Application note
MTL surge protection

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Lightning surge protection for electronic equipment - a practical guide

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1 INTRODUCTION

1.1 Voltage surges and lightning strikes

Voltage surges are momentary increases in the normal working voltage of a system. Sometimes referred to as 'spikes', 'overvoltages' or 'transients', these surges can affect power cables, data/telephone cables and instrumentation wiring, causing anything from data loss to the total destruction of equipment. Typical causes include fluorescent light switching, blown fuses and nearby lightning activity — the last of these being potentially the most dangerous.

Lightning storms are on the increase globally — including the UK where more than 420,000 lightning strikes to ground were recorded in 1994. Also on the increase is industry's reliance on sensitive electronic instrumentation, computers and communication networks. These make uneasy bedfellows as lightning-induced voltage surges damage or destroy delicate equipment with all the consequent costs associated with repairs, replacements and downtime.

1.2 Lightning protection — standards, devices and dangers

The current Electrical Wiring Regulations (BS7671) refer to the British Standard for Lightning Protection BS6651. This identifies two distinctive forms of lightning protection, i.e. one designed to protect the building structure and fabric and a second to protect sensitive equipment inside the building.

The traditional mesh of copper tapes on roofs and walls and their associated earth rods, properly installed, protect the bricks and mortar but not, except to a very limited degree, electronic equipment within the building. The latter need protecting with 'surge protection devices' (SPDs).

SPDs do not (indeed cannot) protect equipment against direct lightning strikes. Their concern is to neutralise voltage surges on cables caused by inductive or resistive coupling from nearby lightning strikes. In particular, SPDs should be fitted on the mains power supply lines and incoming data/signal cables to/from all critical sensitive equipment. Cables such as these — and consequently any equipment associated with them — are particularly at risk as they are partly installed outside the building where they are more vulnerable to the effects of nearby lightning strikes. A strike within 100m of cables or buildings can induce surges up to 5kV and 1.25kA.

Also at great risk are sites powered from overhead cables. Any direct lightning strikes to the power network will travel along the cables to the detriment of any equipment powered by these since surges on mains power cables can rise to a level of more than 6kV and 3kA.

1.3 Guide to protection

This publication provides an easy-to-read guide to the dangers induced by lightning strikes and cost-effective ways to combat these with surge protection devices.

2 LIGHTNING ACTIVITY AND VOLTAGE SURGES

2.1 General

A direct lightning strike can cause an enormous amount of physical damage. However, the indirect effects from a nearby strike can also cause damage by inducing voltage surges onto mains and data cables.

Lightning-induced voltage surges are often described as a 'secondary effect' of lightning and there are three recognized means by which these surges are induced in mains or data/telecommunications cables:-

a) Resistive coupling (see section 2.2)
b) Inductive coupling (see section 2.3)
c) Capacitive coupling (see section 2.4)

2.2 Resistive coupling

When lightning strikes the ground near a building it causes a massive rise in ground voltage in the vicinity. This rise in ground voltage affects electrical earthing systems (earthed pipework, etc.) and is conducted back through these into the building where it can travel through the electrical system — creating havoc along its path. Additionally, any data or telecommunications cables connecting the affected building to a second building provide a path for the currents to infect that building also. See figure 1.

2.3 Inductive coupling

A lightning strike onto a lightning conductor forming part of the structural protective system of a building generates a large electromagnetic pulse of energy which can be picked up by nearby cables in the form of a destructive voltage surge. See figure 2.

2.4 Capacitive coupling

Overhead high-voltage power distribution cables are naturally prone to direct

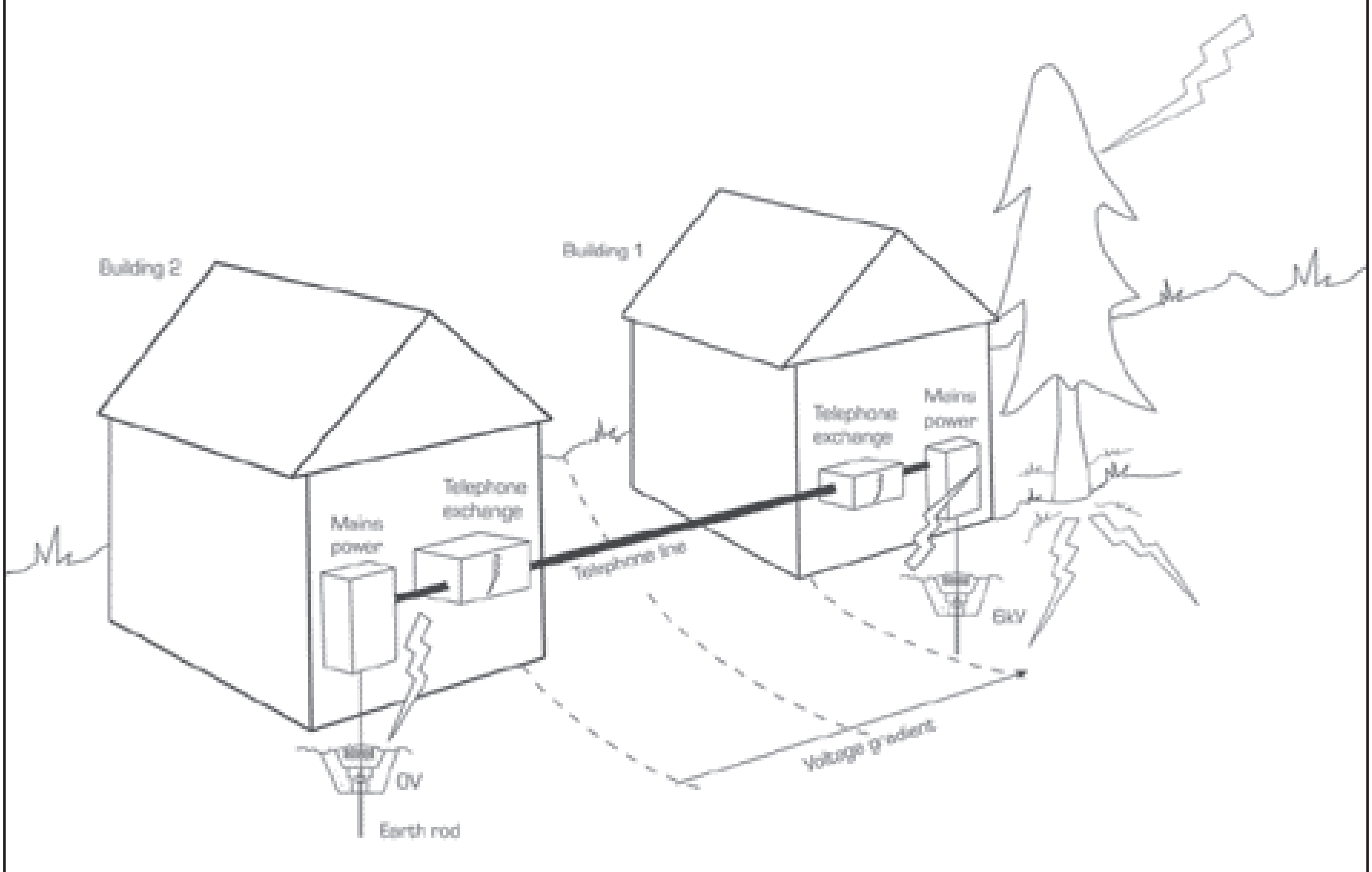

Figure 1 Resistive coupling from a lightning strike near one building

lightning strikes. While much of the lightning energy is dissipated by integral high voltage surge protection devices, a large proportion will travel along the distribution system and, due to its high frequency nature, will capacitively couple through HV/LV power transformers into the power systems of individual buildings, devastating any electronic equipment it feeds. See figure 3.

3 SURGE PROTECTION DEVICES — THE PRINCIPLES

3.1 Magnitude of lightning induced surges

Voltage surges on cabling systems, however they may be caused, are limited in magnitude by the insulation of the cable and any electrical or electronic equipment connected to it. In other words, if a rising voltage is applied to a cabling system, a point will come when the insulation of either the cable or the associated equipment breaks down and the voltage 'flashes over', thus preventing it rising any further.

IEC 60664 defines practical limits for the breakdown voltage of cable insulation within a building. The British Standard for lightning protection, BS6651, defers to IEEE C62.41 (in which measurements of induced voltage surges on cabling systems are discussed) to determine the maximum voltage surge that is likely to travel along a cable and, hence, the maximum voltage surge that a surge protection device (SPD) must divert successfully to protect the equipment connected to the cable.

IEEE C62.41 tells us that the largest surge that is likely to appear on the busbars of the main power distribution board for a building is 6kV and 3kA, defined as 'Category B' (figure 4). Hence, an SPD fitted to the board must be able to divert safely a surge of this magnitude. IEEE C62.41 also explains that the maximum surge current caused by lightning is limited by the impedance of the cabling system, which, in turn, is related to the current rating of the circuit. A low impedance 1kA busbar distribution board could possibly pass 3kA of lightning induced current, whereas a higher impedance 30A twin and earth branch circuit, some distance away from the main incoming distribution board, could pass only 200A due to its higher impedance.

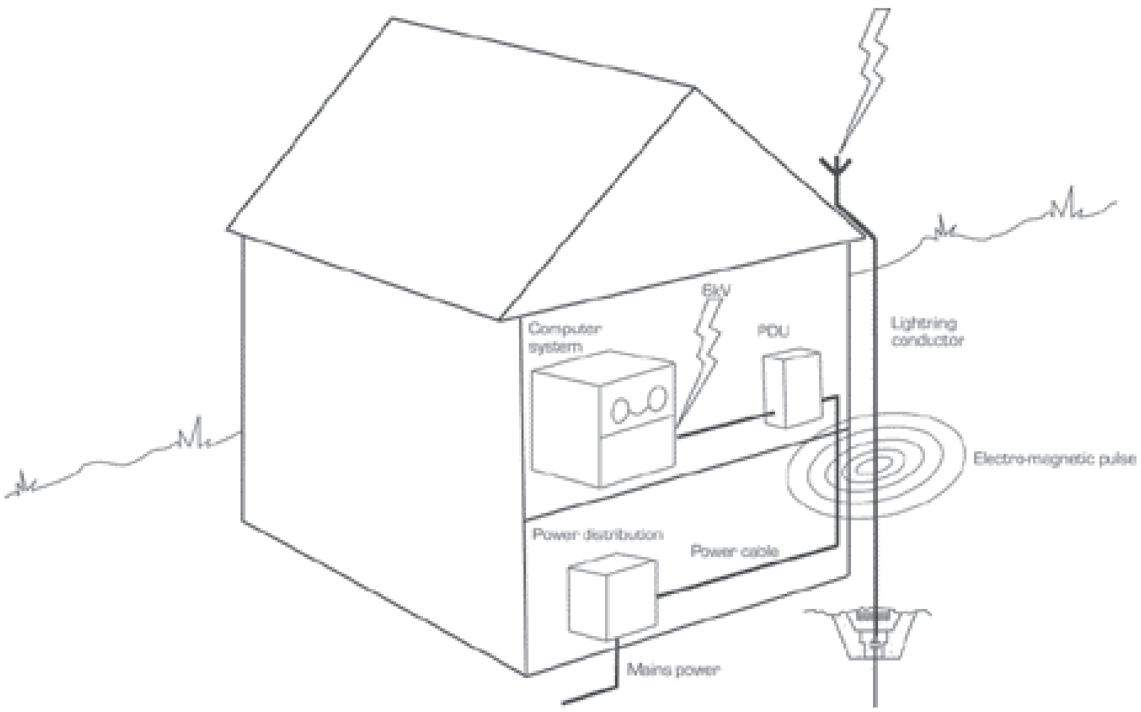

Figure 2 Inductive coupling from a lightning strike on a lightning conductor

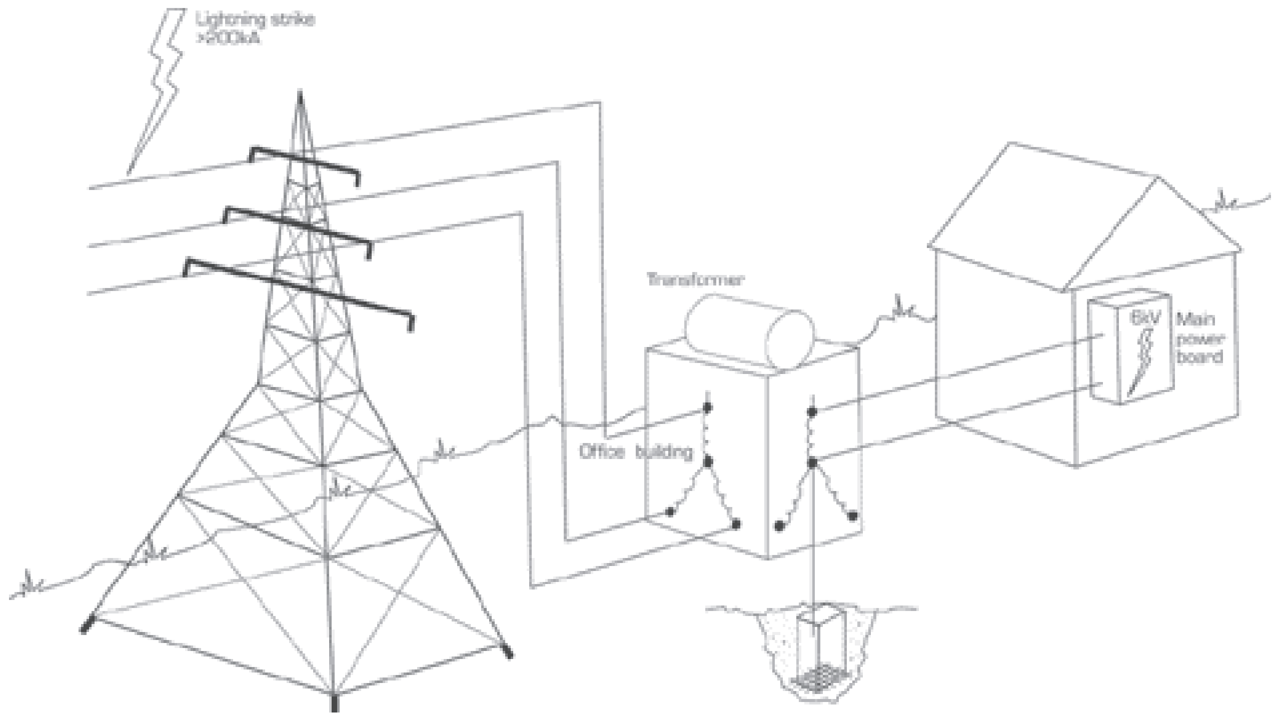

Figure 3 Capacitive coupling from a direct lightning strike on overhead cables

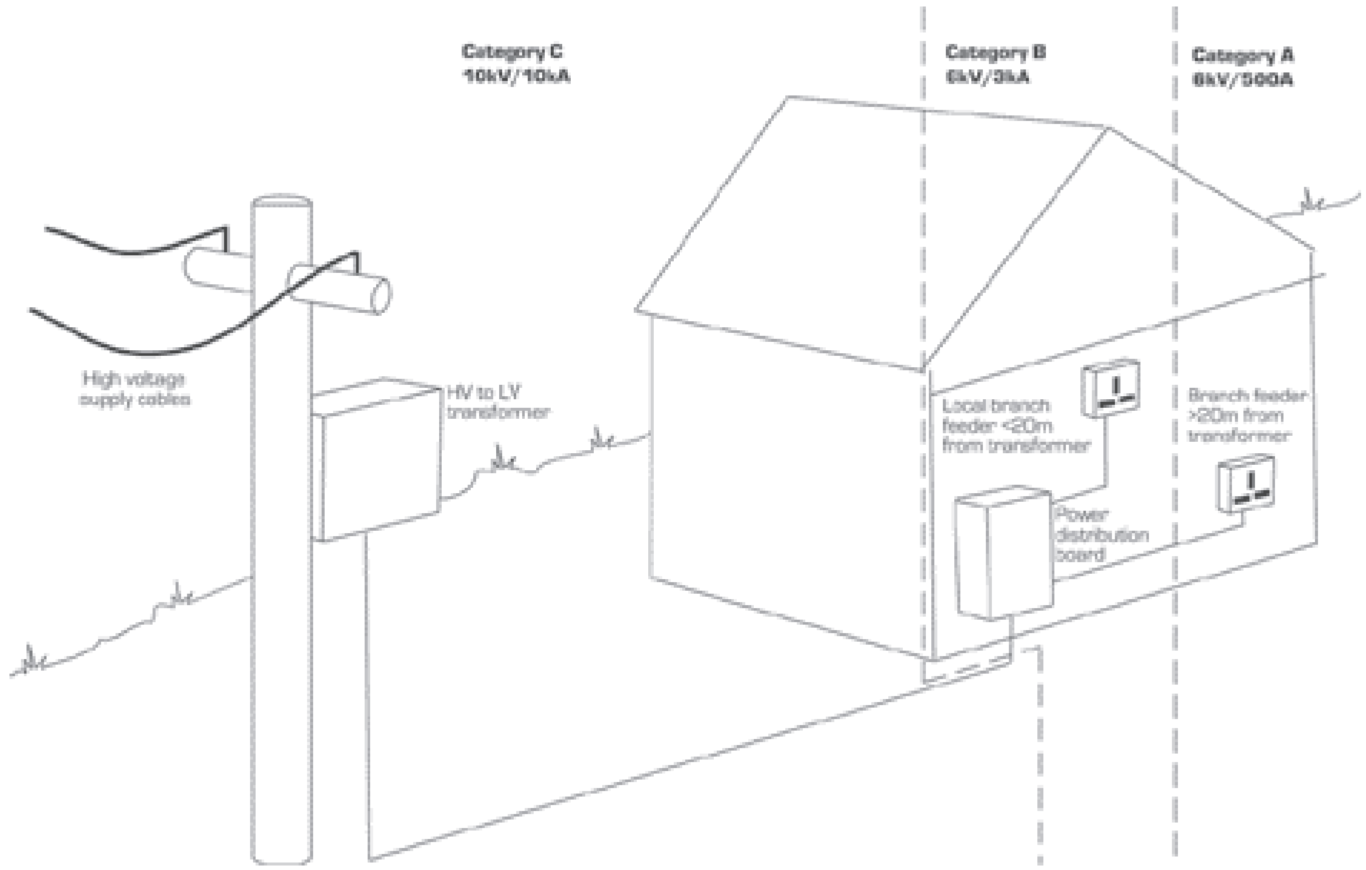

Figure 4 BS6651 and IEEE C62.41 location categories

Data/telecommunications cables linking buildings are generally considered to be in Category C, as the slower surge voltages seen on these systems (10/700µs) are not attenuated in the same way as those on mains power cabling.

Further details on the nature of these surges is provided in TAN 1002.

3.2 Surge protection components

When selecting components for use in a surge protection device, designers are compelled, by the current state of technology, to choose between high current handling capability and high speed operation. Some possible components are strong in one of these parameters and others in the other. In practice, therefore, SPDs often make use of a combination of components, known as a 'hybrid circuit,' for effective protection.

Lightning induced voltage surges can rise from zero to up to 6kV in about 1µs. Surge diverting components must therefore operate quickly. Fuses and circuit breakers do not provide protection as they simply cannot work quickly enough.

Voltage-limiting components used in modern SPDs are usually selected from three main types:—

a) Gas discharge tubes (GDTs)
b) Metal oxide varistors (MOVs)
c) High-speed clamping diodes

Gas discharge tubes can handle very high surge currents, but are relatively slow to start and can thus let through a lot of the surge before they operate (figure 5a).

Metal oxide varistors can handle fairly high surge currents, but their clamping voltage rises the more surge current that passes through (figure 5b).

High-speed suppression diodes can only handle relatively small surge currents, but they do have very accurate and rapid voltage clamping performance (figure 5c).

4 SPDs FOR MAINS POWER SYSTEMS

4.1 General

When considering surge protection for a mains power system, the ability of the whole system to withstand voltage surges should be considered, i.e. the surge protection device (SPD) must be capable of limiting any surge voltages to a level considered safe for the most vulnerable piece of equipment served by the system. It must also be able to divert safely the maximum surge current likely to be experienced by the system it is protecting, i.e. the IEEE defined location category (A, B or C — see section 3.1) should be borne in mind.

Generally, most low voltage power systems (240/415V) and the electronic and electrical equipment with which they are associated, can withstand voltage surges of two to three times their normal peak operating voltage, i.e. around 1kV for 240V (rms) systems, (8/20µs, 3kA waveshape, according to BS6651, Appendix C).

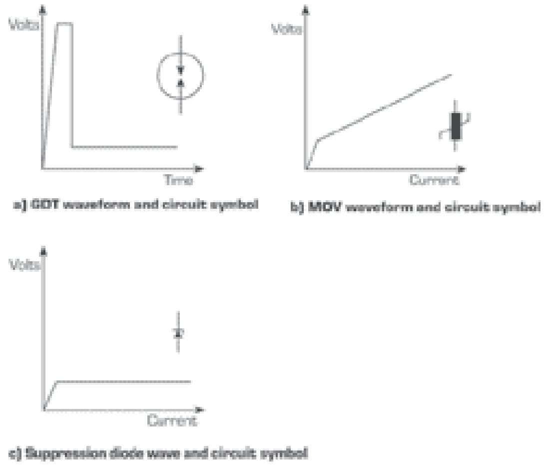

Figure 5 Performance of surge protection components

4.2 'Ideal' specification for a mains power SPD

Table 1 lists the specification parameters that should be considered when selecting SPDs for mains supply applications.

Table 1 Specification parameters for a mains power SPD

Parameter	Required performance
Limiting voltage:* (often known as 'let-through' voltage)	<1kV
Modes of operation:	Phase to neutral Phase to earth Neutral to earth
Peak surge current: †	Category A >1kA Category B >3kA Category C >10kA
Leakage current:	<0.5mA (phase to earth)
Indication:	Visual indication of status
Volt-free contact:	This should be provided for high risk applications, where remote indication of reduced protection is required
IP protection rating:	IP40 for internal applications IP65 for outdoor applications
Temperature/humidity:	Suitable for environment
System impairment:	The SPD should not interfere with the normal operation of the system into which it is connected Note: Gas discharge tubes should not be connected directly across mains cables as they can short circuit the supply

Notes

* As tested on the connection terminals of the complete SPD, when tested with the 1.2/50µs voltage and 8/20µs current waveforms appropriate to their location, e.g. 6kV/3kA for Category B, as defined in BS6651, Appendix C.

† Peak surge current is an indication of the lifetime of the complete SPD, e.g. a device in which the surge protection elements will handle a peak surge of 20kA will withstand many lightning induced currents of 3kA, as defined in BS6651, Appendix C.

5 SPDs FOR DATA/TELECOMMUNICATIONS SYSTEMS

5.1General

When considering surge protection for a data /telecommunications system, the ability of the whole system to withstand voltage surges should be considered, i.e. the surge protection device (SPD) must be capable of limiting any surge voltages to a level considered safe for the most vulnerable piece of equipment served by the system. It must also be able to divert safely the maximum surge current likely to be experienced by the system it is protecting, i.e. the appropriate IEEE defined location categories (A, B or C — see section 3.1) should be borne in mind. As an example, cables outside buildings are 'Category C'.

Generally, most data/telecommunication cabling systems and the equipment with which they are associated, can safely withstand voltage surges of twice their normal peak operating voltage, e.g. around 48V for 24V systems (8/20µs).

Some manufacturers specify a reaction time of '10ns' for their devices. This figure relates to the performance of individual components within the circuit. It cannot relate to the performance of the complete SPD as the impedance of even short connections between the device terminals and the internal components makes such a performance impossible. It is also misleading since the fastest voltage surge the SPD will experience is the 10/700µs waveform used to define its limiting performance. If the device was slow to operate, this would be reflected by its performance and the limiting voltage would be too high.

5.2 'Ideal' specification for a data/ telecommunications SPD

Table 2 lists the specification parameters that should be considered when selecting SPDs for data/telecommunications applications.

Table 2 Specification parameters for a data/telecommunications SPD

Parameter	Required performance
Limiting voltage:* (often known as 'let-through'voltage)	Twice the peak operating voltage of the circuit with which the SPD is used
Peak surge current: †	Category C (low) 2.5kA Category C (high) 10kA
System impairment:	The SPD should not interfere with the normal operation of the system with which it is used
Insertion loss:	Expressed as an equivalent cable run length
Bandwidth:	Normally expressed at the 3dB point in a 50ž system
In-line resistance:	Note: If the value for in-line resistance is 0, then it is possible the SPD will not operate under some conditions, leaving the system unprotected
Voltage standing wave ratio:	An indication of the effect the SPD will have on the network
Shunt capacitance:	This affects the bandwidth
Temperature/humidity:	Minimum and maximum values should be quoted

Notes

* As tested on the connection terminals of the complete SPD, when tested with the 10/700µs current waveforms appropriate to their location.

† Peak surge current is an indication of the lifetime of the complete SPD, e.g. a device that will handle a peak surge of 10kA will withstand many lightning induced currents of 125A.

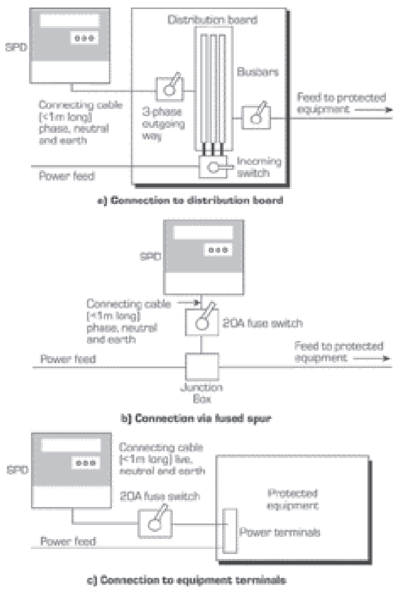

Figure 6 Typical shunt SPD connection details

6 INSTALLATION PRACTICE

6.1 Mains power SPDs

6.1.1 Shunt connecting SPDs

Long connecting leads impair the effectiveness of an SPD installation (1m of 16mm2 earthing cable can generate more than 300V along it's length when a surge of 6kV/3kA is applied to it). Hence, the SPD should be mounted and connected as close to the electrical system it is to protect as possible. See figure 6 for three ways in which this might be done.

6.1.2 In-line connecting SPDs

To reduce the risk of picking up voltage surges in cable runs caused by inductive and capacitive coupling, in-line connecting SPDs should be connected as close to the protected equipment as possible. See figure 7.

6.2 Data/telecommunications system SPDs

Generally, all SPDs designed for protecting data and telecommunications systems connect in-line. These should be located as close to either the protected equipment or to the main power earth for the protected equipment as possible. The length of the SPD connections to the electrical earth of the equipment should be no longer than 1m in length.

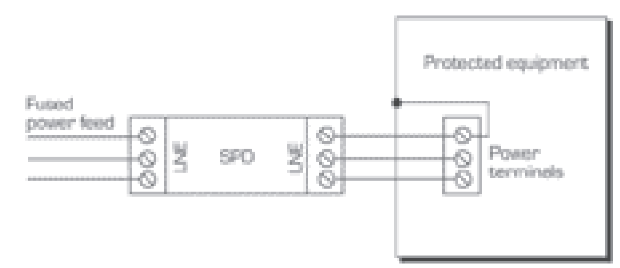

Figure 7 In-line SPD connection details

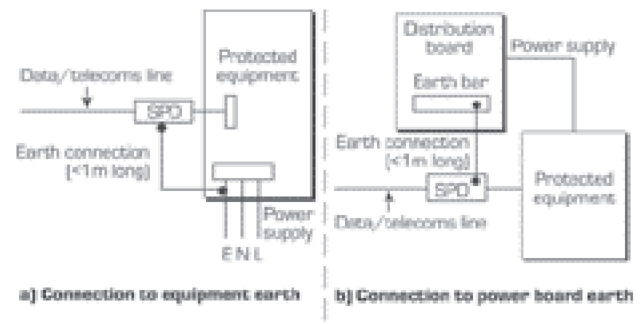

Figure 8 Connections of data/telecommunications SPD earths

Connection of this earth cable can be made to either the earth terminal of the equipment itself, or to the earth bar of the electrical power supply feeding the equipment. See figure 8 for illustrations of both these forms of connection.

7 LIGHTNING PROTECTION SYSTEMS — CHECKLIST

7.1 Introduction

This checklist is designed to help guide users through a brief visual check to establish whether a site is effectively protected against the effects of lightning (according to BS6651, including Appendix C) both with respect to structure and electronic computer networks, telecommunications, and process and control equipment. If the answers to the questions include doubts, a specialist should be consulted to offer advice. Eaton operates a lightning protection consultancy service staffed by experts qualified to provide sound advice from design to implementation. For details, contact your local sales representative via: www.mtlsurge.com/support/distribution/index.htm.

7.2 Structural lightning protection

Tick box

Q1 Does the building have an intact roof conductor network? (Wherever an observer stands on the roof, a lightning conductor should be visible no more than 10m away) ☐

Q2 Does the building have an intact system of down-conductors? (There should be an intact down-conductor located at least every 20m around the perimeter of the building) ☐

Q3 Does each down-conductor connect to an intact earth pit and earth rod? (Check that the down-conductor is securely fastened to the earth rod) ☐

7.3 Protection for internal equipment

Tick box

Q4 Is there a lightning surge protection device (SPD) installed on the main power distribution board/incoming power board? (Check for the correct installation — see section 6.1.1) ☐

Q5 Is an SPD installed on the telecommunication lines feeding modems and telemetry equipment? (Check for the correct installation — see section 6.2) ☐

Q6 If the controls section of switchgear cubicles contain sensitive electronic equipment (e.g. flowmeters, PLCs, computers, etc.) is the power feed into this section protected by a locally connected (i.e. within 1m) in-line SPD? (Check for the correct installation — see section 6.1.2) ☐

Q7 Are data/signal/network cables installed outside the building over distances of more than 10m (either underground or overhead) equipped with SPDs at the controls section end of the cables? (Check for the correct installation — see section 6.2) ☐

Q8 Is any field-mounted equipment that is critical for the process or expensive (e.g. magflows, ultrasonic instrumentation, etc.) provided with locally-mounted (less than 1m distance) SPDs? ☐

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