobby Jack	Initial issue: 17 page document
August 2008	2	Colin Cameron	ITUs added

3. ISSUE AUTHORITY

Author	Owner	Issue Authority
Colin Cameron Lead Engineer Asset Strategy	Alastair Graham Lines and Cables Manager Investment Strategy	Jeff Hunt Investment Strategy Manager …….

4. REVIEW

This document shall be subject to review following initial installations

5. CONTENTS

6. REFERENCES

EnergyNetworks documents

EPS-01-005 Policy for Supplies to Mobile Phone Base Station Sites
EPS-06-001 Approved Equipment Register - Surge Arresters
PSSI 25 Work on Pole Mounted Transformers Supplying Mobile Phone Base Stations Associated with Transmission Towers

ENA Engineering Recommendations

ER G78-2 Recommendations for Low Voltage Supplies to Mobile Phone Base Stations with Antennae on High Voltage Structures

7. BACKGROUND

Engineering Recommendations G78-2 was developed to facilitate the provision of power supplies to mobile phone base stations (MPBS) where the antennae are mounted on the structure of an electricity transmission line tower.

The principles behind this Engineering Recommendation are intended to eliminate as far as reasonably practicable hazards to personnel and equipment by:

1. Preventing the Rise of Earth Potential (ROEP) that may be experienced by the tower footings (when a fault occurs on the transmission line) from being exported into the earth conductors of the distribution system from which the LV supply is taken.
2. Preventing the "Hot Zone" around all such structures from being extended when equipment bonded to the tower is erected in the vicinity.

SP EnergyNetworks have adopted 2 methods specified in G78-2 which satisfy these requirements:

- A dedicated pole mounted substation fed by two or more spans of overhead line. A minimum of two spans are required in order to comply with PSSI 25 earthing requirements.

OR

- An isolating transformer unit (ITU) supplied from a LV network

8. DEDICATED POLE MOUNTED SUBSTATION

The substation pole supports a standard transformer protected by special surge arresters "SA2" (*not duplex arc gaps*). Importantly, *no earthing is installed at the substation pole* – all

equipment is bonded to the tower steelwork which provides the required HV and LV earth connections. An “H” terminal pole is shown in the drawings; however a “lame leg” structure is also acceptable, as is an in-line substation pole (“H” or “lame leg”).

The supply to the MPBS is via a LV underground cable installed in a continuous duct from the substation pole to the cut-out position at the MPBS.

A “connection pole” provides the connection between the local HV underground or overhead network. This pole supports a set of standard surge arresters “SA3” and a set of HV isolating links, fuses or sectionalisers (“Smartlinks”) as appropriate.
The two poles specified above must be separated by two or more spans of HV overhead line (see Fig. 1 below). Where an “in-line” substation pole is used, two “connection poles” must be installed, in the overhead line on either side of the substation.

The MPBS may be either an “insulated base design” or “locally earthed design” – the same supply arrangements are to be used in both cases. It is expected that all new installations will be of the insulated base design.

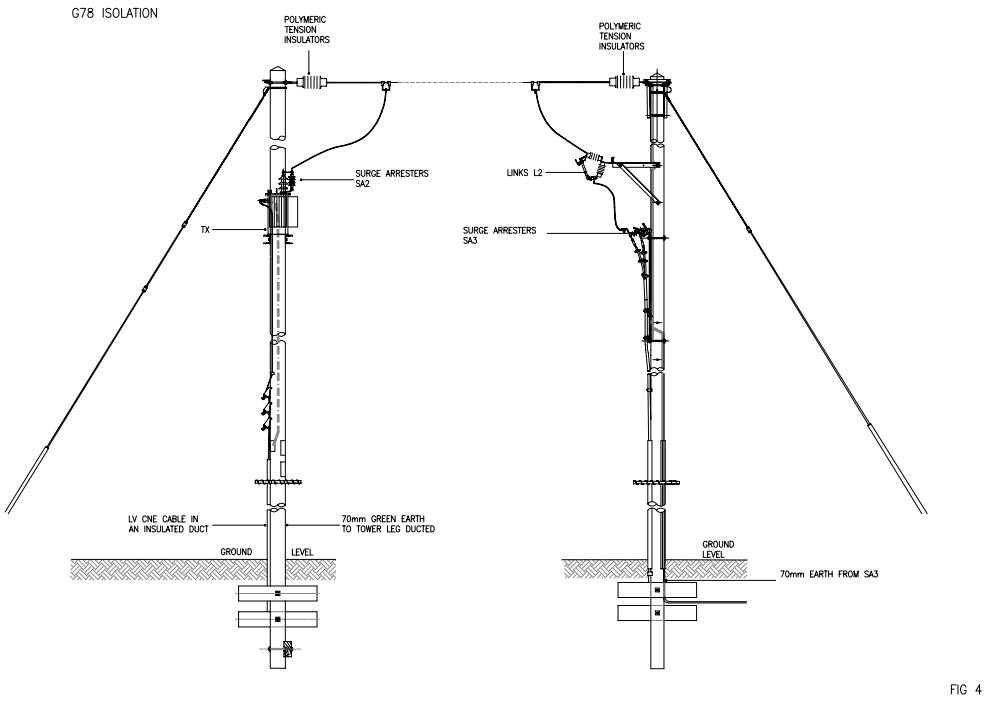


Fig 1 Example of connection to network via HV underground cable

A maximum of two MPBS at the same transmission tower may be supplied from one substation pole – separate ducts and service cables should be provided to each MPBS from the substation.

The dedicated pole mounted substation must not be used to supply any other customers.

8.1 Position of Substation Pole

Refer to Fig. 2. The substation pole shall be positioned to the side of the transmission line noting the following design rules:

1. The pole must not be positioned under the tower line conductors.
2. The pole must be a minimum of 20 metres from the outside conductor of the tower line.
3. The pole must be a minimum of 5 metres away from the mobile phone base station.
4. The maximum distance of the pole from the MPBS or tower is limited by the voltage drop in the service cable, but should not exceed approximately 90 metres if coiled ducting is used (this is the maximum continuous length of duct that can be installed without joints).

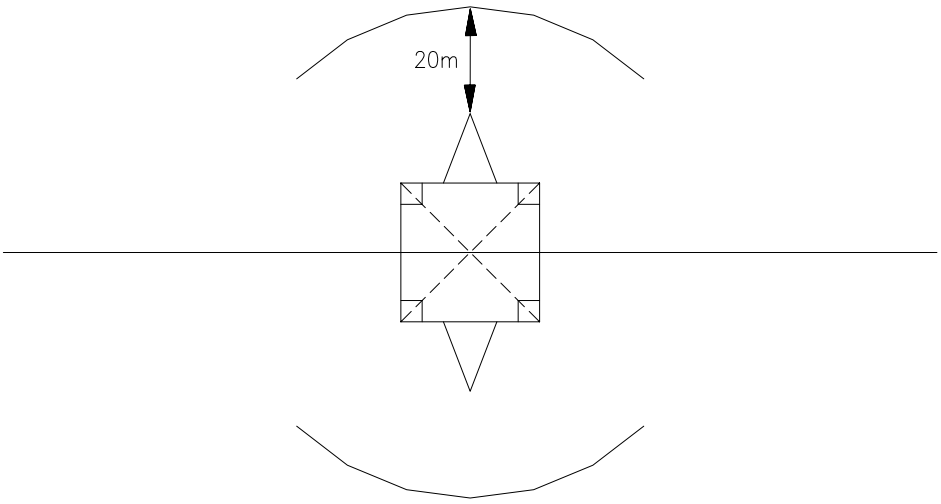


Fig. 2 Acceptable areas for the location of the substation pole

8.2 Position of network connection pole

Refer to Figs. 3 and 4.

The tower owner shall, before a connection arrangement is designed, provide information about the Rise of Earth Potential (ROEP) that may be experienced at the tower footings together with the extent of the "Hot Zone" around the tower. This information will include:

1. ROEP – A voltage value in kilovolts. This value affects the construction design. The design shown in this Code of Practice is effective up to a 21kV ROEP. Sites where the ROEP exceeds 21kV will not be supplied.
2. Extent of Hot Zone – A distance will be given to indicate the position of the 650V contour from the tower footings. This will effect the position of the network connection pole.

The point of connection into the local HV distribution system must take account of the effect of the "Hot Zone" around the tower footings and the possible interaction with the earth connection of surge arresters SA3. This is particularly true where the connection is made into an underground cable system. In this case the network connection pole must be situated outside the "Hot Zone" (i.e. outside the 650V contour) of the tower, see Fig. 3 overleaf.

Where a connection is to be made via an overhead spur into an existing overhead line SA3 may be located within the 'hot' zone of the tower footings. This is because the earth connections of the surge arresters will not be connected to an earth screen of a distribution system cable, hence there is no issue of transfer potential. However, SA3 must be located between the transformer providing supplies to the tower mounted equipment and any other pole mounted equipment, (see Fig. 4 overleaf). This location of SA3 will provide protection of pole mounted equipment on the remainder of the system from lightning surges that may affect the tower. It is important that the earth electrodes for SA3 are installed such that they do not bridge the earth gap to the tower footings established by the span(s) of overhead line. Where SA3 is installed within the area enclosed by the 650V contour then the earth electrodes must be installed so as not to fall within the effective zone of any earth electrodes from other pole equipment in the vicinity.

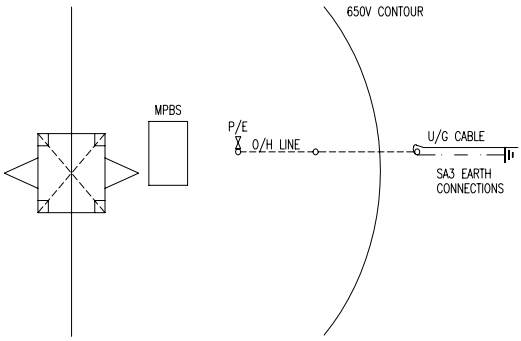


Fig. 3 Acceptable location for the network connection pole and earth electrodes associated with SA3 – supply via HV underground cable

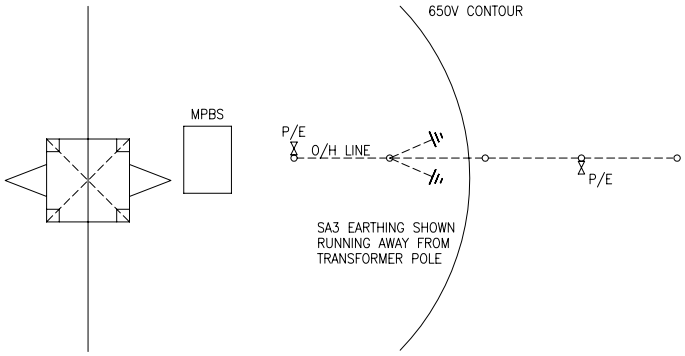


Fig. 4 Acceptable location for the network connection pole and earth electrodes associated with SA3 – supply via HV overhead line

8.3 Construction

The drawings provided in Appendices 2-4 comprehensively detail the construction of both the substation pole and the network connection pole. They also detail how connection is made to the customer and the special earthing provisions made.

8.4 Safety

The requirements of the ScottishPower Safety Rules and PSSI 25 in particular must be complied with at all times. Work shall only be carried out when prevailing weather conditions are favourable. Adverse weather conditions have a significant effect on the probability of the tower structure being subjected to a Rise of Earth Potential due to lightning and faults.

8.5 High voltage equipment

- The substation pole shall be of “H” or “lame leg” construction.
- The substation pole may be of either terminal or in-line design.
- 33kV stay insulators shall be used where stays are fitted to the substation pole.
- Standard fuse isolator mounts (24kV rating) shall be fitted on the network connection pole. Solid links, expulsion fuses or sectionalisers (“Smartinks”) shall be fitted to the fusemounts.
- A standard pole mounted transformer shall be installed, with the duplex arc gaps removed and surge arresters (SA2) fitted using special brackets.
- Surge arresters SA2 are non-standard. Only surge arresters specifically Approved as a G78-2 SA2 arrester shall be used in this position. Standard surge arresters shall not be used.
- Surge arresters SA3 are standard units.
- Details of Approved SA2 arresters, transformer mounting brackets and T-bracket for SA3 arresters are provided in Appendix 5.
- The lower 3m of stay wire and rod shall be insulated from ground level with special ducting (see Appendix 1) to prevent touch contact.
- The substation and network connection poles are labelled with G78-2 warning signs.
- The pole substation name should start with G78-2 (e.g. G78-2 Sandyford Toll PTE).

8.6 LV Installation

- Standard LV fuse mounts shall be used.
- Standard service cable (for sizing see EPS-01-005) is used to supply the customer. The cable is installed in ducting throughout. No cable joints are permitted.

- The cable ducting is a special seamless design with a thicker than normal polythene wall (see Appendix 1 for details). Two ducts must be installed: one for the LV cable and one for the earth conductor. The ducting must completely insulate these cables from a point above the anti-climbing guard on the substation pole through to their respective equipment connection points. Ducting shall be installed at a minimum depth of 1m in one continuous length (or jointed using compression fittings – see Appendix 1) and shall be sealed at both ends to prevent water ingress.
- The LV cable terminates in a standard cut-out.

8.7 Earthing Arrangements

- No local earth electrodes shall be installed at the base of the substation pole.
- All pole steelwork is bonded to the transformer tank earthing point.
- The transformer LV neutral is bonded to the transformer tank earthing point.
- The combined HV and LV neutral earth is earthed only by connection to the transmission tower leg.
- The earth connection is made using 70 mm² copper, pvc insulated earthing conductor installed in ducting (see Appendix 1) throughout. The ducting must completely insulate this cable from a point above the anti-climbing guard on the substation pole through to the point of connection with the tower leg. Ducting shall installed at a minimum depth of 1m in one continuous length (or jointed using compression fittings – see Appendix 1) and shall be sealed at both ends to prevent water ingress.
- The earth connection plate on the tower leg shall be provided and fitted by the tower owner.
- The connection of the earthing conductor to the tower leg connection plate shall only be made by the tower owner. This connection shall be secured in a manner that makes removal difficult and a warning label shall be fitted. This connection shall not be made until immediately prior to commissioning and energisation of the installation.
- The tower earth connection *shall not* be disconnected without the agreement of both Energynetworks and the tower owner.
- No Energynetworks earth terminal is provided for the customer.

9. ISOLATING TRANSFORMER UNIT (ITU)

An Isolating Transformer Unit (ITU) is a 1:1 ratio 3 phase double wound transformer manufactured to BS171 ; IEC 60076 and IEC60726 where applicable. The primary winding is insulated from the secondary winding and the enclosure sufficient to withstand an impulse voltage of 150kV and 50kV power frequency.

9.1 Earthing

The ITU (see Appendix 5 - : MPBS Supply and Earthing General Arrangement (ITU)) must be mounted on an Insulated Base (specified in ER G78-2 para. 3.2.2). The transformer tank is earthed via the Mobile Phone Base Station earth bar for example to the tower steelwork.

An earthing terminal will not be provided by EnergyNetworks and the supply connection is considered to be TT as defined in BS7671. The MPBS earth bar/base is connected directly to the HV structure without passing through isolation links minimising the risk of the earth becoming disconnected.

Exposed metallic parts of the ITU connected to the tower earthing system must be at least 500mm above ground. This excludes the incoming and outgoing cabling which enters through G78-2 compliant ducting from below. Signs warning : DO NOT CONNECT ANY EQUIPMENT IN THIS COMPARTMENT TO EARTH will be attached in prominent positions on the incoming compartment.

A minimum separation distance of 5m shall be maintained between the incoming cable and the HV structure unless evidence of the impulse withstand capability between the LV cable conductors and the HV structure can be established.

9.2 Ownership

The ITU and MPBS will be owned and maintained by the customer. The customer must ensure the ITU and MPBS are fully compliant with Engineering Recommendation G78-2 at the application stage.

9.3 LV Service Cable Installation

- Standard LV fuse mounts shall be used.
- Standard service cable (for sizing see EPS-01-005) is used to supply the customer. The cable is installed in ducting throughout. No cable joints are permitted.
- The cable ducting is a special seamless design with a thicker than normal polythene wall (see Appendix 1 for details). Ducting shall be installed at a minimum depth of 1m in one continuous length (or jointed using compression fittings – see Appendix 1) and shall be sealed at both ends to prevent water ingress. The duct shall be installed between the LV cabinet of the ITU to the edge of the 650V contour (supplied by the customer).0
- The LV cable terminates in a standard cut-out.

9.4 Construction

The drawing in Appendix 5 details the construction and earthing of the ITU and MPBS and details how the connection is made to the customer and the special earthing provisions required.

10. COMMISSIONING (POLE MOUNTED AND ITU INSTALLATIONS)

Certain specific commissioning tests for G78-2 installations are required in addition to those normally carried out. These are defined in ER G78-2 and are reproduced below:

a. Inspect ducting to ensure correct dusting has been used and joints and sealing systems are adequate to prevent ingress of water and to maintain required voltage withstand properties.
b. Check correct connection of the earth from the MPBS to the tower leg. Connection should be made at the bottom of the leg and taken to the MPBS without addition of sharp bends that may unduly increase the impedance of the connection.
c. Check surge arrester SA1 is correctly installed (by MPBS operator) beneath the MPBS platform and that the earth connection of this surge arrester is connected to the bottom end of the insulators supporting the platform and to the local earth electrode. This bonding to be achieved by the use of 25x4 mm copper tape or equivalent.
d. Check that adequate measures have been taken to prevent the growth of vegetation beneath and around the MPBS platform.
e. Check the correct type of surge arresters (SA2) have been selected for the pole mounted transformer and they have been installed between the phase conductors and the transformer tank.
f. Confirm the location of the ROEP contours have been provided by the tower owner and that surge arresters (SA3) have been installed at the correct location.
g. Confirm that tests have been completed to check the integrity of the earth connections at the tower leg, the transformer tank and the MPBS platform
h. Confirm that tests have been completed, demonstrating continuity of the earth connections between the transformer tank and the tower leg and also between the MPBS platform and the tower leg.
i. Confirm that the earth loop impedance of the lv supply at the meter position has been tested and the figure recorded to provide a datum for future tests to be carried out by the MPBS owner.

APPENDIX 1: SEAMLESS DUCTING

The approved ducting for application to this Code of Practice is as detailed below:

Manufacturer: Polypipe civils (Tel. 01509 615100)
Bishop Meadow Ind Est
Bishop Meadow Rd
Loughborough
Leicestershire
LE11 5RE

Contact: Steve Kite (Sales Director 07793 967408) or Judith Beach

Type reference: ***110SDR17.6*** (Duct) external diameter 110mm, wall thickness = 6.2 mm, internal diameter approx. 97mm). (To house 95mm² Waveform cable)

HPPE 10811090 Long Radius Bend (LRB) (see note **(1)**)

PD004X50E (Duct) (ext. dia. 60mm) wall thickness = 5mm, (int. dia. Approx. 50mm) this duct can be used to house the 70mm² earth conductor between the transformer pole and the tower.

RB94X6Y (Duct) (ext. dia.110mm) wall thickness = 8mm (int.dia. Approx. 110mm This duct is coloured yellow and can be used to cover the stay rod and stay wire from 150mm below ground level. (Minimum of 3metres above ground, and sealed).

Availability: 50 m and 100 m coils and 6 m long "sticks" (see note (**2)**).

SEALING DUCT ENDS

All duct ends shall be sealed with waterproof expanding foam at the tower, pole, and cut-out position. Jointers foam shall be wrapped around the LV cable and earths, pushed down the duct a minimum of 150mm to give the expanding foam a base.

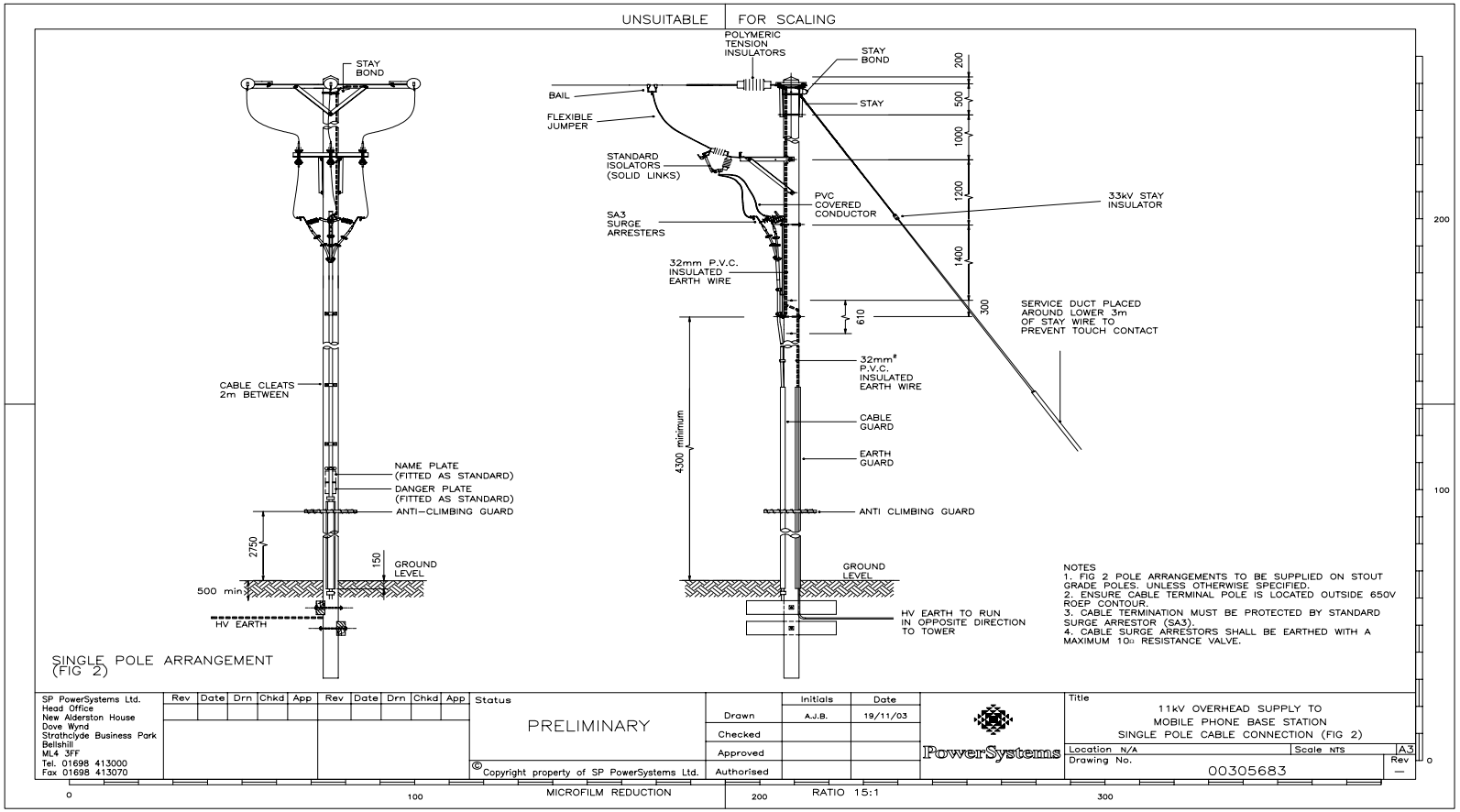
(Expanding foam can be purchased from any reputable builders merchants)

Note (1) A 95mm² Waveform LV cable has a minimum bending dynamic radii of 500mm therefore the above LRB must be used. This LRB can be installed using either compression fittings or electro-fusion welds. Both are an approved method of jointing. It is also important that all joints are watertight.

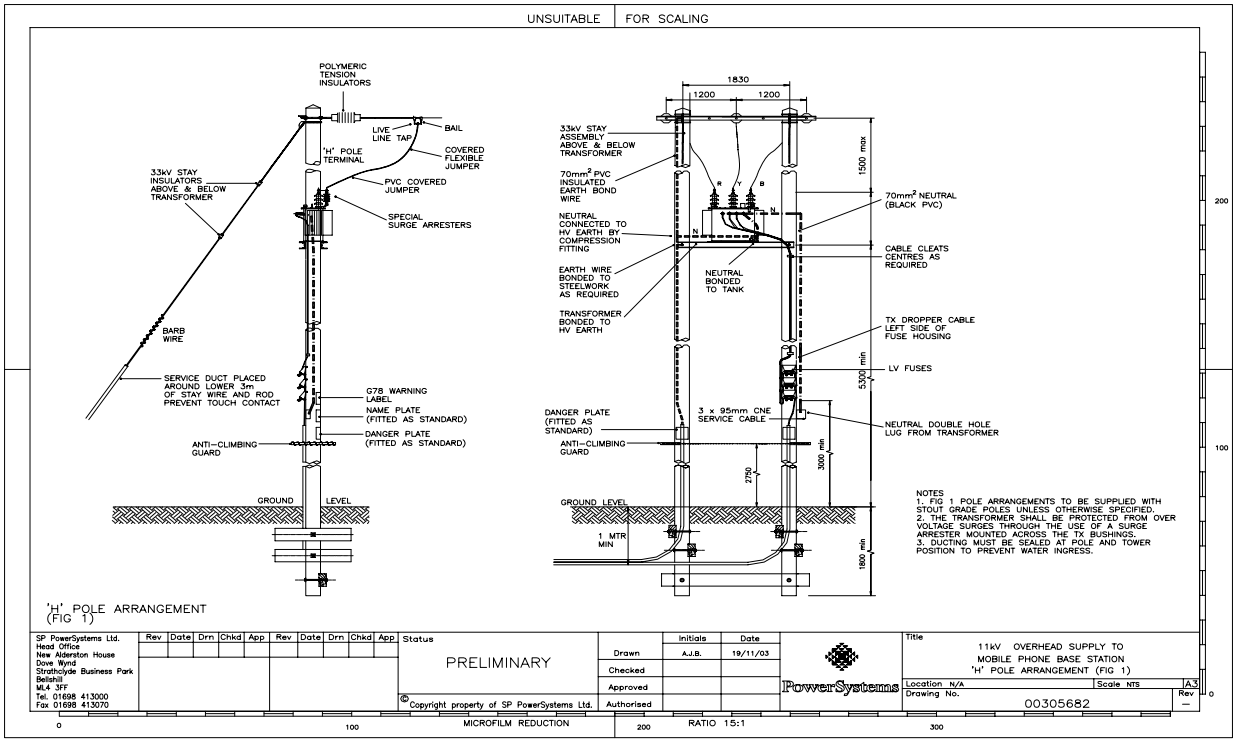
If compression joints are the preferred option, state the duct and the LRB size at the time of ordering.

Note (2) Where “sticks” are used in preference to continuous coiled ducting, joints shall be made using compression fittings. The use of “push-fit” joints is not acceptable.

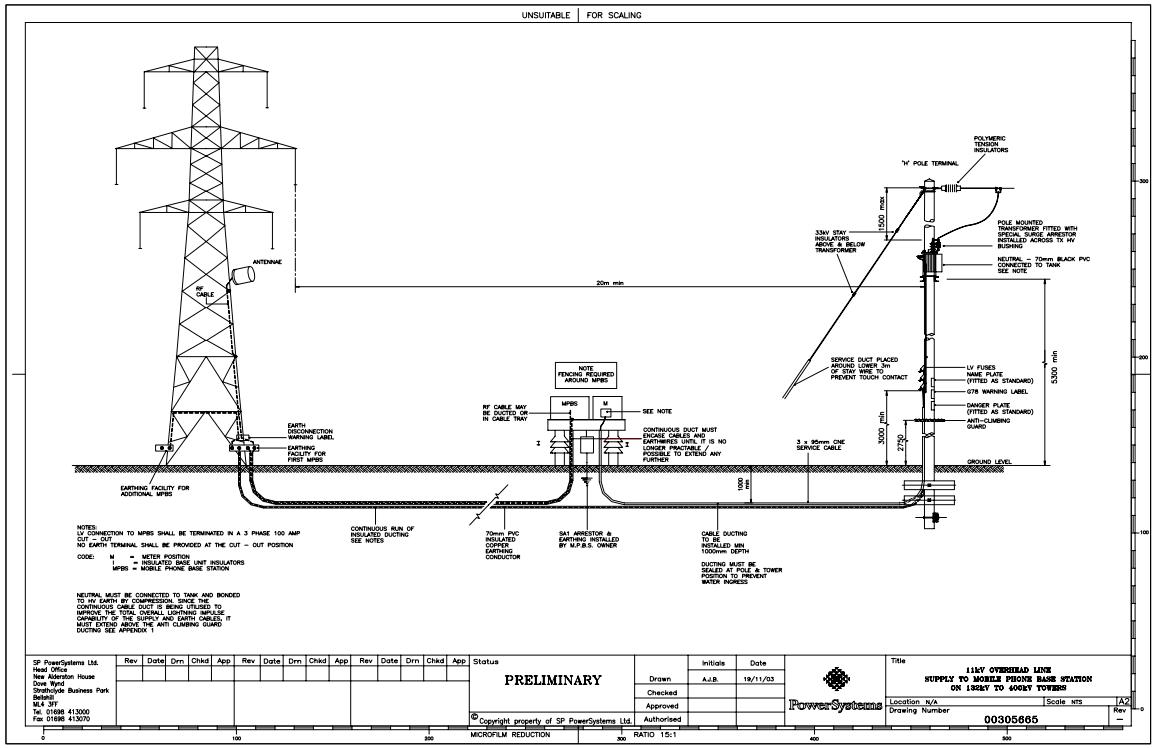
APPENDIX 2: NETWORK CONNECTION POLE GENERAL ARRANGEMENT – HV UNDERGROUND CABLE SUPPLY



APPENDIX 3: SUBSTATION POLE GENERAL ARRANGEMENT



APPENDIX 4: MPBS SUPPLY AND EARTHING GENERAL ARRANGEMENT (DEDICATED POLE MOUNTED S/S)



APPENDIX 5: MPBS SUPPLY AND EARTHING GENERAL ARRANGEMENT (ITU)

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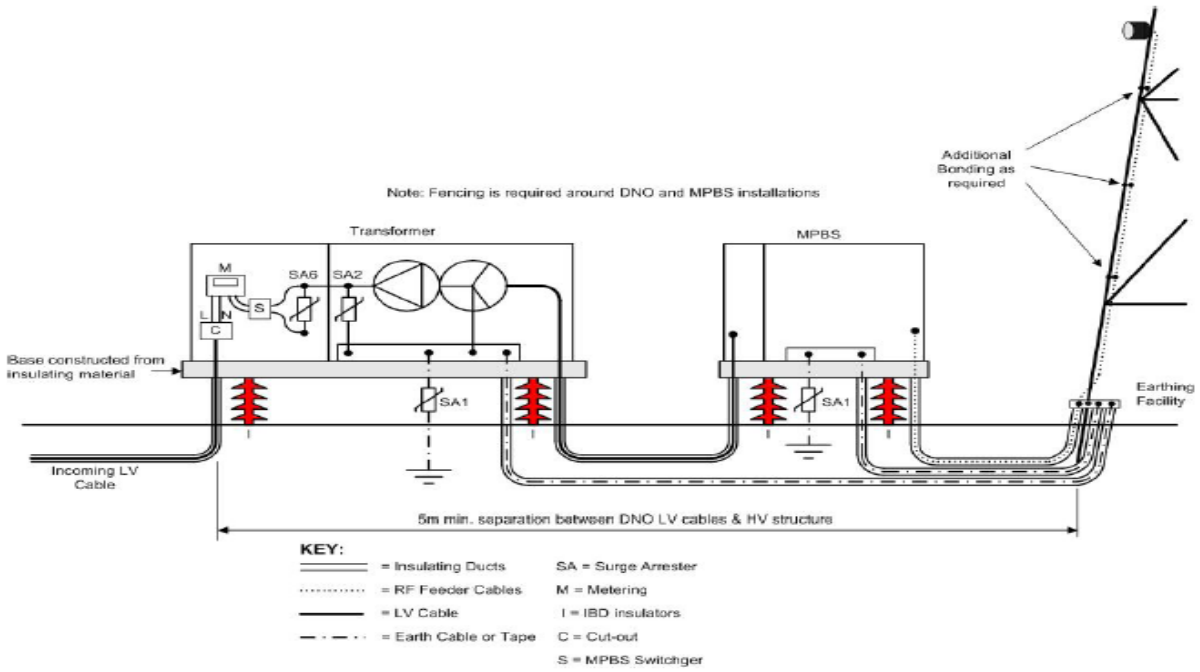

Figure A1.6 Connection to LV Isolation Transformer

APPENDIX 6: SURGE ARRESTER AND MOUNTING BRACKET INFORMATION

SA2 Surge Arresters

Cooper 18kV Varigap arrester (30.6kV Temporary Over Voltage (TOV) and a residual voltage of 47.1kV). Part number UHG1808LLH30AAA.

Obtainable (minimum order 12 pcs.) from:
Langley Engineering Limited
16 The Markham Centre
Theale
Reading
Berks
RG7 4PE
Tel: 0118 9305990
Contact: Keith D L Smith (Managing Director)

Transformer mounting brackets (tinned copper) for SA2 Arresters

Obtainable from:
Pauwels Trafo
Dublin Road
Cavan
Ireland
Tel: 00353 (049) 4331588
Contact: Margaret Duke

G78-2 SURGE ARRESTER BRACKETS			Quantity
Transformer			HV Arrester Bracket Code
Phase	kVA	kV	E402-9331 0674-684
3	50	6.6, 11	3
3	100	6.6, 11	3
3	200	6.6, 11	3
1	25	6.6, 11	2
1	50	6.6, 11	2

Pole mounting T-bracket for SA3 arresters

Tyco code EPPA031.

Obtainable from:
Tyco Electronics UK Ltd
Tel: 01423 563992

This bracket can be used for supporting SA3 surge arresters especially at intermediate or tee-off poles. It is important that all the arresters are linked together with minimum 35mm² copper green/yellow PVC earthing cable.The required earth resistance value for these arresters = 10Ω or below. An earth spike is required at the base of the pole. Any additional earthing required should be bare copper or deep-driven to obtain the required value. If the earth track is being excavated then it should be directed in the opposite direction from the tower.