Recommendations

for the loss prevention in electronic equipment installations

Part 6: Protection against electrical disturbances

RC3
Part 6

FPA Fire Protection Association

InFiReS

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The aim of the FPA series of Recommendations is to provide loss prevention guidance for industrial and commercial premises and systems. The series continues a long tradition of providing authoritative guidance on loss prevention issues started by the Fire Offices' Committee (FOC) of the British insurance industry more than a hundred years ago and builds upon earlier publications from the Loss Prevention Council and the Association of British Insurers.

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INTRODUCTION

It is important for organisations to ensure that electronic equipment installations are functioning correctly and that systems are isolated from electrical disturbances which are manifest in power supply variations and electrical interference.

These may affect the operational capability of electronic equipment by way of data corruption, data loss and physical damage to the hardware. It is therefore essential that procedures are set up to determine the probability and impact of such disturbances to limit the exposure of electronic equipment.

SCOPE

These recommendations provide guidance measures to protect electronic equipment installations from disturbances arising from power supply variations, electromagnetic radiation, electrostatic discharge, and electrical interference transmitted through power and communication lines.

These principles are applicable to installations for large commercial electronic data processing, electronic communications equipment, electronic equipment and industrial process control. They may also be applied to small electronic equipment installations.

1 DEFINITIONS

1.1 *Electromagnetic compatibility (EMC)*

An electronic system is said to be electromagnetically compatible if it functions properly within its intended electromagnetic environment. It should not act as a source of electromagnetic interference to surrounding electrical systems. (Requirements on electrical equipment to meet minimum levels of electromagnetic compatibility – emission and immunity – are presented in the EU Electromagnetic Compatibility (EMC) Directive (ref. 1).)

1.2 *Electrical disturbance*

Electrical disturbance is the collective term used within these recommendations to describe any form of electrical disruption of the operation of electronic equipment. Electrical disturbance can be subdivided into two distinct branches: power supply variations and failures, and electrical interference. These terms are described below and are graphically represented in Figure 1.

Table 1: Summary of the main forms of electrical disturbance, their effects on electronic equipment and the recommendations for protection against such disturbances.

DISTURBANCE	ELECTRICAL EFFECT	RECOMMENDATION
Power Failure and Voltage Variations or locally for key items of equipment in a large multi-occupancy building	• Damage to equipment • Data loss	• Installation of a Constant Voltage Transformer and an Uninterruptible Power Supply at the mains input of the building
Lightning Strike to or in close proximity to building	• Damage to hardware and software • Data loss • Data corruption	• Installation of a lightning conductor complying with BS 6651:1999 • Installation of a surge protector on the power and communication lines at the input to the building • Provide radiative shielding to power and communication lines • Use of secondary light duty circuit breakers at each appliance
Electrostatic Discharge	• Possible data loss or corruption • Possible damage to hardware	• Installation of anti-static mats • Provision of good earthing or grounding of equipment • Installation of an air ioniser in the office
Radiated Electromagnetic Fields arising from: • Lightning Strike • Overhead Powerlines • Transformers • Substations • Electrified Railways • Transmitters • Portable Phones	• Possible damage to hardware and software • Data loss • Data corruption	• Provide radiative shielding to power and communication lines • Electrical isolation of equipment, for example, optical fibre • Use of light duty circuit breakers at each appliance

A full description of each method of protection is given in section 5 of these recommendations.

(i) *Power supply variations and failures.* This relates to disturbances caused to the electronic equipment by any form of fluctuation of voltage or current supplied by the power supply outside the tolerance level of the electronic equipment specified by the manufacturer.

(ii) *Electrical interference.* A collective term that includes any form of external electrical interference manifest within the electronic equipment. Such interference can be placed within three distinct groups, namely line-borne, electrostatic discharge and electromagnetic.

1.3 *Uninterruptible power supply (UPS)*

An uninterruptible power supply (UPS) is an arrangement for supplying electrical power and is placed between a regular power supply and the system to which it regularly supplies electricity. In the event of a power cut or a surge or fall in power then the UPS acts to provide continuous, unvarying, back-up electrical power.

2 RESPONSIBILITIES

2.1 Responsibilities for the general design, installation and maintenance of electrical disturbance protection systems should be clearly defined and documented.

2.2 All relevant parties – including insurers, manufacturers of electronic equipment and specialist consultants – should be consulted before electrical disturbance protection systems are installed.

3 SOURCES OF ELECTRICAL DISTURBANCE

Electrical disturbance may be subdivided into two types:

- power supply variations and failures; and
- electrical interference.

3.1 *Power supply variations and failures*

Most electrical equipment is designed to operate from power supplies where the voltage and frequency are controlled within narrow limits. However, unusual events – such as power surges, sudden demand from users drawing from the same substation or damage to the mains line – can result in temporary fluctuations in voltage or frequency outside normal limits. This can have detrimental effects upon the operational capability of electronic equipment, resulting in data corruption or loss and physical damage to the hardware. Although power supply variations and failures can cause real hazards to the operational capability of electronic equipment, this threat has largely been overcome by incorporating a UPS device at the input of the building's mains power supply.

3.2 *Electrical interference*

Three sources of electrical interference can cause damage/malfunction to electronic equipment:

- line-borne interference;
- electrostatic discharge; or
- radiated electromagnetic fields.

3.2.1 *Line-borne interference*

Two types of electrical cable or line are connected to electronic equipment:

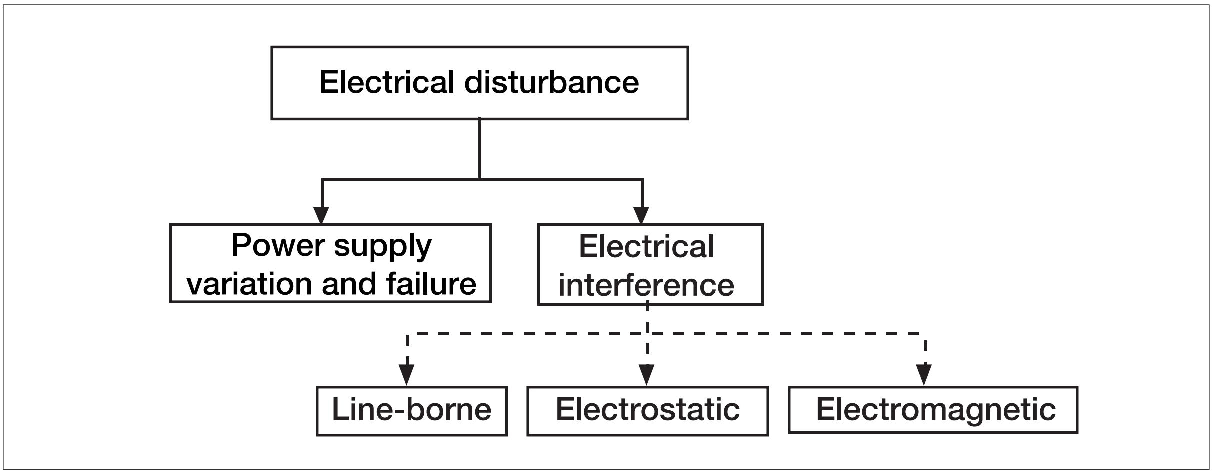
(a) the power line supplying power from the external mains supply; and

(b) the data communication line, which may take the form of a modem link – that is, a telephone line or interface cable connection to a local area network of electronic equipment.

Line-borne interference can originate from many sources and may be manifest in several forms. If the magnitude of this interference is greater than the tolerance levels of the electronic equipment then all forms of line-borne interference can cause:

- corruption of data stored within the memory;
- corruption of data signal trains transmitted to and from the electronic equipment; and/or
- damage to the hardware, causing spurious operation and degradation of the equipment.

Figure 1: Schematic representation of electrical disturbance



Clearly, all can have a devastating consequence for a business. Typical examples of such interference are shown in Figure 2.

Generally, a transient over-voltage can cause direct (sometimes latent) hardware failure, whereas background electrical noise, which is more prevalent, results in spurious operation. Signal pulses from other data lines in close proximity or transmitted radio signals may also induce interference onto data lines causing data corruption. Methods of protection are discussed in section 5.

The potentially most damaging form of line-borne interference is that of transient over-voltages induced by lightning. These can be generated in two ways:

- an increase in ground potential caused by a lightning strike; and
- the radiated effect of a lightning strike, which can induce transient over-voltages directly onto power and data cables.

Such transient over-voltages can be many times the accepted maximum level suitable for equipment, and may cause significant damage. Other forms of interference can be introduced to electronic equipment via power and data lines from electrical equipment in the locality and within the building. Such interference may also take any of the forms identified in Figure 2. For example, switchgear can introduce transient over-voltages; the operation of heavy-duty electric motors can introduce electrical noise; and the use of digital communication networks or devices may introduce pulse trains (regular digitised voltage fluctuations) to data lines.

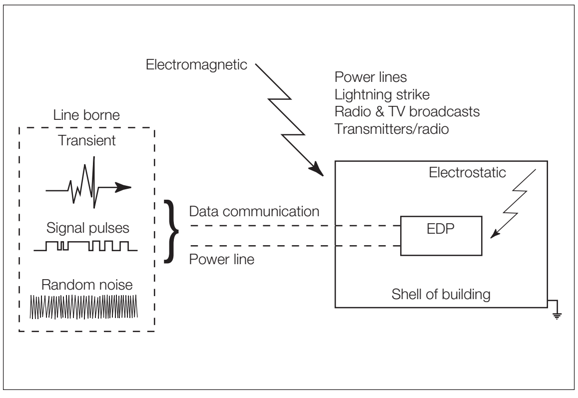


Figure 2: Sources of electrical interference

3.2.2 *Electrostatic discharge*

Electrical interference to electronic equipment can also be caused by the static electricity discharge of charged bodies (usually the human body as far as the electronic equipment is concerned) onto the equipment. When a charged surface – a computer operator's hand, for example – is brought close to or into contact with a keyboard or a sensitive piece of hardware the trapped charge is quickly released onto the equipment. This flows to ground as a transient over-voltage. Electrostatic voltages in excess of 15kV can be generated in this way and can be caused by simply standing up from a chair and walking across a carpeted room. The effect from a charged body touching or coming into close proximity to sensitive equipment can cause failure of microelectronic circuits or spurious operation of the equipment.

3.2.3 *Radiated electromagnetic fields*

Electromagnetic radiation covers a broad and diverse spectral range including radio waves, television transmissions, microwaves, infrared and visible light. Electrical devices all radiate electromagnetic fields in one form or another. All electrical equipment is now required to comply with the Electromagnetic Compatibility Regulations 2005 (ref. 1). Electromagnetic emissions from electrical equipment are limited to approved levels, thus controlling the electromagnetic environment in which other products must operate. Interference from radiated electromagnetic fields can also be introduced into the workplace by many external sources, including the following:

- lightning strike;
- local overhead domestic grid and railway power lines; and
- military, emergency services, radio and television, radar or other transmitters located in the proximity.

All these sources can produce electromagnetic fields strong enough to induce electrical noise and transient over-voltages onto data and power lines. In addition, many internal sources can also cause unwanted radiated electromagnetic fields; examples include mobile radios, pagers, and mobile telephones. Electromagnetic fields do not normally cause damage to electronic equipment, but in extreme conditions can cause failure if the field strength is sufficiently strong. In general, though, electromagnetic fields may result in spurious operation of electronic equipment and cause data corruption.

4 ASSESSMENT OF SOURCES OF ELECTRICAL DISTURBANCE

4.1 To assess the effect on electronic equipment from electrical disturbances, an assessment of the electrical environment within which the equipment is situated should be carried out. Key areas and equipment should be identified. Appropriate methods of protection should be incorporated as described in section 5. Equipment and processes susceptible to the disturbances categorised in section 3 should be identified. This assessment should include the level of susceptibility of the equipment to all categories of electrical disturbance and the consequences of any failure.

Power line disturbances and interference on communication lines can be measured using specialist instrumentation. Background electromagnetic field strengths can also be measured and the resultant measured values should be compared with manufacturers' operating specifications. It should be noted that such measurements may not detect infrequent, but possibly repetitive, bursts of interference.

Following this susceptibility audit, the electrical disturbances categorised in section 3 should be assessed, measured or predicted. With particular reference to the effects of lightning, both BS 6651: 1999 (ref. 2) (which is due to be withdrawn in 2008) and Parts 2 and 4 of the IEC 62305 suite of documents (refs 3-4) address suitable risk assessment methods and recommended precautions in detail. Nevertheless, any susceptibility audit should take special note of the following:

Exterior of the building:

- the susceptibility of the building housing the electronic equipment to lightning strike involves probability calculations based on the geographical location and type of building. (Note: BS 6651: 1999 provides for probability calculations in clause 10 for the structures. General information is also available in RC35: *Recommendations for the protection of buildings against a lightning strike*) (ref. 5);
- the inherent electrical screening properties of the building structure (BS 6651 clauses 18 and 19 and Annex C cover these aspects) (ref. 2);
- The existence of radiated electromagnetic fields (for example, proximity to main overhead power lines, transformers, substations and motors and overhead electrified railway lines);
- the reliability and stability of incoming power lines and an assessment of the effect of other users drawing power from the same substation;
- the proximity to Ministry of Defence, civil aviation or other establishments which may generate localised adverse electromagnetic field or power line transient conditions; and
- the use of mobile generators and transmitters;

Interior of the building:

- the susceptibility of electronic equipment in the building should be the subject of a risk assessment identifying all equipment at risk. This will include the type of equipment, location within the building, incoming services, building-to-building data lines and, in some cases, equipment on or connected to the outside of the building. (Once again BS 6651-1 and the draft IEC 62305 suite of documents (refs 2, 3 and 4) provide suitable guidelines. General information is also available in RC35: *Recommendations for the protection of buildings against a lightning strike* (ref. 5));
- the use of electrical machinery or processes that could introduce switching transients on the power or data cables;
- the use of furnishings that may cause high levels of electrostatic charge (for example, carpets);
- the presence of electromagnetic radiation from devices such as two-way radios, pagers and cordless and mobile telephones;
- electromagnetic radiation from medical and similar equipment;
- the use of multi-core cables servicing more than one system and the problems of induced interference;
- the type of data network connection in use. Fibre-optic cables and wireless connections may be less susceptible to certain effects than traditional network data connections and cables.

5 METHODS OF PROTECTION

5.1 *Voltage variations and power failures*

The installation of data processing and other electrical equipment should be planned to reduce interference problems. It is recommended that equipment should be installed such that sensitive electronic equipment and cables are separated as far as possible from known sources of electrical disturbances.

5.1.1 Voltage variations

Voltage variations outside the capabilities of the equipment can be eliminated by employing devices variously known as constant voltage transformers, voltage regulators or line conditioners. Some of these devices may introduce distortion into the voltage waveform and are therefore not suitable for use with many types of electronic equipment. Manufacturers should be consulted for specific recommendations.

5.1.2 Power failure

Power failure protection requires a UPS. This may take the form of a static rectifier/invertor system with batteries or a stand-by diesel engine-operated generator. The rectifier/inverter system will provide an uninterruptible, no-break power supply, whereas the latter only provides power after the engine has been started and run up to speed. Normally, a static invertor system with batteries is provided to cover for interruptions lasting up to, say, half an hour. Longer interruptions would be covered by a stand-by generator.

5.2 *Line-borne interference*

5.2.1 Protection against line-borne interference can be achieved in three ways:

- *Electrical isolation.* The provision of a conductive cladding on data lines should eradicate radiated interference. Substitution of electrical data lines by fibre-optic cables can prevent line-borne interference from affecting equipment to be protected. Many fibre-optic cables contain metallic protective cladding, which can provide a conductive link between buildings. This should therefore be electrically insulated or bonded to earth at each end.

- *Electrical interference filters.* The installation of decoupling filters can remove unwanted low amplitude electrical noise, but not transients, on power and data lines. These filters may be incorporated within the equipment.

- *Surge or transient over-voltage protectors.* These are predominantly voltage-sensing devices that – at a predetermined voltage – suppress or divert the excess energy by absorption or by short-circuiting. Three important characteristics of transient over-voltage protection devices normally specified are:

(i) *let-through voltage or transient control level.* This is the maximum voltage that the transient over-voltage suppression system will allow to pass to subsequent equipment. Typically, this is set at two to three times that of the normal supply peak voltage;

(ii) *modes of protection.* Transients can be produced along many conduction paths within electrical connections and equipment. Manufacturers should clearly state to which conduction path their let-through performances relate; and

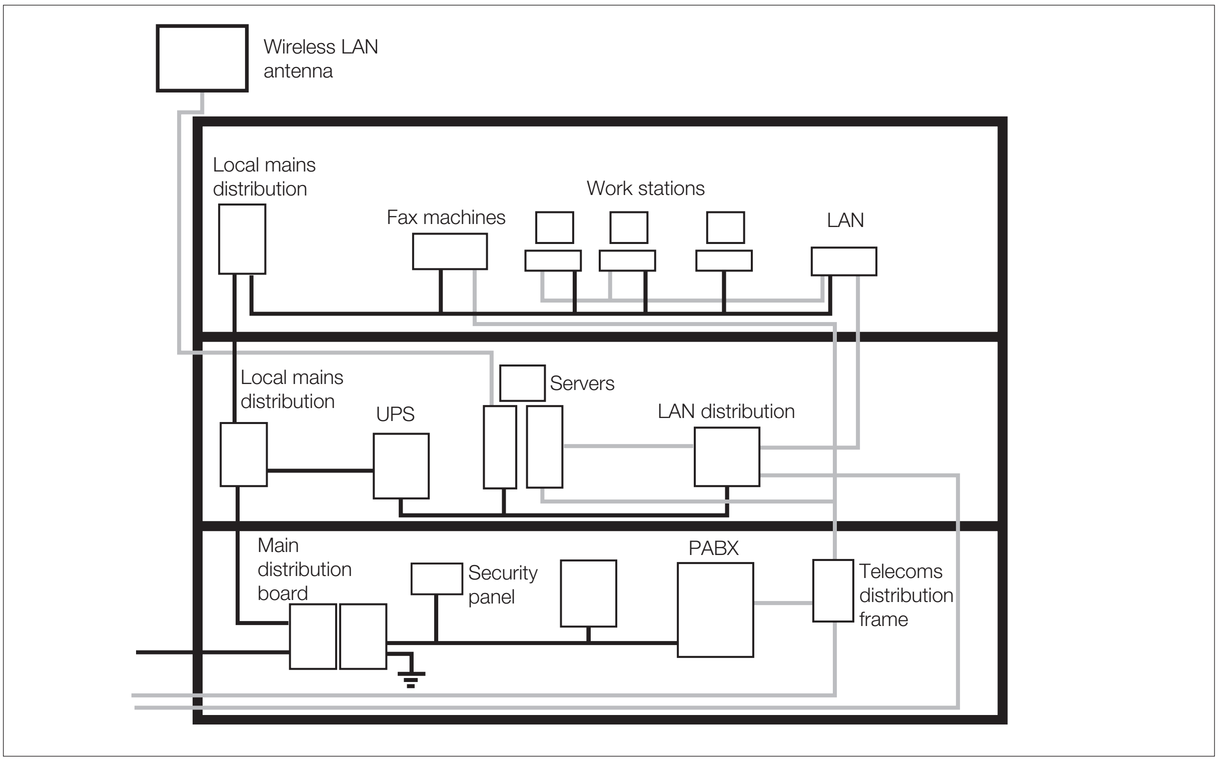
(iii) *maximum transient current.* This is the maximum transient current that the protection device can withstand without damage to itself.

5.2.2 For power line protection, a transient over-voltage device should be installed. The chosen device should be able to survive a worst-case scenario for transient over-voltages. They should also be capable of controlling let-through voltages to levels less than the damage threshold of the equipment being protected. As well as the magnitude of the transient over-voltage, the ability of a device to survive and to achieve an appropriate let-through voltage also depends on where the device is installed. Each location for transient over-voltage protectors and transient over-voltage risk assessment calculations are categorised in Annex C of BS 6651:1999 (ref. 2). Recommended practice for surge voltage protection equipment is described fully in IEEE C62.41–1991 (ref. 6).

5.2.3 Secondary, light duty transient over-voltage protectors may be installed at individual work stations or computer cabinets, where inbuilt protection is considered inadequate. These protectors will give added protection against externally derived interference and will also protect against transient over-voltages created within the building. The characteristics of the primary transient over-voltage protection systems must be coordinated to ensure satisfactory total protection. Users should check with manufacturers or suppliers of UPS devices to confirm that the equipment offers full protection.

5.2.4 For the protection of data communication, signal and telephone lines, transient over-voltage protectors should be fitted where lines enter the protected building. They should also be provided for data communication, signal and telephone lines where they enter any building in which electronic equipment is located and on lines that traverse electrically noisy areas. It should also be ensured that a protector installed on a line does not distort or attenuate the signal.

Figure 3: Typical electronic equipment network



5.2.5 Earthing arrangements can cause additional disturbance to data and power lines if not properly designed. The following should be noted:

(i) All equipment and services should be electrically earthed in accordance with the requirements of BS 7671 (ref. 7). Duplicated earth paths should be avoided since these can cause virtual circuits allowing interference and damage. All earth conductors and fixings should be capable of handling likely leakage currents.

(ii) All conducting parts of the building structure should be satisfactorily bonded and earthed to meet the recommendations given in BS 6651: 1999 (ref. 2); the electrical resistance between the structure and earth should be less than 10Ω. This will help to reduce the probability of voltage differences produced along earth conductors during lightning strikes.

5.3 *Electrostatic discharge*

Electronic equipment may be protected from electrostatic discharge by application of one or both of the following schemes:

- reducing or eliminating the conditions favouring the build up of electrostatic charge; and
- installing an active protection system to the electronic equipment.

5.3.1 Reducing or eliminating the build up of static electricity can be achieved in several ways. Conductive floor materials may be installed in the workplace and earthed antistatic mats may be placed at an operator's work station to provide an earth point for the operator's hands. This will reduce build up of static charge and prevent arcing. It is possible to create an ambient environment that promotes leakage of trapped charge from surfaces. This may be achieved by increasing the humidity of the workplace. Another method is to install an air ioniser.

5.3.2 Electronic equipment can also be protected from static electricity by preventing discharge current from flowing through susceptible circuitry by providing an alternative path for discharged current to flow. This is achieved by earthing the equipment and is normally carried out during manufacture. The manufacturer's instructions for individual equipment should be consulted for each case.

5.3.3 Normally electronic equipment should be designed to tolerate an electrostatic discharge without causing any damage to the hardware or spurious operation. Transient upsets to the system, such as a small flicker of the screen, is normally tolerated.

5.4 *Radiated electromagnetic interference*

5.4.1 Radiated electromagnetic fields caused by lightning strike, as described in 3.2.3, can cause major interference and it is normally recommended that equipment, particularly computer equipment, is located away from the shell of the building and not located on the top floor of buildings. The only exclusion to this is where the building construction provides for electrical screening as described in clauses 18, 19 and Annex C of BS 6651: 1999 (ref. 2). Electronic equipment should also be located at a sufficient distance from major cable runs as these may cause a similar problem. Appendix C7 of BS 6651: 1999 should be consulted.

5.4.2 Structures prominent in their locality are most susceptible to direct lightning strikes. In view of this, it is preferable that vital equipment and services are located in low rise buildings. However, safeguards – such as the use of lightning conductors – should always be employed.

5.4.3 Lightning conductors should meet the recommendations given in BS 6651: 1999 (ref. 2). Key areas of concern are:

- the construction of the lightning conductor and its electrical resistance to earth;
- the type of lightning conductor and its relationship to the protected building, both in terms of location and physical connection (for example, electrical bonding with the main electrical earth board or in the building);
- the dimensions of the lightning conductor and its ability to handle the current and energy elements of a lightning discharge; and
- the ability of the conductor to retain integrity in all foreseeable environments.

5.4.4 Lightning conductors do not provide full protection against all the effects of lightning. Interference from lightning can manifest itself by introducing interference on power and data lines, both within the protected building and remote from the site, as mentioned in section 3. In addition, the radiated electromagnetic fields set up around the building structure and lightning conductors have to be taken into account. Therefore, the installation of lightning conductors alone will not offer suitable protection to electronic equipment and surge protection devices will need to be installed.

5.4.5 Earth potential surges created by a nearby lightning strike can cause damage where an external reference voltage is involved, for example, remote terminals, remote instrumentation or telemetry. The most satisfactory protection is obtained by electrically isolating the external equipment, for example, by using fibre-optic cables.

5.4.6 Where the building does not afford any protection, radiated electromagnetic fields entering the building from power lines and transmitters can be reduced by incorporating a wire mesh within the shell of the building. Such measures are extreme and costly and are normally only appropriate when the problem is great and where the processes within the building are susceptible to the fields and critical for operations. However, in extreme cases where disturbances are commonly experienced, electronic equipment may be provided with some protection by housing it within a metal cabinet suitably earthed.

5.4.7 Externally created fields are likely to induce line-borne interference. The measures recommended in 5.2 should help to combat interference at the input to the building. In addition, it is recommended that the power and communication cables are shielded against radiated interference. Two methods of achieving this are illustrated in Figure 4. The first method (Figure 4.1) shows the buried protected cable shielded by two unsheathed cables. These cables should be positioned equidistant above the protected cable. The basis of the protection is that the shield cables should absorb any field interference before the interference reaches the protected cable. In the second method, which is the more common technique (see Figure 4.2), the cable is directly shielded in a metal conduit.

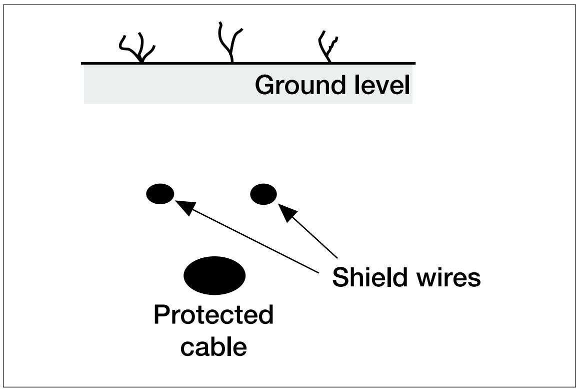


Figure 4.1: The use of shield cables

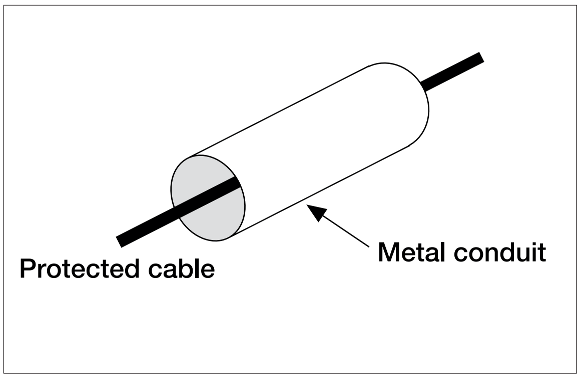


Figure 4.2: Direct shielding with metal conduit

5.4.8 Where there is an ongoing problem of induced interference to data lines, consideration should be given to the use of fibre-optic cables.

6 INSTALLATION, MAINTENANCE AND SERVICING

All installation and maintenance work relating to electrical protection systems should be undertaken by a United Kingdom Accreditation Service (UKAS) accredited organisation. These include the NICEIC, the Electrical Contractors Association (ECA) or the Scottish trade association SELECT. The National Association of Professional Inspectors and Testers (NAPIT) and the Safety Assessment Federation (SAFed) are two UKAS accredited inspection bodies for companies that do not carry out electrical installations/alterations but do perform independent inspection and testing in accordance with BS 7671 (ref. 7).

6.1 Electrical equipment shall be inspected and maintained by a competent and suitably qualified person working for an appropriately qualified contractor.

6.2 Ensure that installation work does not create electrical disturbance to existing protected equipment.

6.3 All completed installation work should be checked and commissioned to ensure correct operation. The contractor should provide written confirmation to the user that the installation is fully operational.

6.4 Lightning conductors should be installed and inspected in accordance with BS 6651: 1999 (ref. 2). General guidelines are also outlined in RC35 (ref. 5).

6.5 All electrical protection systems should be subject to an annual maintenance inspection. Physical protection systems such as lightning conductors should be maintained in accordance with clause 34 of BS 6651: 1999 (ref. 2).

6.6 Protection equipment suppliers should be asked to provide information on the actions to be taken after a major surge event, such as a nearby lightning strike. Some equipment may require to be replaced after such an incident (or after a limited number of such incidents).

7 USE

7.1 Senior management should ensure the suitability of those responsible for overseeing the protection systems, arranging maintenance and operating/resetting of the protection systems as required.

7.2 Any alterations to the building, to internal structures and to the use and type of equipment may necessitate changes to the protection system. Ensure that the protection systems are fit for purpose both during alterations and after.

8 REFERENCES

1. Electromagnetic Compatibility Regulations 2005 (SI 2005/281), The Stationery Office.
2. BS 6651: 1999: *Code of practice for protection of structures against lightning,* British Standards Institution.
3. BS EN 62305-2: 2006: *Protection against lightning – Part 2 Risk management.*
4. BS EN IEC 62305-4: 2006: *Protection against lightning – Part 4 Electrical and electronic systems within structures.*
5. RC35: *Recommendations for the protection of buildings against the effects of lightning strike,* 2005, Fire Protection Association.
6. *Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits,* C62.41–1991 (revised 1999), Institute of Electrical and Electronic Engineers (IEEE).
7. BS 7671: 2001: *Requirements for electrical installations (IEE wiring regulations, 16th edition),* British Standards Institution.

9 FURTHER READING

BS EN 61643: Low voltage surge protective devices. Several parts. British Standards Institution

IEC 61643-1: Surge protective devices. Several parts. British Standards Institution

CENELEC TS 61643: Low-voltage surge protective devices. Several parts. British Standards Institution

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