Electrical services – Health Technical Memorandum 06-01 Electrical services supply and distribution: Part A – Design considerations

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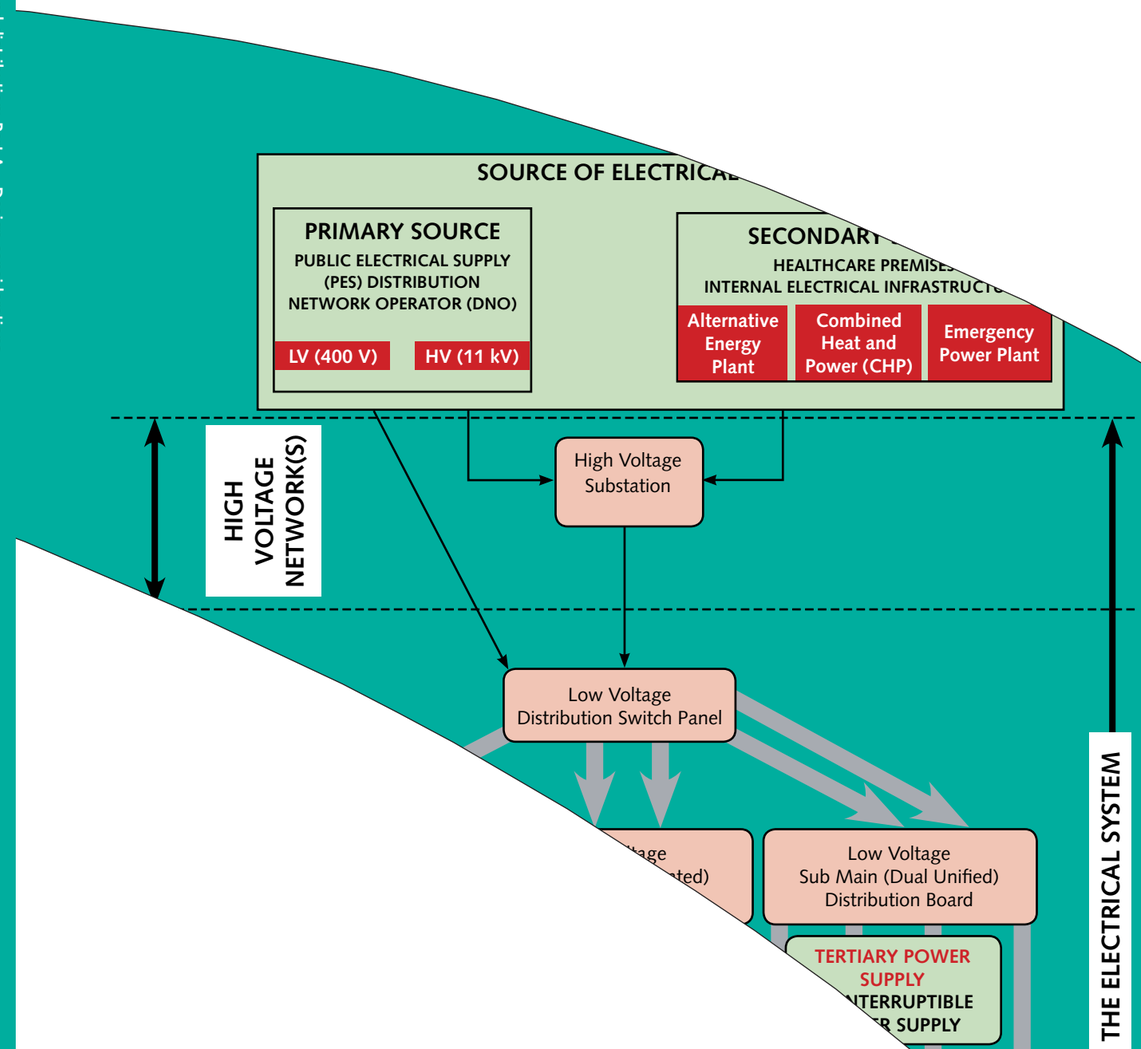
Electrical services
Health Technical Memorandum 06-01: Electrical services supply and distribution

Part A: Design considerations



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Part A: Design considerations

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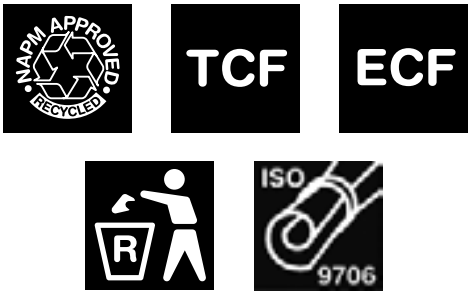


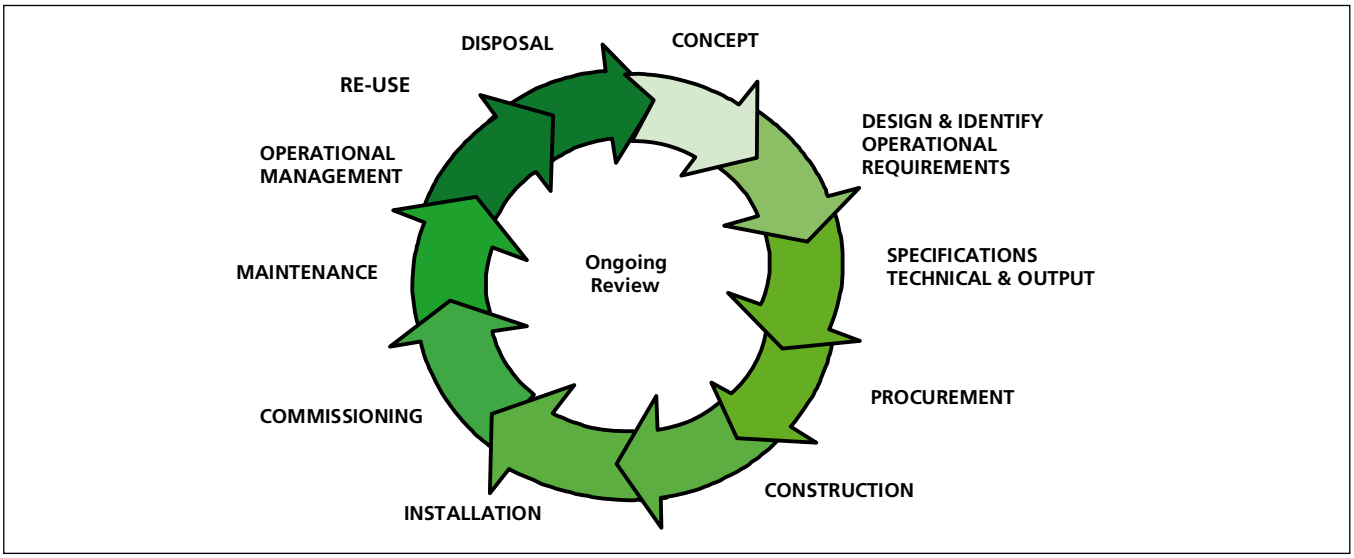
Preface

About Health Technical Memoranda

Engineering Health Technical Memoranda (Health Technical Memoranda)
give comprehensive advice and guidance on the design, installation and operation of specialised building and engineering technology used in the delivery of healthcare.

The focus of Health Technical Memorandum guidance remains on healthcare-specific elements of standards, policies and up-to-date established best practice. They are applicable to new and existing sites, and are for use at various stages during the whole building lifecycle:

Figure 1 Healthcare building life-cycle



Healthcare providers have a duty of care to ensure that appropriate engineering governance arrangements are in place and are managed effectively. The Engineering Health Technical Memorandum series provides best practice engineering standards and policy to enable management of this duty of care.

It is not the intention within this suite of documents to unnecessarily repeat international or European standards, industry standards or UK Government legislation. Where appropriate, these will be referenced.

Healthcare-specific technical engineering guidance is a vital tool in the safe and efficient operation of healthcare facilities. Health Technical Memorandum guidance is the main source of specific healthcare-related guidance for estates and facilities professionals.

The core suite of nine subject areas provides access to guidance which:

- is more streamlined and accessible;
- encapsulates the latest standards and best practice in healthcare engineering;
- provides a structured reference for healthcare engineering.

Structure of the Health Technical Memorandum suite

The series of engineering-specific guidance contains a suite of nine core subjects:

Health Technical Memorandum 00
: Policies and principles (applicable to all Health Technical Memoranda in this series)

Health Technical Memorandum 01
: Decontamination

Health Technical Memorandum 02
: Medical gases

Health Technical Memorandum 03
Heating and ventilation systems

Health Technical Memorandum 04
Water systems

Health Technical Memorandum 05
Fire safety

Health Technical Memorandum 06
Electrical services

Health Technical Memorandum 07
Environment and sustainability

Health Technical Memorandum 08
Specialist services

Some subject areas may be further developed into topics shown as -01, -02 etc and further referenced into Parts A, B etc.

Example: Health Technical Memorandum 06-02 Part A will represent:

Electrical Services – Electrical safety guidance for low voltage systems

In a similar way Health Technical Memorandum 07-02 will simply represent:

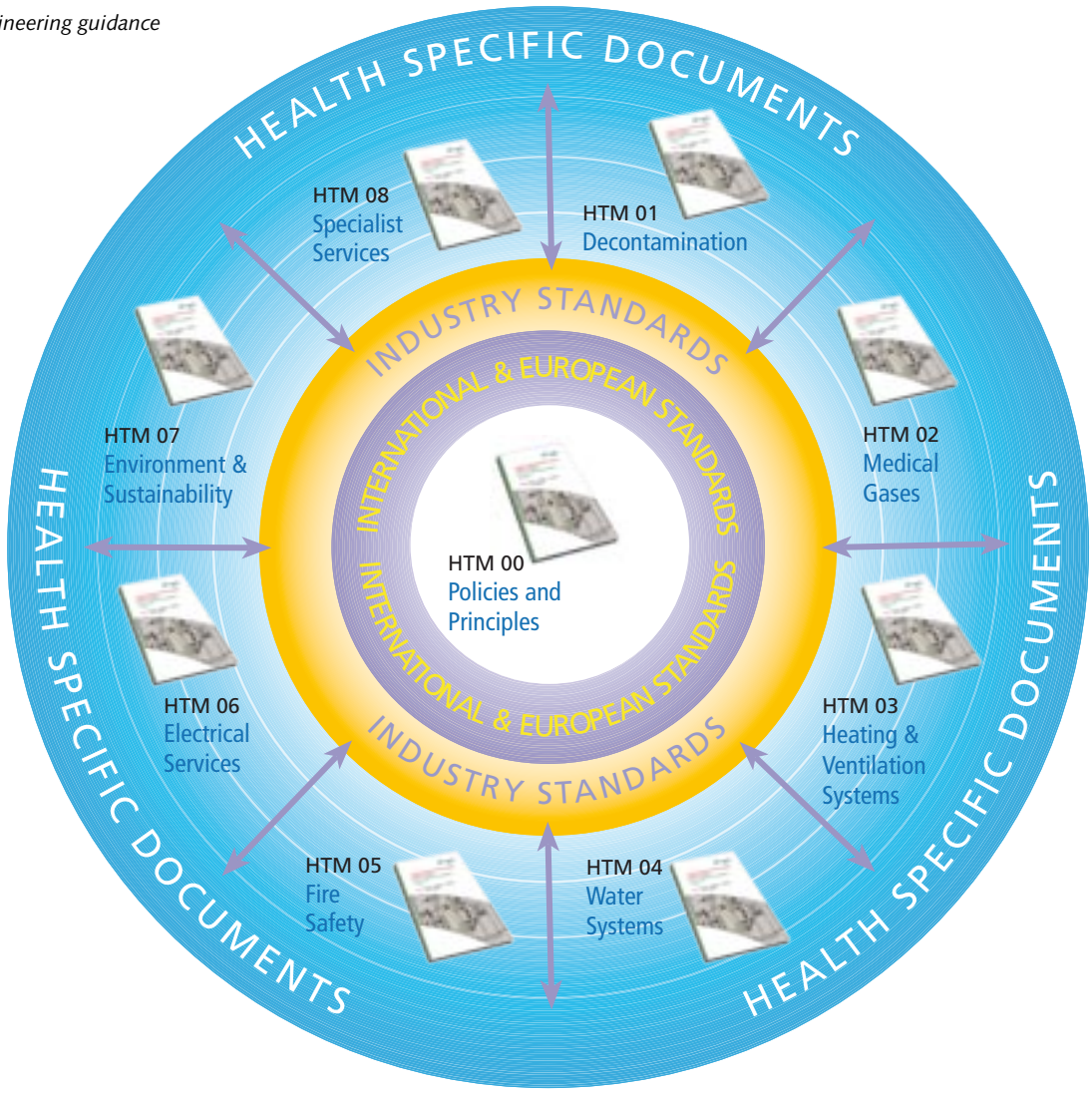
Environment and Sustainability – EnCO_2de.

All Health Technical Memoranda are supported by the initial document Health Technical Memorandum 00 which embraces the management and operational policies from previous documents and explores risk management issues.

Some variation in style and structure is reflected by the topic and approach of the different review working groups.

DH Estates and Facilities Division wishes to acknowledge the contribution made by professional bodies, engineering consultants, healthcare specialists and NHS staff who have contributed to the review.

Figure 2 Engineering guidance



Executive summary

Health Technical Memorandum 06-01 – 'Electrical services supply and distribution' replaces Health Technical Memorandum 2007 – 'Electrical services supply and distribution' and Health Technical Memorandum 2011 – 'Emergency electrical services', and absorbs Health Technical Memorandum 2014 – 'Abatement of electrical interference'.

This part (Part A) provides guidance for all works on the fixed wiring and integral electrical equipment used for electrical services within healthcare premises.

This document should be used for all forms of electrical design work ranging from a new greenfield site to modifying an existing final subcircuit. The relevance of each section will depend on the extent of the design works.

It provides guidance to managers of healthcare premises on how European and British Standards relating to electrical safety such as the IEE Wiring Regulations BS 7671, the Building Regulations 2000 and the Electricity at Work Regulations 1989 can be used to fulfil their duty of care in relation to the Health and Safety at Work etc Act 1974.

Acknowledgements

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1 Scope of Health Technical Memorandum 06-01

1.1 Health Technical Memorandum 06-01 – 'Electrical services supply and distribution' replaces Health Technical Memorandum 2007 – 'Electrical services supply and distribution' and Health Technical Memorandum 2011 – 'Emergency electrical services', and absorbs Health Technical Memorandum 2014 – 'Abatement of electrical interference'.

1.2 This part (Part A) provides guidance for all works on the fixed wiring and integral electrical equipment used for electrical services within healthcare premises. The document should be used for all forms of electrical design work ranging from a new greenfield site to modifying an existing final subcircuit.

1.3 This document provides guidance to managers of healthcare premises on how European and British Standards relating to electrical safety such as the IEE Wiring Regulations BS 7671, the Building Regulations 2000 and the Electricity at Work Regulations 1989 can be used to fulfil their duty of care in relation to the Health and Safety at Work etc Act 1974.

1.4 The policies and principles of all engineering services are described in Health Technical Memorandum 00 – 'Policies and principles', which should be read in conjunction with this document.

Abbreviations and definitions

24 x 7: 24 hours a day, 7 days a week

ac: alternating current

ACB: air circuit breaker

AMD: assumed maximum demand

AVR: automatic voltage regulator

BASEC: British Approvals Services for Electrical Cables

BEMS: building energy management system

BMS: building management system

BS: British Standards

BSRIA: Building Services Research and Information Association

CCM: CIBSE commissioning manual

CCTV: closed-circuit television

CDM: Construction Design and Management Regulations

CE: European Conformity

CENELEC: The European Committee for Electrotechnical Standardization

CHP: combined heat and power

CIBSE: Chartered Institute of Building Services Engineers

CPC: circuit protective conductor

CT: current transformer

DB: distribution board

DBU: distribution unit

dc: direct current

DNO: distribution network operator

DRUPS: diesel rotary uninterruptible power supplies

DTC: diagnostic and treatment centres

EC: European Community

ECG: electrocardiogram

EEA: European Economic Area

EEC: European Economic Community

EI: extreme inverse

EMC: electromagnetic compatibility

EMCD: electromagnetic compatibility directives

EMI: electromagnetic interference

EPR: electronic patient records

ERB: earth reference bar

ERIC: Estates Return Information Collection

ESD: electrostatic discharge

ETSI: European Telecommunications Standards Institute

EU: European Union

FL: full load

GRP: Glass-reinforced plastic

GSM: global system for mobile communication

HBC: high breaking capacity

HBN: Health Building Note

HDU: high dependency unit

HFN: Health Facilities Note

HGN: Health Guidance Note

HRC: high rupturing capacity

HV: high voltage (11 kV)

HVAC: heating ventilation and air-conditioning

ICU: intensive care unit

IDMT: inverse definite minimum time

IEC: International Electrotechnical Commission

IEE: Institute of Electrical Engineering

IGBT: Insulated-gate bipolar transistor

IM&T: information management and technology

IMD: insulation monitoring device

IP: ingress protection (rating)

IPS: isolated power supplies (also known as medical IT)

ISO: International Standards Organisation

ISS: intake substation

IT: impedance terra earthed (derived from an isolated power supply)

ITU: intensive therapy unit

IV: intravenous

LBTC: logbook template customisable

LBTS: logbook template standard

LDRP: labour delivery room and post partum

LPS: lightning protection system

LV: low voltage

M&E: mechanical and electrical

MCB: miniature circuit breaker

MCC: motor control centre

MCCB: moulded-case circuit breaker

MD: maximum demand

Medical IT: medical impedance terra (earthed) also known as IPS

MEIGaN: Medical Electrical Installation Guidance Notes

MET: main earth terminal

MRI: magnetic resonance imaging

NEAT: NHS Environmental Assessment Tool

NHS: National Health Service

OCB: oil circuit breaker

OJEC/OJEU: Official Journal of the European Community/Union

ONAN: oil natural circulation, air natural flow

PEC: protective earth conductor

PEI: primary electrical infrastructure

PELV: protected extra LV

PES: public electrical supply

PET: protective earth terminal

PF: power factor

PFC: power factor correction

PFI: Private Finance Initiative

PPE: personal protective equipment

PPS: primary power source

PSCC: prospective short-circuit current

PV: photovoltaic cell

PVC: polyvinyl chloride

RCBO: residual current breaker with overcurrent

RCD: residual current device

REF: restricted earth fault

RMU: ring main unit

SCADA: supervisory control and data acquisition

SCBU: special care babies unit

SELV: separated extra LV

SF_6: sulphur hexafluoride

SI: Système Internationale

SP & N: single phase and neutral

SPS: secondary power source

TETRA: trans-European trunked radio access

TFL: time fuses links may also be referred to as tlf time-lag fuses

THD: total harmonic distortion

TN-C: combined neutral and earth throughout the electrical distribution system

TN-C-S: neutral and earth is combined at point of supply and separate throughout the electrical installation

TN-S: separate neutral and earth throughout the electrical system

TP & N: three-phase and neutral

TPS: tertiary power supply

UMTS: universal mobile telecommunications service

UPS: uninterruptible power supply

VRLA: valve regulated lead acid (battery)

VT: voltage transformer

XLPE: cross-linked polyethylene

Applied part: part of a medical electrical device which in normal use necessarily comes into physical contact with the patient for the device to perform its function

or

can be brought into contact with the patient

or

needs to be touched by the patient.

Authorised Person (HV): a person appointed to take responsibility for the effective management of the safety guidance given in Health Technical Memorandum 06-03 – 'Electrical safety guidance for high voltage systems'.

Authorised Person (LV): a person appointed to take responsibility for the effective management of the safety guidance given in Health Technical Memorandum 06-02 – 'Electrical safety guidance for low voltage systems'.

Dual-unified distribution: separate primary and secondary circuits collectively forming the electrical distribution of the healthcare facility. The secondary supply is equal to the primary supply; that is, both primary and secondary circuits are fully rated and provide a resilient distribution.

Designer: a person (or organisation) with the responsibility to design the electrical services technically correct and in a safe manner. The designer need not be a direct employee of the healthcare organisation.

Essential: any part of the electrical distribution and/or final circuits that can be automatically transferred between either the primary or secondary supply circuits.

Medical electrical equipment: electrical equipment intended to diagnose, treat or monitor a patient under medical supervision which will make physical or electrical contact with the patient, transfer energy to and from the patient, or detect such energy flows.
Note: equipment is not covered by this Health Technical Memorandum. The Medicines and Healthcare products Regulatory Agency (MHRA) is the government agency which is responsible for ensuring that medical equipment works and is acceptably safe.

Medical IT (IPS): IT electrical system having specific requirements for medical installations. The system will include a monitoring device to provide an alarm on loss of IMD connections, insulation failure, overload and high temperature.

Medical location: location intended for the purpose of diagnosic treatment (including cosmetic) or monitoring a patient under medical supervision.

- *Group 0* Medical location where no applied parts are intended to be used.
- *Group 1* Medical location where discontinuity of the electrical supply is not a risk to human life (unless the location is part of a Group 2 location).
- *Group 2* Medical location where discontinuity of the electrical supply can cause danger to life.

Note: "discontinuity" means any unplanned loss of the power supply (*see* MEIGaN).

MEIGaN: Medical Electrical Installations Guidance Note published by MHRA.

Normal (non-essential): any part of the electrical distribution and/or final circuits connected only to the primary distribution and with no means of being connected to the essential (secondary) distribution.
Note: in some distributions, manual reconfiguration may allow the normal circuits to be temporarily connected to the essential (secondary) distribution.

Patient: living person undergoing healthcare, therapy or diagnostic investigation (including dental and cosmetic).

Patient environment: any area in which intentional or unintentional contact can occur between the patient and parts of the electrical system or between the patient and other persons in contact with parts of the system (see Figure 44).

Point of use: Electrical distribution points where electrical equipment may be connected. This may be an accessory or isolator etc.

Protected extra LV: a SELV system that is earthed at one point only. Additional protection against direct contact is achieved by barriers and/or enclosures. Alternatively the insulation will have a "withstand" test voltage of 500 V dc for 60 seconds.

Residual risk: a risk that has not been fully mitigated by the design process.

Segregated distribution: an electrical distribution that includes separated primary and secondary circuits not of equal size or capacity. The secondary circuits are the only circuits that are supported by the standby power system.

Separated extra LV: an LV system (normally not exceeding 50 V ac or 120 V ripple-free dc) derived from a safety source such as an isolating transformer to BS EN 61558-1:1998 and BS EN 61558-2.

Single point of failure: a connection point (other than a point of use) where any upstream single fault will cause the loss of supply to the downstream parts of the distribution.

Stakeholder: a person (or organisation) with vested interest (not necessary pecuniary) in the electrical services quality and provision at healthcare premises. The stakeholders will normally be an employee of the healthcare organisation.

Tertiary power supply: a third supply that supplements the primary and secondary supplies, usually in the form of an UPS or battery system.

Unified distribution: primary (normal) and secondary (essential) circuits combined as one circuit to form a common electrical distribution of the healthcare site. Where the secondary power source does not provide 100% capacity of the primary power source, local automatic devices will be required to isolate the non-essential circuits whenever the primary power source is not available.

2 Introduction

Overview

2.1 Health Technical Memoranda 2007, 2011 and 2014 have been superseded and combined into one document: Health Technical Memorandum 06-01.

2.2 Health Technical Memorandum 06-01 Part A addresses design considerations for the electrical services supply and distribution within any healthcare facility. Part B addresses the operational management and maintenance of the electrical services supply and distribution within any healthcare facility. Both parts provide best practice guidance on the design and operational management of electrical services within healthcare premises.

2.3 Throughout this document, the following voltages are used (see BS 7671:2001 for the defined voltage bands):

Extra low voltage	50 V ac or 120 V ripple-free dc
Separated extra low voltage (SELV)	50 V ac or 120 V ripple-free dc
Protected extra low voltage (PELV)	50 V ac or 120 V ripple-free dc
Low voltage	230 V phase to neutral, phase to earth or line-to-line (medical IT) 400 V phase to phase
High voltage	11,000 V phase to phase 6350 V phase to neutral

2.4 This document has been divided into 18 chapters:

- Chapters 1 and 2 set out the structure of the Health Technical Memorandum;
- Chapters 3 to 11 deal with design issues. Although this Health Technical Memorandum is written for new works and developments on a greenfield site, it should be used for all works and adaptations to the fixed wiring of any healthcare facility;
- Chapters 12 to 17 describe how the electrical services should be installed and put together from the various distribution centres to the final circuits and point of use locations.

Chapter 3 provides guidance on what needs to be considered when planning a new development in terms of the electrical services.

Chapter 4 explains how the design options should be assessed to minimise the risk of system failure and the consequential impact to patients and users of the healthcare premises. The chapter introduces the concept of clinical risk in terms of the clinical function of a department within the healthcare facility. The chapter also considers the business continuity risks in a similar manner. The chapter provides a risk matrix that may be used in the evaluation of the distribution strategy.

Chapter 5 defines the required standard of the electrical supply.

Chapter 6 describes the techniques to be used that will provide an appropriate resilient electrical system for any healthcare facility (or part within a healthcare facility).

Chapter 7 describes the physical electrical switchrooms, their construction, location, and environmental requirements.

Chapter 8 continues the descriptions of switchrooms that may be used for alternative, including emergency, power supplies.

Chapter 9 provides the details of the electrical equipment that will be found in the primary and secondary distribution centres. The chapter provides information on the protection and isolation methods of the electrical services and distribution.

Chapter 10 provides details of battery units that may be used to start standby generator plant or provide more local power to items such as uninterruptible power supplies (UPS) or inverter units.

Chapter 11 provides details on how the electrical distribution system may radiate or absorb electromagnetic interference and how these problems may be mitigated.

Chapter 12 describes the general wiring formats in relation to earthing and insulation.

Chapter 13 describes the full earth systems to be used. The chapter has a section for HV, LV, and switchroom earths. In addition, the specific requirements for isolated power supplies, earthing radiographic rooms and circuits with high leakage currents are discussed. The method of providing earth monitoring systems to BS 4444:1989 for mobile trailer units is also considered in the guidance. The chapter concludes with the requirements for lightning protection systems.

Chapters 14 and 15 describe the various cable types and the respective methods of installing them in healthcare premises.

Chapter 16 describes the various final circuits, including uninterruptible power supplies, isolated power supplies, fixed equipment temporary supplies and alarm circuits.

Chapter 17 provides designers and stakeholders with an insight into the validation and commissioning tests required before a new installation may be signed off and formally accepted.

Appendices and **References** can be found at the end.

How to read this Health Technical Memorandum

2.5 This document has been written in a top-down format. The design process for new builds is likely to follow a similar planning, design and construction order to that of this document.

2.6 It is recommended that designers and stakeholders review Chapter 4 as well as Chapter 6 for all projects.

2.7 Designers and stakeholders should review any other chapter in relation to the nature of the particular project.

3 Initial considerations

3.1 This chapter introduces the design element of the document. The intent is to assist designers and stakeholders to develop the design of electrical networks for new builds, but equally it applies to modifications to existing installations. Some sections of this chapter can be addressed prior to or during the outline design stage, but all sections can be addressed before the detailed electrical design stage.

Sources of supply

3.2 All healthcare premises require an electrical connection to the public electrical supply (PES), which will be provided and operated by the distribution network operator (DNO). Electrical supplies to large healthcare premises are mainly at 11 kV (high voltage), while smaller healthcare premises may be supplied at 400 V (low voltage). The supply frequency at both voltage levels will be 50 Hz (see the Electricity Safety, Quality and Continuity Regulations 2002 for further details). Within this Health Technical Memorandum, the connection to the PES will be referred to as the "primary source of supply". Any embedded generating plant and/or combined heat and power (CHP) plant can be used as the primary source of supply, provided appropriate measures for resilience, maintenance and safety have been included.

3.3 Many healthcare premises will require resilience of the internally distributed electrical installation, which should be provided according to the clinical risk assessments (see Chapter 4). The resilience may be provided by embedded sources of electrical power from plant such as:

a. secondary source of supply:
   (i) standby generators;
   (ii) CHP systems;
   (iii) wind turbines;
   (iv) photovoltaic systems.

b. tertiary source of supply:
   (v) uninterruptible power supplies (UPS), rotary or silent;
   (vi) UPS static;
   (vii) battery packs.

3.4 Adequate stocks of the fuel used by standby generators and/or CHP will need to be maintained. The fuel for wind turbines (wind) and/or photovoltaic systems (solar) may not always be readily available at the optimum volumes, and therefore these sources of power should not be considered as essential power sources. UPSs use batteries as a power source, which have a definitive autonomy dependent on the connected load. UPS and battery supplies should only be considered as a short-term measure. The PES connection may be used as the secondary source of supply where appropriate measures for capacity, resilience, maintenance and safety have been included with the embedded sources of electrical power. However, it may be less viable to provide a dual PES connection than it is to provide additional on-site secondary power supplies, for example standby generators.

Resilience

3.5 Large healthcare premises should generally be supplied by a dual PES (ideally both at 100% fully rated) arranged with either an automatic or a manual change-over system. In order to maximise the resilience of dual supply arrangements and minimise the actual single point of failure, the supplies should be diverse. Where possible, they should originate from separate DNO substations, in turn ideally fed from separate parts of the National Grid, with independent cable routes to and across the healthcare site to the substations.

3.6 Having two separate HV supply feeders is an additional safeguard for larger premises; whether this is practicable largely depends on the local distribution system and the DNO.

Essential/non-essential supplies

3.7 When planning for new installations, the option of segregated non-essential and essential electrical systems or a unified electrical system (that is, duplex or simplex) should be evaluated.

3.8 The need for more essential supplies increases the demand on the standby system. Electrical supplies in the healthcare sector are growing at a rate of between 3% and 6% year on year. A suitable philosophy should be agreed with estates staff to reflect this growth before sizing the standby plant and distribution strategy.

3.9 A risk-orientated approach should be adopted, and different categories of the essential and non-essential load identified to assign appropriate standby provision (historically, it has been customary to have a discrete segregated essential/non-essential service combination). For clinical areas, there should be 100% essential load provision. A segregated duplicated essential system could be used to overcome the inherent single-fault breakdown potential. This would also facilitate the operational opportunity to test and periodically validate electrical installations.

3.10 The provision of two segregated systems, each of smaller power capacity, should be balanced against having one larger unified power system in terms of economics and reliability in emergencies. The availability of the distribution and final subcircuits for testing, validation and upgrading of systems should also be taken into consideration.

3.11 In systems that employ a segregated duplicated essential service, thought should given to the space needed for separate feeders, independent risers and stand-alone distribution board (DB) cupboards so as to reinforce the system resilience. This will help to ensure that a local failure will not compromise the entire system.

3.12 Even when two segregated systems are provided (essential/non-essential), an emergency coupling should be normally locked open between them. This allows the standby generator to be connected to both systems if necessary; for example, during a prolonged outage, some normally non-essential services may become essential, such as catering and laundry. In addition, with the coupling it is possible to provide a larger test load.

3.13 Where essential, non-essential and duplex essential circuits are installed, diverse cable routes should be provided, and the possibility of a single cable fault damaging both circuit cables should be minimised as much as possible.

3.14 In areas where there are many essential subcircuits, separate cable trays should be used for the routing of duplex essential and non-essential circuit cables.

3.15 Consideration should be given to the requirements of BS 5588 and fire-protected cables or cable routes.

Primary sources of supply

3.16 This section deals with the primary supply, distribution and sub-distribution of the primary electrical infrastructure (PEI), and presents best practice configurations for both HV and LV DNO supplies (see Figure 1). The configurations are presented generally in order of resilience, from low to high. The selection of a particular configuration will be dependent on the specific factors of each individual design in terms of available DNO supply, type of healthcare facility, category of patient etc. Whichever configuration is selected, it should be based on a risk analysis to determine the appropriate level of resilience (see Chapter 7).

3.17 The configurations presented in this section should not be taken as being definitive, prescriptive or restrictive. They are intended as a guide to best practice and not intended to restrict innovation in any design.

Secondary main sources of supply – generation

3.18 This section deals with secondary supplies of the PEI and presents best practice configurations for both HV and LV standby supplies (see Figure 2). The configurations are presented generally in order of resilience, from low to high. The selection of a particular configuration will be dependent on the specific factors of each individual design. Whichever configuration is selected, it should be based on a risk analysis to determine the appropriate level of resilience (see Chapter 8).

Tariff negotiations and private generation

3.19 At an early stage of the design process, designers and stakeholders should assess the capacity of the new electrical load. Negotiations with an electrical energy supplier should be initiated at this early stage. Where the building services operator is

Figure 1 Primary electrical infrastructure for healthcare premises

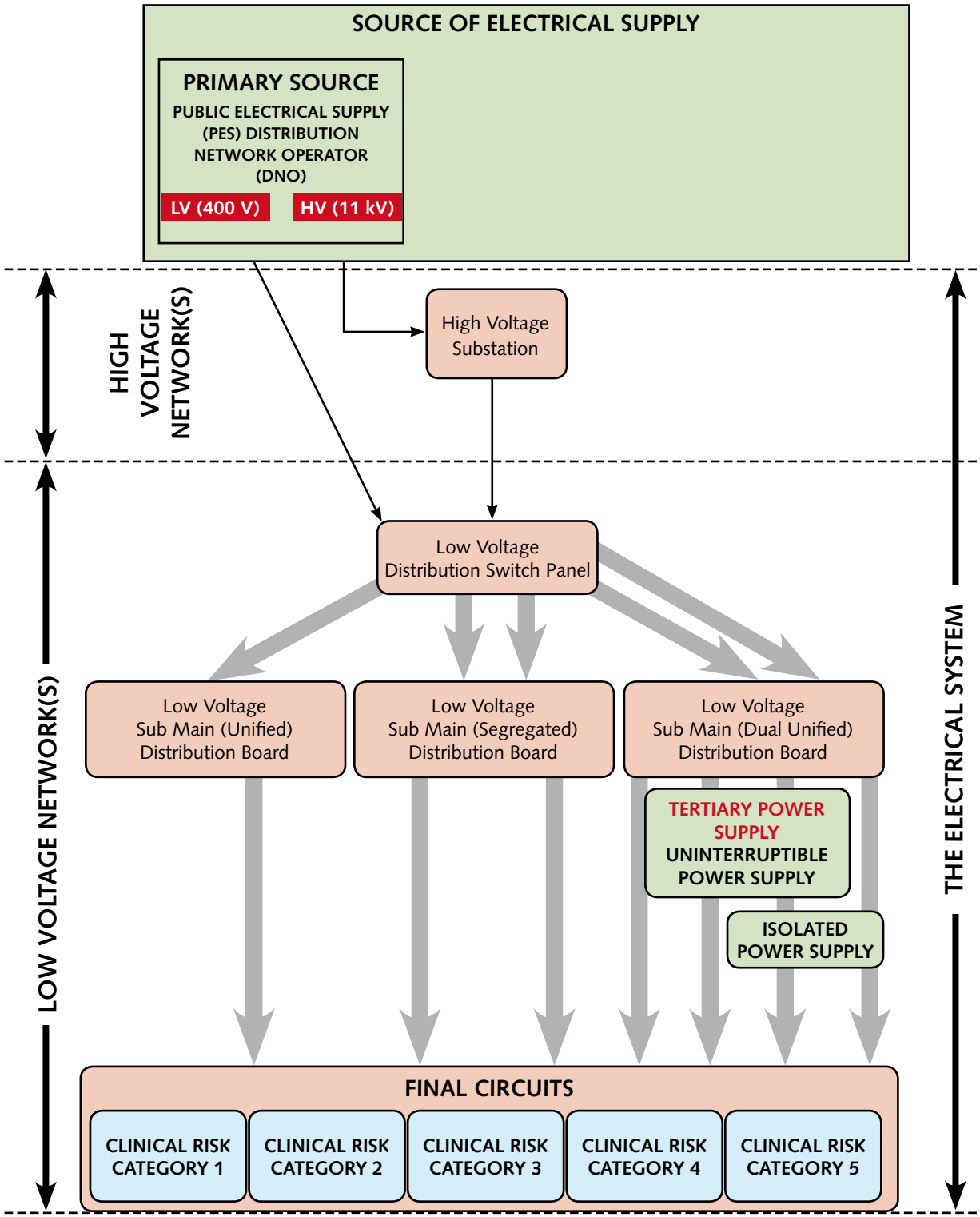
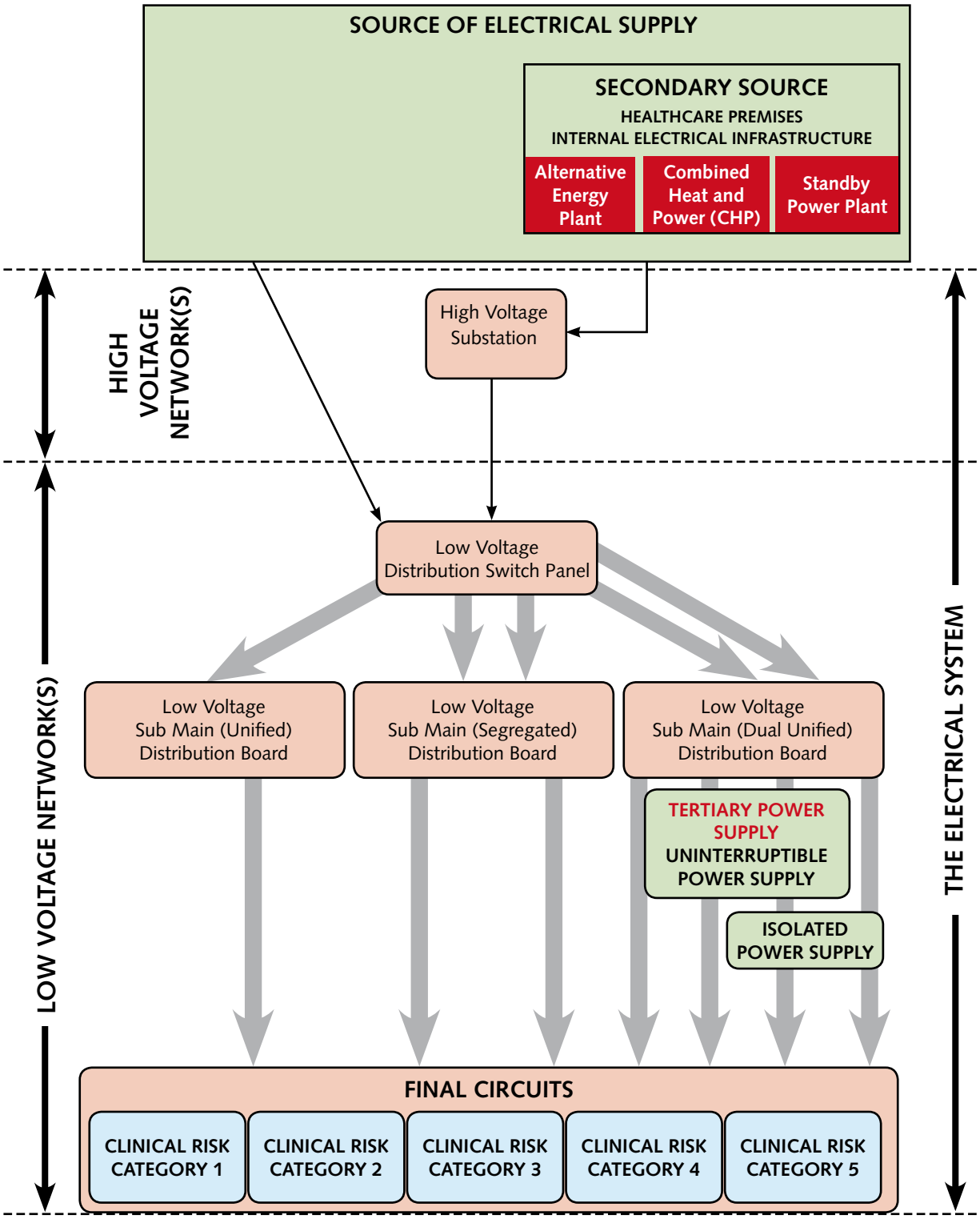


Figure 2 Secondary electrical infrastructures for healthcare premises



responsible for the purchase of electrical energy, they will also be responsible for the negotiations. However, in the more usual case where the electrical energy is a pass-through cost, or where the building services operator is the healthcare organisation, the healthcare organisation will be responsible for the above negotiations.

3.20 The opportunities for alternative energy sources should be explored wherever practical. For example, sources such as CHP or wind power will reduce the net carbon emissions and potentially provide an improved economic solution. Where alternative energy sources are used, the resilience of such plant should be considered. This may be in the form of "N+1" CHP plant or suitable alternative supply from the DNO.

3.21 Healthcare organisations should use the NHS Environmental Assessment Tool (NEAT) both to help find out how their facilities and services impact on the environment and to estimate the level of environmental impact taking place (http://www.dh.gov.uk).

3.22 Where the proposed alterations are for modification and/or adaptations to the internal electrical infrastructure, tariff negotiations may not be required. Nevertheless, the use of alternative power sources should still be considered to offset the increased electrical demand.

3.23 Guidance on the environmental benefits of alternative energy sources can be obtained from:

- Building Services Research and Information Association (BSRIA) (http://www.bsria.co.uk);
- Chartered Institute of Building Services (CIBSE) (http://www.cibse.org);
- Combined Heat and Power Association (CHPA) (http://www.chpa.co.uk);
- Department for Environmental Food and Rural Affairs (http://www.defra.gov.uk);
- The Carbon Trust (http://www.carbontrust.co.uk).

See also Health Technical Memorandum 07-02 – 'Encode'.

Supply voltages

3.24 The DNO will deliver the PES at the customer's intake terminals at a declared voltage in accordance with the requirements of the Electrical Safety, Continuity and Quality Regulations 2002. Each healthcare facility will have an electrical supply at one of the following voltages:

11 kV	Large acute hospital, typical floor area greater than 8500 m^2
11 kV/400 V	Medium-sized acute hospital, typical floor area 5500 m^2 to 8500 m^2
400 V TP & N	General/community hospitals, health centres, large off-site clinics, off-site administrative buildings, stores and decontamination facilities
230 V SP & N	GP and dental practices, small off-site clinics

The types of healthcare facility in the above list are for illustration and are not definitive. For voltage tolerances in the above list, see the latest issue of the IEE Regulations (BS 7671:2001), and the Electricity Safety, Quality and Continuity Regulations 2002.

3.25 Some larger sites may have multiple feeds (at the intake point) with an internal distribution network (see Chapters 6–8). In such cases, the declared voltage will be either 11 kV or 400 V. Such connection arrangements provide an improved resilience of supply.

3.26 Some healthcare sites, particularly older sites that have expanded over a number of years, may have multiple intake points (which may not all be at the same supply voltage). The various intake points should be consolidated to a single or multiple feeds at a common point. Such arrangements will provide economies with tariff and standing charges.

3.27 The DNO may arrange with the healthcare facility (under a wayleave agreement) to have their own electrical equipment, including transformer, on-site. This arrangement is frequently used in rural areas where the healthcare facility is some distance from the nearest DNO substation. In such cases, the DNO's electrical equipment will be at a higher voltage (11 kV) to that supplied at the healthcare site's intake terminals (400 V).

Design of installations for growth and change

3.28 Changes in medical technology and healthcare practice have had an effect on the requirements for electrical power in healthcare. Examples include:

- cook-chill: the introduction of cook-chill has meant more meals are cooked electrically and ward-based "regeneration ovens" have been introduced;
- electronic patient records (EPR) and patient entertainment systems: although these have a very low electrical power requirement, such systems require a significant increase in containment and space.

3.29 Alterations to existing installations, unless planned and allowed for during the original construction, can be costly, particularly when structural changes are involved.

3.30 Healthcare premises are frequently remodelled within the economic life of an electrical installation. Designers and stakeholders should identify means of remodelling the electrical distribution and determine to what extent any flexibility for remodelling should be incorporated with the initial design.

3.31 Each electrical distribution centre should include an element of equipped and unequipped enclosures for retrofitting of switches, protective devices and so on.

3.32 The designers should evaluate, by risk assessment, the degree of remodelling and natural expansion that will be incorporated into the initial installation. The risk assessment should reflect both clinical and commercial risks.

3.33 This allowance for growth and remodelling should be incorporated into the adopted distribution strategy (see Chapter 6).

Assessment of existing electrical systems

3.34 Designers will need to make a reasonable assessment of any existing electrical services that are to be modified or connected to as part of the proposed works. For existing sites, the building logbook (see Chapter 17) will provide details of the existing electrical systems, periodic test results (including fault levels), applied diversity, load profile and schematic drawings of the electrical system and/or network. Examination of the settings on all adjustable protection devices will identify the extent of any tolerance within the grading and discrimination of such protective devices.

Greenfield site

3.35 Where the proposed works is a new building site and not part of an existing hospital complex, the assessment of existing electrical systems may be limited to an understanding of the DNO's infrastructure in the area. This knowledge will help in determining the cost associated with any reinforcements.

New-build on existing site

3.36 Where the proposed works are a new building site within part of an existing complex, the assessment of existing electrical systems will determine the extent of any spare capacity at the proposed connection point. The connection point may be at the site intake or embedded in the internal distribution network. This knowledge will help to determine the practicalities and cost associated with any reinforcements of switchgear, protection devices and cables.

New equipment on existing site

3.37 Where the proposed work is limited to the installation of new equipment or the modifications of sub-distribution and final circuits, the power requirements and an understanding of the existing distribution (including final subcircuits) will determine the most appropriate connection point and any reinforcements of switchgear, protection devices and cables.

Load profile

3.38 Designers and stakeholders should understand the electrical profile of the healthcare facility at an early stage. This will prove invaluable in assessing the viability of any secondary and/or tertiary energy sources (for example CHP plant). Where the healthcare facility is an existing site, electrical demand data records should be available. The data may be available from the building energy management system (BEMS), the utility supplier (in the form of digital pulse metering) or from the Estates Return Information Collection (ERIC).

3.39 Table 1 indicates a typical range of power densities found in healthcare premises over a five-year period. The actual figures will reflect the technology used and the particular department. Power densities at the lower end of the range reflect average power densities of large healthcare premises. Power densities at the upper end of the range reflect power densities for smaller healthcare

premises such as GP surgeries. The figures do not take account of any growth. Power densities at the lower end do not necessarily imply any improved efficiency over power densities at the higher end. However, power densities outside the range may give cause for further investigation.

Table 1 Typical range of power densities for a healthcare facility over a five-year period

Power	W/m^2	GJ/100 m^3
General power	9–25	3.7–10.3
IM&T power	3–6	1.2–2.5
Medical power	5–15	2.0–6.2
Lighting		
General	9–15	3.7–6.2
Special	0.9–1.5	0.4–0.6
Task	1.35–2	0.5–0.8
Medical	0–1	0–0.4

3.40 Figure 3 shows a typical daily electrical profile for a hospital. The annual profile is shown in Figure 4. The actual shape and kVA values are unique to the site and a function of the size and clinical facilities provided.

3.41 The various options of providing the electrical energy required to satisfy the load profile should be evaluated. Where the profile indicates a relatively short peak maximum demand, which is high in relation to the average demand, the cost of the DNO connection will be disproportionately expensive, as the cost of the connection is only optimised at the maximum demand period. In such cases, the healthcare organisation should consider developing some of the electrical energy from on-site alternative energy sources such as CHP or wind power. Where alternative energy sources are used, the resilience of such plant should be considered.

Figure 3 Typical diurnal electrical profiles for a hospital

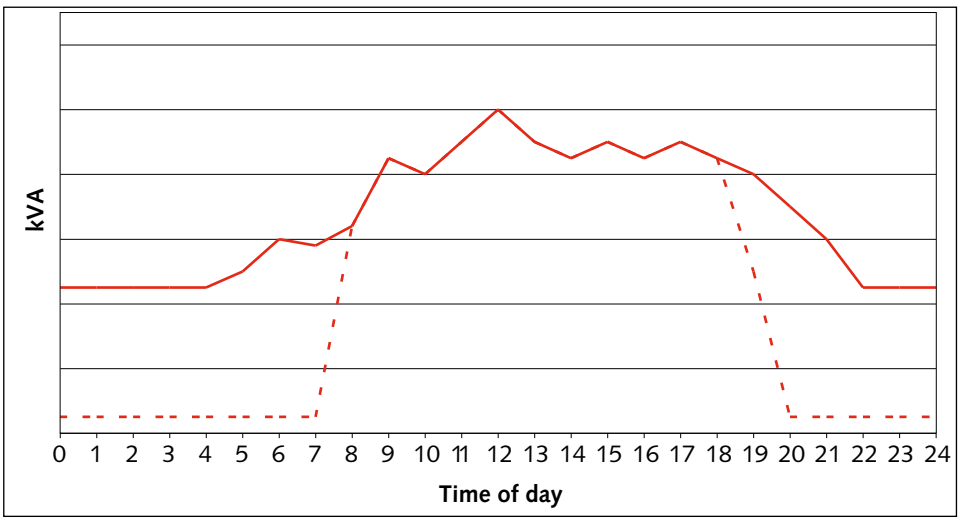
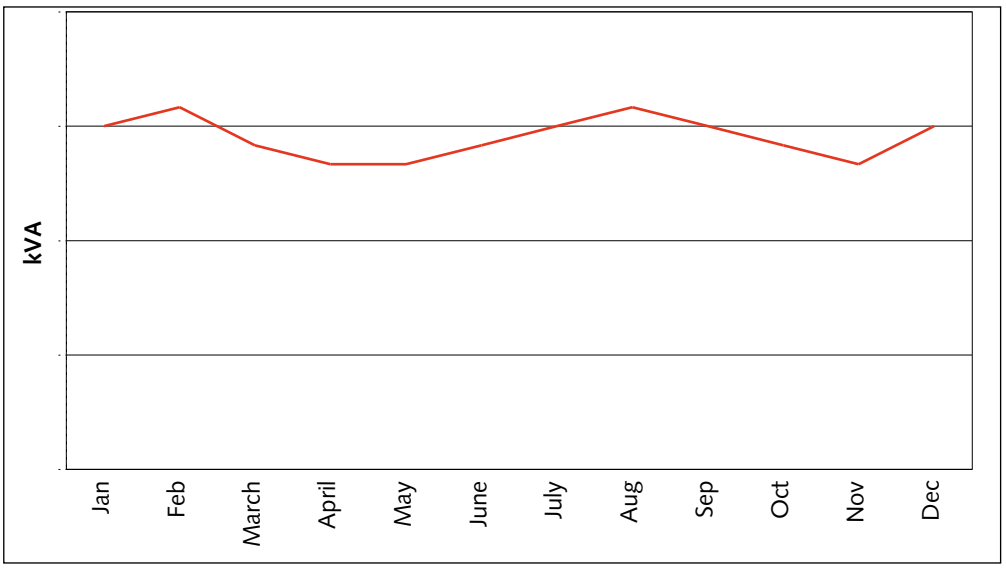


Figure 4 Typical annual electrical profiles for a hospital



Diversity factors

3.42 The electrical diversity factor is the ratio of instantaneous power to the total installed power. Diversity factors can be applied to each element of the electrical service (for example the lighting load or low-power load) or to a whole department. Where the healthcare site is large and has multiple substations, the diversity factors can be calculated for each individual substation. It should be clear that the diversity factor for a particular service (for example lighting) may differ during the day and year, while the diversity of, say, the chiller plant may have a different cycle. Similarly, the diversity variation for one department (for example radiography) may be higher on weekday mornings than in the afternoon, while the accident and emergency department may peak in the early evenings.

3.43 The above variations in actual diversity will reflect the true load profile as identified in paragraphs 3.38–3.41 above.

3.44 Designers should assess the actual diversity factors for each service and department to make a value judgement of the site-wide normalised diversity. This figure can then be applied to the total installed power and the allowance for growth to determine the electrical capacity of the DNO connection. Table 2 shows some typical figures.

Table 2 Typical electrical diversity factors for healthcare premises

	Power density (W/m^2)	PF	Building diversity	Substation diversity	Connected load diversity	Off-peak diversity	Growth factor
AHU fans	15–25	0.95	0.7–0.90	1.00	0.7–0.90	0.68	0.10
Building services pump	1–3	0.95	0.7–0.90	1.00	0.7–0.90	0.68	0.10
Lifts	5–8	0.95	1.35–0.23	0.50	0.3–0.5	0.6	0.05
Chiller	25–35	0.95	0.9–0.95	1.00	0.9–0.95	0.8	0.05
General low power	9–25	0.95	0.49–0.60	0.70	0.7–0.85	0.65	0.20
Information systems	3–6	0.95	0.80	0.80	1	0.65	0.20
Medical equipment	6–16	0.95	0.35–0.49	0.70	0.5–0.7	0.2	0.20
General lighting	9–15	1.00	0.49– 0.63	0.70	0.7–0.9	0.8	0.15
Specialist lighting	0.9–1.5	1.00	0.35–0.63	0.70	0.5–0.9	0.5	0.15
Task lighting	1–2	1.00	0.45–0.54	0.60	0.75–0.9	0.4	0.15
Medical lighting	0–1	1.00	0.42–0.54	0.60	0.7–0.9	0.7	0.15

Notes:

Power density: The power density relates to the relevant internal floor area of the healthcare premises.

Power factor (PF): Power factor is assumed to be the corrected power factor at each substation.

Building diversity: The building diversity reflects that not all substations within the healthcare premises will have the same operating profile. The building diversity is the product of the connected load and substation diversity. The building diversity is the actual demand seen at the point of common coupling with the PES.

Substation diversity: Substation diversity reflects that not all areas, of any one substation, will have the same operating profile, for example clinics and 24-hour areas. The substation diversity is multiplied by the connected load diversity to produce the building diversity.

Connected load diversity: Connected load diversity reflects that any electrical system (fixed medical equipment etc) will not be operating at full demand or used to maximum capacity at all times of the day.

Off-peak diversity: Off-peak diversity reflects that not all equipment will be used (to the same profile) at night as in the day (for example 12-hour clinics etc). The off-peak diversity is not used in these calculations, but will be an element used in the energy calculations.

Growth factor: Growth factor is an allowance for the natural expansion in electrical equipment used, and potential remodelling of the hospital. Growth factor is applied to switchgear, cable sizes, and transformer sizes etc. The function of the growth factor is to ensure that the electrical network will not need premature replacement.

Consideration for EMC requirements

3.45 Electrical installations must be compliant with the requirements of the Electromagnetic Compatibility Regulations 2005. The regulations describe the electrical installation as a manufactured item, and therefore require the installation to be tested for electromagnetic radiation and absorption. Procurement contracts for electrical equipment associated with the distribution of the electrical installation should stipulate that the equipment must be compliant with the Electromagnetic Compatibility Regulations 2005.

Roles and responsibilities

3.46 The Electromagnetic Compatibility Directive (EMCD) and the Electromagnetic Compatibility Regulations 2005 describe who is responsible for meeting compliance. There are only two parties involved – the manufacturer and the operator. In a healthcare building project:

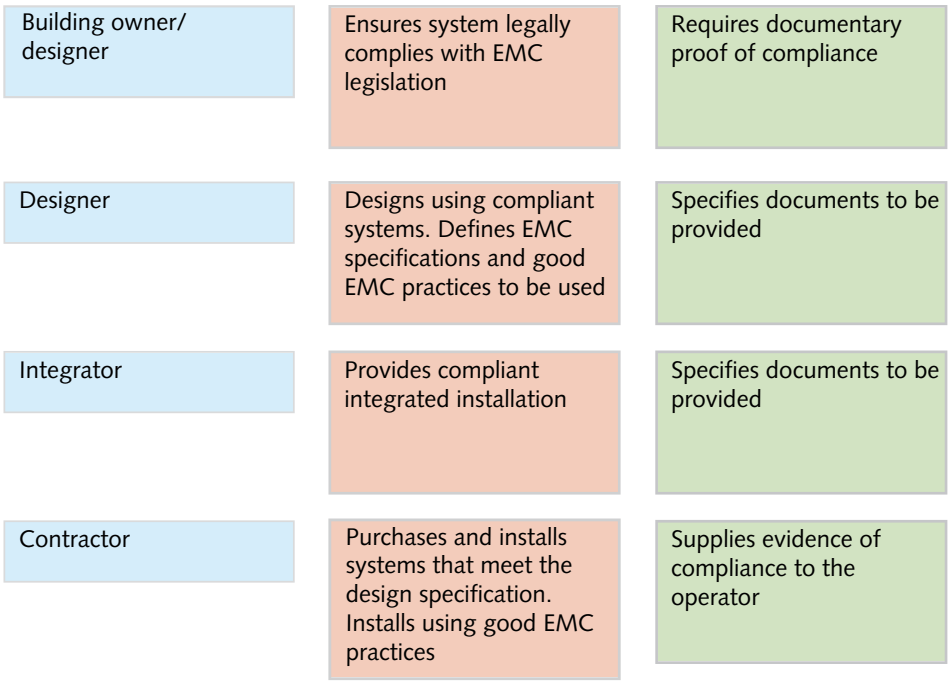
- the designer and installer of an integrated heating, ventilation and air-conditioning (HVAC) or power distribution control system are the "manufacturer";
- the manager of the healthcare premises and the building services maintenance organisation are the "operators".

It will not always be possible to design-in equipment that is CE-marked to show compliance with the EMCD. An installation may comprise CE-marked and non-CE-marked equipment. Supply of non-CE-marked equipment is acceptable providing the installer who is integrating them into the system can be sure that they will not cause undue interference to the installation or be overly sensitive to the electromagnetic environment where the equipment will be used.

3.47 The designer should obtain a technical file from the installer demonstrating that good engineering practice has been applied, and should show details of any concessions granted to items that are not compliant with the installation specification, but which may be used without detrimental effects.

3.48 Designers and stakeholders may assume that any equipment which is supplied for operation in the medical environment will have sufficient immunity to operate successfully in that environment, and it should not emit excessive radiation. The above statement assumes that the healthcare organisation has an approved policy for the procurement of medical equipment which does not involve the designers or stakeholders of the electrical installation.

Figure 5 Roles and responsibilities



Access for maintenance

3.49 In order to comply with the Construction, Design and Management Regulations (CDM) 1994, designers need to give due account for access and maintenance at a very early stage of the design, irrespective of the size, complexity and extent of the proposed installation.

3.50 Electrical services should not compromise the space and access routes for other services such as mechanical and public health. Maintenance tasks should be carried out with the minimum disruption to continuity of supply and business.

3.51 The following documents provide additional information:

- Health Technical Memorandum 06-01 Part B – 'Operational management';
- Health Technical Memorandum 00 – 'Policies and principles';
- Defence Works Functional Standard DMG 08 – 'Access and accommodation for engineering services: space requirements for plant access, operation and maintenance';
- manufacturers' operational and maintenance manuals.

Commissioning procedures

3.52 Designers should consider how the installation will be commissioned and how the required test measurements will be made. This will include the inspection of services that may be hidden at the time of handover. It will also include the implications of any phased occupation (see Chapter 17 for more information).

3.53 The design team should make an application to connect the new works to the DNO or healthcare site prior to doing so. At this point, the installation should be suitably safe and ready to be energised.

Connection to the DNO

3.54 Where the new installation will be connected directly to the DNO's network (PES), the application to connect will take the form of a "completion certificate" as identified in BS 7671:2001. The DNO will be entitled to conduct a range of tests to be satisfied that the installation is safe for energising and that any fault currents which may arise are cleared before injecting into the DNO's network.

3.55 In cases where the new installation includes embedded generator plant (including CHP or PV cells), the DNO will need to understand the methods used to clear any faults from the internal energy sources in order that they are not reflected onto the DNO's network.

3.56 For greenfield sites, it may be necessary to coordinate the activities of the DNO, meter operator and energy supplier before a connection can be completed (see paragraphs 8.29–8.47).

3.57 The DNO will reserve the right not to connect a new installation where the installation fails to comply with its criteria.

Connection to the healthcare site network

3.58 Where the new installation will be connected into part of the healthcare site's existing network, the application to connect will take the form of a "completion certificate" as identified in BS 7671:2001. The healthcare facility will be entitled to conduct a range of tests to be satisfied that the installation is safe for energising and that any fault currents which may arise are cleared before reflecting onto the remaining part of the healthcare site's network.

3.59 The site engineer should reserve the right not to connect a new installation where the installation does not comply with the guidance given in this Health Technical Memorandum and local electrical safety guidance. The site engineer may also reserve the right not to connect a new installation where the installation compromises the distribution strategy of any other part of the electrical network.

3.60 At a very early stage of the design (or if appropriate, procurement planning), the designer should assess the power requirement and subsequently make a request for a suitable supply.

Supply from the DNO

3.61 Where the new supply will be direct from the DNO, the designer should contact the DNO for the appropriate forms. The cost of the supply will reflect the level of infrastructure reinforcement.

Supply from internal connection point

3.62 Where the new supply will be connected to part of the healthcare facility's existing internal distribution, the designer should liaise with the site engineer to determine the most appropriate connection point, and the required method and degree of reinforcement of the internal distribution.

4 Understanding risk and ownership

4.1 This chapter deals with the assessment of risk and the need to ensure that the design of the primary electrical infrastructure (PEI) adequately protects the end-user, and in particular patients, from electrical failures. It promotes multidisciplinary design-team and stakeholder involvement throughout the design process to ensure an appropriate distribution strategy (see Chapter 6), incorporating resilience, redundancy and duplication as necessary. This should identify any "residual risks" from the design. The identification of the residual risks will enable the healthcare organisation to manage their collective ownership of risk management and hence make appropriate non-electrical and/or fixed wiring operational and emergency contingency plans in accordance with DH Emeregency Planning Guidance.

Introduction

4.2 A failure can occur at any point or at any time in any electrical system, regardless of the design standards employed. The design and installation of PEI systems inherently allows failure (by operation of a protective device) to minimise the risk of danger and/or risk of injury. This is true of internal PEI systems as well as the wider PES network delivered by the DNO. The effects of accidental damage and the need for maintenance and training should not be overlooked. It is essential that an appropriate level of risk management is considered and practical emergency contingency plans are always available and ready to implement.

Need for risk assessment

4.3 Appropriate controls should be put in place to reduce any risk to an acceptable manageable level. It is essential that, at the very least, legislative requirements be met and risk be managed proactively.

4.4 A complete risk assessment for a sustainable electrical supply is a key duty of care owed to patients, staff and visitors.

4.5 The design process should ensure that single points of failure are minimised by providing the appropriate level of resilience at the point of use. Risk management carefully balances the approach to a design strategy with the cost/benefit relationships, where cost represents investment, business continuity and operational risk.

4.6 Failures of the PEI system are commonly considered as a consequential effect of the failure of the incoming DNO supply, main transformer, main switchboard etc. In these cases, it is assumed that the emergency power system (secondary and/or tertiary power supply) is available. However, failure of the PEI itself is also possible. All potential points of failure should therefore be considered during the design process. The emergency supply system design may be different for each type of failure.

Note

An inappropriate level of resilience or response to a failure may compromise patient safety.

Ownership and design

4.7 The duties of the stakeholders involved in the design, or assessment and operation, of an existing infrastructure should ensure (as far as reasonably practicable) that all risk levels and the likelihood of an electrical failure are balanced against the consequences of such failures. All stakeholders and designers should understand and accept the intended operation, limitations and inherent possible failure scenarios of the electrical system and, where necessary, implement contingency arrangements where risks of electrical failures cannot be, or are not, mitigated within or by the electrical system itself. These risks will include those inherent and residual from the design strategy (see Chapter 6). For example, the stakeholders and designers may agree that it is an acceptable risk that clinical risk Category 1 and 2 areas (see paragraphs 4.12–4.24) need not have any embedded secondary

power source (SPS) to cover an outage of the electrical system. The management of such residual risks may therefore be to reorganise any postponed elective consultations.

Risk profile

4.8 This Health Technical Memorandum divides risk into two core elements: clinical risk (subdivided into patient and non-patient areas) and non-clinical business continuity risks (subdivided into medical services and engineering services). Designers and stakeholders should consult with medical and technical staff to evaluate the overall risk and the measures proposed to address the perceived outcomes. Most critical within this assessment is the mobility and degree of healthcare support provided to the patient, including medical procedures, critical care and continuity of treatment.

4.10 Small healthcare premises such as GP practices and health clinics/centres may have areas that fall into Category 1 and possibly Category 2. Community hospitals may have departments in Categories 1, 2 and 3, but unlikely in Category 4 or 5. Large acute healthcare premises and above may well have departments in all categories. There is no rule that definitively places healthcare premises in any one category, or defines one category for a particular healthcare site.

4.11 Each healthcare facility will have a mixture of categories (clinical risks and non-clinical business continuity risks) in varying ratios. The assessed higher clinical or non-clinical and business continuity risk for any particular area will determine the adopted electrical infrastructure strategy for that area. Designers and stakeholders should evaluate the economics of providing different distribution strategies (see Chapter 6) for each risk category area, or of applying an appropriate distribution strategy for the highest-order risk category to many or all areas.

Clinical risk

4.12 Within any healthcare environment, there are wide ranges of departments with complex requirements and potential risks. The risk management process will categorise each department in terms of susceptibility to risk from total (or partial) loss of electrical supply.

4.13 The consequence of a power failure is assessed and categorised against some broad clinical patient groups and patient care plans. This is on a scale from ambulant through to critical care. Consequence is also related to the organisation in terms of contingency arrangements, emergency preparedness and business continuity, all of which have a financial implication. There is also the operational consequence of the electrical system in terms of the operation and maintenance of the infrastructure from the point of view of both its physical construction and installation, and the managerial and technical staff structure in place to operate the electrical infrastructure.

4.14 The level of consequence of a power failure may be evaluated as increasing with patients' clinical category, for instance, and the level of consequence per category will equally be dependent on the duration and extent of the failure.

4.15 IEE Guidance Note 7 (also IEC 60364-7-710) addresses "special locations". Chapter 10 of the IEE guide deals with specific in-patient areas and classifies the dependence certain healthcare departments have on a sustainable electrical supply. The guide relates in part to the reliability of electrical supplies and their subsequent safety requirements. These classifications are ranked in time performance (seconds) to re-establishing a supply following an interruption, whether controlled or otherwise.

4.16 Within a GP practice or health centre, it may be assessed as acceptable to have single points of failure in a system, given that patients are likely to be more mobile than patients in critical care areas, and staff will be able to move away from the affected area in the event of a power failure. At the other end of the scale, for example in critical care areas, the consequence of a prolonged, or even a very short, power failure could be serious health disabilities or, in the worst cases, fatality. In this instance, a more resilient infrastructure with additional levels of secondary and/or tertiary power supplies would be appropriate.

4.17 While it is not intended to be absolute, this section should be sufficient to prompt the necessary discussion at all stages of the design process. The categories given are intended to demonstrate a range of patient risk from an electrical fault or loss of electrical supply.

4.18 Consideration of the categories in Figure 6 should establish a minimum acceptable risk option at the

point of treatment or care. For the purpose of this guidance, the patient levels described are not intended to be exhaustive, but rather an aid to consider the issues.

Category 1 – Support service circulation

4.19 These areas do not directly relate to the patient environment of any group under Chapter 10 in 'IEE Guidance Note 7'. The areas include circulation spaces, waiting areas, offices and non-patient care areas such as laboratories or finance departments. Consequently, engineering services do not have an immediate effect on the clinical treatment or safety of patients (notwithstanding the requirements of the escape lighting and so on that may be provided from a local tertiary power source).

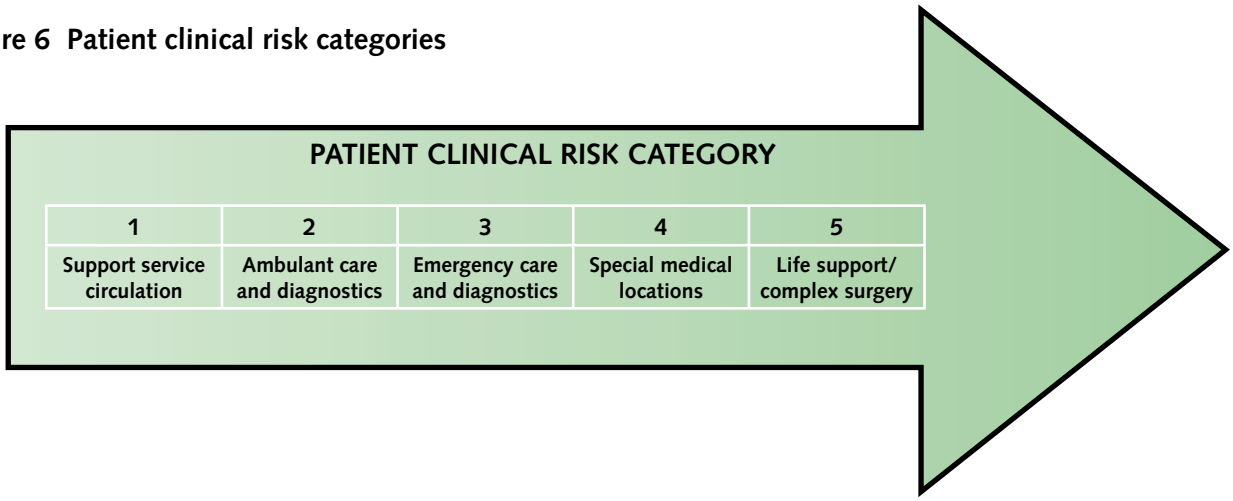
Category 2 – Ambulant care and diagnostics

4.20 These areas do not directly relate to the patient environment of any group under Chapter 10 in 'IEE Guidance Note 7'. The areas may include patients in consultation (excluding examination) or general out-patient areas. Loss of supply may give rise to disruption, inconvenience and a reduced environmental quality but would not directly compromise patient clinical treatment and safety. The loss of electrical power to other engineering services (for example ventilation or medical gases) equally will not cause concern for the safety of the patient or staff. There may be a business continuity risk if these areas are not connected to the SPS for supply failures that last greater than three hours (notwithstanding the requirements of the escape lighting etc that may be provided from a local tertiary power source).

Category 3 – Emergency care and diagnostics

4.21 These areas relate to the patient environment of group 0 under Chapter 10 in 'IEE Guidance Note 7'. The areas will include mental health wards and some maternity areas. Patients are not generally connected to any electro-medical equipment. However, medical monitoring or medical test equipment may occasionally be used and connected externally to the patient's body for a short or intermittent time (for example patient monitors or ultrasound machines). Clinical treatment and patient safety will not be compromised by an interruption of electrical power. However, the interruption of electrical power should be limited to less than 15 seconds for other engineering services used in the support of the clinical treatment such as medical gases, hot and cold water, HVAC, communication etc (notwithstanding the requirements of the escape lighting etc that may be provided from a local tertiary power source).

Figure 6 Patient clinical risk categories



Category 4 – Patients in special medical locations

4.22 These areas will relate to the patient environment of group 1 under Chapter 10 in 'IEE Guidance Note 7'. The areas may include LDRP (labour, delivery, recovery, post-partum) areas (maternity), endoscopy rooms, accident and emergency general/minors, haemodialysis areas, ECG areas, nuclear medicine, radiography diagnostic, magnetic resonance imaging (MRI), endoscopic examination rooms, urology treatment areas, or therapy rooms and ultrasound. Patients may have electro-medical equipment, medical monitoring or medical test equipment connected externally to their body for a prolonged period. Clinical treatment and patient safety may be compromised (but not endangered) by any interruption of electrical supply. Electrical protective devices should include an RCD, but may not require an IPS circuit. Supplementary equipotential bonding will be required in the patient environment. Any interruption of the electrical supply to medical equipment should be limited to within 15 seconds. Consideration may be given to providing an alternative electrical supply (tertiary power supplies) within 0.5 seconds, subject to the range of patient treatment. Other engineering services used in support of clinical treatment should be connected to the SPS within 15 seconds of any interruption of the electrical supply (notwithstanding the requirements of the escape lighting and so on that may be provided from a local tertiary power source).

Category 5 – Life support or complex surgery

4.23 These areas will relate to the patient environment of group 2 under Chapter 10 in 'IEE Guidance Note 7'. The areas are defined as operating theatre suites, critical care areas, cardiac wards, catheterising rooms, accident & emergency resuscitation units, MRI, angiographic rooms, PET and CT scanner rooms. Patients may have electro-medical equipment, medical monitoring or medical test equipment (for example intracardiac procedures) connected externally or internally to their bodies for a prolonged period. Clinical treatment and patient safety may be compromised by any interruption of electrical supply. A patient's natural electrical resistance is significantly reduced when electro-medical conductive parts are placed in the body. Supplementary equipotential bonding (within the patient environment) should be provided for patient safety. Best practice provision should include, but not be limited to, IPS systems and the provision of an alternative electrical supply (tertiary power supplies) within 0.5 seconds of any interruption of the electrical supply if required by the medical equipment. Other engineering services used in support of the patient clinical treatment should be connected to the secondary power source (SPS) within 15 seconds of any interruption of the electrical supply (notwithstanding the requirements of the escape lighting etc that may be provided from a local tertiary power source).

4.24 Tertiary power supplies such as a UPS (see paragraphs 16.3–16.19) or a battery, within the equipment, may be considered as a method to limit the interruption of electrical supply to less than 0.5 seconds. Standby generator(s) (see Chapter 8) may be considered as a method of limiting the interruption of electrical supply between 0.5 seconds and 15 seconds. In Category 4 or Category 5 areas, a patient may be at risk from both a general loss of supply and a local final subcircuit fault. In Category 5 areas, enhanced levels of resilience for the provision of patient therapies may be required. This may be provided by interleaved circuits at the bed-head or pendant. Such arrangements will assist in the ability to perform maintenance with minimal disruption.

Non-clinical and business continuity risk

4.25 While clinical risk is the important factor in the design of PEI in healthcare premises, it does not just relate to the criticality of patients. There are numerous supporting elements and departments essential to continuity of care and business continuity.

4.26 The failure of these services should be assessed on the same basis as the clinical risk. The increasing reliance on information technology and electronic medical records is an obvious example of this,

where the loss of electrical power could affect essential diagnosis of a patient or the ability to operate a clinic. Essential items of building services and plant may also necessitate the closure of departments in the event of a power failure where these services are not adequately protected by a resilient electrical system.

4.27 Consideration of the categories in Figure 7 should establish a minimum acceptable risk option at the point of treatment or care. For the purpose of this guidance, the non-clinical and business continuity described is not intended to be exhaustive, but an aid to consider the issues.

Category 1 – Business support services

4.28 The business support areas are departments such as finance, stores, laundries and workshop areas. In general, an interruption of the electrical supply may not compromise the treatment or welfare of patients. It may be appropriate to provide a single-conversion UPS (see paragraphs 16.3–16.19) to allow certain systems such as computer applications to shut down safely. Electrical load management systems may prove useful where the interruption to the electrical supply (for these areas) is for more than four hours (see paragraphs 8.17–8.19; notwithstanding non-patient safety measures with the provision of a tertiary power source).

Category 2 – Building services safety and security

4.29 The requirements for these facilities are covered by various British and European legislative documents, for example BS 5839-1:2002. Typically, battery packs or single-conversion UPS systems will support such requirements. An interruption of the electrical supply could compromise the safety and welfare of patients. These facilities may be included on the SPS, where the sum of their respective loads would only represent a very small percentage of the SPS. An understanding of the need for maintenance and the capacities of any such battery packs employed on these facilities will be required (notwithstanding the requirements of the escape lighting etc that may be provided from a local tertiary power source).

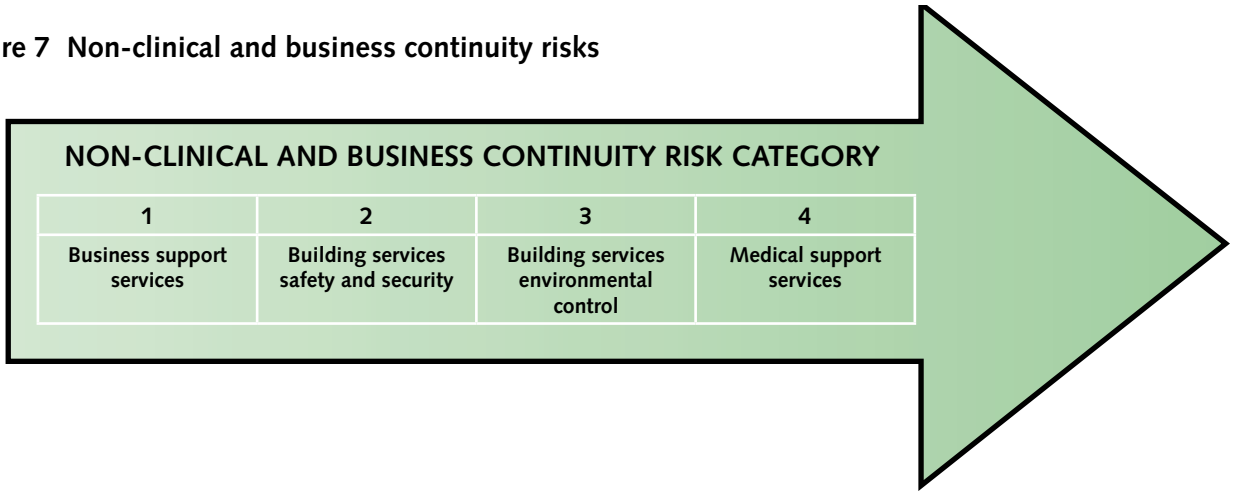
Category 3 – Building services environmental control

4.30 The building services environmental control systems will include HVAC systems, hot water services, energy centres and building energy management systems. In general, an interruption of the electrical supply could represent a compromise to the treatment or welfare of patients. A single-conversion UPS should be provided to allow certain systems such as computer applications to be shut down safely. Electrical load management systems should be considered where the interruption to the electrical supply (to, say, chilled water systems) gives an unacceptable rise in the internal space temperature by internal heat gains (see paragraphs 8.17–8.19; notwithstanding the requirements of the escape lighting etc that may be provided from a local tertiary power source).

Category 4 – Medical support services

4.31 The medical support areas are departments such as disinfection units, laboratories, medical records, and physiotherapy. An interruption of the electrical supply may represent a slight disruption to the treatment or welfare of patients. A single-conversion UPS (see paragraphs 16.3–16.19) should be provided to allow certain systems such as computer applications to be shut down safely.

Figure 7 Non-clinical and business continuity risks



Electrical load management systems may prove useful where the interruption to the electrical supply (for these areas) is for long periods, say more than two hours (see paragraphs 8.17–8.20; notwithstanding the requirements of the escape lighting etc that may be provided from a local tertiary power source).

Electrical infrastructure

4.32 This Health Technical Memorandum divides electrical infrastructure into two core sections: primary and secondary (see Chapter 6):

- the two types of distribution may share the same cables, which defines a unified electrical infrastructure;
- where there are two sets of cables common to the primary and secondary distribution, the network is said to be a dual-unified distribution;
- where the primary and secondary distribution has entirely separate cables, the distribution strategy is said to be a segregated distribution.

The most resilient distribution strategy will have both dual-unified distribution and primary and secondary power sources.

4.33 Business continuity risk assessments evaluated by "cause-and-effect" models may be used to analyse the impact of electrical failures on departments which are reliant on the services provided. Within the integrated departmental model, consideration should be given to the cause and effect of electrical failures which escalate exponentially with time.

4.34 Cause-and-effect risk models are used to analyse the global electrical infrastructure from intake to point-of-use equipment. The risk evaluation should consider single electrical faults that cascade into multiple electrical faults and unrelated simultaneous multiple faults (see Chapters 6 and 9).

4.35 A distribution strategy should be developed that drives the risk of failure of an electrical supply (at the point of use) to a low or residual risk (Figure 8). A lower distribution strategy with increased redundancy of primary and/or secondary power supply plant – which still achieves the same risk level indicated above – should be adopted. Further consideration may be given to accepting a slightly higher risk factor than the indicated lowest possible for a particular clinical area.

Resilience

4.36 Overall, the PEI can be considered in three main sections:

- supply;
- distribution;
- point of use.

4.37 The essential elements of a resilient infrastructure are:

- redundancy;
- moving the first "single points of failure" as near to the point of use as possible;

Figure 8 Electrical failure risks evaluation to clinical categories

RISK OF ELECTRICAL FAILURE BY INFRASTRUCTURE

Risk by clinical category (refer to Chapter 4 under 'Clinical risk')	Distribution strategy (refer to Chapter 6)				
	Unified distribution	Unified and segregated distribution	Dual supply unified and dual unified distribution	Dual supply unified and dual unified distribution	Dual primary and secondary supply unified and dual unified distribution
Life support complex surgery	HIGH	HIGH	SIGNIFICANT	MODERATE	LOW
Special medical locations	SIGNIFICANT	SIGNIFICANT	MODERATE	MODERATE	LOW
Emergency care and diagnostic	MODERATE	MODERATE	MODERATE	LOW	RESIDUAL
Ambulant care and diagnostic	MODERATE	MODERATE	LOW	LOW	RESIDUAL
Support services and circulation	LOW	LOW	RESIDUAL	RESIDUAL	RESIDUAL

- appropriate access for practical maintenance and testing procedures.

4.38 The resilience required to maintain essential supply in the event of not only primary failures but also secondary failures should be considered. A suitable assessment of the likelihood of concurrent failures occurring within a foreseeable period should be made, and therefore the operation and inter-relationship of the system and its component parts should be fully understood. With regard to the consequence and risk, any reasonably foreseeable secondary failures should be appropriately protected against. An example here may be a standby generator failing to start (second-line fault) on a supply blackout (first-line fault).

4.39 Incoming electrical supplies may be constrained by what the DNO is able to provide, or what has been assessed as cost-effective for the type of healthcare facility. The distribution strategy should maintain the minimum acceptable resilience level throughout the internal electrical system.

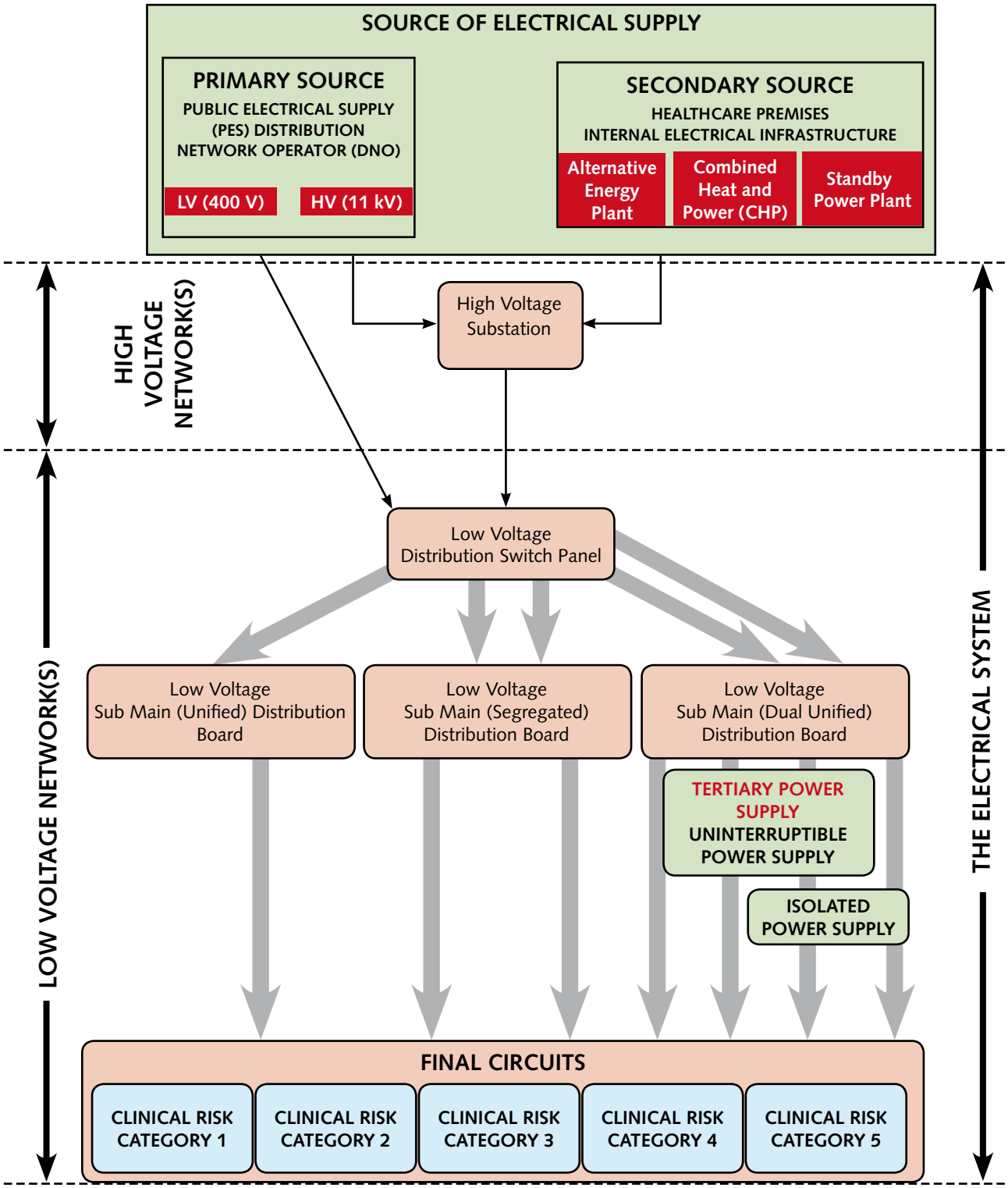
4.40 An iterative design process will help stakeholders to assess the distribution strategy. The process may be used to determine the location of the first single point of failure in addition to the method used to mitigate the risks on the distribution downstream of that point. The provision of tertiary supplies (UPS) on final distribution boards or the ability to manually reconfigure the distribution may be suitable risk mitigation.

4.41 The effects of electrical power failures due to faults at any level within the infrastructure can be designed out by the robustness of the network resilience. The distribution strategy should include adequate resilience and access space so that routine testing and maintenance can be carried out safely, without placing patients, staff and users at unnecessary risk. Such strategies may call for a redundancy in certain electrical equipment, for example generators, UPSs and IPSs. The provision of resilience for maintenance is considered best practice.

Electrical infrastructure system selection

4.42 A number of different elements link together to form the primary and secondary infrastructure system (see Figure 9). Some of the elements will be optional dependent on design strategy (see Chapter 6) and required resilience issues based on assessed risk from power failures. All possible configurations of the electrical infrastructure elements will have risk-mitigation strategies associated with the possibility of power failures occurring. Similarly, each element will link to other elements, and the links and interactions between them will present additional risk minimisation. The overall risk of a power failure occurring can be mitigated by the correct selection of element configurations and interconnections. Standard system and component configurations at appropriate infrastructure sections can be broadly categorised in terms of their resilience and therefore residual risks. Evaluating the cause and effect can make selection of the appropriate configurations apparent at the point of use (deepest part) of the infrastructure.

Figure 9 Electrical infrastructure generic flow diagram



5 Power quality

5.1 The quality of the electrical supply is the responsibility of the DNO, which will comply with the requirements of the Electrical Safety, Quality and Continuity Regulations. However, the use of the electrical energy within healthcare premises can affect the quality of the internal distribution in terms of power factor and harmonics.

5.2 Healthcare premises have numerous switch mode power supplies and inherently high inductive electrical loads and unless corrected, the power factor will be poor, requiring large transformers, cables and high-energy cost. Improving a typical poor power factor from say 0.75 lagging to an appropriate power factor of say 0.95 lagging will reduce the kVA demand by 20% and will be reflected as a utility cost savings. The actual inductive load will vary throughout the day and year. The inductive load will also vary across the site according to the location of mechanical plant, lifts and to some extent the clinical departments.

5.3 The normal supply frequency is 50 Hz with a tolerance of ±1%. The nature of the electrical equipment used throughout the site can inject secondary frequencies that cause significant disturbances to the internal distribution and the supply. The majority of secondary frequencies, known as harmonics, are generated from switch-mode power supplies found in a wide range of electrical and electronic equipment.

Power factor correction

5.4 The usual method of correcting a low power factor uses capacitive reactance to oppose the inductive reactance. Using capacitor banks with automatic step changes will ensure that the net reactance does not produce a leading power factor. There are three basic locations for power factor correction equipment.

Located at the intake point

5.5 Power factor correction can be installed at the main distribution intake point, in which case the entire electrical system will be corrected. The power factor correction equipment should be automatically disconnected if the primary supply is interrupted, and if used in conjunction with the standby generator plant (or CHP plant) adjusted to suit the generator (or CHP plant) manufacturer's recommendations. Where the only power factor correction equipment is located at the intake, the appropriate cable sizes for the higher currents should be used.

Located at sub-main distribution boards

5.6 Power factor correction can be installed at the sub-main distribution board, in which case only the outgoing circuits will be corrected. The advantage of power factor correction units installed at sub-main distribution boards is that several inductive loads can be corrected with one common unit. This will save on the capital cost and space required. Where the power factor correction equipment is located at the intake and sub-main distribution boards, the appropriate subcircuit cable sizes for the higher currents should be used. Similarly, the rating of the sub-main distribution board and protective equipment may need oversizing.

Located on the electrical equipment

5.7 Where individual pieces of equipment generate a high inductive reactance such as large motors, it is advisable to install the power factor correction direct to the motor. This arrangement has the advantage of reducing the voltage drop on the motor supply cable(s) and hence smaller distribution cables can be used.

5.8 Power factor correction equipment may generate harmonic currents as well as allowing the downstream harmonics to pass through. Therefore consideration should be given to the use of detuning inductors within the power factor correction equipment.

5.9 Power factor correction equipment can be installed as an integral part of a switchboard, or as a

freestanding unit. Where a cubicle of the switchboard is used to house the power factor correction equipment, consideration should be given to the effect this will have on future flexibility and remodelling of the power factor correction equipment and/or the switchboard circuits.

5.10 Power factor correction equipment requires natural ventilation to remove the small amount of heat it generates. Further information on the amount of natural ventilation should be available from the manufacturer.

Harmonics

5.11 The normal supply frequency is 50 Hz with a tolerance of ±1%. The nature of the electrical equipment used throughout the site can create secondary frequencies that cause significant disturbances to the internal distribution and the supply. The majority of the secondary frequencies, known as harmonics, are generated from short surge currents and transient currents arising from non-linear electrical loads such as switch-mode power supplies and rotating machinery, variable speed drives and so on found in a wide range of electrical and electronic equipment.

5.12 Surge transient currents are also caused by lightning strikes. Further details on the lightning strikes and surge arrestors can be found in paragraphs 13.39–13.49.

5.13 Even-order harmonic frequencies are self-negating and do not cause a real disturbance to the electrical distribution. Odd-order harmonics with zero rotation effect, known as "Triplen" harmonic frequencies (3rd-, 9th- and 15th-order), and odd-order harmonics (5th, 7th and 11th) can cause significant disturbances leading to high currents and voltages, and overheating of cables and equipment, particularly transformers.

5.14 Electrical systems must comply with the Energy Networks Association's Engineering Recommendations G.5/4, which limits the reflected total harmonic distortion (THD) at point of common coupling. For voltages up to 0.4 kV, the THD is 5%, whereas at 11 kV the THD is 4%. Designers should evaluate the sources of harmonic disturbances within the healthcare site's electrical network and the methods to mitigate the effects. Harmonics can be controlled by the use of harmonic filters (active or passive). The use of oversized neutral conductors (200% to 300%) will carry the harmonic current back to the transformer, which then should be sized for such currents and heat. Consideration should also be given to the use of clean-earth conductors for power supplies to items such as IM&T computer server and hub rooms. A single-phase third-harmonic current on a balanced three-phase circuit can produce currents at 70% of the fundamental current and flow within the neutral conductor. If the harmonic currents reach the distribution transformer they will be reflected into the primary delta winding and circulate. The unchecked harmonic current in the primary winding of a distribution transformer will be dissipated as unwanted heat and noise.

5.15 The network analysis of harmonic currents propagated within the electrical systems should be made and communicated to the supplier of any standby generator. The generator design will need to reflect the anticipated harmonic currents. Harmonic currents not allowed for within the generator design may cause excessive heating, high torque loads and consequently vibration within the generator while running. Only active harmonic filters or isolating passive harmonic filters should be used while the generator is online (see paragraph 5.18).

5.16 The electrical load of a typical healthcare facility with many modern medical facilities and support services may have non-linear loads (propagating harmonic disturbances) at 40% of the overall load. Unless the harmonics are controlled and eliminated downstream from the transformer primary winding, the transformer may need to be derated by the "factor-K method" (as defined in BS 7821), which may typically be 70% of the transformer nameplate kVA rating to avoid transformer damage.

5.17 Alternative methods may include using oversized neutral conductors, using separate transformers for linear circuits and using inductive loads or preferably harmonic filters. Active or passive harmonic filters should be used, which can be located in one of three locations depending on the source and severity of the disturbance.

Located at the intake point

5.18 Harmonic filters can be installed at the main distribution intake point, in which case the entire electrical system will be corrected. Any passive harmonic filters should be automatically disconnected when any standby generator plant is supplying the load. Harmonic filters should not be

located here, as large harmonic currents may require neutrals oversized by as much as 300%.

5.19 Note – for the purpose of this section of the guidelines, the intake point means the HV/LV substation, LV switchboard. Alternatively, where the site has an internal HV network, the intake point means each such substation LV distribution board.

Located at sub-main distribution boards

5.20 Harmonic filters may be installed at the sub-main distribution board, in which case only the outgoing circuits will be corrected. The advantage of harmonic filters installed at sub-main distribution boards is that several sources of harmonic inductive loads can be corrected with one common unit. This will minimise the harmonic disturbance reflected on the sub-main and main distribution cables and save on the capital cost and space required.

Located on the electrical equipment

5.21 Where an individual piece of equipment generates a high transient current or voltage from a switch-mode power supply, it is advisable to install active harmonic filters direct to the equipment. This arrangement has the advantage of reducing the harmonic disturbances on the final subcircuit cables.

Voltage surge protection

5.22 Consideration should be given to the provision of voltage surge protection at the LV intake point, where equipment which may be sensitive to such voltage surges is connected to the distributed installation from the intake.

6 Distribution strategy

6.1 For the purpose of this Health Technical Memorandum, it is assumed that the highest distributed voltage in any healthcare facility will be 11 kV. DNO connections to healthcare facilities may be at elevated voltages such as 33 kV, but it is considered that such voltages are not distributed within the healthcare site. Where healthcare facilities do have a DNO connection at voltages above 11 kV, the strategy for such connections (and if appropriate, distribution) should follow the distribution philosophy described in this chapter. This Health Technical Memorandum only considers any electrical energy used at low voltage as a three-phase or single-phase connection. This Health Technical Memorandum does recognise that some electrical energy used in healthcare premises will be at SELV or PELV, but is only concerned with the fixed wiring at low voltage. In a similar way, electrical energy used at high voltage, for some large vapour compression chillers for example, is acknowledged, but again this Health Technical Memorandum only addresses the fixed wiring at HV.

6.2 When designing the strategy for the electrical network(s), it is essential to take a holistic approach. The electrical system may include HV and LV distribution networks, or just LV distribution networks, depending on the size of the site.

6.3 The topology of the LV network(s) can provide the most resilient service at the point of use. The cost of such security of supply may be compromised if the HV system is not equally resilient. Best practice is achieved when the distribution strategy places the first single point of failure as close to the final subcircuits as practical to satisfy the critical nature of the healthcare facility while remaining financially viable.

6.4 The required system resilience can be achieved in two basic ways, first by having dual circuits and secondly by having an alternative power supply. Standby generators can be connected at the intake point or may be connected at specific LV switchboards. While this chapter describes the resilience provided by generators, it does not describe the starting or control methods, which can be found in Chapter 8.

6.5 The resilience can be enhanced at the final distribution board with the use of tertiary power supplies such as UPS (see paragraphs 16.3–16.19). Alternatively, the resilience can be enhanced with battery packs fitted to medical equipment such as intravenous (IV) pumps. Further guidance on alternative supplies can be found in Chapter 8. This section deals with the strategy and design of the fixed wiring network to achieve the desired resilience.

6.6 To achieve this resilience, all stakeholders and designers should contribute to the risk assessment debate (see Chapter 4).

6.7 The available electrical supply rating should be verified with the DNO. Most DNOs will provide between 500 kVA and 800 kVA as a single LV (0.4 kV) connection. Supply ratings between 750 kVA and 12 MVA should be supplied at high voltage (11 kV). Where a healthcare facility has an assumed maximum demand (AMD) greater than 12 MVA, the DNO connection should be at 33 kV or above. Clearly, where the healthcare facility has an AMD no more than 500 kVA, the internal electrical infrastructure will only be at low voltage; other AMDs will require an HV and LV internal infrastructure.

Design for resilience

6.8 Throughout this Health Technical Memorandum (and in common parlance) resilience is expressed in terms of "N+1". This Health Technical Memorandum considers N+1 to mean the normal total requirement plus one resilient unit. For example, where the electrical demand is 1000 kVA, two transformers at 1000 kVA would satisfy the N+1 definition. However, three 500 kVA transformers would also be defined as N+1, as the normal element comprises two units. When

calculating the resilience of a system it is important to consider elements that are mutually inclusive and not mutually exclusive. For example, the standby generator complement (with a common point of coupling) would be a mutually inclusive system. The standby generator complement and primary electrical infrastructure at a common point of coupling are mutually exclusive. Best-practice electrical distribution strategy solutions provide resilience to the first-fault conditions at a common point of coupling. Distribution strategies that provide resilience above the first-fault condition (at a common point of coupling) are unlikely to be economically viable. Distribution strategies that provide N+1 resilience at several different points of common coupling are more robust and economically viable.

Supply connections

6.9 In electrical supplies to large healthcare premises (in electrical terms this means greater than 2 MVA), a general arrangement with a dual-PES connection should be adopted, arranged with either an auto-changeover or a manual-selection switch. Dual supplies with diverse routes may be considered an economic strategy to maximise the resilience and minimise the actual single point of failure. They should originate, if possible, from separate DNO substations, ideally fed from separate parts of the National Grid, with independent cable routes to the healthcare site's substations. However, the origin and nature of the PES supply routes will largely be beyond the control of the designer or stakeholders.

6.10 Two separate HV supply feeders (or LV if appropriate) may provide an additional safeguard (for the healthcare site) against a PES connection failure. Whether this is practicable largely depends on the local distribution system and the DNO. The healthcare organisation will not be in control of the PES network and therefore cannot influence the value of a second diverse routed connection. The healthcare organisation has more control over any embedded resilience and internal backup power sources, which may provide more robust security of electrical power.

Risk of transformer failures

6.11 The only moving part of a transformer is the tap-changing mechanism, which may be discounted when considering transformer reliability. As a result, transformer reliability can be as high as 99.999% (or 0.001% unreliable), which could mean 5.25 minutes unavailability per year. However, the issue is the time to repair or replace a faulty transformer, which may be at least one week. Distribution strategies that have two transformers with a common primary supply but have their secondary linked by a normally open bus coupler would provide a transformer system resilience of N+1. While both transformers are on duty, they would share the instantaneous load at 50% each. Opportunities for transformer and busbar maintenance are improved, as well as improved continuity of supply following a transformer outage. Such arrangements are shown for the intake substation (ISS) in Figure 13. Transformers connected in parallel or operating transformers on no load are not recommended.

Risk of generator failures

6.12 Generators have many moving parts requiring lubrication, cooling and control. The standby generator controls are electronic and electromechanical devices used to modulate the output in response to the demand inputs. Standby generators should be maintained in an operational readiness state in order to provide their principal function of standby supply. Generator reliability may be of the order of 99.95% (or 0.05% unreliable), which equates to 4.5 hours unavailability per year. The majority of generator failures are a result of the generator not starting or occur during the first five minutes after starting.

6.13 Distribution strategies that have two standby generators (each rated at full load) with a common point of coupling with the distribution network would provide generator system resilience of N+1. Three standby generators, similarly connected, all rated at 50% of the connected design load, would also provide a generator system resilience of N+1. Three generators each rated at 100% of the connected design load would provide N+2, but may be difficult to justify economically. Opportunities for standby generator and busbar maintenance are improved, as well as improved continuity of supply following a generator outage (while the sets are on line). Such arrangements are shown in Figure 17.

Other reasons for failure of electricity supply

6.14 The following list provides further reasons for failure of the main internal electrical distribution systems, all of which are minimised by adopting

the guidance within this Health Technical Memorandum (Parts A and B) and the guidance given in Health Technical Memorandum 06-02 – 'Electrical safety systems':

- cable faults within the private network;
- inappropriate grading of protection devices;
- poorly designed network with common points of failure;
- reliance on one form of standby protection;
- accidental isolation.

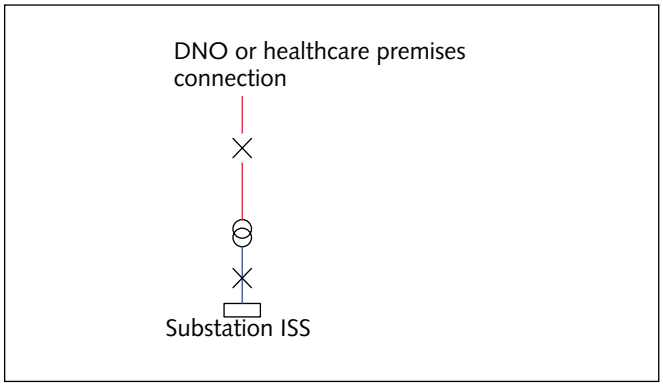
Distribution system – high voltage

6.15 Healthcare premises with an AMD greater than 800 kVA will require an internal HV network. There are two basic forms, radial networks (for AMDs up to say 3.5 MVA) and ring networks (for AMDs above 3.5 MVA).

6.16 The following simplified schematics are provided to show the main HV supply arrangements. They are arranged generally in order of resilience from low to high, but their selection as a design solution will be dependent on the supply arrangement available from the DNO, the type of healthcare facility, and the level of assessed risk with regard to end-users. Where typical HV distribution arrangements are shown connected to the LV distribution, these are included only to assist in the understanding of the LV arrangements. LV distribution arrangements are considered more fully in paragraphs 6.31–6.59. This section does not describe the control of any standby generator system (see Chapter 8 for details).

HV network – one radial circuit with one substation only

Figure 10 HV network – one radial circuit, one substation



6.17 A single HV supply from the DNO feeds onto the healthcare site's HV-switchboard part of the substation. This would typically be up to, say, 1500 kVA.

6.18 This type of distribution strategy is appropriate for a small to medium-sized acute hospital. As there is only a primary source of supply, this system creates a single point of failure right through to the LV distribution switchboard(s). Designers and stakeholders should consider the benefits afforded by the additional resilience that may be required, dependent on the clinical risks (see Chapter 4).

6.19 The resilience of the HV supply of Figure 10 may be enhanced by including a secondary source of supply at the intake, as a second DNO connection, or an LV standby generator at the LV switchpanel. Clearly, generators at the LV switchpanels would add resilience to the internal distribution. Having multiple LV standby generators is unlikely to provide any economic benefit.

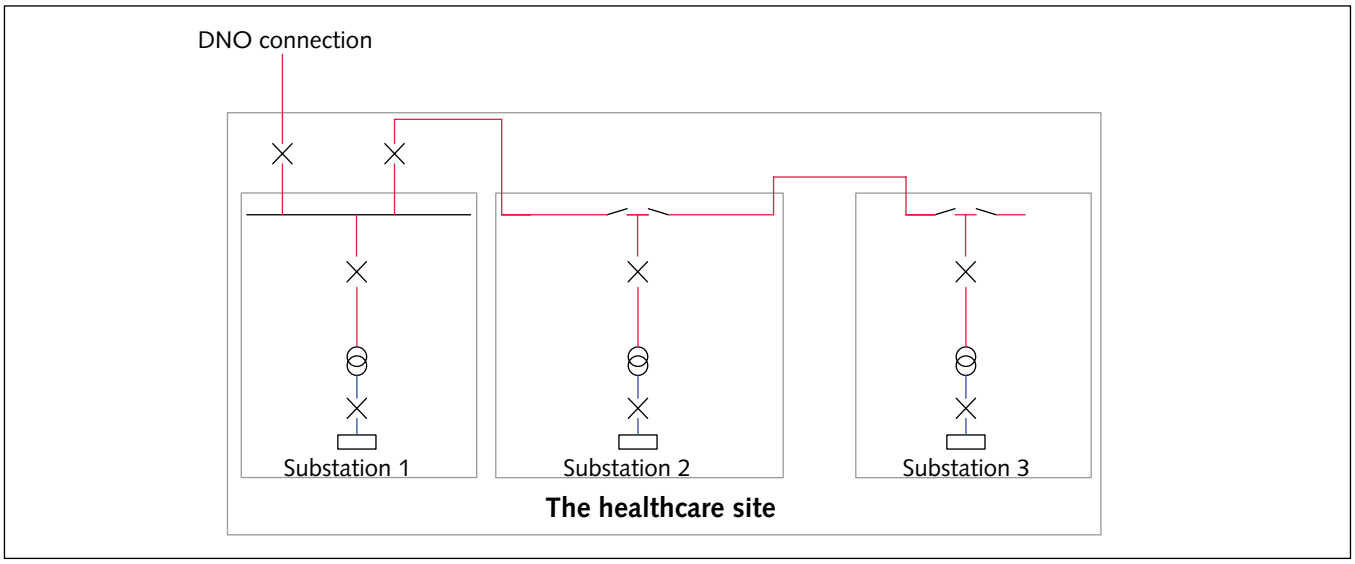
HV network – one radial circuit with three substations

6.20 In Figure 11, a single HV supply from the DNO feeds onto the healthcare site's HV-switchboard part of the substation. From the intake substation, a single HV radial circuit connects up to two more HV substations. Each of the substations would typically be up to say 1500 kVA; however, the AMD for the healthcare site would be between 800 kVA and 3.5 MVA.

6.21 This type of distribution strategy may be appropriate for a healthcare site with many detached buildings. The areas served by any single substation do not exceed a clinical risk assessment of Category 2. As there is only a primary source of supply, this system creates a single point of failure right through to the LV distribution switchboard(s). The benefits afforded by additional resilience that may be required are dependent on the clinical risks (see paragraphs 4.12–4.24).

6.22 The resilience of the HV supply may be enhanced by including a secondary source of supply at the intake as a second DNO connection. Additional transformers at each substation (all 100% rated and not connected in parallel), or LV generator(s) connected at the LV switchpanels, may also enhance the infrastructure resilience. The second transformers at each substation will provide additional resilience and reduce the impact of transformer failure and maintenance. Standby

Figure 11 HV network – one radial circuit, three substations

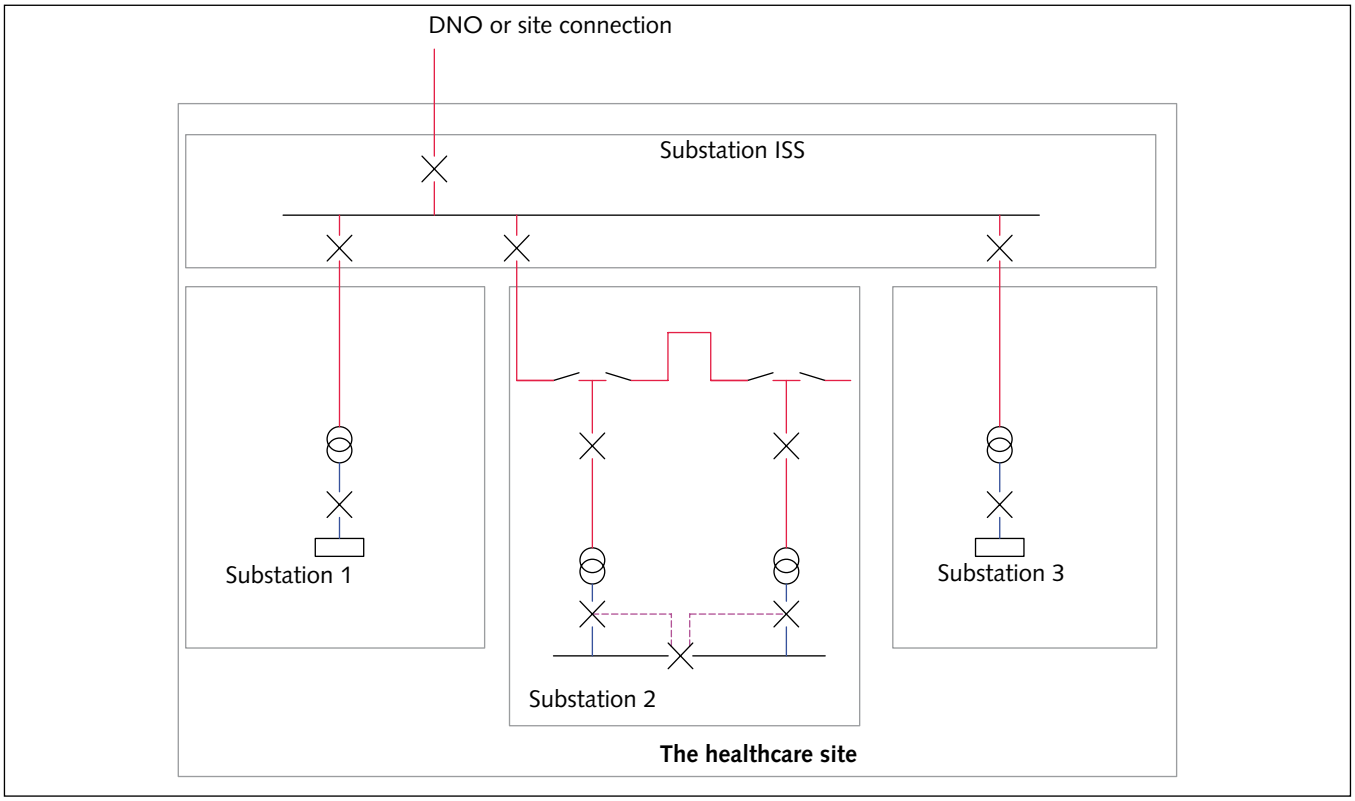


generators could be local to each substation or in a common central facility, depending on the spread of the site. Clearly, the generator at LV switchpanels would add resilience to the internal distribution. Having multiple LV generators at a common central facility may provide economic benefit to the healthcare facility during maintenance periods.

HV network – three radial circuits each with one substation

6.23 In Figure 12, a single HV supply from the DNO feeds onto the healthcare site's HV-switchboard part of the substation. From the intake substation, three HV radial circuits, each with one substation, are connected. Each of the substations would typically be up to 1500 kVA; however, the AMD for the healthcare site would be between 800 kVA

Figure 12 HV network – three radial circuits each with one substation



and 3.5 MVA. This distribution network is an enhancement of that in Figure 11 above, as failure of any part of the internal HV electrical infrastructure will affect a smaller area. The dual 100%-rated transformers (not operated in parallel) of substation 2 will provide improved transformer and switchgear maintenance opportunities for that area.

6.24 This type of distribution strategy may be appropriate for a healthcare premises with many detached buildings. The areas served by any one substation do not exceed a clinical risk assessment of Category 3. As there is only a primary source of supply, this system creates a single point of failure right through to the LV distribution switchboard(s).

6.25 The resilience of the HV supply of Figure 12 may be enhanced by including a secondary source of supply at the intake as a second DNO connection. Standby LV generator(s) connected at the LV switchpanels will enhance the infrastructure resilience and facilitate improved transformer maintenance opportunities. Standby generators could be local to each substation or in a common central facility, depending on the spread of the site. Clearly, the standby generator at LV switchpanels would add resilience to the internal distribution. Having multiple LV generators at a common central facility may provide economic benefit to the healthcare facility during maintenance periods.

HV ring network – ring with four substations

6.26 In Figure 13, a single HV supply from the DNO feeds onto the healthcare site's HV-switchboard part of the substation. From the intake substation one HV ring-circuit connects to all other internal HV substations (which may be more than the four shown here). Each of the substations would typically be up to say 1500 kVA; however, the AMD for the healthcare site would be greater than, say, 3.5 MVA. This distribution network is an enhancement of that in paragraphs 6.23–6.25, as failure of any part of the internal HV ring electrical infrastructure will affect a smaller area. Following a ring distribution fault, the manual or automatic operation (where the switchgear has suitable controls) of network ring switch positions will restore the inherent resilience.

6.27 The HV ring network of Figure 13 indicates the four basic types of HV substation: single and dual ring main units, single or dual circuit breakers. The intake substation should consist of circuit breakers, and all field substations should have a common switch type. See Chapter 9 for additional details of HV protection and switchgear details.

6.28 This type of distribution strategy may be appropriate for a large acute hospital with several other support facilities on the same site. The areas served by the ISS substation and substation 3 may include clinical risk assessments of Category 4 or Category 5. The areas served by substation 2 and substation 4 may include clinical risk assessments of Category 3. As there is only a primary source of supply, this system creates a single point of failure right through to the LV distribution switchboard(s).

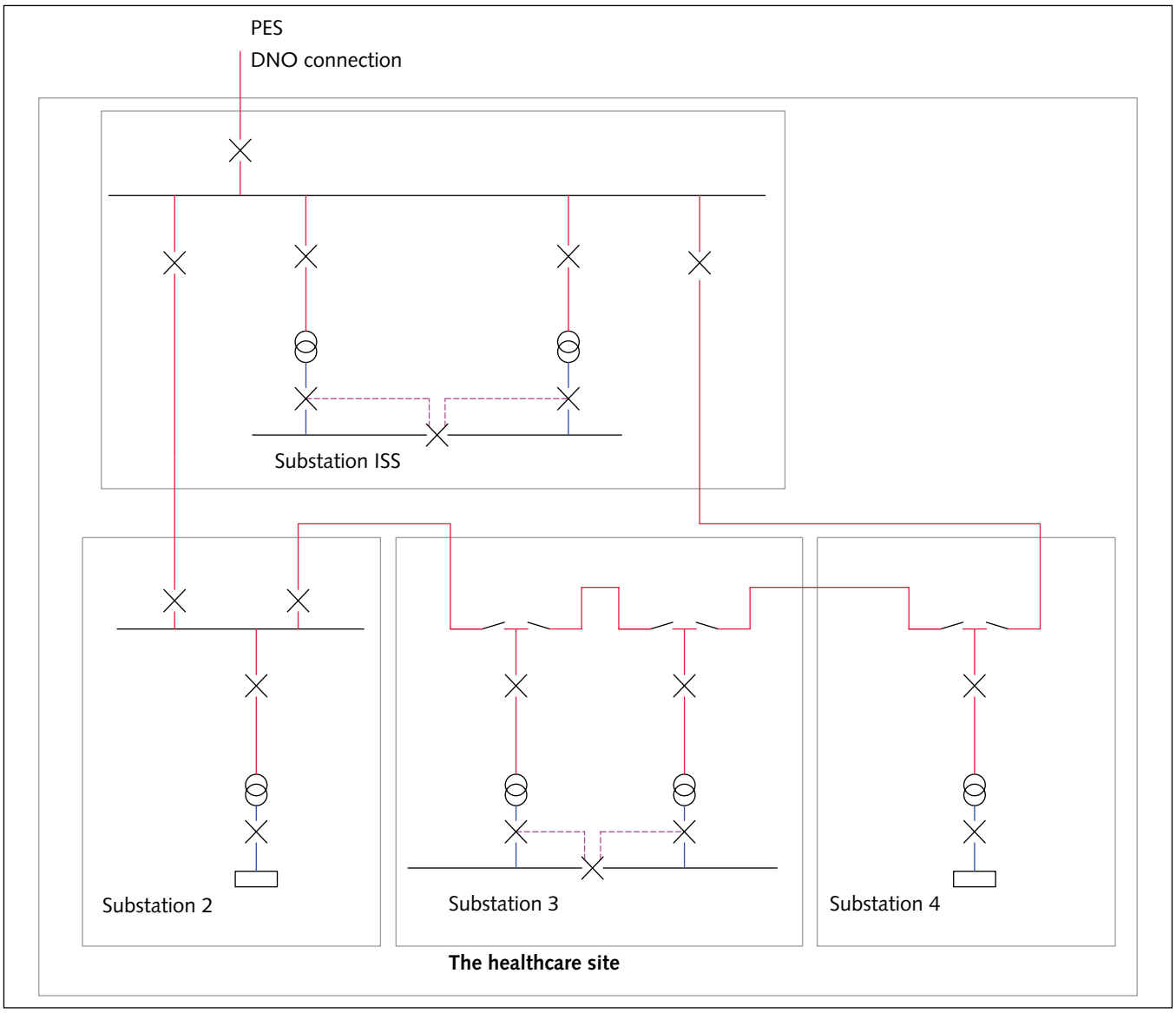
6.29 The resilience of the HV supply of Figure 13 may be enhanced by including a secondary source of supply at the intake, as a second DNO connection. Additional transformers at each substation (all 100% rated and not connected in parallel), or standby LV generator(s) connected at the LV switchpanels, may also enhance the infrastructure resilience. The transformers at each substation may provide resilience and assist in transformer failure and/or maintenance. Standby generators could be local to each substation or in a common central facility, depending on the spread of the site. Clearly, the generator at LV switchpanels would add resilience to the internal distribution. Having multiple LV standby generators at a common central facility may provide economic benefit to the healthcare facility during maintenance periods.

6.30 The resilience of the HV ring network can also be enhanced if the ring normally operates in a "closed ring" control. Electrical faults may then be isolated to a discrete section of the ring (typically one substation leg or between two substations) and hence not affect the supply to any part of the healthcare site. An alternative level of resilience may be available by the introduction of a switch control monitoring and management system to the HV ring switch. Such a system can automatically reconfigure the HV network open position of the closed ring, and hence restore power to all areas, well within in a few minutes (see Chapter 9).

Primary and secondary distribution systems

6.31 All LV distributions should be configured as TN-S systems as defined by the IEE Regulations

Figure 13 HV ring network – ring with four substations



BS 7671:2001. Within special areas, medical risk Categories 4 and 5 and wet areas such as post-mortem rooms, the wiring system would be configured as a medical IT system with non-tripping earth fault for patient areas and tripping for wet areas by insulation monitors to IEC 61557-8 (see paragraphs 13.6–13.14 for more details). Consideration may be given to the use of a protected extra LV (PELV) system or a separated extra LV (SELV) system.

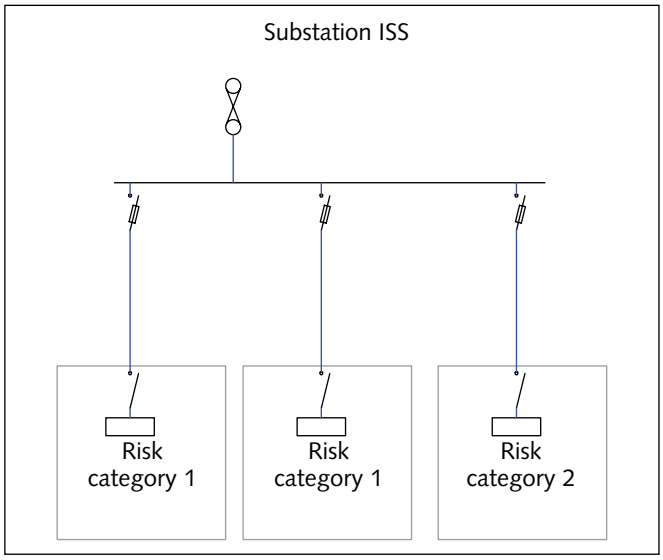
6.32 The following simplified schematics are provided to show the main LV supply arrangements. They are arranged in order of resilience from low to high, but their selection as a design solution will be dependent on the supply arrangement available from the DNO, the type of healthcare facility, and the level of assessed risk with regard to end-users.

6.33 The method of fire protection should be considered for essential distribution circuits, and the opportunities for flexible remodelling. For compliance with BS 5588, essential circuits associated with life-support services should be either fire-rated or fire-protected.

6.34 Single line representation is used in the diagrams for single- and three-phase distribution. Where typical HV distribution arrangements are shown connected to the LV distribution, these are included only to assist in the understanding of the LV arrangements. HV distribution arrangements are considered more fully in paragraphs 6.15–6.30.

Primary supply – unified infrastructure

Figure 14 Primary supply – unified distribution system



6.35 This is the simplest form of LV infrastructure with a primary supply only, direct either from the DNO or from a single HV transformer arrangement, feeding a unified LV distribution network. The transformer switchgear and main cables should be rated to take the AMD and an allowance for growth (see paragraphs 3.28–3.33).

6.36 The first single point of failure will be the connection point (to the DNO healthcare site's transformer). A LV infrastructure of this kind is appropriate for clinical risk Categories 1 or 2 (see paragraphs 4.12–4.24). This infrastructure does not provide for inconvenience-free maintenance opportunities. Therefore, the infrastructure lends itself to healthcare premises that do not operate 24 hours a day/7 days a week (24/7) facilities, and hence give rise to operational windows in business continuity.

6.37 Enhancing the infrastructure resilience and adding a facility to connect a mobile generator plant at the intake may improve the maintenance opportunities and business continuity. Alternatively, a tertiary power source, single-conversion UPS (see paragraphs 6.3–6.19) may be connected to dedicated equipment such as computer systems.

6.38 An assessment of the potential for expansion and/or remodelling of the healthcare premises should be made, to understand how the LV distribution of Figure 14 could accommodate such adaptations.

6.39 This simple arrangement may be appropriate for GP practices, health centres and office accommodation, dependent on the assessed level of risk posed by a failure.

Primary and secondary supply – unified and segregated infrastructure

6.40 This form of LV infrastructure has a primary supply, connected directly to either the DNO or the healthcare site's transformer, and a non-distributed secondary supply connected at an internal LV switchboard. The transformer, switchgear and main cables should be rated to take the AMD and an allowance for growth (see paragraphs 3.28–3.33). However, the standby generator is rated only for the segregated essential part of the healthcare site's electrical demand.

6.41 The first single point of failure will be the connection point (to the DNO healthcare site's transformer) for the unified non-essential circuits. However, the segregated essential circuits have a single point of failure much nearer the point of use. This infrastructure does not fully provide for inconvenience-free maintenance opportunities to all areas. Therefore, the infrastructure lends itself to healthcare premises that have part 24/7 facilities and part non-24/7 facilities. Enhancing the infrastructure resilience and adding additional standby generator units to the essential circuits may improve the maintenance opportunities and business continuity. Alternatively, a manual load management system coupled with the facility to interconnect the essential and non-essential circuit (via cables or a manual bus coupler) may offer a similar increased resilience (see Chapter 9).

6.42 An assessment of the potential for expansion and/or remodelling the healthcare premises should be made, to understand how the LV distribution of Figure 15 could accommodate such adaptations.

Primary and secondary supply – unified and dual-unified infrastructure

6.43 This form of LV infrastructure (see Figure 16) has a primary supply connected directly to either the DNO or the healthcare site's transformer, and a distributed SPS also connected at the intake LV switchboard. The transformer, standby generator, switchgear, and main cables should all be rated to take the full assumed maximum demand and an allowance for growth (see paragraphs 3.28–3.33).

6.44 The first single point of failure will be at the main LV switchboard for the unified circuits, and at the point of use for the dual-unified circuits. A LV infrastructure of this kind is appropriate for clinical risk categories 2, 3 or 4, where the dual-unified circuits are used in Category 3 or 4 risk areas (see paragraphs 4.12–4.24). This infrastructure may provide for inconvenience-free maintenance opportunities in the Category 3 or 4 risk areas. However, the same opportunities do not exist in the Category 1 and Category 2 risk areas, where the infrastructure resilience is only achieved by the standby generator subject to the operating demand. There is no resilience with the distribution cables

Figure 15 Primary and secondary supply – unified and segregated infrastructure

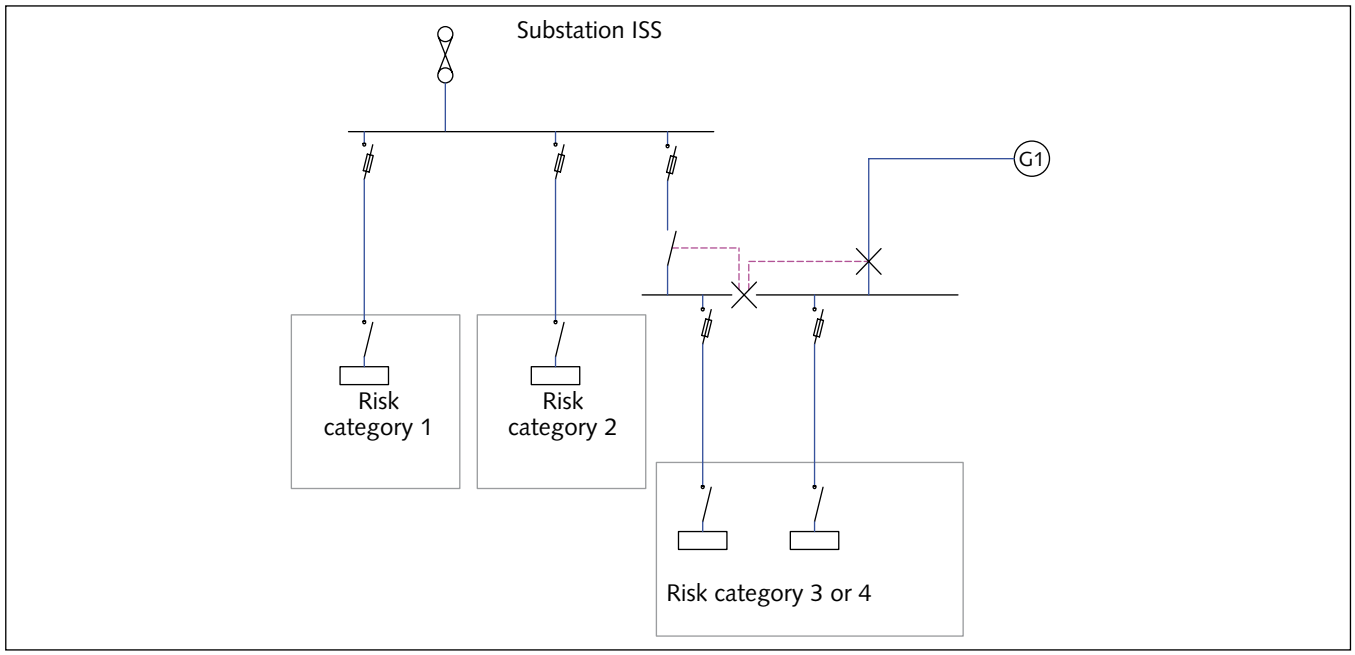
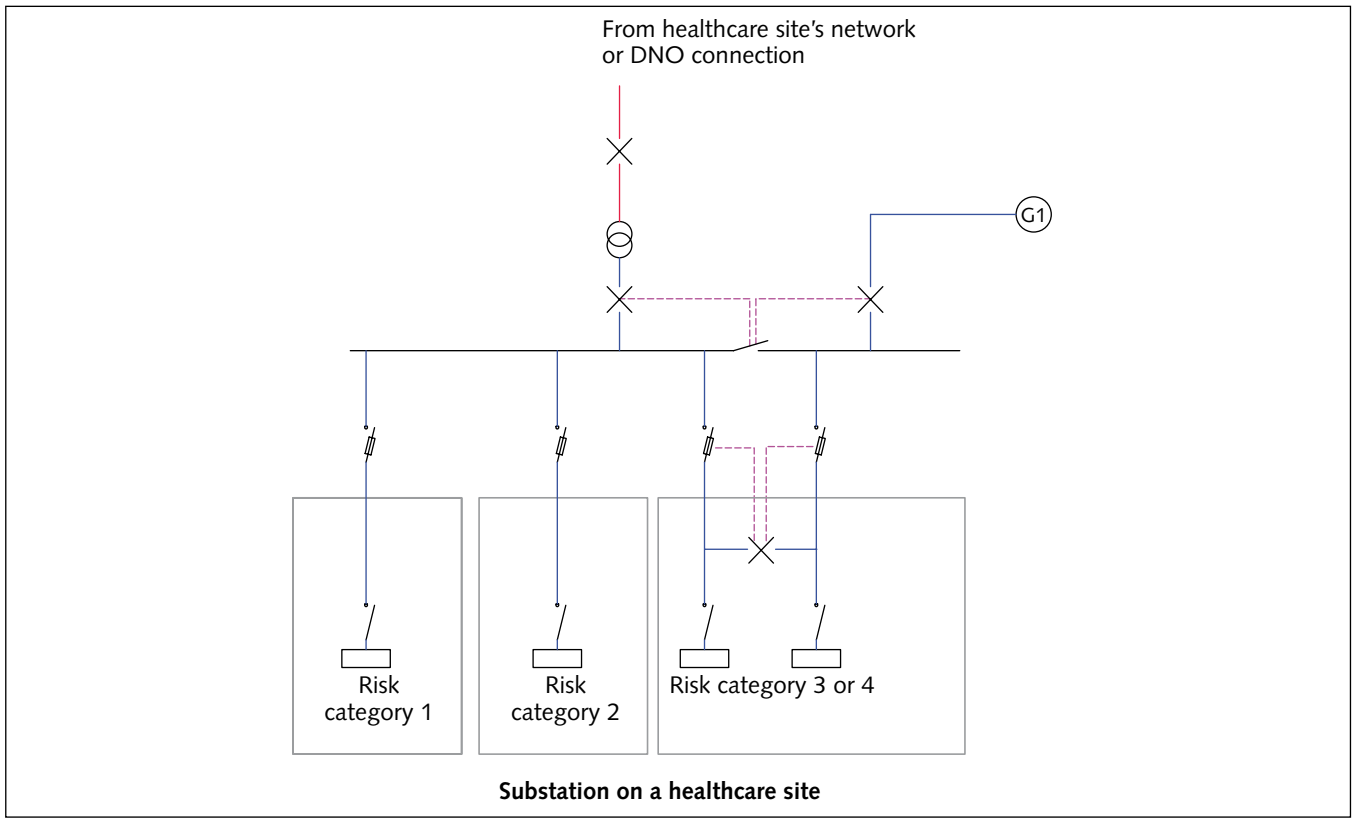


Figure 16 Primary and secondary supply – unified and dual-unified infrastructure



and/or switchgear for the Category 1 and Category 2 risk areas. The unified circuit infrastructure lends itself to that part of the healthcare premises that do not operate 24/7, and the dual-unified circuit infrastructure (Category 4) lends itself to those which do operate 24/7.

6.45 Enhancing the infrastructure resilience may be achieved by adding a tertiary power source. A single-conversion UPS may be connected to dedicated final circuits of the unified distribution. Enhancing the dual-unified infrastructure resilience and adding additional standby generator units may improve the maintenance opportunities and business continuity for the Category 3 or 4 risk areas.

6.46 An assessment of the potential for expansion and/or remodelling the healthcare premises should be made, to understand how the LV distribution could accommodate such adaptations. This arrangement may be appropriate for a general acute or large acute hospital with additional support services, dependent on the assessed level of risk posed by a failure.

Dual primary and dual secondary supply – unified and dual-unified infrastructure

6.47 The LV infrastructure shown in Figure 17 has a dual-primary supply, connected directly to either the DNO or the healthcare site's transformer, and a dual-distributed secondary power supply also connected at the intake LV switchboard. The transformer, standby generator, switchgear and main cables should all be rated to take the AMD and an allowance for growth.

6.48 The first single point of failure will be at the main LV switchboard for the unified circuits, or at the point of use for the dual-unified circuits. A LV infrastructure of this kind is appropriate for clinical risk categories 2, 3 or 4, where the dual-unified circuits are more appropriate for Category 4 or 5 risk areas (see paragraphs 3.28–3.33). This infrastructure may provide for inconvenience-free maintenance opportunities in the Category 3 or 4 risk areas. However, the same opportunities do not exist in the Category 2 risk areas, where there is no resilience with the distribution cables and/or switchgear. Therefore, the unified circuit infrastructure lends itself to that part of the healthcare premises that does not operate 24/7.

6.49 Enhancing the infrastructure resilience may be achieved by adding a tertiary power source. A single-conversion UPS (see paragraphs 16.3–16.19) may be connected to dedicated final circuits of the unified distribution. Enhancing the dual-unified infrastructure resilience and adding additional standby generator units may improve the maintenance opportunities and business continuity for the Category 3 or 4 risk areas.

6.50 An assessment should be made of the potential for expansion and/or remodelling of the healthcare premises and how the LV distribution of Figures 16 and 17 could accommodate such adaptations. This arrangement may be appropriate for general acute or large acute hospitals with additional support services, dependent on the assessed level of risk posed by failures.

6.51 Figure 17 shows a potential connection point for a CHP plant. The schematic only provides one of many potential electrical connections for the CHP plant. Designers and stakeholders should assess the ideal CHP connection based on the opportunity to "black start" the CHP sets, and to synchronise the CHP with the PES supply and/or standby generator supply.

6.52 In reality, the CHP location may be driven by the thermal and environmental requirements rather than the electrical connection. For example, locating the CHP plant close to the boiler plant may provide a more beneficial connection for the reclaimed heat energy into the boiler return pipework. In addition, the CHP engine exhaust can be ducted alongside the boiler flues.

Dual primary and dual HV secondary supply – dual-unified infrastructure

6.53 The LV infrastructure illustrated in Figure 18 has a dual primary supply, connected to the healthcare site's transformer, and a dual distributed SPS connected directly to the internal HV network. The transformer, standby generator, switchgear, and main cables should all be rated to take the full assumed maximum demand and an allowance for growth (see paragraphs 3.28–3.33).

6.54 The first single point of failure will be at the point of use for all circuits. A LV infrastructure of this kind is appropriate for clinical risk categories 4 or 5 where the dual-unified circuits are Category 5 (see paragraphs 4.12–4.24). The Category 5 risk areas have the added installed resilience of tertiary power supplies, double-conversion UPSs and IPSs. This infrastructure may provide for inconvenience-free maintenance opportunities in all areas, particularly

when the final subcircuits are interleaved (see paragraphs 6.60–6.64).

6.55 The potential for expansion and/or remodelling of the healthcare premises should be assessed in terms of how the LV distribution could accommodate such adaptations. The arrangement may be appropriate for a large acute hospital with additional support services, dependent on the assessed level of risk posed by a failure.

Dual primary and dual LV secondary supply – dual-unified infrastructure

6.56 This form of LV infrastructure is illustrated in Figure 19 and has a dual primary supply connected to the healthcare site's transformer, and a dual distributed secondary power supply connected directly to the internal HV network, via step-up transformers. The transformer, standby generator, switchgear and main cables should all be rated to take the AMD and an allowance for growth (see Chapter 3).

6.57 This form of LV infrastructure is the same as that in paragraphs 6.53–6.55 except that the standby generators are low voltage with step-up transformers.

6.58 The IPS connection arrangement in Figures 18 and 19 is only one such possible arrangement. Designers may wish to consider not supporting the IPS with a UPS as per Figure 41.

6.59 Many large healthcare premises will have a mixture of clinical risk areas (see paragraphs 4.12–4.24) and consequently may require an overall distribution

Figure 17 Dual-primary and dual-secondary supply – unified and dual-unified infrastructure

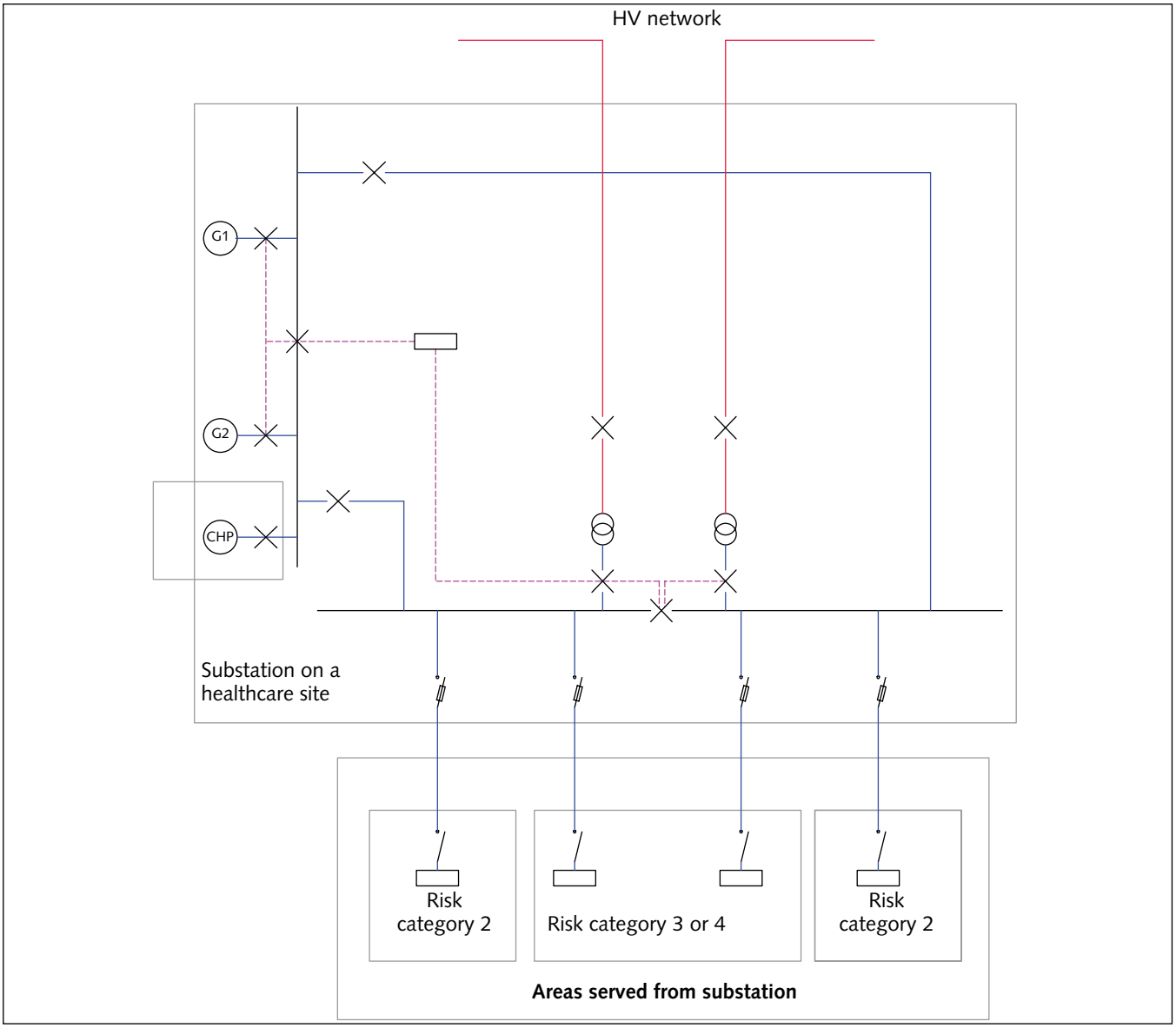
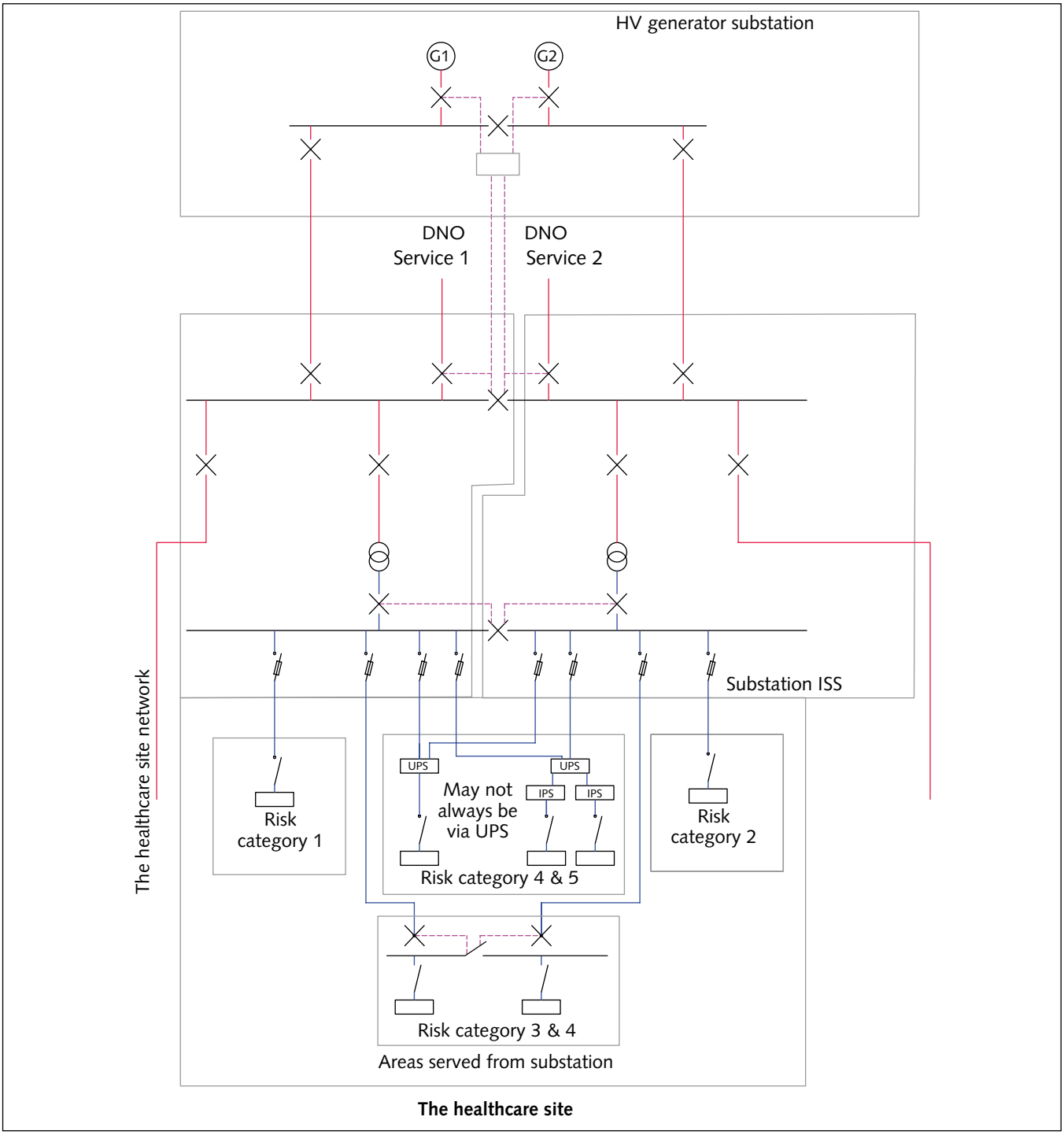


Figure 18 Dual primary and dual HV secondary supply – dual-unified infrastructure

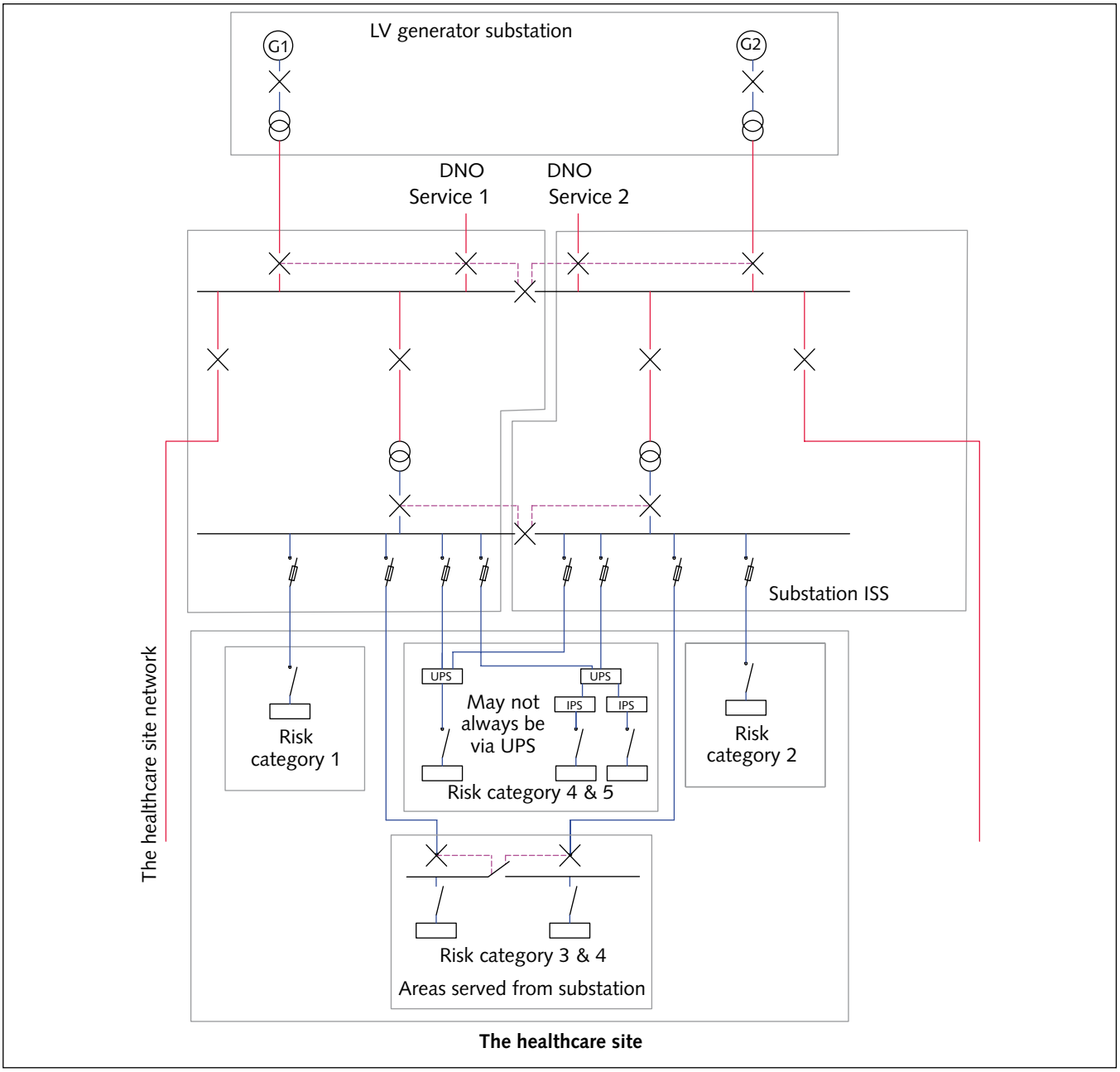


strategy based on a mixture of the above examples. Designs with a single distribution strategy, best suited to the highest category of clinical risk across the whole healthcare site, are less complex and easier to control. The design strategy principles promoted by this Health Technical Memorandum achieve the best opportunities for flexibility and remodelling.

Final circuits

6.60 This section describes how the design strategy of final subcircuits can assist in the security of the supply at the point of use. The nature and type of distribution to the final distribution boards are described in paragraphs 6.31–6.59 (for low voltage). For simplicity, it will be assumed that the final distribution board only has one supply, but adjacent distribution boards (where referred to) are supplied from a different sub-distribution panel.

Figure 19 Dual primary dual LV secondary – dual-unified infrastructure



Fixed equipment

6.61 Designers should carefully consider how to provide protection of the final circuit to fixed equipment such as fluoroscopy machines. For example, two supplies with an auto-changeover switch could be provided. Alternatively, a UPS could be provided that would provide sufficient power for task completion in the event of circuit failure.

Power outlets

6.62 Power outlets include sockets, spurs and connection units regardless of how the circuit is wired (ring or radial). Assessments of the advantages of arranging circuits in an interleaved manner per room or bed should be made. For example, if the interruption to a socket subcircuit resulted in no available power in a out-patient consulting room, the effect might not be too dramatic – whereas in clinical risk Category 4 and 5 areas, the patient environment should have at least two IPS circuits at the bedhead, ideally derived from different sides of a common substation (see Figure 19). Electric bed motors, patient warming systems etc, which do not require the IPS facility, will be connected to a socket circuit from the TN-S system. The outgoing circuits should be interleaved between two adjoining theatres, or for 50% of sockets at the bedhead where an IPS monitors the outlets. Designers

should consider the advantages of providing a UPS for each of the IPS systems in any clinical risk Category 5 area.

Lighting circuits

6.63 The distribution strategy for final circuits supplying luminaires need not be significantly different from the strategy employed for the low-power outlets in the same area. Where the secondary power plant does not provide 100% cover of the lighting circuits, lighting circuits (in one area) derived from distribution boards can be interleaved with secondary power supplies and those with primary power supplies only. Alternatively, interleaving lighting circuits from the same distribution board may be an acceptable derogation. It may be possible to justify only one lighting circuit in non-clinical areas.

7 Primary power – distribution centres

HV substations

7.1 Guidance on the number, type and location of any HV substations incorporated within the site's electrical distribution is given in Chapter 6. This section provides guidance on the design of HV substations owned by the healthcare organisation (or nominated agent). This Health Technical Memorandum does not govern substations that are owned by the external DNO, usually limited to the main intake point. However, designers and stakeholders should liaise with the external DNO to ensure that such substations have suitable access and space provision. HV substations that include an integral space for the external DNO's HV cables and equipment may be appropriate, providing that adequate control and areas of responsibility can be clearly defined. For the purpose of this guidance, HV substations are deemed to be the total area of the HV switchgear and transformer enclosure.

Location

7.2 External and internal locations can be suitably adapted for HV substations provided the design adheres to the principle of the following guidance. External substations can be located at ground or roof level. Internal substations can be located at any floor, including ground level.

7.3 HV substations located in close proximity to the principal LV switchboard afford the best opportunity to regulate earth faults between the two items (see paragraphs 7.52–7.54 for the location of LV switchrooms).

7.4 External substations should be located away from any live vegetation by a minimum distance of 3 m. The clear zone includes above the construction and subterranean areas. Low-maintenance grassed areas are an acceptable derogation from this requirement.

7.5 The location of internal substations should be in accordance with the recommendations given in Firecode (Health Technical Memorandum 05) and the adjacencies described therein.

7.6 HV substations should not be located under bulk water (or any other fluid) storage areas.

Construction

7.7 External HV substations should be constructed on well-drained surfaces (with catchments for any spilled oil, if appropriate). The electrical equipment should not be within reach from outside the perimeter fence of the substation.

7.8 External HV substations can be constructed from brick, concrete or GRP, or be of steel fabrication to the same enclosure standard of an internal HV substation.

7.9 Where external substations have a metallic enclosure construction or the substation is open and surrounded by a metallic fence, see BS 7430:1998 for earthing arrangements.

7.10 Construction of internal substations should include adequate fire precautions to satisfy the recommendations given in Firecode (Health Technical Memorandum 05). The construction of internal HV substations should be sufficiently robust to contain the effects of an electrical explosion emanating from within, and should provide suitable acoustic attenuation. HV substations should be constructed to minimise the effect of electrical interference.

7.11 Walls and fire-resisting partitions forming the HV substation must comply with statutory Building Regulations Part B or be of an equivalent fire-resisting steel-fabricated modular construction. Internal walls should have a suitable finish to reduce dust formation and facilitate cleaning.

7.12 HV substations should be constructed to prevent the ingress of water, including from flood. Specific precautions are required where cables enter the substation from external areas (including subterranean).

7.13 Floors and ceilings should be constructed from reinforced concrete or equivalent fire-resisting

construction. Floors should have a non-slip, dust-reducing finish.

7.14 HV switchroom doors should open outwards and have a total clear opening to allow replacement of switchgear and transformers (see paragraphs 7.17–7.19).

7.15 Substations should be constructed without windows or skylights to minimise the effect of solar heat gain.

7.16 The construction of any HV substation, including the HV side of a transformer, should be designed so as to prevent unauthorised access (see Health Technical Memorandum 06-02).

Access and egress

7.17 External substations should have good access for road vehicles to facilitate plant replacement and maintenance. Where external substations are on the roof, a clear method statement describing the arrangements for plant replacement and maintenance should be provided, without the need to dismantle individual HV switches, circuit breakers or transformers. External substations should be so arranged and constructed as to prevent unauthorised access. See Health Technical Memorandum 06-02 Parts A and B. Gates or other purpose-made openings should provide adequate clearance for plant replacement, inclusive of any manual handling equipment and personnel. There should be a minimum of two sets of gates, on opposite sides, to provide suitable escape routes. For external substations, additional gates will be required to ensure that the maximum travel distance to a safe haven is no greater than 9 m.

7.18 Internal substations should have good access for road vehicles to facilitate plant replacement and maintenance. This will generally mean that they are located on the perimeter of the ground floor or in separated dedicated buildings. Where internal substations are not at ground-floor level, a clear method statement describing the arrangements for plant replacement and maintenance should be provided, without the need to dismantle individual HV switches, circuit breakers or transformers. Internal substations should be so arranged and constructed to prevent unauthorised access. See Health Technical Memorandum 06-02 Parts A and B. Door openings should provide adequate clearance for plant replacement, inclusive of any manual handling equipment and personnel. There should be a minimum of two sets of door openings connecting directly to a safe haven, on opposite sides, to provide suitable escape routes. Additional door openings will be required to ensure that the maximum travel distance to a safe haven is no greater than 9 m.

7.19 The access to any HV substation, including the HV side of a transformer, should be arranged so as to prevent unauthorised access (see Health Technical Memorandum 06-03).

Layout

7.20 The layout of HV substations will depend partially on the distribution strategy employed (see Chapter 6). Internal HV substations should have level room height of 1 m greater than the equipment height, and a clear maintenance space of a minimum 0.8 m on the sides and rear of equipment and 1 m plus the equipment depth in front of the equipment. The requirement may be derogated where the HV equipment is combined onto a switchboard or close-coupled with the transformer. However, it is essential to ensure that all cables and equipment can be serviced and replaced without any modification to the room. Where the distribution strategy has dual supplies and multiple transformers per substation, a physical fire barrier between each section may improve the fire precautions and inherent system resilience. Where the HV equipment includes a withdrawable section (see Chapter 9), the depth of the equipment should be added to the clear maintenance space. The maintenance space will include the headroom above all HV equipment and transformer. The headroom should be a minimum of 1 m measured between the soffit (and the underside of any drop beam) and the highest point of the equipment. Designers should liaise with the structural engineer for the coordination of services within the HV substation. Risk assessments should be undertaken to determine the amount of space to be set aside for future expansion and flexibility (see Chapter 3).

7.21 HV cables used for the supply and interconnection of HV equipment and transformers (including the LV secondary side cables) are best laid in a cable trench or duct. Suitably-installed busbars would be an acceptable derogation from this requirement. Cable trenches or ducts should be of adequate cross-section to facilitate the pulling-in and replacement of additional cables. Cables should be positively fixed to the sidewalls of cable trenches and ducts, and so arranged as to prevent the need for cable crossover.

7.22 HV equipment should sit partially over the cable trench to facilitate final cable connection. Such arrangements will require adequate sidewall construction and edge-wall protection.

7.23 Cable trenches and ducts should have a natural drainage fall, and be sealed to prevent the ingress of water, where they pass through walls. Similarly, the cable trench/duct should provide the same fire integrity as the wall, where the trench/duct passes under the wall, that is, preventing ingress of gas or foam fire-extinguishing fluids.

7.24 HV substations should not be used for any purpose other than HV equipment and cables. The room should not be used for the storage of other items at any time. The room should not be used as a conduit for other engineering services, including drainage.

Fire precautions

7.25 HV substation construction must satisfy the requirements of the Building Regulations Part B. Designers should comply with the "medical adjacencies" as defined in the Firecode series. A full risk assessment (in conjunction with the healthcare premises' fire officer, the local authority's fire officer and a specialist fire consultant) should be made, to address the form of suitable fire-fighting equipment and precautions.

7.26 Internal automatic fire-extinguishing equipment of a gaseous type should be considered where the HV equipment contains flammable material (for example mineral oil). Specialist fire engineers should undertake the design of such fire-fighting equipment.

7.27 The risk of a fire should also be determined by the effect of an electrical fault causing explosions. Such electrical faults will include those that can be assumed to happen and those that may arise from unauthorised interference.

7.28 The fire-extinguishing equipment should include an audible and visual alarm system within the room, immediately outside the room, and to a suitable 24-hour staffed location.

7.29 Fire-extinguishing equipment of the halon or CO_2 type should be replaced and not considered for new installations.

7.30 Where the HV substation is part of a ring network, consideration may be given to having the two network incomers in two rooms separated by a four-hour fire-rated partition wall, the two sections being linked by a fully rated cable.

Environmental requirements

7.31 External open-air HV substations do not require any environmental requirements. Lighting should be provided for security and possible emergency working. Maintenance staff should be protected from bad weather during emergency working. External HV substations of GRP or steel fabrications should have the same environmental conditions as an internal HV substation (given below). Internal HV substations should be illuminated by maintained lighting to an average level of 150 lux at floor level. The illumination should not cast shadows on any instrumentation and working surfaces of the equipment. Escape lighting should provide an average of 5 lux at floor level for three hours, and be supported by grade A standby lighting. Internal HV substations should have natural ventilation to prevent moisture and condensation. HV switchgear would not normally contribute to internal heat gains of the switchroom. Transformers typically radiate between 1.5% and 2% of their rating as heat, which should be removed by crossflow (low to high opposite sides) natural ventilation. The supply and extract air for an HV substation should connect directly to an external wall and should be arranged to prevent short-circuiting. Thermostatically-controlled low-level background heating should be arranged to maintain a room temperature not less than 10°C. Consideration may be given to the provision of LV or SELV sockets, derived from a resilient routed secondary source (standby generator) for the use of competent persons (see Health Technical Memorandum 06-02).

Equipment and notices provided

7.32 HV substations should include the following equipment as a minimum set (see Health Technical Memorandum 06-02):

- safety posters as identified by Health Technical Memorandum 06-02, including first aid/electric shock treatment;
- single line diagrams as identified by Health Technical Memorandum 06-02;
- rubber mats;
- a mimic board – intake sub only (including where appropriate key locks, keys and site logbook);

- a sign positively identifying the LV earthing as a TN-S system;
- a battery charger (for the instruments and power-driven switches, including trip circuits);
- storage space for maintenance tools, with tools;
- fixed lifting equipment.

Transformer enclosures

7.33 The adopted distribution strategy (see Chapter 6) should be used to determine the number of transformers per substation.

Location

7.34 The potential for harmonic interference, fault level, and zone of protection should be addressed when locating transformers. The transformer should be located within 1 to 3 m from the respective HV switchgear, and as close as possible to the respective LV switchgear. External transformers should be located away from any live vegetation by a minimum distance of 3 m. The clear zone includes above the construction and subterranean areas. Low-maintenance grassed areas are an acceptable derogation from this requirement.

7.35 The location of internal transformer enclosures should be in accordance with the recommendations given in Firecode and the adjacencies described therein.

Construction

7.36 External transformer open compounds should be constructed on well-drained surfaces (with catchments slightly greater than the volume of oil, for any spilled oil, as appropriate). The electrical equipment should be placed beyond the reach of personnel stood external to the substation and/or transformer.

7.37 External transformer enclosures of GRP or steel fabrication should have the same environmental conditions as an internal HV substation.

7.38 Construction of internal transformer rooms should include adequate fire precautions to satisfy the recommendations given in Firecode. Where an oil-filled transformer is installed, a bund area should be provided sufficient to hold more than the capacity of oil within the transformer. The transformer enclosure should also provide suitable acoustic attenuation and should be designed to minimise the effect of electrical interference.

Access and egress

7.39 External transformers should have good access for road vehicles to facilitate plant replacement and maintenance. Where external transformers are on the roof, a clear method statement describing the arrangements for plant replacement and maintenance should be provided, without the need to dismantle the transformer. External transformers should form an integral part of the HV enclosure and do not require a dedicated access and egress opening, provided the layout does not restrict the plant replacement and maintenance routes.

7.40 Internal transformers should have good access for road vehicles to facilitate plant replacement and maintenance. This will generally mean that they are located on the perimeter of the ground floor or in separated dedicated buildings. Where internal transformers are not at ground-floor level, a clear method statement describing the arrangements for plant replacement and maintenance should be provided, without the need to dismantle the transformer. Internal transformers should be so arranged and constructed as to prevent unauthorised access (see Health Technical Memorandum 06-02 Parts A and B). Door openings should provide adequate clearance for plant replacement, inclusive of any manual handling equipment and personnel. The footprint of a typical single transformer enclosure (including maintenance areas) is 4 m by 4 m, and hence consideration may be given to the provision of only one door opening. Where the distribution strategy requires two transformers per substation, each transformer should be located in its own enclosure.

Fire precautions

7.41 Transformer enclosures and/or rooms must satisfy the requirements of the Building Regulations Part B. Transformer locations should satisfy the medical adjacencies as defined in the Firecode series. Designers and stakeholders should carry out a full risk assessment (in conjunction with the healthcare premises' fire officer, the local authority's fire officer and a specialist fire consultant) to address the form of suitable fire-fighting equipment and precautions.

7.42 Automatic fire-extinguishing equipment should be provided where internally-located transformers contain flammable material (for example mineral oil). Specialist fire engineers should undertake the design of such fire-fighting equipment.

7.43 The risk of a fire should also be determined by the effect of an electrical fault causing explosions. Such electrical faults will include those that can be assumed to happen and those that may arise from unauthorised interference. The fire-extinguishing equipment should include an audible and visual alarm system within the substation area, immediately outside the substation, and within a suitable 24-hour staffed location (telephonist).

7.44 Transformers suitably rated for external location and located in the open air of a compound may not require any specific fire precautions or extinguishing equipment.

7.45 Fire-extinguishing equipment of the halon or CO_2 type should be replaced and not considered for new installations.

Environmental requirements

7.46 External open-air transformers do not require any environmental requirements. Artificial lighting should be provided for security and possible emergency working. Maintenance staff should be protected from bad weather during emergency working. Internal transformer enclosures should be illuminated by artificial lighting to an average level of 150 lux at floor level. The illumination should not cast shadows on any instrumentation and working surfaces of the equipment. Emergency lighting should provide an average of 5 lux at floor level for three hours. Internal transformer enclosures should have natural ventilation to prevent moisture and condensation, and overheating of the space and equipment. The radiated heat from a transformer is a function of the non-load losses (iron losses) and the full-load losses (copper I2R losses). Total losses for a fluid-cooled transformer will be between 1.5% and 2% of their rating, and for dry-type (cast resin) transformers the total losses are between 1% and 1.5%. Natural ventilation may be achieved by a crossflow of air as illustrated in Figure 20. The total area of an opening may be calculated from a typical formula, for example:

$0.90S^1 = S = (0.18P/(\sqrt{H}))$

where

S and S^1 = lower and upper total opening areas, respectively (m^2)

P = sum of the no-load and full-load losses of the transformer (kW)

H = height difference between the centre lines of the two openings (m).

7.47 The above formula should be corrected for ambient room temperatures above 20°C and/or altitudes above 1000 m.

7.48 Where natural ventilation cannot be secured to maintain a room temperature of 20°C, designers may wish to consider forced ventilation with an airflow rate (q) calculated by:

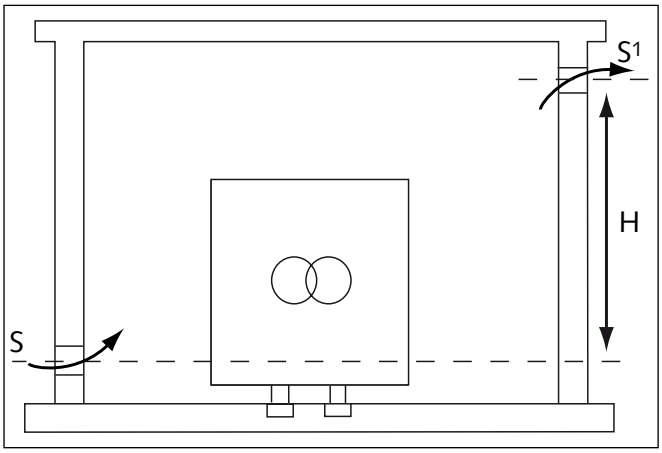
q = 0.081P (for fluid transformers)

q = 0.05P (for dry-type cast-resin transformers)

where

P = total losses of the transformer (kW).

Figure 20 Air flow through a transformer room



7.49 An alternative to the crossflow arrangement may be to have the external wall fully louvred such that there is a 40%–60% free-air area. Provisions for adequate ventilation rates of transformer rooms are a significant factor in determining the location of internal transformer rooms. The transformer room should be thermostatically controlled with low-level background heating to maintain a room temperature above 10°C.

7.50 Two 100%-rated transformers normally operating at 50% and with a common load reduce the copper losses to 40% of the full-load losses.

LV switchrooms

7.51 Guidance on the number, type and location of any LV switchrooms incorporated within the site's electrical distribution is given in paragraphs 7.52–7.54. This section provides guidance on the design of LV switchrooms owned by the healthcare organisation (or nominated agent). LV switchrooms

that are owned by the external DNO and usually limited to the main intake point, are not governed by Health Technical Memoranda. However, a liaison with the external DNO will ensure that such switchrooms have suitable access and space provision. LV switchrooms that include an integral space for the external DNO's LV cables and equipment may be appropriate providing that adequate control and areas of responsibility can be clearly defined.

Location

7.52 External and internal locations can be suitably adapted for LV switchrooms, provided the design adheres to the principle of the following guidance. External switchrooms can be located at ground level or on the roof level. Internal LV switchrooms can be located at each floor level.

7.53 The location of internal LV switchrooms should be in accordance with the recommendations given in Firecode and the adjacencies described therein.

7.54 LV substations should not be located under bulk water (or any other fluid) storage areas.

Construction

7.55 External LV switchrooms can be constructed from GRP or be of steel fabrication provided the enclosure complies with the requirements of internal LV switchrooms.

7.56 Construction of internal switchrooms should include adequate fire precautions and satisfy the recommendations given in Firecode. The construction of internal LV switchrooms should be sufficiently robust to contain the effects of an electrical explosion emanating from within. The construction of LV switchrooms should provide suitable acoustic attenuation and should minimise the effect of electrical interference.

7.57 Walls and fire-resisting partitions forming the LV switchrooms must comply with statutory Building Regulations Part B or be of an equivalent fire-resisting, steel-fabricated modular construction. Internal walls should have a suitable finish to reduce dust formation and facilitate cleaning.

7.58 LV switchrooms should be constructed to prevent the ingress of water, including from flood. Specific precautions are required where cables enter the substation from external areas (including subterranean).

7.59 Floors and ceilings should be constructed from reinforced concrete or equivalent fire-resisting construction. Floors should have a non-slip, dust-reducing finish.

7.60 Doors should open outwards and have a total clear opening to allow replacement of switchgear (see paragraphs 7.62–7.63 below).

7.61 LV switchrooms do not require windows or skylights, which may otherwise increase the effect of solar heat gain.

Access and egress

7.62 External switchrooms should have good access for road vehicles to facilitate plant replacement and maintenance. Where external LV switchrooms are on the roof, a clear method statement describing the arrangements for plant replacement and maintenance should be provided, without the need to dismantle the LV equipment. External switchrooms should be so arranged and constructed as to prevent unauthorised access. See Health Technical Memorandum 06-02. Door openings should provide adequate clearance for plant replacement, inclusive of any manual handling equipment and personnel. There should be a minimum of two sets of doors, on opposite sides, to provide suitable escape routes. For internal substations, additional doors may be required to ensure that the maximum travel distance to a safe haven is no greater than 9 m.

7.63 Internal switchrooms should have good access for lifting equipment to facilitate plant replacement and maintenance. This will generally mean that they are located on the principal circulation corridors. Where internal switchrooms are not at ground-floor level, a clear method statement describing the arrangements for plant replacement and maintenance should be provided, without the need to dismantle the LV equipment. Internal switchrooms should be so arranged and constructed as to prevent unauthorised access. See Health Technical Memorandum 06-02. Door openings should provide adequate clearance for plant replacement, inclusive of any manual handling equipment and personnel. There should be a minimum of two sets of door openings connecting directly to a safe haven, on opposite sides, to provide suitable escape routes. Additional door openings will be required to ensure that the maximum travel distance to a safe haven is no greater than 9 m.

Layout

7.64 The layout of LV switchrooms will depend partially on the distribution strategy employed (see Chapter 6). LV switchrooms should have a clear maintenance space of a minimum 0.8 m on all sides of equipment contained therein. The room height should be even, and at least 1 m greater than the equipment height. It is essential that all cables and equipment can be serviced and replaced without modification to the room. Where the distribution strategy has dual supplies and/or interleaved sub-main distribution, a physical fire barrier between each section may improve the fire precautions and inherent system resilience. Where the LV switchgear includes a withdrawable section (see Chapter 9), the depth of the switchgear should be added to the clear maintenance space. The maintenance space will include the headroom above all LV equipment. The headroom should be a minimum of 1 m measured between the soffit (and/or the underside of any drop beam) and the highest point of the equipment. A risk assessment to determine the amount of space set aside for future expansion (see Chapter 3) should be undertaken. LV switchrooms should not be used for any purpose other than LV switchgear, controls and cables. The room should not be used for the storage of other items at any time. The room should not be used as a conduit for other engineering services, including drainage.

Fire precautions

7.65 LV switchroom construction must comply with the requirements of the Building Regulations Part B. The location should comply with the medical adjacencies as defined in the Firecode series. A full risk assessment should be made in conjunction with the healthcare premises' fire officer, the local authority's fire officer and a specialist fire consultant to address the form of suitable fire-fighting equipment and fire alarm and detection systems.

7.66 The risk of a fire should also be determined by the effect of an electrical fault causing explosions. Such electrical faults will include those that can be assumed to happen and those that may arise from unauthorised interference.

Environmental requirements

7.67 External LV switchrooms of GRP or steel fabrication should have the same environmental conditions as an internal LV switchroom (given below). Internal LV switchrooms should be illuminated by artificial lighting to an average level of 150 lux at floor level. The illumination should not cast shadows on any instrumentation and working surfaces of the switchgear. Emergency lighting should provide an average of 5 lux at floor level for three hours. Internal LV switchrooms should have adequate natural ventilation to prevent build-up of moisture and condensation. LV switchrooms should be arranged so as not to give concern for internal heat gain. The supply and extract air for LV switchrooms should connect directly to an external wall and should be arranged to prevent the air flow short-circuiting. Thermostatically-controlled low-level background heating should maintain a room temperature not less than 10°C. Designers should consider the provision of LV or SELV sockets, derived from a resilient routed secondary source (standby generator) for the use of competent persons (see Health Technical Memorandum 06-02).

Equipment and notices required to be provided

7.68 LV substations should include the following equipment as a minimum set:

- safety posters as identified by Health Technical Memorandum 06-02, including first aid/electric shock treatment;
- single line diagrams as identified by Health Technical Memorandum 06-02;
- rubber mats;
- a mimic board (including, where appropriate, key locks, keys and site logbook);
- a sign positively identifying that the LV earthing is a TN-S system;
- a battery charger (for the instruments and power-driven switches including trip circuits);
- storage space for maintenance tools, with tools;
- fixed lifting equipment;
- other equipment such as safety keys as required by local rules.

7.69 Note that a sign positively identifying the LV earthing as a TN-S system should also be located at each final distribution board, motor control centre and similar locations.

8 Secondary power centres and plant

8.1 This chapter deals with secondary power sources (SPSs) either directly connected to the PEI or connected to a secondary electrical infrastructure (segregated essential/non-essential, A and B etc).

8.2 The use and operating configurations of CHP plant are comparable with standby generators; but with CHP, the thermal energy produced can be harnessed. It is for this reason that CHP plant may be considered as an SPS but not as standby plant. The electrical connection and operating arrangements for CHP plant are discussed in this Health Technical Memorandum only as a generator operating in parallel with the PES (see paragraphs 8.7–8.11). Installation with photovoltaic and/or wind turbines as an SPS is set out in the Energy Network Association's Engineering Recommendations G.83/1.

8.3 Opportunities exist to allow the secondary electrical power sources, such as CHP plant, to become the prime power source and the DNO connection to become the SPS. Designers and stakeholders should consider the holistic risk strategy for such arrangements. Non-technical issues can influence the operating viability of alternative energies such as CHP, including reduced carbon emissions and the rejection of excess thermal energy. The design process should evaluate the resilience of generating plant (such as CHP plant) with multiple sets running at below full duty, or having spare capacity on the DNO connection to the PES.

8.4 The chapter concentrates on standby generators provided with unified and/or segregated electrical infrastructures. The configurations are presented generally in order of resilience, from low to high. The selection of a particular configuration will be dependent on the clinical risks and non-clinical risks. The selected configuration should clearly be consistent with the distribution strategy (see Chapter 6).

8.5 The configurations presented in this chapter should not be taken as being definitive, prescriptive or restrictive. The selected configurations and assessment are intended as a guide to best practice, which should not restrict any design innovation. Healthcare organisations may not have any control over their DNO configuration, and therefore the reliability of a duplicated DNO connection (to the PES) as an SPS should be the subject of a risk assessment. Areas within a healthcare facility (or the whole healthcare facility) where the clinical risk is equal to or greater than Category 3 will always require some form of standby supply. The design process should assess the benefit provided by standby generators where the clinical risk areas are Category 1 or Category 2.

8.6 Where permanent standby provision is installed, the addition of strategically-located mobile generator plug-in points may be an alternative solution for the maintenance provision of embedded units. Such arrangements may be particularly useful where the electrical infrastructure is a unified system. Where mobile generators are considered as part of the electrical resilience, consideration should be given to the hook-up location and the ease of installing potentially very long, trirated cables. Designers and stakeholders should remain mindful of the fact that mobile generators are in fact "mobile" and should be physically secured.

Secondary power general arrangements

8.7 The use of alternative electrical energy sources has become more widespread in the UK since the late 1990s. All forms of such energy have unique availability and viability considerations outside the scope of this Health Technical Memorandum. A useful source of such data can be found on either the CIBSE or BSRIA websites. Designers and stakeholders may wish to consider these energy sources as a way to reduce the carbon emissions locally and the possible benefits available from the renewable obligations commitment (ROCS).

Photovoltaic power secondary power source

8.8 Photovoltaic cells may be a useful background supplementary energy source. Over the normal range of weather conditions, these units can provide an average of 15% to 20% of their total rated output. The use of photovoltaic cells is therefore limited to smaller healthcare premises, or dedicated small circuits of larger healthcare premises.

8.9 CIBSE technical memorandum TM 25 provides a useful guide to the current applications of photovoltaic cells (PV). Any PV system that is used on the site's electrical systems should run only in parallel with the PES supply. There should be a form of positive isolation between the PV output and the incoming PES to prevent island-mode operation and/or back-feeding into the PES via the DNO. These requirements are set out in the Energy Networks Association's Engineering Recommendations G.83/1.

Wind turbine power source

8.10 Any wind turbine system that is used on the site's electrical systems should run only in parallel with the PES supply. There should be a form of positive isolation between the wind turbine output and the incoming PES to prevent island-mode operation and/or back-feeding into the PES via the DNO. These requirements are set out in the Energy Networks Association's Engineering Recommendations G.75/1 and G.83/1, and the Technical Report ETR 113.

8.11 The use of wind turbines should include an assessment of the available wind and potential output of any wind turbine that may be on site, including the space and access requirements.

General – secondary power plant location

8.12 An approach to the DNO should be made to establish an indicative reliability factor for the PES. This will place the designer team in an auditable position when determining the standby power plant location.

8.13 Where the distribution strategy has placed the first single point of failure (see Chapter 6) nearer to the point of use, the standby plant should be connected at the intake point. Where the first single point of failure is much nearer the intake point, distributed secondary power centres should be provided.

8.14 The physical location of SPS plant and primary plant (substation switchroom) should be considered in similar ways. This should address the access for maintenance requirements. With SPSs such as photovoltaic cells and/or wind turbines, these may be located on a flat roof where they may optimise their respective prime energy source (sun or wind).

8.15 Other secondary power plant locations should be considered by taking account of the medical adjacencies and environmental conditions. The medical adjacencies are identified in the Firecode series of documents.

8.16 Where the SPS is the standby power plant, the environmental conditions include exhaust terminations (the Clean Air Act) and noise emission (see paragraphs 8.91–8.93). Where the healthcare site includes a CHP plant, the CHP plant should be located close to the boiler plant to minimise the water distribution pipework (and hence distribution losses). Locating the CHP plant close to the boiler plant will provide other benefits, including a common location for boiler flue and exhaust locations to comply with the Clean Air Act, as well as a common location for the fuel.

Essential power capacity

8.17 An assessment of the essential power requirement should be made from an understanding of the clinical risk areas that require power to be restored within 15 seconds (see Chapter 4). Further consideration should be given to the clinical risk areas that have certain items that should be reconnected within 0.5 seconds. Such items may initially remain connected to a supply, by either internal batteries or a UPS system. Within all clinical risk areas above Category 2, there will inevitably be some equipment of a non-clinical and business continuity risk category. Such risks might compromise the provision of healthcare treatment if they were not also connected to the standby power source after an initial delay in excess of 15 seconds, for example building services environmental control, medical support services etc.

8.18 Assessments for essential power requirements for new developments should be based on the ratings of the above equipment and the general power density of the healthcare premises with an acceptable allowance for growth. Actual detailed load profiles of existing sites may be a useful audit of the essential power capacity assessment, where

the profile covers at least one year. "Camera shot" measurements should be assessed with the risk associated with oversized plant, which may be more flexible and accommodate the allowance of growth.

8.19 When assessing the size and type of emergency power plant, designers and stakeholders should be aware that electrical outages can be very short (less than a few minutes) or for many hours. Consequently, all emergency generating sets should be designed and rated to provide continuous full load for prolonged periods. Where the essential power plant is not connected to the full electrical load, thought should be given to the temporary connections of plant such as the chilled water systems. The provision may require a manual or automatic control system with the ability to "load shed" a limited number of the secondary services such as non-essential lighting. The schedule should be reviewed annually as part of the maintenance regime.

Essential and emergency power provision

8.20 Standby power systems should always be available to provide electrical power to those areas that will enable the healthcare facility to carry out essential functions. The designation of these areas within the healthcare facility should be decided at design stage with involvement of all the stakeholders, and particularly clinicians. The framework of such decision-making should include the clinical risk categories identified in paragraphs 4.12–4.24. Within this general objective, the aim should be to keep electrical installations as simple as practicable and avoid unnecessary segregation of essential and non-essential circuits. Consequently, the design team should contribute towards the medical planning process.

8.21 Developments in clear separate phases should design in the emergency power supply for the final steady state, as far as practicable, at the initial design stage. This will enable the total emergency power supply requirement to be assessed in the planning stages and appropriate areas of accommodation to be allocated.

8.22 For ac standby power supplies, in island mode, required to supply only segregated essential services, a fully-rated four-pole main auto-changeover switch should be provided. It should be connected to supply power to the healthcare facility from two sources, either from the DNO's normal supply via the main switchboard to the essential services switchboard, or in an emergency, from the ac standby power supply to only the essential services switchboard. Thought should be given to the rating of all associated cables with the respective loads and mode of operating the essential power source (island or parallel).

Standby generators

Design criteria

8.23 A range of system designs is considered below, for both LV and HV systems. In small healthcare premises, the most economical and convenient arrangement may be a single diesel standby generator set to supply power to the essential services. However, for larger premises the better arrangement is to share the load between two or more machines. A system of two or more standby generators, with interlocked and interconnected switching, may be necessary to ensure only a single running supply to essential loads.

8.24 The choice between LV and HV generation is usually dependent on the nature of the total site supplies; 11 kV generators have a higher unit cost but can be cheaper or more convenient to distribute electricity to the points of use.

8.25 The design criteria for the standby generator system should consider the advantages of managing the maximum demand profile (from the PES) by operating the generators in parallel. This may be achieved by running any one of the multiple sets in parallel with the PES during high maximum demand periods.

8.26 LV standby generators connected to the HV network may provide a practical solution. However, consideration needs to be given to the space required for the additional transformer(s) and earthing arrangements. Standby generator arrangements including step-up transformers should comply with the Energy Networks Association's Engineering Recommendations G.84. Designers and stakeholders should also consider the capital and life-cycle costs of such transformers and associated switchgear and equipment.

Component parts

8.27 In its basic form, the generating set configuration is formed by an engine, alternator and control panel with associated bed frame. Failure of any of these items will cause the generating set to fail.

8.28 The generating set represents a single point of failure, and maintenance routines should be developed to reduce the risk of failure. Some of the commonest reasons for failure are given in Table 3. Standby power plant should have an N+1 configuration.

Table 3 Typical causes of generator set failure

Fault	Typical cause
Overload	Inadequate testing onto actual site load
Cold engine	Engine heater turned off or heater failed
Flat batteries	Battery charger turned off, charger failed, or batteries too cold
Cold room	Room heater turned off or when the generating set is at standby, room air change rate set too high

Generator configuration

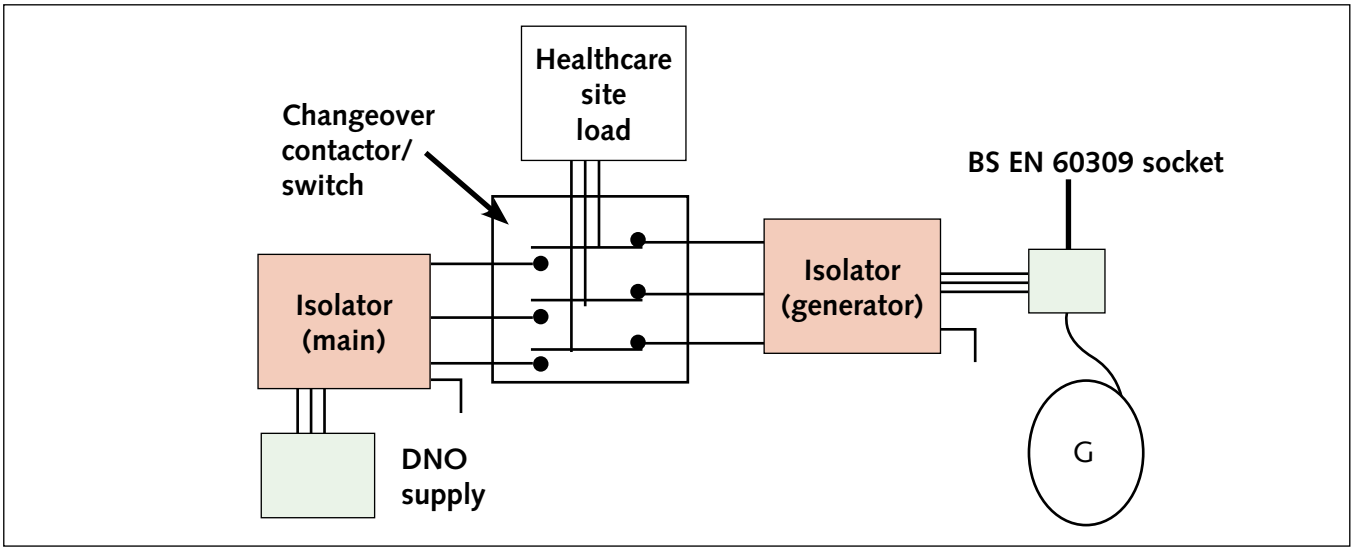
8.29 Standby generators can be arranged in various ways as described below. Each configuration provides different opportunities for routine testing of the generator. Full electrical system tests for a PES failure (blackout) are described in Health Technical Memorandum 06-01 Part B.

Mobile plug-in generator island operation

8.30 A basic LV system comprising one PPS and a mobile secondary generator is illustrated in block format in Figure 21. This is a simple unified system, with standby supply provision likely to be via a plug-in point for a mobile standby generator. Such a simple system may provide a back-up supply to healthcare premises where the clinical risk is no greater than Category 2. Where there is no requirement for a standby supply within 15 seconds, and essential health and safety supplies are provided by UPS or battery units, a plug-in point for a mobile generator may be adequate. The benefit of having such a mobile plug-in point, either for such a simple system, or as an addition for any other supply configuration, is the facilities it offers to effect planned maintenance of the fixed wiring system or downtime of permanent standby generators. The design process should reconcile the availability and security of mobile generators with the benefits of embedded distribution and standby generator resilience. When evaluating the clinical risks against viability of fixed generator provision, the realistic response time to collect and connect a mobile generator (for any scenario) should be considered, particularly if the generator has to be hired. Where it is considered advantageous to provide a mobile plug-in point, managers should consider the purchase of a mobile unit to be kept at a central location, or make emergency arrangements for mobile generators of suitable rating to be obtainable elsewhere at short notice. In planning an installation, it is desirable to reserve a dedicated fenced-off location for mobile generators where they may be easily connected to an allocated switch or plug-in point.

8.31 The connecting of a mobile generator should comply with the Energy Networks Association's Engineering Recommendations G.84, and may be achieved by a plug-in facility (up to 175 kVA) rated to BS EN 60309-1:1999, IEC 60309-1:1999. An external earth lead connection to the generator star

Figure 21 Mobile generator connection



point and, separately, to the generator metalwork should be provided. An earth bar connection should be available for connection to the earth terminal of the generator base plate, regardless of its type and size.

8.32 The electrical supply regulations do not permit a mobile generator to feed back into the PES, as such connections may feed a fault into the PES. Therefore, it is essential that positive isolation from the PES be made before and while any healthcare organisation's mobile generator set is used to energise any part of the electrical network.

Generator(s) in island operation

8.33 Island operation represents the simplest generator control arrangement requirements. Each ac generator will supply electrical power to a discrete, segregated part of the network. There will be no facility or opportunity to connect the generator output to the normal DNO connection.

8.34 Where the SPS plant is connected in island mode and the distribution strategy allows for the classic segregated non-essential and essential circuits (see paragraphs 6.40–6.42), any single room (or space) will have only non-essential or essential circuits and not both circuit types. Where the clinical risk Category 3, 4 and 5 areas are dispersed or are a small percentage of the overall electrical AMD, the safety requirement tends to drive the standby generator rating up. Designers and stakeholders should consider the implications of not being able to test the generators in parallel with the DNO supply. This may mean that the non-essential circuits have to be turned off when the physical essential load is used to test the generators. The alternative to this (preferred) strategy will be to test the generators with a load bank. All generator testing and power restoring (after a DNO outage) will require a short interruption to the electrical power. Standby generator operating in island mode will not require compliance with the Energy Networks Association's Engineering Requirements G.59/1.

8.35 Operating standby generating power plant in island mode may be considered for all clinical risk category areas.

8.36 Figure 22 shows a classic LV system comprising a single PPS with an SPS (the standby generator). The generator(s) is configured to operate in island mode only.

8.37 The electrical system resilience will be N+1 as there is an embedded secondary power source (the generator). Where the clinical risk Category 4 area forms only a small part of the healthcare premises, the generator control may be adjusted such that the healthcare premises areas less than clinical risk Category 4 are only connected to the standby generator when the actual demand is less than the generator rating (see Figure 22). Where a significant percentage of floor area is used as clinical risk Category 4 or above, more than one generator should be provided – rated so that the full essential circuits' AMD can be supported while one standby generator is not available (due to maintenance or faults). Under such circumstances, the generator resilience would also be defined as N+1.

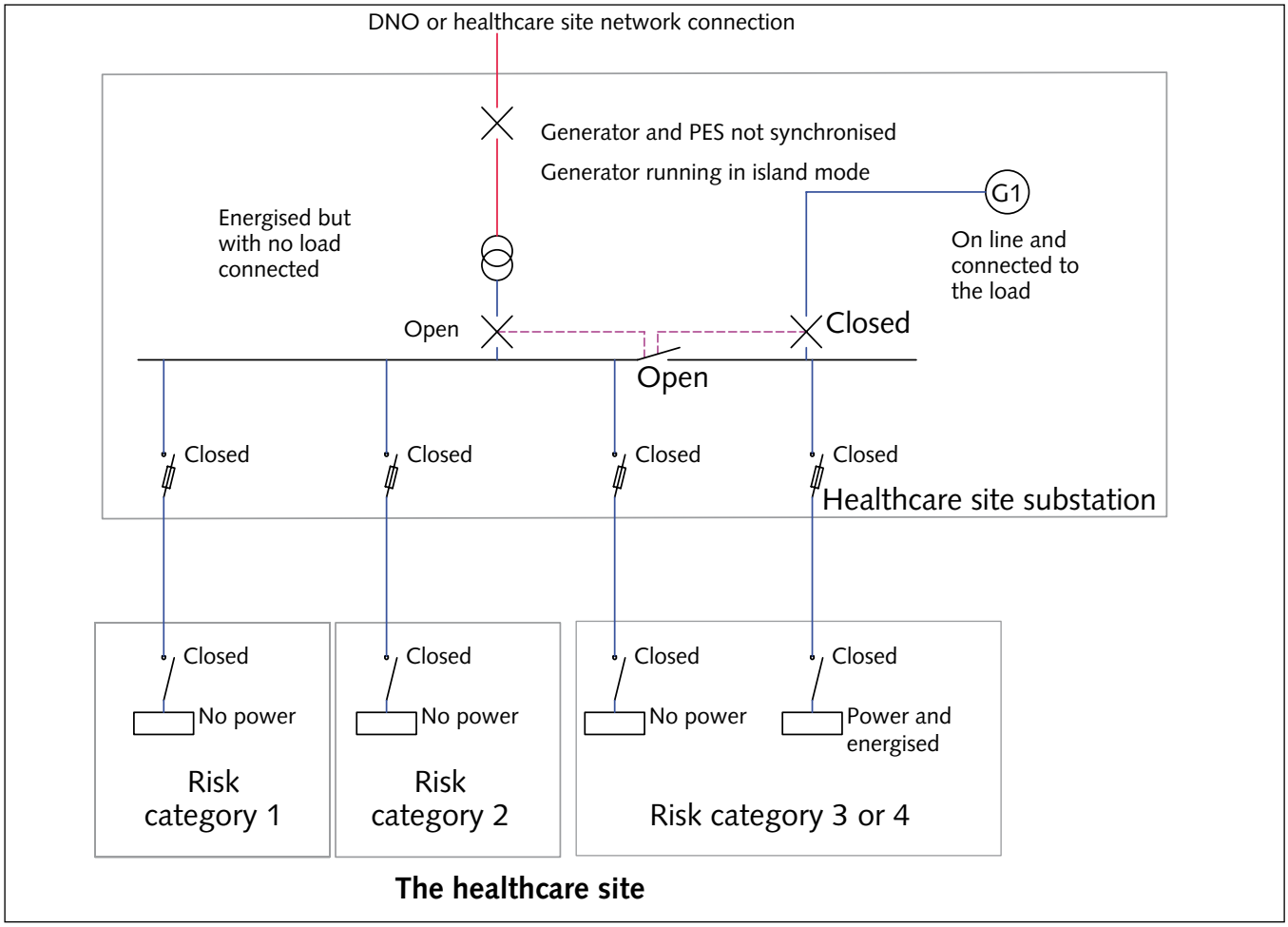
Generator(s) operating in parallel with PES

8.38 Parallel operation represents a more refined control arrangement in the mode of standby generator running. Each ac generator will supply electrical power to any part of the internal electrical infrastructure depending on voltage and the type of parallel operation. For parallel operation with the PES, the generator control regime should be compliant with the Energy Networks Association's Engineering Requirements G.59/1 (short- or long-term).

8.39 Short-term parallel operation requirements of G59/1 allow the embedded generators to run (synchronised) in parallel with the PES for periods between 1 and 5 min, subject to approval of the local DNO. Designers and stakeholders should consider the advantage of this arrangement as a means of having a no-break return to normal PES supply following an outage. The disadvantage of such an arrangement is that the whole building electrical load cannot be used to test the standby generator power capacity. This may mean that the non-essential circuits have to be turned off, when the physical essential load is used to test the generators. However, as the sets meet the G59/1 requirements for short-term parallel operation, the sets can be synchronised with the PES supply and then the non-essential circuits re-energised before the generators are isolated from the load. The alternative to this (preferred) strategy will be to test the generators with a load bank.

8.40 Where the standby power plant is connected in short-term parallel operation and the distribution strategy allows for the classic segregated non-

Figure 22 Generator(s) in island operation



essential and essential circuits (see paragraphs 6.40–6.42), any single room (or space) will have only non-essential or essential circuits and not both circuit types. Where the clinical risk Category 3, 4 and 5 areas are dispersed or are a small percentage of the overall electrical AMD, the safety requirement tends to drive the standby generator rating up. Designers and stakeholders should consider the implications of not being able to test the generators in parallel with the DNO supply.

8.41 The long-term parallel operation requirements of G59/1 allow the embedded standby generators to run (synchronised) in parallel with the PES for any unspecified period of time. Advantages are available with arrangements that provide a facility to test the generators with the essential circuits of the building load. Where the standby generator capacity is less than 100% of the AMD, the generators will run up and synchronise with the PES (for the test regime), and consequently there will not be a need to isolate any part of the electrical system while testing the generators.

8.42 Where the standby power plant is connected in long-term parallel operation and the distribution strategy allows for the classic segregated non-essential and essential circuits (see paragraphs 6.40–6.42), any single room (or space) may have a mixture of non-essential and essential circuit types.

8.43 Best-practice standby-generator connecting arrangements will allow for long-term parallel operation with the PES (that is, fully compliant with G59/1). Assessments of the advantages for business continuity with the additional control and switchgear regulation should be made.

8.44 Operating standby generating power plant in short- or long-term parallel operation may be considered for all clinical risk categories provided that any areas of Category 5 have an intermediate tertiary power source UPS.

8.45 Figure 23 shows a classic LV system comprising a single PPS with an SPS (in this case a standby generator). The generator(s) is configured to operate in island mode only.

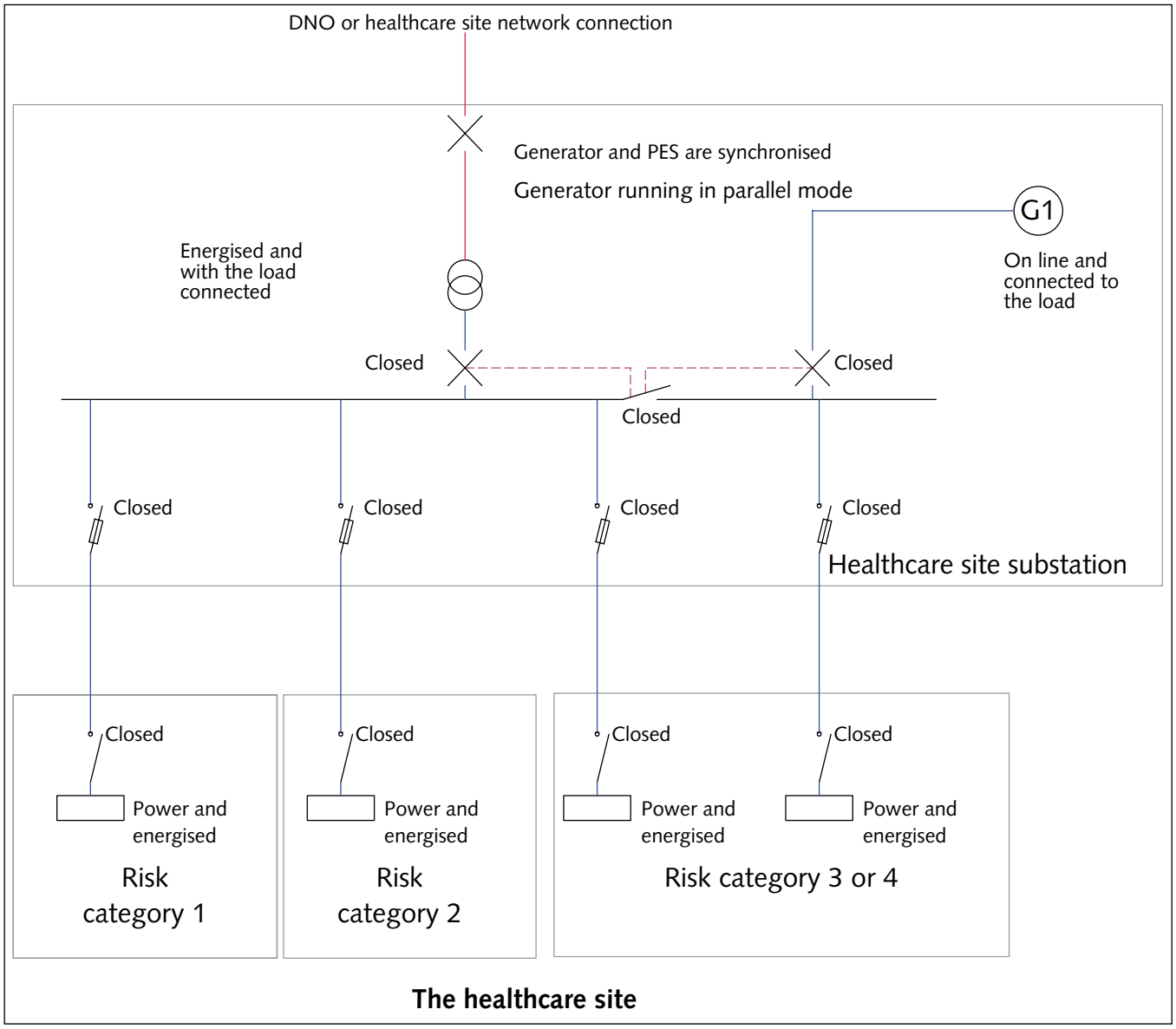
8.46 The electrical system resilience will be N+1, as there is an embedded SPS (the standby generator). Where a significant percentage of floor area is used as clinical risk Category 4 or above, more than one standby generator should be provided – rated so that the full essential circuits' AMD can be supported while one generator is not available (due to maintenance or faults). Under such circumstances, the generator resilience would also be defined as N+1.

8.47 This chapter has discussed the various operating configurations for standby generators based on the generators having a terminal voltage up to 11 kV and/or each generator having an output of less than 5 MW (see Figures 22 and 23; also see Figure 18, which can be used as the configuration for an HV generator connection). Where the site has generators above 20 kV and/or 5 MW, its design should ensure that the generators are fully compliant with the Energy Networks Association's Engineering Requirements G.75/1.

LV generators feeding HV ring main

8.48 The design process might consider using LV (0.4 kV) standby generators connected to the HV network (11 kV), via step-up transformers, where the distribution strategy includes for an HV network. Generators in this configuration can operate either in parallel or in island mode as described in paragraphs 8.29–8.47. When the standby generators have a design potential to allow

Figure 23 Generator(s) operating in parallel with PES



for parallel operation, the electrical system should include neutral-switching contactors.

Generator control

Generating set management

8.49 The generating sets are defined as a standby system. The modes of operation should be well-defined and clearly stated.

8.50 Where the healthcare facility has SPSs including power sources from alternative energy plant (CHP, wind turbines, photovoltaic), designers should liaise with the local DNO to ensure compliance with the requirements of the Energy Networks Association's Engineering Requirements G.83/1.

8.51 Designers are also required to prevent these power sources feeding back into the PES at the instance of an under-/over-voltage or an under-/over-frequency of the SPSs in either the power source or PES. However, such power sources may be arranged to continue to supply the internal essential distribution, and allow the standby generators to synchronise to the CHP supply. (Note – subject to the rating and step load response of the CHP, such arrangements may require the non-essential loads to be isolated, while the standby generators are initialised and connected.)

8.52 Detection of any under-voltage on any phase should be made at the input terminals of the point of common coupling of the primary supply and secondary supply (generator).

8.53 Where the generator(s) cover the full essential load, the phase failure detection will be at the intake point.

8.54 Where the generator(s) provide cover to only part of the electrical load, this will be at the respective switchboard (point of segregation of local non-essential and essential circuits).

8.55 Detection monitoring is required on all phases of the normal supply, such that any single-phase voltage failure in the normal supply initiates a start signal to the essential generator controls.

8.56 The engine-driven generator set for the supply of essential circuit power and lighting should be designed for automatic starting in the event of either a total failure of supply or a prolonged variation in supply voltage from its specified limits. A short delay of between 0.5 and 6.0 seconds is normally chosen at the voltage detector device to discriminate against a fall in normal voltage due to a voltage transient or auto-reclose switching operation (that is, a time delay to establish that the under-voltage is an outage rather than a disturbance). When the chosen time delay confirms the loss of normal supply voltage, the engine start is initiated. A time delay of up to 15 seconds (following the initial confirmation time) is allowed between loss of normal supply and connection of the standby generator to the essential circuits. The essential circuits are defined as those which cannot accept an interruption of electrical energy greater that 15 seconds plus the detection time (that is, clinical risk Category 4 and above). The ac standby generator circuit breaker should close when the generated voltage and frequency are at 95% of nominal values and before the auto-changeover load switch operates. The initial step load applied to the generator should be less than the maximum acceptance factor to prevent the generator's protection shutting the set down again.

8.57 The time-delayed start of the motor and high inductive loads may be achieved by the individual motor controls or by a centralised network control (see Chapter 9).

8.58 Regardless of the actual duration of the outage (PES or internal distribution), provision should be made to ensure a minimum run-time of 20 minutes to allow the generator engine lubrications to reach operating temperatures and fully circulate. The minimum run-time will also facilitate the recharging of the batteries. The minimum run-time should be exclusive of the time required to establish a returned and stable PES supply. Where the mains supply has been restored prior to load transfer, this will mean the generator may be operated off-load.. Where the mains has been re-established within the minimum run-time, the load will be transferred back to the DNO supply and the generator will continue to run off-load until completing the minimum run time.

8.59 The source of run/stop signals should be clear, to ensure that the set automatically runs when mains failures occur at points in the systems that are to be supplied by the set. The position of any simulate-mains-failure switches and mains-return push-buttons should be decided with respect to the system as a whole and in particular the needs of the operator.

8.60 The opportunities to maintain and/or test will affect the management control requirements. For

example, the maintenance requirements may require a level of redundancy in sets, which will then require sequencing controls (see paragraphs 8.61–8.64). Test regimes should facilitate the generator(s) to run in parallel with the PES for business continuity and clinical risk control. Additional details are available in Health Technical Memorandum 06-01 Part B, "Operational management".

Multi-set operation

8.61 For standby generators connected to different points within the network, arrangements with parallel operated sets (which have collective redundancy) should be adopted. Where the clinical risk areas are Category 4 or above, arrangements with multiple generator sets that have inbuilt redundancy should be adopted.

8.62 Where the SPS is via multiple standby generator sets, the total run-up time (detection time of between 0.5 and 6.0 seconds plus run-up of less than 15 seconds) should include the time it will take to synchronise sufficient sets so that their combined acceptance load is greater than assessed essential load (clinical risk Category 3 and above).

8.63 In applications where the system is operating with an N+1 capacity, it should be decided whether the resilient set should operate continuously throughout a mains failure or only run on the failure of a running set. All sets should be started at the instance of a mains failure. After the generator operation has stabilised (normally less than five minutes), the number of online sets is adjusted to suit the actual demand.

8.64 If the number of sets that operate is to be varied to match the required load, care should be exercised in defining the power levels that disconnect a set from load. This figure, which may vary over months or years, should be reviewed on a regular basis. The risk of stopping a running set due to light load running, compared with the reduced risk of operating with excess capacity, should be considered.

Mains return

8.65 To return the electrical power source back to the DNO service, a minimum delay should be agreed to allow the DNO service to be established and stabilised, otherwise the risk of repeated outages (caused by the number of auto-reclose devices) may follow. This should be a minimum of five minutes, and determined by local experience.

8.66 Designers should give further consideration to how the load is actually transferred, either manually or under an automated control system. Where the load is transferred manually, a key switch will be required for this function, and the transfer can be coordinated to the benefits of the healthcare premises. This mode of operation may only require a short-term (less than five minutes) parallel operation under the G59/1 requirements. The load transfer under an automated control system should be gradual to minimise transient voltages, which may otherwise cause an outage of either the DNO supply or the running standby generators. Where the load transfer from the generator(s) to the DNO supply is gradual, a long-term (greater than five minuets) parallel operation agreement under the G59/1 Regulations will be required.

8.67 Long-term parallel operation of generators with the PES as described by the G59/1 regulations has clear advantages for testing generators with the minimum inconvenience to end-users. See the routine online testing of primary and secondary power sources in Health Technical Memorandum 06-01 Part B.

8.68 Additional information can be found in Chapter 9 for the automated management and control of a stage transfer system.

8.69 When all electrical loads have been transferred back to the DNO supply, the standby generator(s) should be allowed to run on for a period to facilitate natural cooling of the engine. This period can be a pre-set time of say ten minutes or at pre-set return temperatures of the lubricant and/or water cooling systems.

Computerised load management of generators

8.70 The electrical infrastructure and distribution strategy may minimise the effect of an electrical fault to the clinical risks areas. However, the most resilient system cannot eliminate the risk. The highest risk of generator failure is during the first five minutes of the set starting online. While the standby generators are providing the only electrical power, variation in demand may result in the generators running on a light load. This is particularly the case with multiple sets. Similarly, the demand variations may cause the generator to become overloaded.

8.71 Where the standby generators do not provide support for the total electrical system of the site, problems may rise during prolonged outages (of the PES). For example, where the chiller plant is not supported by default, building internal temperatures may arise above acceptable levels.

8.72 The design process may consider supervisory control and data acquisition (SCADA) computer systems to automatically control the generators and switchgear status and connected load. This function may also be provided using a PLC system.

Standards and references

8.73 Generating sets should be specified that are compliant with the relevant parts of the following specifications. Particular attention should be given to the governing system of the engine and the voltage regulation system of the alternator:

- generating sets are specified in BS 7698, ISO 8528;
- engines are specified in BS 5514, ISO 3046;
- alternators are specified in BS 4999.

Generator engines

8.74 The choice of generator engine type is determined by the required output and speed. For generators up to 50 kVA, the prime mover may be either a petrol or a diesel engine with four or six cylinders. Generators between 50 kVA and up to 500 kVA are best driven by diesel engines with six or eight cylinders in V formation. Generators in the range of 500 kVA to 1500 kVA are best driven by diesel engines having 12 or 16 cylinders in V formation. From the early 2000s some engine manufacturers have been making 20-cylinder engines used to drive 1500 kVA to 2 MVA generators. The advantage here is that with more cylinder displacement and equal engine speed, a greater load acceptance factor can be applied to the generator.

8.75 The larger engines should all have turbocharge units fitted, while the smaller sets (less than 100 kVA) may be more economical with natural aspiration.

8.76 Engines should be continuously rated, as defined in BS 5514, ISO 3046. They should be capable of operating at the rated load for a period of 12 consecutive hours inclusive of an overload of 10% for a period not exceeding one hour, the prescribed maintenance having been carried out. This is known as a Class A rating.

8.77 Diesel or gas engines should generally be manufactured in accordance with BS 5514, ISO 3046. Four categories of load acceptance are available for various types of engine operation on the basis of percentage load acceptance for the Class A rating:

- Category 1 – 100% load acceptance;
- Category 2 – 80% load acceptance;
- Category 3 – 60% load acceptance;
- Category 4 – 25% load acceptance.

8.78 The advantages of higher acceptance factors should be reconciled with the increased cost of larger generator sets, and the time taken to reach acceptance point with synchronised sets. Naturally-aspirated generators have a higher acceptance factor for a given output rating, but are also physically larger. Generators that can satisfy the Category 2 or 3 of a Class A specification to BS 5514, ISO 3046 may be more economic and appropriate for most healthcare premises.

Batteries and battery charging

8.79 For most generating sets, the means of starting is by an electric starter motor. Air start is available, but for economic reasons is generally restricted to generators greater than 2 MVA for sets at 0.4 kV or greater than 3 MVA for sets at 11 kV.

8.80 The reliability and maintenance of batteries is extremely important. For a generating set to start consistently, the batteries should be in good condition and maintained fully charged while the set is both running and stationary. The maintenance procedures should include the requirements given by the particular battery manufacturer.

8.81 Usually, two battery-charging systems are supplied with a generating set:

- a charger for operation while the set is stationary, usually in the control panel;
- a belt-driven charge alternator that maintains the battery when the set is running.

8.82 For both charging systems the battery should be charged at the correct “float voltage”, and for engine starting the battery should be adequately sized for the “breakaway” (initial starting) voltage

to be acceptable to the engine manufacturer. The use of a BMS should be considered for the monitoring of the battery condition.

8.83 Table 4 gives a range of battery types in ascending cost order. The type of battery to be selected should be assessed with regard to the risk, cost and planned maintenance. The length of battery life should be checked with the battery manufacturer.

Table 4 Battery types

Type of battery	Typical life
Lead acid	3 to 5 years
Sealed lead acid	3 to 7 years
Planté	5 to 10 years
Ni-Cad (Nickel cadmium)	>10 years

Fuel and fuel storage

8.84 The design process should evaluate the fire and pollution implications of storing diesel fuel (the generators' prime energy source). Further advice is available from a guidance note for the Control of Pollution (Oil Storage) (England) Regulations 2001 as published by Defra (Department for Environment, Food & Rural Affairs). Designers should see the Firecode series and medical adjacencies when determining the location of any bulk fuel storage. The volume of diesel fuel oil stored within the day tank and arranged for gravity feed of fuel oil to the engine should be no more than the greater of 750 L or the equivalent of 10 hours' full-load (maximum capacity) running of the generating set. In addition, a fuel oil main reserve for 200 hours' full-load running for each standby generator set should be available on site. Where the standby generators are decentralised, fuel should be pumped from the centralised storage area.

8.85 Where the fuel is not pumped to decentralised standby generator(s), a hand-operated semi-rotary oil pump should be available for transferring fuel oil from oil drums or other vessels to the standby generator(s) day tank. The hand pump should have a filter fitted with screw caps to prevent ingress of dirt when in storage. Where the oil-fired boiler burner plant (or CHP plant) can use the same low-sulphur fuel as the generators, designers may wish to consider sharing the bulk fuel storage. Under such strategies, the stored fuel volume should be assessed on the worse-case demand of 200 hours' continuous full-load generator(s) demand or 10 days' continuous peak thermal boiler-plant demand. Designers should give consideration to how to minimise the effect of stratifying fuel oil where the stored generator fuel is not shared with the boiler plant, which may mitigate such effects. There are ranges of systems for fuel storage and supply that can be considered, and a brief description of some follows.

8.86 Figure 24 shows a basic system comprising a day tank and isolating valve with bulk fill point and hand pump. The tank could be filled using the bulk fill point or via the hand pump from fuel brought to the side of the day tank. However, the generator has no automatic means of maintaining the fuel tank full.

8.87 The addition of bulk tank storage as well as a day tank, as in Figure 25, allows extra capacity to be kept on site. The day tank can now be filled either from the bulk tank, or via the hand pump from fuel brought to the side of the day tank. The bulk tank can fill the day tank either by gravity feed or as a pumped supply. Where the day tank is automatically maintained full by the transfer pumps, at least one pump, powered by an extra LV source or diesel, should be provided. This may assist when the day tank is empty, the generator has stopped and there is no mains electrical power.

8.88 Where fuel can be dumped from day tank to bulk tank, it is important to reduce, by design, the chance of accidental system operation. The entire generating set installation is at risk if the fuel dump is accidentally released, since the day tank would be empty, and during a mains failure there is no supply available to operate the transfer pumps. Where a 24 V dc supply is required to maintain the dump valve closed, the source of that supply should be carefully considered, as a reduction or failure of this voltage would also cause all fuel to be dumped from the day tank. Operation of the dump valve should also be monitored and alarmed. The bulk tank capacity should maintain sufficient empty space to receive the full contents of the day tank.

8.89 The addition of the fire safety-valve feature needs to be carefully considered and risk assessed against the potential disruption of a premature generator set failure. If the generator is sited away from other buildings and provided with automatic fire detection, the ability to maintain electrical supply while making a managerial decision regarding the fire condition may be preferential in terms of risk. In addition to the guidance given by Defra,

Figure 24 Fuel day tank with hand fill

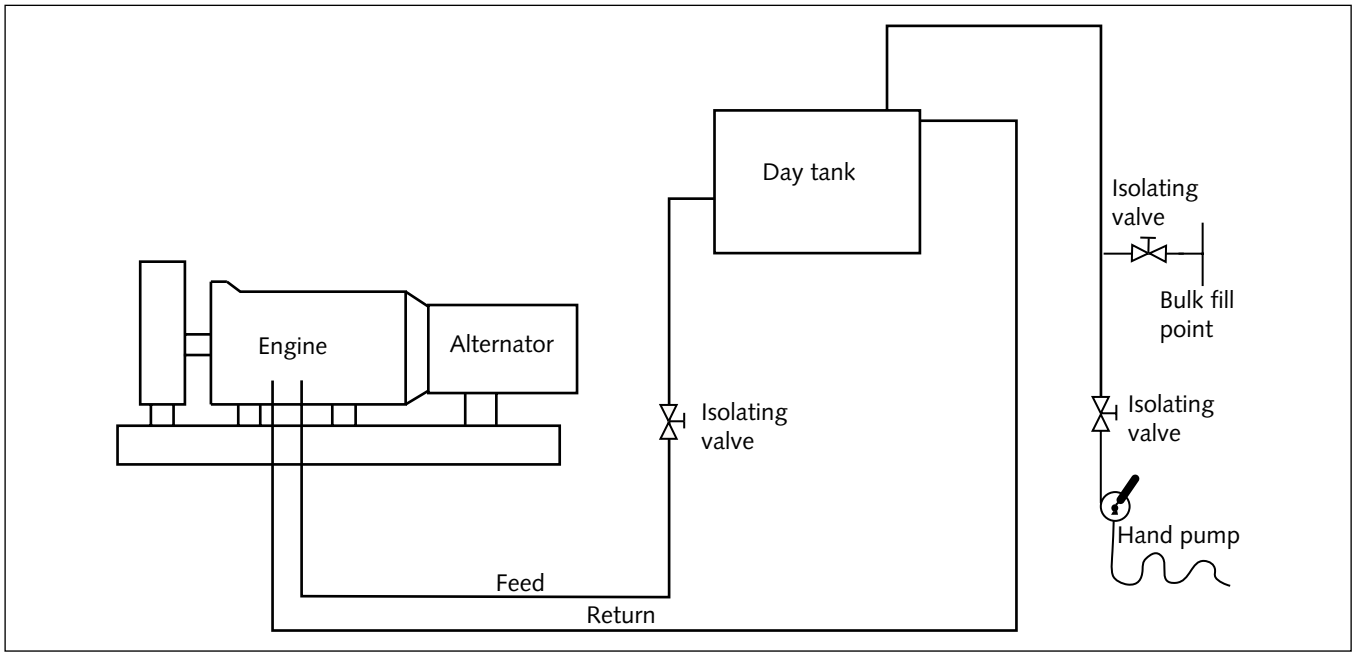
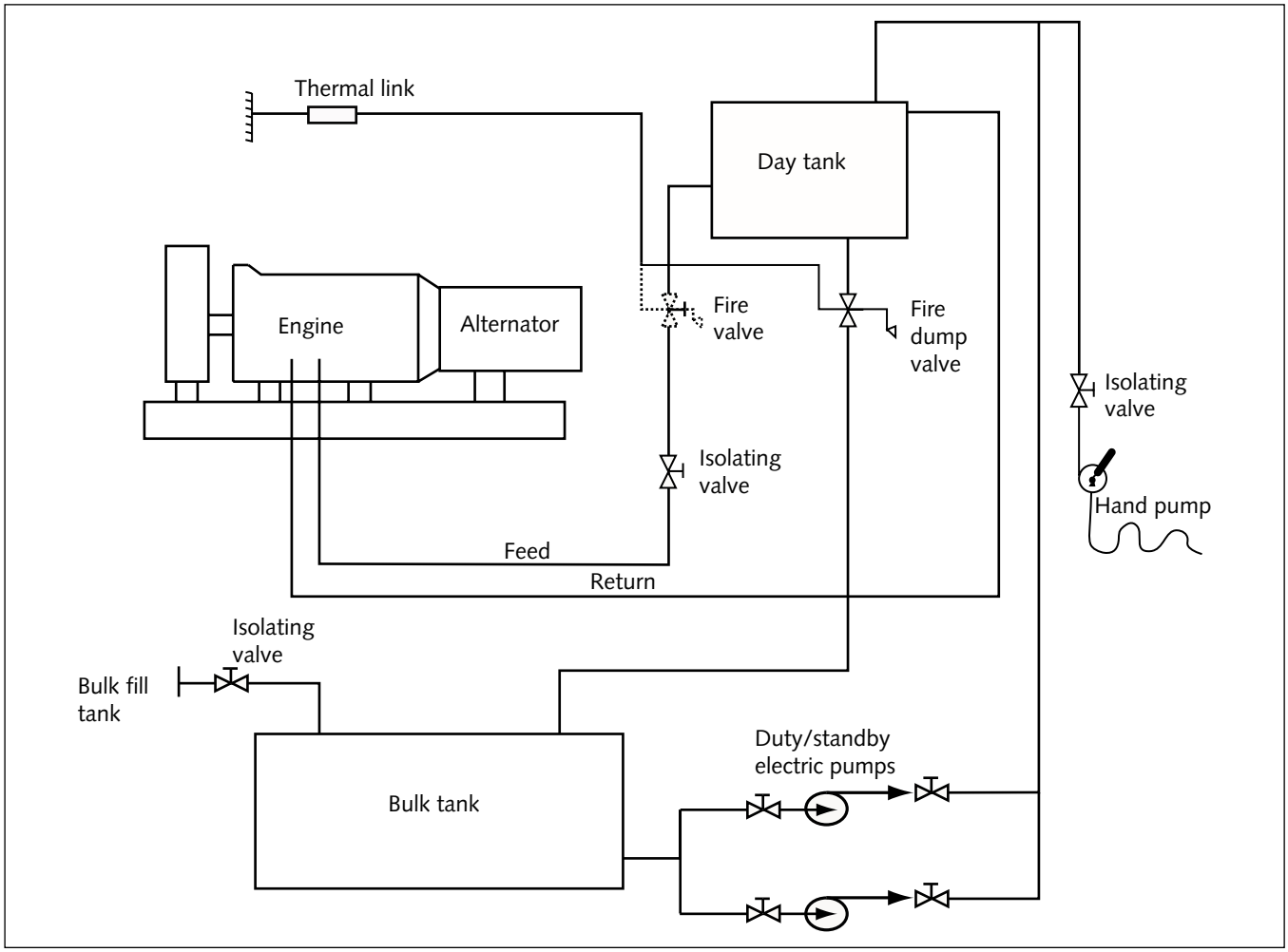


Figure 25 Fuel day and bulk tanks with dual pumps and fire dump



installations must comply with local regulations from the fire department, district surveyor and local council. For large generating sets, the quantity of fuel to be stored could become significant in both the day and bulk tanks. Both the size and the location of bulk fuel tanks should be carefully considered. Fuel in the bulk tank can remain unused for significant periods and may deteriorate. It should be subject to routine testing. The risk associated with fuel leakage should be assessed. Containment may be required for day tank, bulk tank and associated fuel transfer pipework, both from the bulk tank to the day tank and from the day tank to the engine. The use of tank bunds and double-skinned transfer pipes should be considered. To reduce the possibility of fuel spillage, controls should be included to ensure that should a day tank become overfilled, any fuel transfer systems are automatically switched off; similarly if a bulk tank is overfilled, visual indication is given at the fill point.

Exhaust systems

8.90 The exhaust system associated with a generating set should include a silencing system that reduces the noise level to acceptable limits at the point of discharge. Due consideration should also be given to the position of the discharged gases with regard to smell and gas condensation temperatures. The engine exhaust will be the hottest part of the generating set and will operate in the region of 450°C at full load. The system should be lagged where it is considered to present a safety hazard or heating problem. Design of exhaust systems should take due consideration of the possibility of condensation from the exhaust gases at the final exit to avoid the possibility of corrosion. Where the discharge point of the gases is remote from the generating set, it may be necessary to increase the diameter of the pipework to overcome any back-pressure. Exhaust gases are a fire and pollution hazard, and are increasingly regulated, with the need to fit catalytic converters and particulate filters. Installations must comply with local regulations for environmental health, fire safety officers, district surveyors and local councils, and must comply with the Clean Air Act. The final termination point of the exhaust should be kept away from any fenestration and/or air intakes.

Environmental considerations

8.91 A generating set should be configured to operate on low-sulphur fuels. Noise from standby generators can cause significant disturbance if not attenuated. Designers should address the air intake noise by suitable attenuation so that the sound pressure level in the generator enclosure is less than 85 dbA, or operatives should wear personal protective equipment (PPE). The generator enclosure and air removal system should also be attenuated so that the sound pressure level satisfies the local environmental conditions. This will require an understanding of the nighttime background noise levels near the generator house. The need for PPE should be assessed, and a risk assessment should be undertaken.

8.92 The following is a list of typical conditions in a generating set that will require operational procedures to provide a safe environment:

- hot surfaces:
  - a running engine operates at approximately 90°C and the exhaust at 550°C, which requires guarding;
- rotating parts:
  - all moving parts should be protected by guards;
- batteries filled with acid:
  - leakage, venting, filling together with electrical connection and disconnection should be controlled;
  - procedure for cleaning a spill, together with controlled disposal of waste materials;
- antifreeze that can spill:
  - procedure for cleaning a spill, together with controlled disposal of waste materials;
- noise levels that typically exceed 105 dbA in close proximity to set:
  - the use of ear protection is essential;
- electricity generation at voltages of 0.4 kV or 11 kV:
  - all protective cover plates should be in position.

8.93 The maintenance of a generating set will periodically result in batteries, lube oil and antifreeze requiring to be replaced. Each of these items has environmental consequences, and a safe disposal policy should be enforced that includes an audit trail documenting the controlled disposal.

9 Protection and switchgear

9.1 This chapter considers the various types of switchgear at 11 kV and 0.4 kV that may be appropriate for healthcare premises. It is important to review the distribution strategy (see Chapter 6) before selecting switchgear and protection types. This is of particular importance when making modifications to existing electrical network(s). An understanding of the implications for maintenance and the spare-part requirements should be ensured before selecting different generic types of switchgear. Detail of spatial planning for switchgear is provided in Chapters 7 and 8.

High-voltage switchgear

9.2 The type of HV switchgear selected should be comparable with the type of HV substation. While this statement may seem obvious, many manufacturers are making compact ingress protection-rated enclosures for internal switchgear to be used semi-externally. Similarly, some installers are housing typical external switchgear (ring main units) inside buildings due to the competitive pressures for available land space and reduced component cost.

9.3 The main forms of HV switchgear are oil, SF6 and vacuum, all of which can be used for a switch disconnector or circuit breaker. Switchgear assemblies (functional units) can be in the form of a single component or multiple units, linked via a busbar, to form a composite HV switchpanel. Functional units can be withdrawable, semi-withdrawable or fixed-pattern. The difference offered by each system is the compactness and opportunities for servicing or replacing faulty functional units. (Many devices include two functions: for example, disconnector and circuit breaker in one device, except the switch is often a single-function device.)

Withdrawable units

9.4 Withdrawable units are generally truck-mounted components which sit in a specific chamber and connect between the common busbar and cableway. Withdrawable units tend to have the largest physical size of all switchgear for a given rating. The units have a very safe interlock and shutter mechanism that prevents access to live parts when the truck is removed. The truck can be located in the "cable busbar" position, "cable earth" position or "busbar earth" position, just by the relative position of the truck in the housing. To replace a withdrawable unit, the unit is lowered from its normal in-service position and wheeled away from the chamber. Withdrawable units can be replaced (with a spare unit) within half an hour. With withdrawable units it is possible to prove a circuit dead, while the truck has been removed, with the aid of a purpose-built "voltage indicating stick". There is no equivalent method of proving a circuit dead on the other types of HV switchgear. Note that the oilswitch oil circuit breaker is only available as a withdrawable unit. Where the withdrawable unit includes electrical interlocks, the electrical interlock integrity to other withdrawable units should be maintained when the device has been withdrawn.

Semi-withdrawable units

9.5 Semi-withdrawable units are generally frame-mounted components which sit in a specific chamber and connect between the common busbar and cableway. Semi-withdrawable units tend to have the medium physical size of all switchgear for a given rating. The units have a very safe interlock and shutter mechanism that prevents access to live parts when the unit is withdrawn from its frame. The unit only has one service position and provision for cable earthing. To replace a semi-withdrawable unit, the unit is released from its normal in-service position; fixing bolts have to be removed before the unit can be fully removed. Semi-withdrawable units can be replaced (with a spare unit) within one to two hours. In order to prove a circuit dead, specially-connected indicating lamps are connected between cable and busbar.

However, there is not a 100% foolproof method of proving the lamp circuit.

Fixed-pattern units

9.6 Fixed-pattern units are frame-mounted components which sit in a specific chamber and connect between the common busbar and cableway. Fixed-pattern units tend to have the smallest physical size of all switchgear for a given rating. The units have a safe interlock and shutter mechanism that prevent access to live parts. However, the units cannot be withdrawn or used for cable/busbar earthing, as the unit only has one service position. To replace a fixed-pattern unit, the full switchpanel has to be isolated and stripped down. Fixed-pattern units will therefore take the longest time of all switch assembly types to replace. In order to prove dead, specially-connected indicating lamps are connected between cable and busbar. However, there is not a 100% foolproof method of proving the lamp circuit. Consideration should be given to the method of cable earthing where fixed-pattern units are used. Cable earths may be difficult when fixed-pattern units are used at both ends of the cable. It is also recommended that every switchpanel have a local means of earthing the busbars.

9.7 Where the switchgear device includes a circuit-breaker function, thought should be given to the type of arc-interrupting material (oil, SF6 or vacuum) in terms of the environment, health and safety, and maintenance requirements.

9.8 Oil switchgear has a good legacy and reliability; however, any controlled or fault operation of the switchgear creates a controlled spark interrupted by the oil, which degrades the oil. Hence, the oil circuit breaker device (OCB) should be serviced after any three fault operations of the breaker. Mineral oils are not environmentally friendly, and special disposal requirements should be observed. Silicon oil is a suitable replacement for mineral oil, but the switchgear maintenance requirement remains unchanged.

9.9 SF_6 switchgear uses the properties of sulphur hexafluoride (SF_6) for arc interruption and hence is smaller than the OCB for the same rating. Under normal use, SF_6 is a colourless, odourless, non-toxic and non-flammable gas, giving advantages for internally located switchgear. The switchgear maintenance requirements are related to a fault condition or a lowering of the gas pressure (normally held at 1 bar g). The SF_6 circuit breaker can still operate satisfactorily with a reduced gas pressure. The disadvantage of SF_6 is that the gas can dissociate and produce an odour when exposed to a high-energy spark of a fault condition. The dissociated gas can produce particulate dust and other by-products that are a skin irritant. The health and safety aspects of SF_6 have tended to drop this form of circuit breaker from favour. Where SF_6 switchgear is used, appropriate hazard signs should be fixed to the switchroom doors.

9.10 Vacuum switchgear uses a vacuum chamber to interrupt the arc generated by the circuit breaker tripping or automatically opens under fault conditions. The disadvantage of vacuum switchgear is the instability of the arc under fault conditions. As the vacuum bellows opens, the spark can collapse and remake three or four times before the energy is sufficiently lowered to effect isolation. The repetitive arcing may cause HV transients in the load circuit.

9.11 The selection of any particular switchgear type should include a review of the life-cycle costs of the respective types. However, best-practice designs are focused on the implications of a fire arising from any explosion within the HV equipment. Equally important will be the protection type that can be used and the method of reconfiguring the HV network following a fault. The selection of the particular switchgear type should also consider the means of earthing the cable (at both ends).

High-voltage busbar sections

9.12 As mentioned in the previous section, certain switchgear types allow for earthing cables and busbars. In addition, they provide a means to positively prove dead. Where the selected type of switchgear does not allow this function, the HV switchpanel should be split into two sections separated by a cable length. If the cable terminates onto each section of the switchpanel via a disconnector circuit breaker combination, it may be possible to replicate the advantages of the withdrawable device (except, that is, the opportunity for fast replacement times).

9.13 One clear advantage of the cable link on the HV bus section is the opportunity to build a fire barrier between the two sections of the panel. Similar facilities can be achieved with two ring main units used on a common substation.

High-voltage protection devices

9.14 On HV networks, the protective devices are fuse links or relays which automatically operate local or remote circuit breakers. At high voltage the opportunities to grade fuse links and provide a level of discrimination are significantly less than those for the LV fuse link, particularly as the HV current approaches 45 A (800 kVA). Relays can have very fast operating time compared with fuses, which explains why relays are the preferred protective device for voltages above low voltage, typically 50 ms, 2.5 cycles (digital/numerical relays) and for electromechanical relays 150 ms (7 cycles). Time fuse links are used for some HV applications.

High-rupture-capacity (HRC) fuse links to BS 2692, IEC 60298

9.15 These fuse links are suitable for fitting into HV ring main units. They are equipped with a striker pin (actuated by a small pyrotechnic device) which is used to operate a trip mechanism disconnecting all phases. The speed of the device at large currents is such that they are able to limit the current to the fault. The size of the fuse is determined by the transformer size and its inrush current (normally 12 times transformer full load for 0.1 s). The range of fuses available are from 5 A to 125 A, covering transformer sizes from 50 kVA to 1600 kVA. To assist with network discrimination it is recommended that HRC fuses are limited to protection of transformers up to and including 800 kVA.

Time fuse links to ESIS 12.6

9.16 Time fuse links, also known as time-lag fuses (TLF), are designed to Electricity Supply Industry Standard (ESIS) 12.6. The links are used in conjunction with a current transformer (CT) to operate an HV circuit breaker via an ac trip coil. The range of fuses available is 3 A, 5 A, 7.5 A, 10 A, 12.5 A and 15 A. When used with the appropriate CT ratio they can be used to protect transformers having a range from 200 kVA to 2000 kVA. TLFs are normally designed to protect against overcurrent and earth faults. The yellow phase is used for earth fault protection and the fuse on this phase is either reduced or omitted; this makes grading between TLFs in series with each other very difficult.

Inverse definite minimum time (IDMT) relays

9.17 The two previous devices are current-operated only. The IDMT relay in its basic electro-mechanical form is adjustable both in the current setting known as a plug setting (PS) and a time setting know as a time multiplier setting (TMS). The relay is fed via CTs by varying the CT ratio. Plug and time settings enable the relay to be used in any part of the distribution network and in series with each other. The modern relays are electronic; these have the added advantage of more settings and curves, enabling them to mimic HRC fuses, time fuse links and LV ACBs. They can also be configured to display HV current, removing the need for ammeters. The latest IDMT relay can also be connect to BMSs or connected to the Internet for remote interrogation or operation.

Bias differential relays

9.18 Bias differential relays are used in unit protection schemes (the trade names for these relays being Translay and Solkor). They are configured in pairs at either end of a feeder cable or at a transformer. They will only operate if the fault is within their zone of protection; all other faults will cause no action. Unit protection schemes are used on closed ring networks and on interconnectors, that is, cables connecting two sources of supply (primary and secondary).

Earth fault passage indicators

9.19 Earth fault passage indicators are devices which are connected to cable entry points on HV switchgear. They are used to indicate when an earth fault has passed through the cable. Early versions dropped a coloured disc on the unit, and the Authorised Person (HV) would then walk the system and disconnect the faulty section. The latest devices can be individually connected to a central location and used as part of an automatic restoration system.

Grading of protection systems

9.20 Grading of protection systems is carried out to ensure, so far as is possible, that only the faulty equipment is disconnected when a fault occurs.

9.21 Discrimination by time separation is achieved by making the protective devices, which all detect and respond to the fault current, progressively slower to operate the further they are from the point of fault. This is the normal method of ensuring grading on open ring or radial distribution systems using HRC

fuses, time fuse links and IDMT relays. In order to ensure that grading is achieved there are typical minimum acceptable time separations between the various devices, and these are as shown in Table 5 and Figure 26. However, fixed grading margins are only appropriate at high fault levels that lead to short relay operating times. At lower fault current levels with longer operating times, typically when the HCP is supported using standby generators, relays may fail to grade corrrectly.

9.22 Discrimination with stability is achieved by making the protective devices detect, and respond to, only faults which require their operation, thus ensuring that only the faulty equipment is isolated. This is the normal method of ensuring grading on closed ring distribution systems using unit protection relays. As the unit protection relays detect, and respond to, only faults calling for their operation, there is no necessity to build in time delays for time separation purposes.

Network reconfiguration after a fault or outage

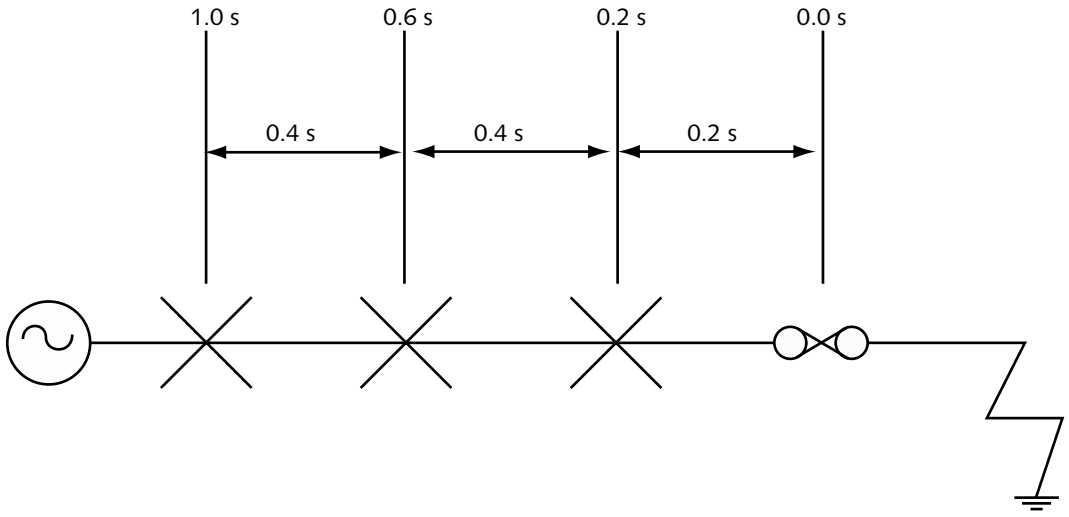
9.23 The HV protection system should be designed to disconnect the faulty part of the system with minimum disruption. The type of HV distribution strategy (see paragraphs 6.26–6.30) and the type of functional unit used will determine the time taken to restore supplies to the health section of the network.

9.24 A fault on a radial circuit will cause all users on the circuit to be affected until the system can be reconfigured, and any users downstream of the fault will be disconnected until the fault has been repaired. On ring circuits utilising ring main units (RMUs), users on the affected parts of the ring (depending on the position of any open point) will be disconnected until the fault is located. Normally all users will be restored after reconfiguration of the system. Protection control units are now available that will reconfigure the network automatically using fault detection systems and powered switches on RMUs and circuit breakers, restoring power in

Table 5 Time separation of protective systems

Smaller protective device (nearer to fault)	Larger protective device (further from fault)	Minimum time separation (seconds)
HRC fuse	HRC fuse	Limited options for grading using I^2t (ie let-through energy) values
HRC fuse	Time fuse links	0.2
HRC fuse	IDMT relay	0.4
Time fuse links	Time fuse links	Will not grade satisfactorily
Time fuse links	IDMT relay	0.4
IDMT relay	IDMT relay	0.25–0.3

Figure 26 Progressive time separation



minutes rather than the normal manual restoration which can take up to an hour – even longer when staff are not in attendance.

9.25 Networks with a closed ring topology using circuit breakers and unit protection will disconnect the section of the ring under fault, normally leaving all users unaffected.

9.26 The design of the HV protection should be consistent with the distribution strategy. The protection systems relate to the network type, and should not be the principal selection process. The advantage of using IDMT relays with adjustable settings to allow for the remodelling of the HV network is that they may also provide greater flexibility for future developments of the healthcare site.

9.27 Where the standby plant consists of HV generators, it will be essential to incorporate an automatic control system to reconfigure the network(s) after any HV fault conditions. HV protection systems that include facilities to reconfigure the network automatically should be associated with the clinical risk and business continuity assessment.

Distribution transformer types

9.28 The number and rating of transformers should be determined by the distribution strategy (see Chapter 6). The transformer rating should also be selected according to the AMD, fault level, and the prospective short-circuit current (PSCC). The transformer rating should be limited to 2000 kVA. The parallel operation of power transformers is not recommended by this Health Technical Memorandum. Transformers may be operated in parallel only with due care and consideration for the increased fault level. Where more than one transformer is used in a common substation (either independent or in parallel), they should all be of the same vector group, same voltage transformation, and have a percentage impedance within 10% of each other, for example 6% and 5.4% or 6.6%.

9.29 Transformers of all types are denoted by their winding configuration, phase displacement between primary and secondary windings, and percentage impedance. The notations start with the HV winding configuration, followed by the LV winding configuration, and then phase displacement expressed in clock-hour positions. Capital letters are used to denote the higher voltage. The most common type of distribution transformer used in healthcare premises is a Dyn11. This means the primary windings are delta-connected, the secondary windings are star-connected, and the secondary windings lag the primary windings by 30°. "Zigzag" transformers have a Z as the winding notation.

9.30 Transformers used in healthcare premises fall into one of two types, defined by the method of cooling the windings. The types are fluid cooled (either mineral or synthetic oils), cast resin, and air-cooled or exposed winding type.

9.31 Transformers used for IPS units are discussed in paragraphs 16.27–16.48.

Fluid-type transformers

9.32 The windings are ideally insulated to Class F (that is, allow a 100°C differential temperature between the winding and the adjacent area). The windings are cooled by circulating oil, usually synthetic silicon oils. The oil transfers the winding heat to the external face of the transformer where it is radiated by air. This type of cooling is referred to as "oil natural circulation, air natural flow" (ONAN). Silicon oils are a dielectric fluid (K3), which are preferred because of their high flash point (greater than 300°C).

9.33 Fluid-cooled transformers less than 1600 kVA are generally hermetically sealed. This requires the transformer oil tank to take up any expansion in oil volume due to the heating. Larger oil-cooled transformers have an oil conservator located on the top of the transformer. Expansion of the oil is controlled by the volume of dried and filtered air allowed into the conservator.

9.34 Designers may wish to consider a further advantage of the oil-cooled transformer with conservator. A gas detector can be used in the conservator to operate a relay that disconnects the primary side supply if the oil contains gases caused by faults or air impurities. This type of relay is known as a "Buchholz relay". However, the conservator and Buchholz relay tend not to be viable on transformers less than 10 MVA. For transformer ratings less than 10 MVA, alternatives such as the distribution strategy given in Figure 17 may be appropriate.

9.35 Where the transformer oil tank contains more than 50 L of silicon oil, the transformer should be enclosed in a two-hour fire-compartmented enclosure. Where the fluid is a dielectric such as

mineral oil (O1), high hydrocarbons (K1) or esters (K2), fire compartmentation is required with fluid capacities above 25 L.

9.36 See paragraphs 7.33–7.50 for details of the transformer room location and construction.

Dry-type transformers

9.37 The windings are ideally insulated to Class F (that is, allow a 100°C differential temperature between the winding and the adjacent area). The resin transfers the winding heat to the transformer outer casing where the heat is radiated in much the same way as with the fluid-cooled transformer. This type of cooling is referred to as "no inner circulation and air natural flow secondary" (AN).

9.38 Cast-resin transformers may be totally enclosed in their own housing, or of the open-winding type. Clearly, the open-winding type cannot be used externally. Further safety precautions regarding access to the transformer room are required for open-winding dry-type transformers. Cast-resin transformers tend to vibrate and hum more than fluid-cooled transformers and consequently collect dust, which requires regular cleaning, say annually. (See Health Technical Memorandum 06-01 Part B.)

9.39 See paragraphs 7.33–7.50 for details of the transformer room location and construction.

Package substation

9.40 Package substations are composite units with the HV switchgear close-coupled to the transformer side. In some cases the LV switchgear is also close-coupled to the transformer. Package substations always use dry-type cast-resin transformers.

9.41 Designers and stakeholders should consider package substations, which offer a cost-effective solution in terms of the requirements and access for maintenance. Due to the close-coupled arrangement, maintenance may take longer and will affect larger parts of the systems. Care should be taken to ensure that only HV Authorised Persons (AP(HV)) have access to the HV equipment.

9.42 Package substations may provide an effective solution for dedicated single loads such as large chiller stations. Package substations may also provide effective solutions where the distribution strategy has a high resilience, such as the dual-unified network (see Chapter 6).

9.43 See Chapter 7 for details of the package substation's location and construction.

Transformer protection

9.44 For a general overview of transformer protection systems, see paragraphs 9.14–9.27. HRC fuse links are suitable for transformers rated up to 800 kVA, while TLF fuse links, which can also provide earth fault protection, are a more appropriate protection form for transformers in the range of 200 kVA to 2 MVA. Unit protection is not economic or effective on transformers less than 10 MVA. Protection of fluid-filled transformers can be achieved with a Buchholz relay. Dry-type cast-resin transformers have a thermistor integral with the windings which will isolate the transformer on high winding temperatures caused by a fault current or other reasons. The most common faults with transformers used in healthcare premises are more to do with the cables connecting the primary and secondary windings to the network. An IDMT relay with the sensing CTs configured to give "earth fault and protection" can monitor either the HV connecting cables or the LV connecting cables. (Note that overcurrent/overload protection will be provided by the LV circuit breaker.) By connecting pilot wires between the HV and LV circuit breaker, a system known as "intertripping" can be used to ensure that no power can be supplied into the fault, regardless of the IDMT relay being on the HV or LV side.

Generator protection

9.45 Generators are essentially provided to maintain a supply when part of the internal distribution has failed, or the PES has failed. Therefore, the protection design intent should be different, and more tolerant of fault conditions, before operating any generating isolating devices.

9.46 Designers and stakeholders should consult with manufacturers regarding the generator damage curve and short circuit decrement curve before calibrating the protective devices.

9.47 The main fault condition to be considered in relation to a generator is the earth fault. Generators should be able to generate adequate fault currents to clear a system earth fault without shutting down. However, an earth fault on the local cable between the generator and network should be cleared instantly. An IDMT relay with two separate relays, one configured for restricted earth fault (REF)

and the other affording overcurrent and overload protection and network earth fault protection, can be considered. However, care needs to be taken in their grading, as the generator short-circuit decrement current may influence the operation of any other IDMT relays on the network.

Low-voltage switchboards

9.48 The type of LV switchgear selected should be comparable with the type of LV substation. While this statement may seem obvious, many manufacturers are making compact IP-rated enclosures for internal switchboards to be used semi-externally.

9.49 The main feature of LV switchboard switchpanels is the form of construction (form of separation). The forms are defined in BS EN 60439-1 and BS EN 60439-3 for final distribution boards (see Figure 27, which illustrates the main forms). Designers and stakeholders should assess the opportunities for maintenance and remodelling of the distribution when selecting the form of separation. The selection of a switchboard switchpanel form can be related to clinical risks and business continuity risks. Note that any work on a switchboard of any type should be managed under the electrical safety regulations. See Health Technical Memorandum 06-02 – 'Electrical safety guidance for low voltage systems'.

9.50 Designers should select the form of separation for switchboards, switchpanels or final distribution boards based on the area covered and type of load connected to the outgoing circuits. Switchboards and switchpanels may serve more than one clinical function, and therefore the opportunity to isolate the switchboard switchpanel (for any form of maintenance) is reduced. A switchboard or switchpanel with a minimum form of separation (Form 4) should be used. Form 2 separation may be suitable for final distribution boards. Where space is available, all LV switchboard switchpanels should be located in dedicated electrical switchrooms, electrical risers, or plantrooms with controlled access. Where this is not achievable, electrical switchboard switchpanels should have lockable devices to prevent unauthorised access or interference. See Health Technical Memorandum 06-02 – 'Electrical safety guidance for low voltage systems'.

Form 2

9.51 Form 2 assemblies are enclosures that provide protection against contact with any live parts and provide internal separation between the busbar and functional units, but there is no separation between individual functional units. Compliant variations include insulated or non-insulated busbars, cable terminations separated or not separated from the busbar but not from the functional units. Each functional unit should have a facility that enables it to be locked in the off (de-energised) position (see Health Technical Memorandum 06-02 – 'Electrical safety guidance for low voltage systems'). Final distribution boards with Form 2 separation are an acceptable standard.

Form 3

9.52 Form 3 separation units are available; however, by considering the merits of distribution boards and switchpanels with Form 2 and Form 4 separation respectively, such units have little advantage within a healthcare environment.

Form 4

9.53 Form 4 assemblies are enclosures that provide protection against contact with any live parts and provide internal separation between the busbar and functional units and between functional units. Cableways are also separated from each other. Compliant variations include insulated or non-insulated busbars, cable terminations separated or not separated from their respective functional unit.

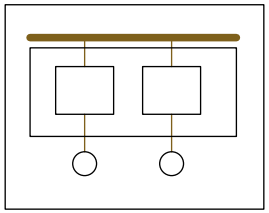
9.54 The main compliant variations of Form 4 switchboards, switchpanels are how the external cables are terminated (glanded-off). Cables can be glanded-off at the switchpanel frame, with conductors terminated in a common cableway, or separated from the cableway. Alternatively, the cables can be brought into the switchpanel and glanded-off at individual gland boxes associated with one functional unit. Each functional unit should have a facility that enables it to be locked in the off (de-energised) position (see Health Technical Memorandum 06-02 – 'Electrical safety guidance for low voltage systems').

Motor control centre (MCC)

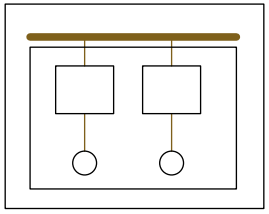
9.55 Motor control centres tend to include an LV protection section and a control section. Control technology continues to advance, from

Figure 27 Forms of separation

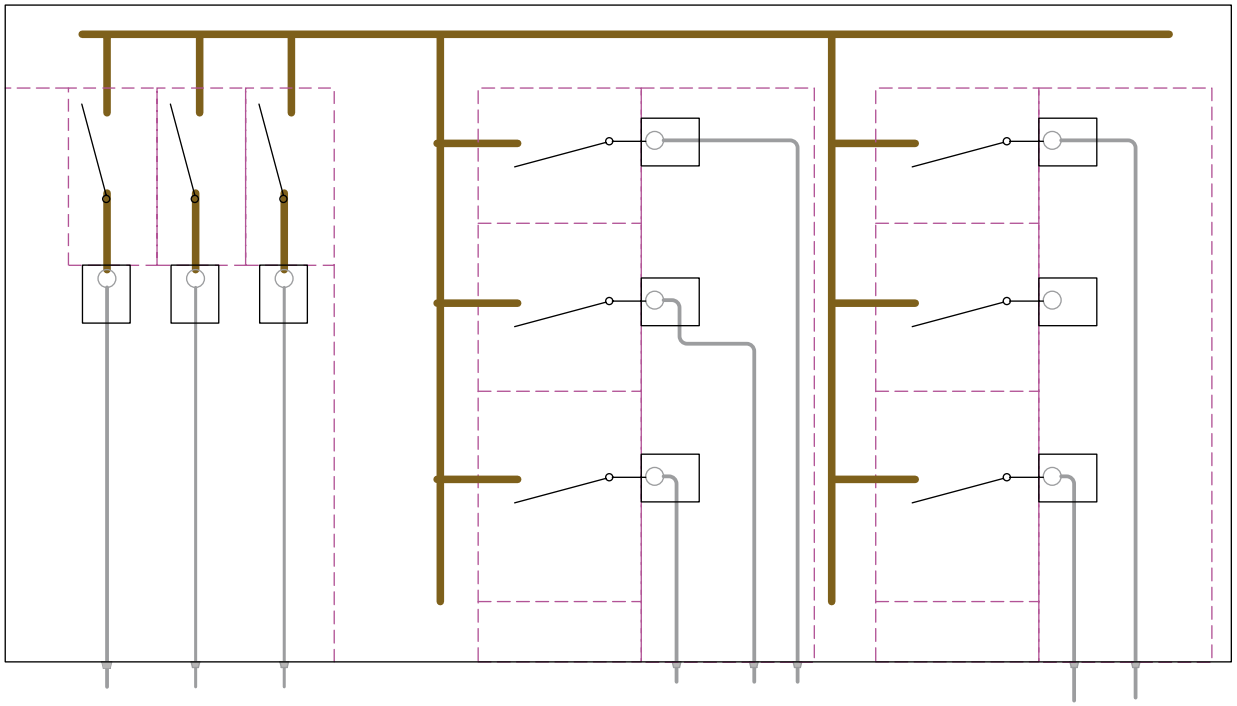
BS EN 60439-1 Switchgear forms of separation



Form 2A
Terminals **NOT** separated
from Busbars



Form 2B
Terminals **ARE** separated
from Busbars



Form 4 Type 6. Busbars separated from functional units. Functional units separated and separated from cable terminals which are in separate boxes. Cables glanded externally

electromechanical devices to pneumatic controls to electronic numeric controls and so on.

9.56 Designers should therefore consider the main safety requirements and opportunities to isolate small sections of the MCC. Best-practice solutions separate any LV protection devices from the control section, making the two sections a minimum of Form 3 separation. Within the LV section, the form of separation should be at least Form 4. Where the protection and control sections are in one composite panel, it should be possible to open the control section without providing direct access to the protection section.

9.57 An MCC should be located within a plantroom (which itself has controlled access). The supply to the MCC should be limited to 250 A, in accordance with BS EN 60439-3.

Final distribution boards and consumer units

9.58 Consumer units and distribution units (DBUs) do not fall into the same forms of separation construction requirements of BS EN 60439-1. Their requirements are identified in BS EN 60439-3.

9.59 DBUs should be located within dedicated electrical switchrooms, risers or plantroom areas. Where this is not practical, the DBUs should have a local device to prevent unauthorised access, or be surrounded by a lockable cupboard.

9.60 The benefits of remodelling and design flexibility cannot be understated when selecting switchboard switchpanel forms. Standardising on one form, particularly when the building is large, has significant merits. Form 4 type 1 switchboards which have separate compartments for insulated busbars and each functional unit, with cables glanded-off externally to the panel frame and conductors terminated within the respective functional unit, may provide best-practice solutions for healthcare premises with clinical risk categories 1, 2 or 3. Form 4 type 6 switchboards which have separate compartments for busbars and each functional unit, with cables glanded-off externally to the panel frame and conductors terminated in termination boxes external to the respective functional unit but in a common cableway, may provide best-practice solutions for healthcare premises with clinical risk categories 4 or 5.

Low-voltage protection devices

9.61 The type of LV switchgear selected should be comparable with the type of LV substation. While this statement may seem obvious, many manufacturers are making compact IP-rated enclosures for internal switchgear to be used semi-externally.

9.62 The main forms of LV switchgear are air circuit breaker (ACB), high rupturing capacity (HRC) fuse, high breaking capacity (HBC) fuse, moulded-case circuit breaker (MCCB), miniature circuit breaker (MCB) cartridge fuse, and rewireable fuse. These forms of protective device can be assembled in the moving part or fixed part of the respective switchgear. Assemblies can be in the form of a single component or multiple units, linked via a busbar, to form a composite LV switchpanel. Switchpanel components can be withdrawable, semi-withdrawable or fixed-pattern. The difference offered by each system is the compactness and opportunities for servicing or replacing faulty components. In spite of the switchgear-type name, many devices include two functions, for example a disconnector and circuit breaker in one device, except that the "switch" is often a single-function device.

Switch

9.63 A switch is a mechanical device that can carry and break a current under normal circuit conditions. The switch may be modified to allow for automated operation by other protective devices. A switch may not provide adequate separation distance between disconnected parts of a circuit conductor.

Disconnector

9.64 A disconnector is a mechanical device that carries the design current for its intended purpose. A disconnector cannot break a normal current nor make or break a fault current. The disconnector will provide adequate separation distances between disconnected parts of the circuit conductor.

Fuse

9.65 A fuse can provide the fundamental function to rupture a fault current that may flow in a correctly designed electrical circuit. The fuse can provide overcurrent protection and fault current (both short-circuit and earth fault) protection. The fuse has different characteristics, making it suitable for a

range of electrical loads, for example the general range and motor range.

Circuit breaker

9.66 The circuit breaker is a more advanced form of protective device than the standard fuse. The fusing element can have a tolerance range to delay the rupturing action. The circuit breaker is available in five basic formats for LV circuit protection:

- air circuit breaker – ACB;
- moulded-case circuit breaker – MCCB;
- miniature circuit breaker – MCB;
- residual current device – RCD;
- residual current breaker with overcurrent – RCBO.

9.67 The fusing elements of all types of circuit breaker have two parts: a current transformer providing adjustable electromagnetic setting, and a bimetal strip providing adjustable thermal setting. Note that some smaller MCBs do not have an adjustable range, but still operate with a tolerance range.

9.68 The RCD provides protection against earth leakage, with typical ranges at 10 mA, 30 mA, 100 mA, 150 mA and 300 mA.

9.69 The RCBO is a combination protective device of the MCB and RCD functions; however, the earth fault sensing element of 150 mA and 300 mA are not normally available in this combination.

9.70 MCBs and RCBOs have a range of characteristic curves, Type A, B, C or D (earlier devices were 1, 2 and 3). The separate RCD devices only sense an earth leakage current. RCBOs and RCDs used in medical locations should be type A or B and should have a tripping current of 30 mA.

9.71 The design should consider the selected protective device that will clear overload currents and short-circuit faults within the prescribed disconnection times of BS 7671:2001. Clearly, the protective device rating and disconnection times are related to the earth fault loop impedance. Designers should consider the use of RCBOs or RCDs where the earth loop impedance cannot generate sufficient earth fault currents to operate the protective device within the appropriate disconnection times (5 seconds for stationary equipment and 0.4 seconds for portable equipment). Designers should be mindful of the earth leakage current that may flow in the protective conductor under normal conditions.

9.72 Designers may wish to consider the use of RCBOs/RCDs for areas where the natural environment may be damp and hence the body contact resistance may be lowered. Such areas will include laboratories, kitchens and workshops.

9.73 Designers may wish to consider the use of RCBOs/RCDs for dedicated cleaners' sockets.

9.74 Designers should be mindful that RCBOs may be subject to nuisance tripping caused by the occasional high earth leakage currents that may be generated when equipment is switched on.

Low-voltage busbar sections

9.75 Where the LV distribution strategy includes for dual-unified circuits supported by two 100%-rated transformers, it may be useful to link the two sections of the main LV switchpanel via a "bus coupler-bus-tie". However, maintenance access to the bus coupler may require the full isolation of the switchpanel. Although such devices have very low maintenance requirements, it may also be useful to consider splitting the LV switchpanel into two sections, linked by a cableway and two ACBs. An advantage of such an arrangement may be to install a fire barrier wall between the two sections. Designers and stakeholders should see this as an expensive option and carefully assess the merits accordingly.

Discrimination of protective devices

9.76 The IEE Regulations BS 7671:2001 require that the characteristics and setting of a protective device for overcurrent should provide any intended discrimination within its operation. While the regulations do not call for discrimination for fault currents, by default a protective device should so discriminate.

Discrimination with HBC/HBC fuses

9.77 HBC fuses will conform to the requirements of BS 88.

9.78 Discrimination will ensure that the total let-through energy (I^2t) of the minor (downstream) device is not greater than the pre-arcing energy ($I^2t_{(pa)}$) of the major (upstream) device. Where the protective device has an operating range (MCB, MCCB), it is important to check that the normal operating current (I_n) of the major device is greater than *x* times the prospective short-circuit current at the downstream protective device in question

(where *x* equates to the multiplying factor applied to the downstream device; see BS EN 60898-2).

Discrimination with MCB/MCCB

9.79 The MCB (or MCCB) device can provide discrimination for overload and fault current between the upstream and downstream device. In order to provide overload protection, the nominal current setting (I_n) of the upstream device should be greater than the instantaneous rating of the downstream device (which will be *x* times I_n according to the MCB type). In order to provide discrimination of fault currents (both short-circuit and earth fault), knowledge of the prospective short-circuit current (PSCC) and earth fault current is required. Discrimination will occur if these values, for the downstream device, are less that the nominal current setting of the upstream device. Manufacturers' advice should be obtained for the actual let-through energy (I^2t) which will also determine the discrimination of series MCBs.

9.80 The use of MCBs on some final circuits may cause nuisance tripping; for example using MCBs (or RCBOs) on fluorescent lighting circuits, where the non-linear transient current of the inductive control circuit may cause early tripping of the protective device through its internal CT. Consideration should therefore be given to using an RCBO/RCD with earth leakage characteristics of type A or B.

Discrimination with MCB/fuse

9.81 Discrimination between a fuse (as the upstream protective device) and an MCB for the downstream device may occur if the lower instantaneous operating current (range) of the MCB crosses the tripping curve of the fuse above the prospective fault current level and earth fault current level of the downstream device. Discrimination checks should be made based on the manufacturers' declared let-through energy (I^2t). See Table 6.

Discrimination with RCDs

9.82 RCDs will provide earth fault protection. In order to discriminate between two RCDs as the upstream and downstream protective devices, designers need to use the time-delay setting on the upstream device.

9.83 Designers may wish to consider that full discrimination may not be required on all circuits. Opportunities exist to take advantage of a grading between fuse element curves. Where the discrimination is a little uncertain and the risk of such relative high fault currents are low, the circuit is said to have "limited" discrimination and may be acceptable. The advantage here would be the reduced size of protective devices, especially with the more upstream devices.

Automatic load management of switchgear (HV, LV)

9.84 The electrical infrastructure and distribution strategy may minimise the effect of an electrical fault to the clinical risk areas, but the most resilient system will not totally eliminate the risk. The fundamental reasons electrical systems have protective devices is to limit the effect of a fault. Effective discrimination (see above) and correct selection of protective devices will isolate the smallest appropriate section of the infrastructure. Best-practice distribution strategies may provide an alternative supply route which could be initiated more quickly or safely than replacement of a protective device.

9.85 The distribution system may initiate the standby generator plant until the fault is rectified or isolated. The reconfiguration of an electrical network (whether the system is a dual-unified supply or segregated supply) may be made manually or automatically.

9.86 Where the network is an HV ring circuit (open or closed), the operation of a protective device may result in the standby generators supplying some areas.

Table 6

MCB type	Nominal Current (I_n)	Overload Characteristics	Instantaneous Tripping range	Instantaneous Tripping
B	All	1.45 I_n	3 I_n to 5 I_n	5 I_n
C	All	1.45 I_n	5 I_n to 10 I_n	10 I_n
D	All	1.45 I_n	10 I_n to 20 I_n	20 I_n

9.87 Healthcare premises with significant sections of clinical risk Category 3 areas and above may benefit from quick reconfigurations of the electrical distribution following a fault on the network. Therefore the use of a supervisory control and data acquisition (SCADA) computer system to automatically control the switchgear status and reconfigure the network(s) would be useful.

SCADA systems are modular in design and may be added to retrospectively. The SCADA system can be applied to any part of the HV and/or LV networks including all power sources.

9.88 SCADA systems should be hard-wired with monitored circuits wherever they are used.

10 Tertiary power supplies

10.1 Tertiary power supplies (TPSs) should not be considered as a long-term energy source in the same way that primary power or secondary power units are. TPSs are generally used as a back-up supply for a given period of time (autonomy) or to start SPSs. The batteries considered are those used for uninterruptible power supplies, battery inverter units and batteries used to start standby generator engines.

10.2 Batteries used in control systems, such as motor drives on switchgear, have been excluded from this Health Technical Memorandum. Likewise, batteries used for electric vehicles are also excluded from the content of this Health Technical Memorandum. The foregoing exclusions are justified, as their respective systems do not form part of the fixed wiring systems of healthcare premises.

Batteries for uninterruptible power supplies

Battery type

10.3 There are a number of battery cell types in use today for UPS applications. The most appropriate are the valve regulated lead acid (VRLA) battery types, which are more commonly known as sealed lead acid cells. The VRLA battery is a near-zero-gassing battery cell, and hence presents a lower environmental hazard to the UPS or surrounding area. With no toxic gasses emitted from the battery, there are no special venting requirements for the battery unit. The VRLA battery is almost universally used for modern UPS systems, due to their low maintenance and because of the reduced requirements for vented gas extraction, this being a serious consideration when using wet cells.

10.4 VRLA batteries complying with BS 6290-4:1997 – with threaded insert connection posts, flame-retardant case materials and a ten-year-designed life – are the minimum acceptable standard. While BS 6290-4, 10-year-designed-life batteries have the initial penalty of higher investment costs than standard five-year-life batteries, they offer significant long-term benefits in terms of security of function and reduced long-term costs.

Battery life

10.5 Battery life is a function not only of load cycling, but of charging methods and the environment. VRLA batteries will function for a short time period over a wide range of temperature typically from –15°C to +50°C. However, for normal continuous use their ambient operating temperature should be ≈20°C, otherwise their life expectancy will be reduced considerably, typically to 50% at 30°C and to 25% at 40°C. Continued operation at high temperatures also may bring fire danger due to case splitting and resultant acid spillage, which in turn may result in uncontrolled battery dc earth faults. It is therefore very important that the battery location has a suitable environment with adequate ventilation/cooling to maximise battery life. Note that in practical terms, even with the recommended regular maintenance, VRLA batteries are normally changed at 80% of their designed life. Battery life should be in accordance with the range given in Table 4.

10.6 Correct charging of VRLA batteries is very important, and should be with low or minimum ac ripple and typical charge values of 2.27 V per cell. At elevated temperatures, it is necessary to reduce the battery charge voltage to below 2.27 V per cell to prevent over-charging.

Battery arrangements

10.7 Designers should consider the opportunities for maintenance of the UPS battery assembly. Batteries can be arranged as single or split banks. The use of split battery banks allows the UPS to remain online (at reduced battery autonomy) while half of the battery system is being serviced.

Battery autonomy

10.8 Single-conversion UPS units are generally used for small personal computers or computerised processors dedicated to medical/laboratory equipment, such as blood gas analysers. Battery autonomy is typically in minutes up to say 15 minutes, depending on the particular application. Designers should consult with staff for the actual requirement. Single-conversion UPS units are most commonly used to safely shut down systems following an outage of the PPS, or depending on the particular need, between the period of mains failure and SPS standby generators becoming available. The battery autonomy for single-conversion UPS units should be less than 30 minutes.

10.9 Double-conversion UPS units are most commonly used for TPS to dedicated final circuit outlets, used for example in clinical risk Category 4 or 5 areas. The most usual application of a double-conversion UPS is to provide tertiary power to IPS systems, particular those for the IEC 60364-7-710 Group 2. The batteries maintain an electrical supply following an outage of the PPS and prior to the SPS standby generators becoming available. Where the UPS battery provides TPS to non-operating-theatre low-power applications, the battery autonomy should provide clinical staff with enough time to start "hand bagging" or connecting supplementary equipment battery packs. Consequently, battery autonomy of 15–30 minutes may be appropriate. Where the UPS battery provides tertiary power to operating theatre low-power applications, the battery autonomy should provide operating theatre staff enough time to facilitate "patient closure" for all theatre cases. Consequently, battery autonomy of 60 minutes may be appropriate.

10.10 Clearly, designers should consult with stakeholders and clinical staff to determine the most appropriate battery autonomy.

Batteries for inverter units

Battery type

10.11 See paragraphs 10.3–10.4.

Battery life

10.12 See paragraphs 10.5–10.6.

Battery arrangements

10.13 Three main types of battery inverter unit are used in healthcare premises. Batteries within the self-contained emergency escape lighting and signage are generally in small packs with cells connected in series or parallel series groups. Their physical size allows these battery packs to be replaced in a single step, taking only minutes. Batteries for either the central emergency escape lighting signage or operating theatre operating lamps are housed in cabinets and connected in parallel-series cell groups. Battery maintenance is achieved by disconnection of any one parallel group. Designers should consult with manufacturers to ensure that the optimum number of parallel cell groups are provided to minimise the reduction of battery autonomy during replacement.

10.14 Designers should consider the opportunities for maintenance of the inverter units' battery pack. Batteries can be arranged as a single or split bank. The use of split battery banks allows the inverter units to remain online (at reduced battery autonomy) while half of the battery system is being serviced.

Battery autonomy

10.15 Four main types of inverter unit are used in healthcare premises. Battery inverter units used for self-contained emergency escape lighting and signage have a three-hour battery autonomy as required by BS EN 1838, BS 5266-7. Central battery units for emergency escape lighting should also have a three-hour battery autonomy.

10.16 Battery inverter units for theatre lamps should have a minimum of three hours' battery autonomy.

10.17 Battery inverters used for fire alarm and detection systems, or other alarm systems, should have sufficient autonomy to drive the systems (in quiescent mode) for 24 hours, followed by a 30-minute period where all sounders, indicators and communications are operated with the normal sound pressure level outputs. For a healthcare facility that may be closed over a weekend and bank-holiday period, an autonomy of 100 hours may be more appropriate. This requirement is independent of any secondary power supply (SPS) that may be available.

Generator batteries

Battery type

10.18 See paragraphs 10.3–10.4.

Battery life

10.19 See paragraphs 10.5–10.6.

Battery autonomy

10.20 Generator batteries are normally specified for *x* Ampere Hours (AHr), where the battery capacity *x* should be able to provide sufficient power when discharged by 25% to attempt three successive starts each of ten-second duration with a three-second interval, while the ambient temperature is 0°C. Generator battery systems should be capable of turning the generator engine continuously for 60 seconds at an ambient temperature of 0°C.

10.21 Usually two battery-charging systems are supplied with a generating set: the constant charger is a charger for operation while the set is stationary, usually in the control panel; and a belt-driven charge alternator maintains the battery when the set is running.

10.22 For both charging systems the battery should be charged at the correct float voltage, and for engine starting the battery should be adequately sized for the breakaway (initial starting) voltage to be acceptable to the engine manufacturer.

11 Electromagnetic compatibility

Standards

11.1 The Electromagnetic Compatibility (EMC) Regulations enact the requirements of the EMC Directive for the UK. From the UK Regulations, regulations 28 and 30 require that those who supply relevant equipment should show that:

- it conforms to the protection requirements;
- it meets the conformity assessment requirements;
- the CE marking is properly applied;
- it has an IEC declaration of conformity certificate.

11.2 Regulation 29 requires that no person should take into service relevant equipment unless it conforms to the protection requirements. For example, equipment covered by the EMC directive is taken into service when the end-user that operates the equipment, for example a building management system, first uses it. "Taking into service" does not include the area of energising, testing and commissioning of the equipment by the manufacturer before handover to the end-user. The equipment manufacturer will be in a position of overall control in ensuring that the essential protection requirements are satisfied, and assumes legal responsibility for compliance. Data should also be provided for the end-user to ensure that these requirements are satisfied throughout the operational life of the equipment.

11.3 From the point of view of the legislation, it is not sufficient to integrate CE-marked equipment and claim that the large "system" hence complies because compliant equipment has been used. Compliance of the large "system" should be demonstrated either by testing and/or by presentation of a rationale as to why the system complies.

Procurement requirements

11.4 Problems from electromagnetic interference (EMI) will be minimised by procuring equipment that complies with relevant standards, is supplied with a relevant EMC declaration of conformity (DOC), and is installed and maintained using good EMC practices.

11.5 It is essential that those designing and specifying equipment for use in the NHS environment must give their relevant purchase departments an EMC specification that is sufficiently detailed that suppliers are made aware of their contractual obligations with respect to EMC.

11.6 Procurers, system integrators and designers should be knowledgeable about the EMC performance levels that equipment is expected to meet when correctly installed and operated. To be able to distinguish between the requirements and declarations of compliance statements for the various directives, a procurement document should be written that covers the various directives.

11.7 As a first step, EMC requirements should consider appropriate standards; a selection is provided in Tables 7 and 8. The standards are a selection for equipment that may be expected to be present in healthcare premises. This is not an exclusive list, and as standards evolve over time, the relevant websites should be consulted for changes. A complete list of all regulations quoted in this Health Technical Memorandum can be found at the end of the document.

11.8 As well as helping to set the environment, standards are used to show compliance with the EMC Directive and with UK regulations. For equipment to be legally sold within Europe, the equipment must comply with harmonised standards, reference to which has been published in the Official Journal of the European Union (OJEU). Again, reference to the European Union's website will help identify those standards that have been referenced in the OJEU.

Table 7 EMC standards

BS EN 12015:2004	Product family standard for lifts, escalators and passenger conveyors – emissions
BS EN 12016:2004	Product family standard for lifts, escalators and passenger conveyors – immunity
BS EN 45502-2-1:2003	Active implantable medical devices. Particular requirements for active implantable medical devices intended to treat bradyarrhythmia (cardiac pacemakers)
BS EN 62040-2:2006	Uninterruptible power systems (UPS). Electromagnetic compatibility (EMC) requirements
BS EN 50098:1999	Customer premises cabling for information technology; Part 1: 1999: ISDN basic access; Part 2: 1996: 2048 kbps ISDN primary access and leased line network interface
BS EN 50130-4:1996	Product family standard – Immunity requirements for components of fire, intruder and social alarm systems
BS EN 50173-1:2002	Information technology. Generic cabling systems. General requirements and office areas
BS EN 50174:2001	Information technology. Cabling installation; Part 1: 2001: Specification and quality assurance; Part 2: 2001: Installation planning and practices inside buildings; Part 3 (draft for comment): 2002: Installation planning and practices outside buildings
BS EN 50310 2000	Application of equipotential bonding and earthing in buildings with information technology equipment
BS EN 55015:2001	Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment
BS EN 55022: 1998	Information technology equipment – Radio disturbance characteristics – Limits and methods of measurements
BS EN 55024: 1998	Information technology equipment – Immunity characteristics – Limits and methods of measurements
BS EN 60947 (1996–2003)	BS EN 60947: Specification for LV switchgear and control gear (8 parts)
BS EN 61000-3-2: 2006	BS EN 61000-3-2:2006. Electromagnetic compatibility (EMC). Limits. Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)
BS EN 61000-3-3:1995, IEC 61000-3-3:1994	Electromagnetic compatibility. Limits. Limitation of voltage fluctuations and flicker in LV supply systems for equipment with rated current ≤ 16 A
BS IEC 61000-3-4: 1998	Electromagnetic compatibility. Limits. Limitation of emission of harmonic currents in LV power supply systems for equipment with rated current greater than 16 A
BS EN 61000-3-11:2001, IEC 61000-3-11:2000	Electromagnetic compatibility. Limits. Limitation of voltage changes, voltage fluctuations and flicker in public LV supply systems – Equipment with rated current ≤ 75 A and subject to conditional connection
BS EN 61000-6-1: 2001	Generic Standards – Immunity for Residential, Commercial and Light Industrial Environments
BS EN 61000-6-2:2005	Electromagnetic compatibility (EMC). Generic standards. Immunity for industrial environments
BS EN 61000-6-3: 2001	Generic Standards – Emission for Residential, Commercial and Light Industrial Environments
BS EN 61000-6-4: 2001	Generic Standards – Emission for Industrial Environments
BS EN 61547:1996, IEC 61547:1995	Equipment for general lighting purposes. EMC immunity requirements
BS EN 61800-3: 2004	Adjustable speed electrical power drive systems – EMC product standard including specific test methods

Table 8 EMC standard by equipment type

Type of equipment	Applicable standard(s)
Access control units	Generic for emissions BS EN 50130-4:1996
Air handling units	Generic
Audio amplifiers	Generic
Battery charger	Generic
Boilers	Generic
CCTV control panels	Generic but not BS EN 55022/BS EN 55024
Chillers	Generic
DRUPS	BS EN 62040-2
EDS	BS EN 61000-6-2 BS EN 61000-6-4
Extract fans	Generic
Fire detection and voice alarm system	BS EN 50130-4:1996 BS EN 50270
HV switchgear	Generic
HVAC control system	BS EN 60730-2
ISM equipment	BS EN 55011 BS EN 55014-1 BS EN 55014-2
IT equipment used in BMS/EMS, CCTV, access control, intruder alarm, and fire detection systems	BS EN 55022 BS EN 55024
Lifts	BS EN 12015:2004 (emission) BS EN 12016:2004 (immunity)
Lighting equipment	BS EN 55015:2001 BS EN 61547:1996, IEC 61547:1995
LV switchgear	BS EN 60947
Power distribution units	Generic
Water pumps (for either potable or fire water)	Generic

EMC phenomena

11.9 EMC phenomena are divided into radiated and conducted aspects, and a special case for electrostatic discharge (ESD), that is, radiated emissions, conducted emissions, radiated immunity and conducted immunity.

Standards and levels

11.10 In any analysis of the healthcare environment or for setting procurement requirements for equipment to be installed in those environments, the first reference is to EMC standards. Those standards that are specific to the health environment will have included in them the relevant phenomena that the equipment can be expected to operate to.

11.11 Given the information in Tables 9–11, the system designer who is advising on the type of equipment for procurement and/or installation should advise the suppliers of the relevant standards for any compliant equipment.

Table 9 Radiated emissions: levels for some typical equipment standards

Specification	Frequency (MHz)	Limit (dB(µV/m))	Comments
BS EN 61000-6-3	30–230/ 230–1000	30/37	
BS EN 61000-6-4	30–230/ 230–1000	40/47	
BS EN 12015	30–230/ 230–1000	40/47	
BS EN 50130-4	30–230/ 230–1000	30/37	
BS EN 55015(1)	0.009–0.07 0.07–0.15 0.15–2.2 2.2–3 3–30	88(1) 88–58(1) (2) 58–26(1) (2) 58(1) 22(1)	Measured in a 2 m diameter loop
BS EN 55022	30–230/230–1000	30/37 40/47	Class B Class A
BS EN 62040-2:2006	30–230/230–1000	30/37 40/47	Class B Class A
BS EN 61800-3	30–230/ 230–1000	30/37 40/47 40/47 40/47	First environment Unrestricted <25 A Restricted <25 A Unrestricted >25 A Restricted >25 A

Notes:
(1) conducted emissions on AC port
(2) conductor disturbances

Table 10 Conducted immunity levels for some typical equipment standards

Specification	Frequency (MHz)	Modulation (% AM)	Applied test level (V)			Comments
			Power port	Signal port	Functional earth	
BS EN 61000-6-1	0.15–80	80% 1 kHz	3	3	3	
BS EN 61000-6-2	0.15–80	80% 1 kHz	10	10	10	ITU bands: 3 V
BS EN 12016	N/A	N/A	N/A	N/A	N/A	
BS EN 50130-4	0.15–100	80% 1 kHz	10	10	N/A	CCTV: 3 V
BS EN 55024	0.15–80	80% 1 kHz	3	3	N/A	
BS EN 62040-2:2006	N/A	N/A	N/A	N/A	N/A	
BS EN 61800-3	N/A	N/A	N/A	N/A	N/A	
BS EN 61547:1996, IEC 61547:1995	0.15–80	80% 1 kHz	3	N/A	N/A	

Table 11 Electrostatic discharge (ESD) test levels for some typical equipment standards

Specification	Discharge (kV)	
	Air	Contact
BS EN 61000-6-1	8	4
BS EN 61000-6-2	8	4
BS EN 12016	8	4
BS EN 50130-4	8	6
BS EN 55024	8	4
BS EN 62040-2:2006	8	6
BS EN 61800-3	8	6
BS EN 61547:1996, IEC 61547:1995	8	4

Electromagnetic environment

11.12 The environment within a building is made up of sources that are located within the building (that is, equipment that is the source of electromagnetic radiation, for example transformers, MRI suites) and sources that are generated externally to the building. The external sources will usually be intentional transmitters, together with strong radiating unintentional transmitters such as railways (see Table 12).

Table 12 Electromagnetic sources

Frequency (MHz)	Description
70–85	Fire and rescue radio
122.15	Air band communications
153.675	Pagers
170.65	PMR mobiles
197.325	PMR mobiles
427.7	PMR base station
461.65	PMR mobiles
380–420	TETRA
450	Police radio
486–606	TV broadcasting band
903–951	GSM
1812.75	DCS base station
2144.25	3G UMTS base station

11.13 Emergency services' mobile units (PMR and TETRA) will also be present, as these operate at much higher transmission levels than GSM mobiles and can be expected to be present in the non-specialist areas of healthcare premises, that is, clinical risk categories 1–3 inclusive. Building and system control panels located in corridors will be subject to these higher levels.

11.14 In hospitals particularly, cable lengths in excess of 30 m, running either horizontally or vertically, will be encountered. These lengths are ideal for picking up and conducting frequencies up to around 400 MHz. System designers should always consider the use of screened cables, metal trunking and cable ladders to minimise interference into plant or building systems equipment.

Designing systems for EMI control

11.15 Electromagnetic interference (EMI) does not stop at interfaces, either conducted on cables or radiated. The positioning of M&E systems within the building has the potential to affect the performance of other installed systems.

11.16 The electromagnetic environment should be divided into zones where equipment will be compatible for both emissions and immunity. At boundaries, a risk assessment will be required to determine whether mitigation measures need to be implemented to reduce the potential cross-boundary interference.

EMC control for power systems

11.17 Uninterruptible power supplies (UPS) and battery rectifiers are a source of mains-injected harmonic interference. For this reason, they should be located in zones away from equipment which may be affected by their emissions, for example IT systems.

11.18 Power transformers are a concentrated source of low-frequency magnetic interference. For each type, their location and cubicle screening should be considered in relation to sensitive equipment (that is, those likely to be affected by radiated magnetic fields). This particularly applies to theatres where cathode ray tube systems are used, as on-screen distortion effects will occur.

11.19 The influence of the transformer and the route of unscreened or single-core main LV cables should not be ignored. There may be magnetic coupling with the steel and reinforcement bars of the building structure, thus inducing a network of currents flowing in the steel to earth with associated localised secondary magnetic fields.

EMC control for cables and cable-containment systems

11.20 Single-phase power cables, including power feeds and lighting circuits, carrying up to 250 V should not be grouped with sensitive cables (that is, data cables).

11.21 No data, telecommunications or any other sensitive cabling should be placed near three-phase cables, as these are normally used for heavy electrical inductive loads, for example air-conditioning, welding equipment and motors.

11.22 All cabling should avoid any close proximity to radio or television transmitters, beacons and overhead transmission lines.

11.23 Cables carrying high-level impulse energy produce a large frequency distribution of disturbances due to their fast rise times. Special precautions need to

be taken with these types of cabling: efficient screening, clean earthing at both ends, and an increase in the separation with adjacent cables would need to be implemented.

11.24 All cables should be terminated whenever possible in accordance with their intended terminating impedance.

11.25 The characteristic impedance of cables should be selected to match closely the impedance of the terminating equipment. This reduces the amplitude of standing waves created by reflections due to mismatches in impedance transition.

11.26 All power-cable screens or armour should be bonded at both ends of the run to an earth plate using 360° peripheral glands.

EMC control for general systems

11.27 Personal transmitters/receivers, main transmitters and local radar devices should be evaluated to ensure that they do not cause random operations or failure of electronically controlled equipment. Personal transmitter/receivers are particularly likely to cause this problem.

11.28 Checks should be made with these devices on all new plant installed, at a convenient time, to ensure there is no susceptibility.

Intentional apertures

11.29 Apertures are always required in rooms to allow services to enter and leave. Rooms that are required to have a screen to prevent electromagnetic interference (EMI) in the healthcare environment, rarely require the same performance as a screened room used for EMC measurements. However, the same techniques for screening apertures can be used to allow services to enter.

11.30 Where holes in the shield are essential for such items as ducting, pipework or cables, the hole should be filled by placing a mesh screen over the hole and ensuring that the duct, pipework or cables are electrically connected to the mesh screen.

11.31 A mesh screen has an attenuation determined by the size of the largest hole in the mesh. It is better to use a number of similar size apertures to run multiple items through the mesh, than one large aperture that takes all the items required to go through the screen.

11.32 If a large aperture is unavoidable, the principle of using a "waveguide beyond cut-off" can be used (see Figure 28). Using this type of aperture will enable cables etc to pass through, although attenuation performance is reduced. Multiple waveguides should be used (see Figure 29) where many services need to pass through a screening shield.

Figure 28 Single waveguide

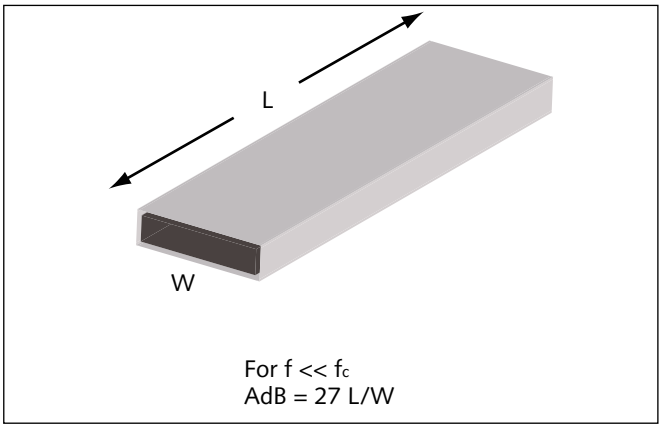
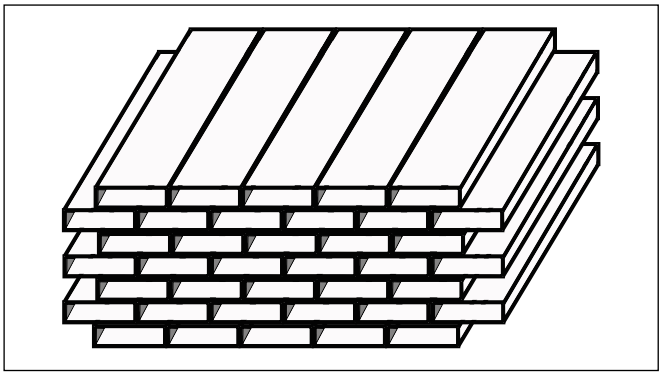


Figure 29 Waveguide array



11.33 Where screened cables need to penetrate through a screen, conductive cable penetration blocks (see Figure 30) should be considered to maintain the continuity of the cable screens and screened room.

Figure 30 EMC compliance measures

Cable segregation and separation

11.34 To reduce the possibility of power-cable to signal-cable coupling and the associated EMC risks, the best approach is to use separation between power and sensitive service cables. It is advised to run fire alarm cables in a separate conduit from other service types. Signal and telecommunications cables should not be run in the same tray as power cables. Table 13 indicates the separation distances between power and signal cables, where the cables are not screened or screened at their respective voltage level.

11.35 Note the screening should be bonded to an earth return at both ends of the cable.

Cable screening, trunking and trays

11.36 Various types of cable tray or conduit may be used and run in parallel over an appreciable distance. The crosstalk between the cables they contain may be important. The recommended separation distance between the cables in the trays depends on two parameters:

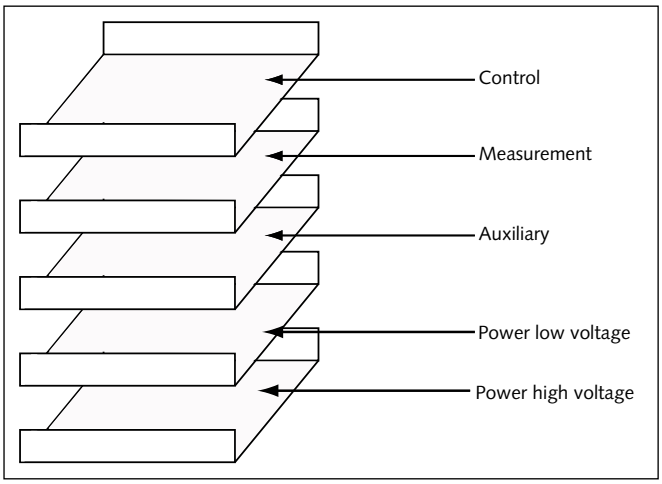
- the quality of the cable tray as protective earth conductor (PEC);
- low transfer impedance (high shielding effectiveness).

Crosstalk characteristics

11.37 Cables with a low crosstalk may require shielding against the (magnetic) fields causing the crosstalk currents.

11.38 Using trays or racks of sufficient wall thickness to separate cables can provide both PEC and reduction in crosstalk. They can often be laid next to each other. Another solution is to keep some distance between shallow conduits for the different types of cable, for example by stacking them (see Figure 31).

Figure 31 Stacking cable trays to avoid crosstalk



11.39 Cable-tray stacking achieves a combination of separation of segregated cable types with the additional benefit of screening introduced by the trays themselves. Solid trays with no gaps are the ideal tray type for this application. Trays often have slots for easy attachment of cables; the most beneficial of these are those with a short slot parallel to the axis of the tray. Those with slots perpendicular to the tray axis should not be used.

11.40 Caged trays constructed with large gaps in the screen should certainly not be used where

Table 13 Recommended minimum separation distance between power and signal cables

Not enclosed environment for example on tray/basket	Minimum separation distances for various power cables (mm)		
Signal cable	**No metallic sheath or screen for example twin and earth or singles**	**Steel wire armoured**	**MICC**
Plain	150	125	Touching
UTP	75 below 100 MHz 125 above 100 MHz	50	Touching
Screened	Touching	Touching	Touching
Enclosed environment for example trunking		**Metal separator**	**Plastic separator**
Unscreened power lines, or electrical equipment and unscreened data IT lines		150	300
Unscreened power lines, or electrical equipment and screened data IT lines		30	70
Screened power lines, or electrical equipment and unscreened data IT lines		2	
Screened power lines, or electrical equipment and screened data IT lines		1	2

electromagnetic screening is an issue, as they offer no screening benefits and are generally insufficient as parallel earthing conductors.

Trunking and tray interconnection and termination

11.41 When a metallic cable tray or trunking system is implemented, inevitably sections will need to be interconnected for extended runs. Particular care will be necessary in order to maintain electrical continuity between the various sections. Ideally, the parts should be welded over their full perimeter, although it is recognised that this is not always achievable in practice. Riveted, bolted or screwed joints are adequate if the contact surfaces are good conductors (there should be no insulating coating or paint). Ensure that they are safeguarded against corrosion and that good electrical contact between the separate sections can be maintained.

11.42 It is important that the shape of the metallic section should be maintained over the full length of the run. Bonding via a short earth wire connection between two sections of the tray or trunking system may have a low dc resistance, but will have high impedance to high-frequency (a few MHz upwards) currents.

11.43 This means that for extended runs the centremost sections are effectively floating at high frequencies, thus reducing performance. This has both personnel safety and EMC implications. Figure 32 shows the recommended practice for interconnecting cable trays and trunking systems.

11.44 For right-angle and corner interfaces, the same principles should be applied with L-shaped joints attaching interconnecting sections.

Using conductive structural supports as runs for cables

11.45 Metallic structural support elements in buildings can also serve EMC objectives where room for cable trays or trunking is limited. Steel beams of L-, H-, U- or T-section can form a continuous earthed structure that offers relatively large cross-sections and therefore low impedance and large surfaces with many potential intermediate connections to earth. Cables can be laid against such beams as shown in Figure 33.

Identification of critical systems

11.46 Mechanical and electrical equipment being procured currently will have been designed to comply with either the light or heavy industrial generic or product-specific standards. Such equipment will be generally immune when located in its intended environment. Designers should identify environments where levels higher than those specified in standards will be encountered, and apply mitigating measures, for example prevention of the use of mobile phones close to control systems while screening enclosure doors are open. Many M&E systems not normally considered critical are critical when their misoperation causes reduced operational efficiency,

Figure 32 Recommended interconnection of cable trays and trunking

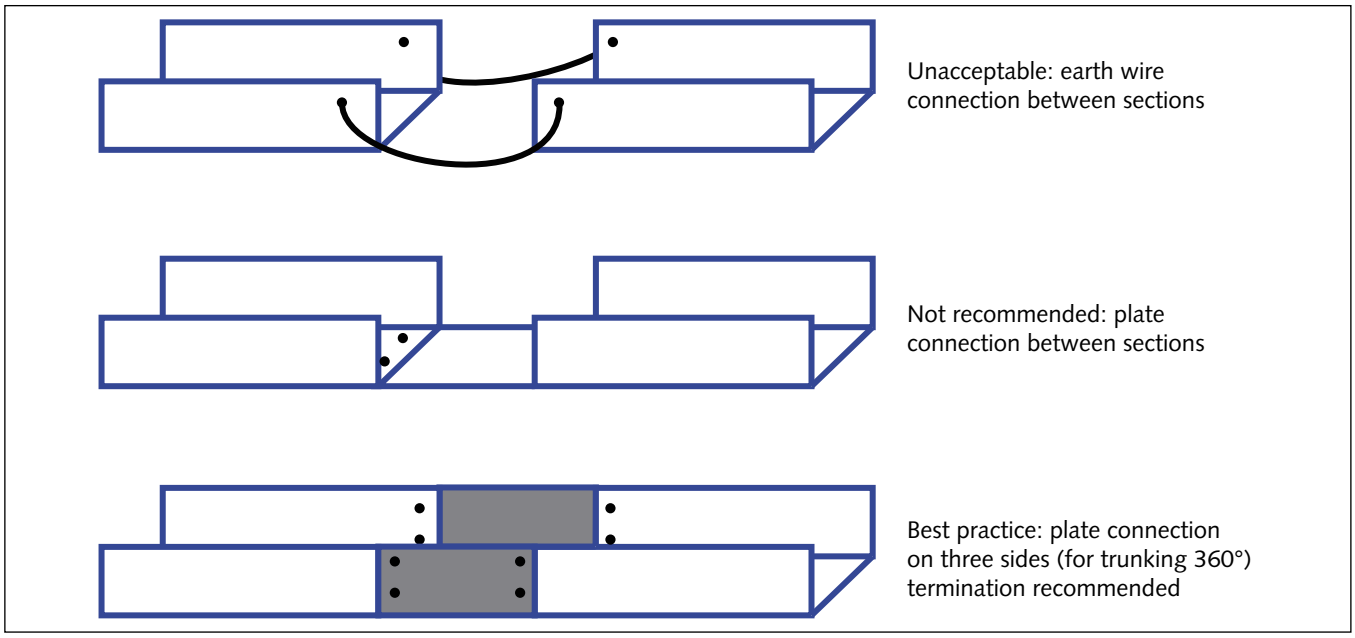
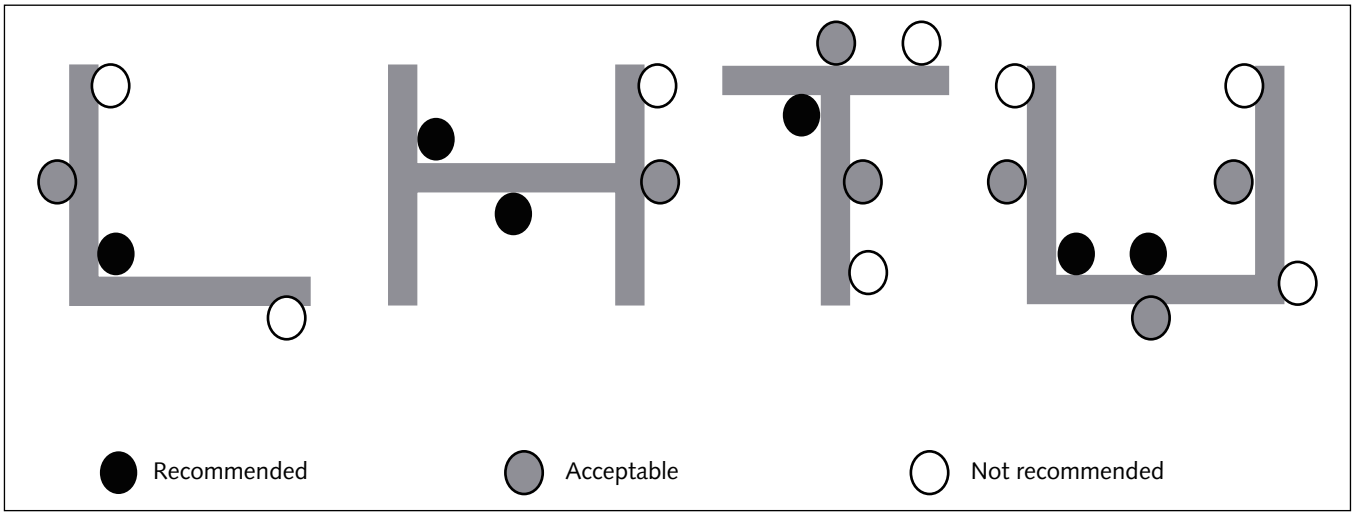


Figure 33 Location of cables inside metallic structural supports



for example heating and ventilation systems, fire alarm systems.

Earthing and bonding

11.47 Earthing and bonding (or equipotential bonding) is often confused. The terms are defined in the following way. Earthing is the connection of the exposed conductive parts of an installation to the main earthing terminal of that installation. Bonding is an electrical connection maintaining various exposed conductive parts and extraneous conductive parts at substantially the same potential. Earthing arrangements are described in detail in Chapter 13.

11.48 Earthing is also used to contribute to the mitigation of disturbances for installations with sensitive and interconnected electronic and electrical systems. These requirements, that is, shunting of unwanted power-frequency and high-frequency currents and lowering the voltage difference between two points of the system, are the same for lightning, personnel safety, installation protection and EMC. Each one of these considerations places constraints on the design, since lightning and personnel safety dictate the design of the earth electrode; safety and installation protection dictate the size for the earthing conductors; and EMC behaviour requirements determine the layout of the earthing network.

11.49 Given the above, the following EMC implementation rules are recommended.

11.50 Wherever possible, the TN-S system should be used. Exceptions exist with IT configured systems, or where a high continuity of supply is required by the application (for example in hospitals) or by national regulations.

11.51 Non-linear loads (fluorescent lamps, switched-mode power supplies etc) on distribution networks can generate harmonic currents which may overload the neutral conductor. Correction methods for such systems are provided in Chapter 5. The controlled earth return current of a TN-S system is shown in Figure 34.

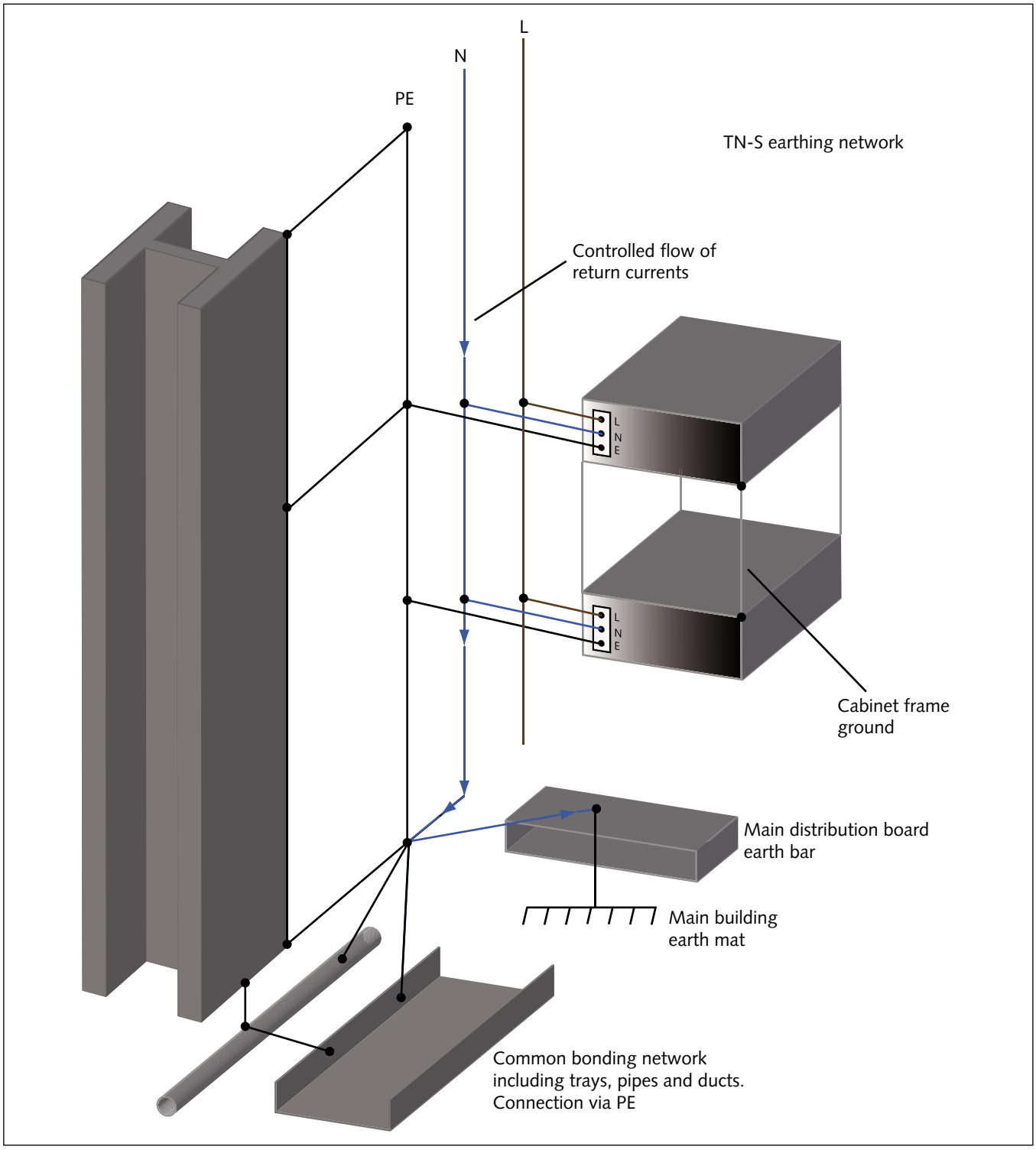
11.52 A clean earth will utilise dedicated earth conductors, which are fed back to the main earth terminal (MET).

11.53 The intent for any earthing system should be to maintain a low impedance at most harmonic frequencies. This means maintaining an equipotential between all the cabinets in the data centre. The likelihood that this can be achieved is increased by a localised connection to the mesh bonding network of the room.

11.54 The mesh bonding network is intended to be created by the use of interbonding sections of the 1.2 m^2 earth mesh (25 mm^2 copper straps) in the raised flooring using bonding straps between 50% of the pedestal supports for each floor panel. At least a 16 mm^2 earthing conductor should be connected to the nearest point on the mesh bonding network from the local distribution board's earth bar. All underfloor cable trays and risers which pass through the raised floor should be bonded to the earth mesh using an earth strap. All surrounding metallic cable trays, conduits, pipework, risers and ducts in the roof void should be interbonded using earth straps or preferably

solid metal strips which are galvanically compatible with the contact metal. Galvanic potentials should not exceed 300 mV otherwise there is a potential risk of long-term degradation of the bonds.

Figure 34 Controlled returned current flow in a TN-S installation



12 Wiring systems

12.1 All wiring systems will be of a form defined in the IEE Regulations BS 7671:2001. Where appropriate, the primary internal distribution will be a three-phase HV network. The next tier of distribution will be a mixture of three-phase and single-phase LV systems.

High voltage

12.2 HV wiring systems will, in general, be used only for distributing high power around the site. This Health Technical Memorandum does not promote the use of HV equipment. However, consideration may be given to the use of HV chiller plant where the chillers have a high mechanical duty and hence electrical load requirement. The manufacturer's advice should be used.

12.3 Certain radiographic and diagnostic equipment generates a high voltage as part of the equipment process. Such applications are not part of the fixed wiring systems and are therefore not covered by this Health Technical Memorandum.

Low voltage

12.4 All LV systems will be installed as TN-S systems as defined by the IEE Regulations BS 7671:2001, unless the wiring is of a type defined below.

Medical IT

12.5 The system may also be known as an isolated power supply (IPS; see Definitions). The system will include a monitoring device with an alarm for disconnection, insulation failure, overload and high temperature. Medical IT wiring systems will in general be limited to a medical location of Group 1 or Group 2 areas (see Definitions) and post-mortem facilities.

Protected extra low voltage systems

12.6 In general, PELV systems as described by the IEE Regulations BS 7671:2001 are not covered by this Health Technical Memorandum. PELV systems may be used within medical locations Group 1 or 2. PELV systems may also be considered appropriate for wet areas such as kitchens, trolley wash-down areas or mortuaries.

12.7 The nominal limit for PELV is 50 V ac or 120 V ripple-free dc. However, as prescribed by BS EN 60601-1, IEC 60601-1, this limit is reduced to 25 V ac and 60 V ripple-free dc when these systems are used in medical locations of Group 1 and Group 2.

Separated extra low voltage systems

12.8 The nominal limit for SELV is 50 V ac and 120 V ripple-free dc. However, as prescribed by BS EN 60601-1, IEC 60601-1, this limit is reduced to 25 V ac and 60 V ripple-free dc when these systems are used in medical locations of Group 1 and Group 2.

12.9 Normally, protection by insulation of live parts and by barriers or enclosures applies only to SELV systems where the nominal voltage exceeds 25 V ac or 60 V ripple-free dc. Where the SELV system is within a medical location Group 1 or 2, protection by insulation of live parts and by barriers or enclosures should always be provided. Placing live parts out of reach, only, is not acceptable within medical locations Group 1 or Group 2.

13 Earthing

13.1 The earthing arrangements for the full electrical system should comply with the requirements of BS 7430:1998 and BS 7671:2001. In general terms, the earthing arrangements will take the form of a TN-S system. The exception to this fundamental requirement will be that certain areas, defined in this chapter, will meet the earthing requirements of an IT-earthed system.

High-voltage earthing methods

13.2 Where the PES is rated at high voltage (11 kV) and the termination point is at low voltage (0.4 kV), the responsibility of the HV earthing will lie with the DNO. Where the healthcare organisation meters and purchases electricity at a high voltage, but has no internal HV network, the DNO will remain responsible for the earthing provision of the HV earthing. Designers will need to liaise with the DNO whenever any new development or significant internal remodelling of the healthcare facility's electrical services is undertaken. Managers of healthcare premises will be required to provide the DNO with full access rights to any part of the facility that they may require to access in order to maintain the HV earthing systems. Where the electrical distribution strategy includes an HV network, the designer of the electrical system should ensure that the electrical systems are adequately earthed. Where the healthcare facility includes more than one HV substation, each substation should be linked by an HV earth conductor. This will be particularly important where a single building is served from more than one HV substation.

13.3 A suitably-sized copper conductor will collectively bond all exposed metalwork associated with HV equipment at an HV substation. The cross-bonding conductor should have a green-yellow sheath and be buried at a depth of 600 mm within the substation area. Where the substation is not at ground or at subterrain level, the substation exposed metalwork will be earthed via a copper drain wire of the HV network cable.

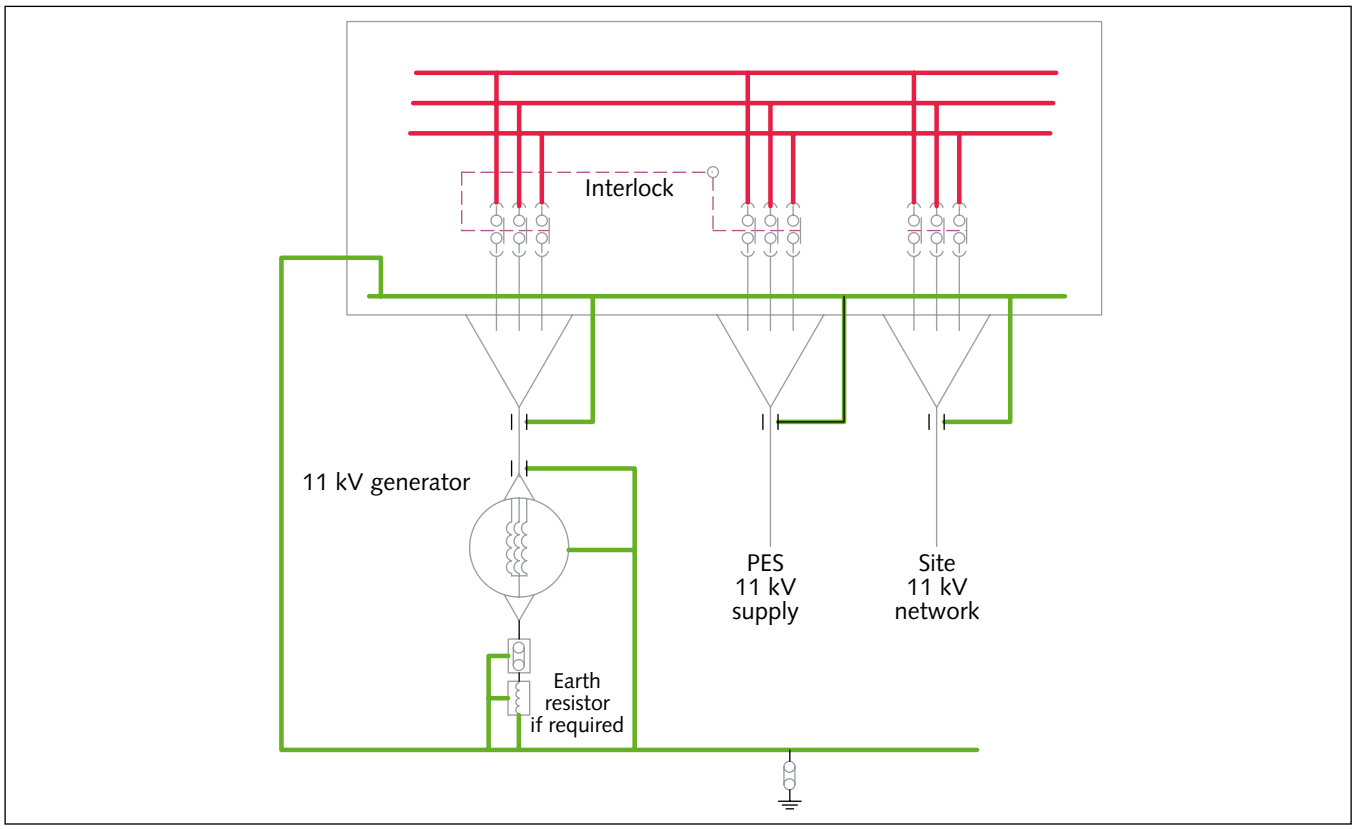
High-voltage network cables

13.4 All HV cables forming part of the HV distribution network should have a copper wire as part of the armouring of the cable. HV cable glands should be rated above the prospective fault current of the system to which they are assembled. The glands should have integral earth lugs from which equipotential bonding copper strip connects to the main copper earth bar. Consideration may be given, if required, to the cable armour secured at the cable gland being isolated or separated from the equipment by an island-type insulating gland. In order to prevent dangerous high earth fault currents circulating within the structure of the healthcare facility, the HV cable earths should not come into direct contact with any exposed conductive part of the facility.

High-voltage generator earths

13.5 All HV generators will be earthed. Designers should evaluate the earthing by a neutral earthing reactor or an earthing transformer. Thought should be given to the potential for circulating neutral currents and/or harmonic currents in the delta-wound generator stator, and how these may be negated with the addition of an earthing transformer. The generator earthing arrangements should ensure that an adequate fault current can be developed to operate any protective device within the electrical network. Figures 35 and 36 show typical high-voltage generator earthing configurations.

Figure 35 HV generator earths – island mode



Low-voltage main earthing methods

13.6 Where the PES is rated at low voltage (0.4 kV), designers will liaise with the DNO to determine the responsibility of earthing the PES supply cable, which will usually be with the healthcare organisation.

13.7 A suitable supplementary equipotential bonding copper conductor will collectively bond all exposed metalwork and conductive parts associated with the LV switchpanels in the switchroom to the local ERB. The cross-bonding conductor will be a bare hard-drawn copper tape of a minimum cross-sectional area of 50 mm by 6 mm and in accordance with BS 7671 IEE Regulation 543. A suitable copper earth cable or tape will bond each ERB to the respective LV substation main earthing terminal (MET). A suitable supplementary equipotential bonding copper conductor will collectively bond all exposed metalwork and conductive parts associated with the LV substation to the local MET. All extraneous metalwork will be cross-bonded and either directly or indirectly connected to the MET. The MET will be directly connected to the star point of the respective distribution transformer secondary winding. All transformers associated with the primary and secondary electrical distribution (see Chapters 7 and 8) should have a dedicated MET directly connected to the earth electrode with the earthing conductor. The earthing conductor will be sized to carry, without risk of danger, the greatest earth fault current and earth leakage currents likely to occur, having due regard for the thermal and electromechanical stresses. An earthing conductor and demountable link will interconnect each MET where the substation has multiple distribution transformers.

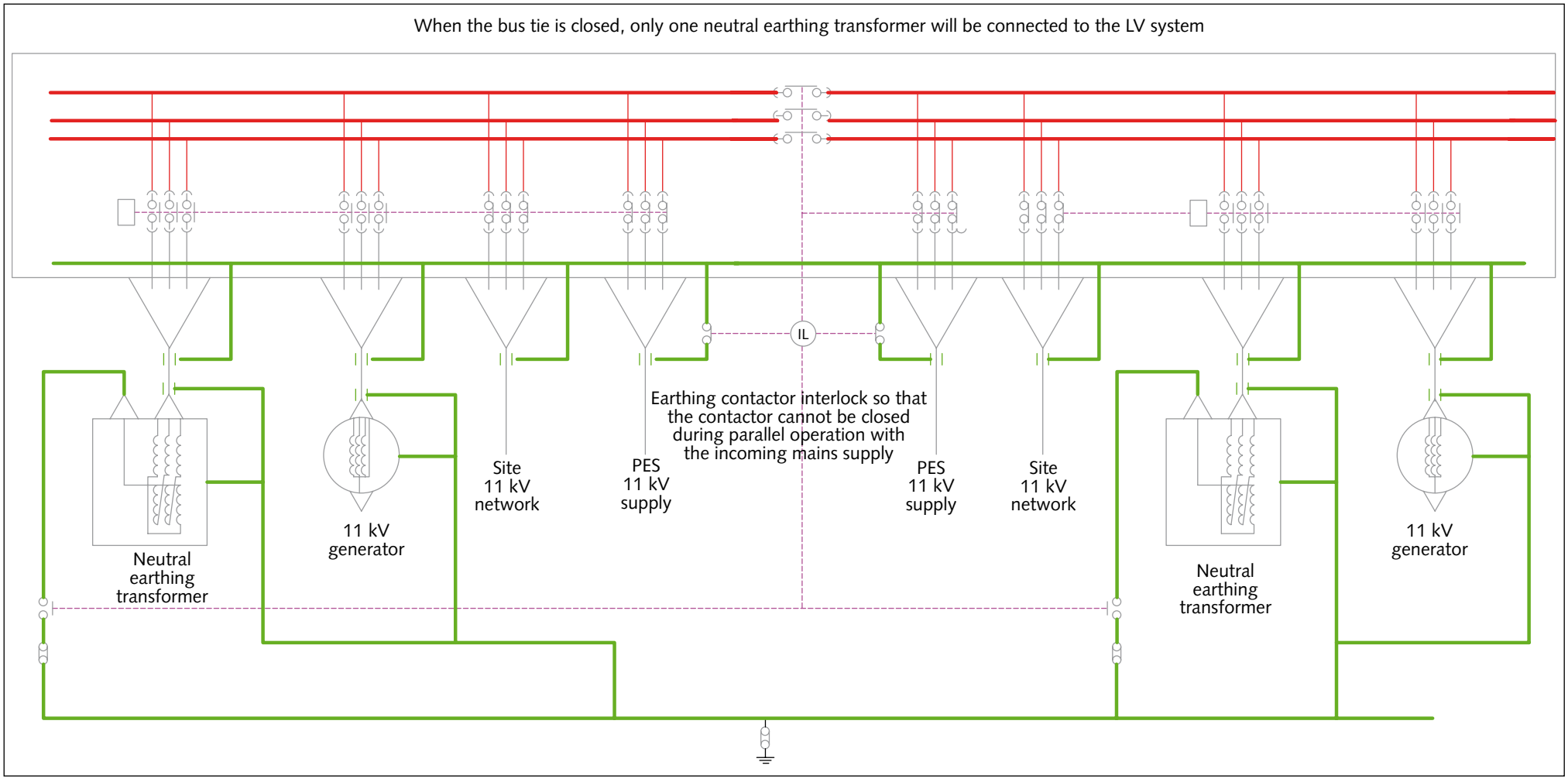
13.8 Where appropriate, any fixed equipment clean earths will be bonded to the MET of the respective LV substation either directly or via an ERB in the LV switchroom.

13.9 Where appropriate, any information management and technology clean earths will be bonded to the MET of the respective LV substation.

13.10 Where the LV and HV system earths are separated, the resistance of the LV earth electrode should be less than 20 Ω.

13.11 Where the electrical system includes both HV and LV networks, designers may wish to interconnect the earths from the two earthing systems. Subject to approval of the DNO, this may be achievable if

Figure 36 HV generator earths – parallel operation (TN-S)



the combined earth resistance is less than 1 Ω, and any earth fault current does not give a rise of a 430 V potential in the parallel earth circuits. Where the combined earth resistance cannot be reduced to 1 Ω, the LV earth electrode should be at least 3 m from the HV earth electrode and/or any HV extraneous conductive metalwork.

Low-voltage generator earths

13.12 It should be ensured that an adequate fault current can be developed to operate any protective device within the electrical network. The earthing arrangement may require an earthing reactor or earthing transformer.

13.13 The resistance of the generator star-point-connected earth electrode should be less than 20 Ω.

13.14 Figure 37 shows a typical earthing configuration.

Switchroom earths

13.15 All LV distribution switchrooms should have a visible earth reference terminal made from hard-drawn bare copper.

13.16 A suitably-sized copper conductor will collectively bond all extraneous and exposed conductive parts associated with the switchroom LV switchgear to the local ERB. The circuit protective conductor (CPC) from each final distribution board should be bonded to the local ERB, and covered by a green-yellow sheath. All extraneous metalwork will be cross-bonded and either directly or indirectly connected to the ERB.

13.17 Where appropriate, any fixed equipment clean earths will be bonded to the ERB of the respective LV switchroom.

Earths for radiographic rooms

13.18 In general terms the designer of the electrical hard-wired system will have a responsibility for the earthing system to the ERB within each radiographic room (see also paragraph 13.23).

13.19 In all radiographic rooms an ERB will be provided. Designers should liaise with the radiographic equipment manufacturer to establish the size of the earthing conductor and associated ERB. An individual earthing conductor will be directly connected to the ERB (of each radiographic room) and the MET at the respective distribution board.

13.20 Where the radiographic room has high electromagnetic field radiation, such as in a magnetic resonance imaging (MRI) room, the room will be provided with a Faraday cage to isolate any such magnetic fields from the building structure and surrounding rooms. The ERB in these rooms will be made of a non-magnetic material and housed in a non-magnetic enclosure (usually clean ABS). The ERB will be directly bonded to the room side of the Faraday cage. An earthing conductor will be directly connected between the Faraday cage and the MET of the respective substation.

13.21 The Faraday cage will have suitable apertures for the provision of any EMC filter equipment for conductors of any electrical or communication system. The radiographic equipment manufacturer/supplier should specify the detail of the filter equipment.

13.22 All fixed electrical equipment connection points will be positively bonded to the ERB with a resistance no greater than 0.1 Ω.

13.23 The electrical installation for radiographic diagnostic and imaging facilities should comply with the Medicines and Healthcare products Regulatory Agency (MHRA) document 'Medical Electrical Installation Guidance Notes' (MEIGaN).

Medical IT or isolated power supply earths

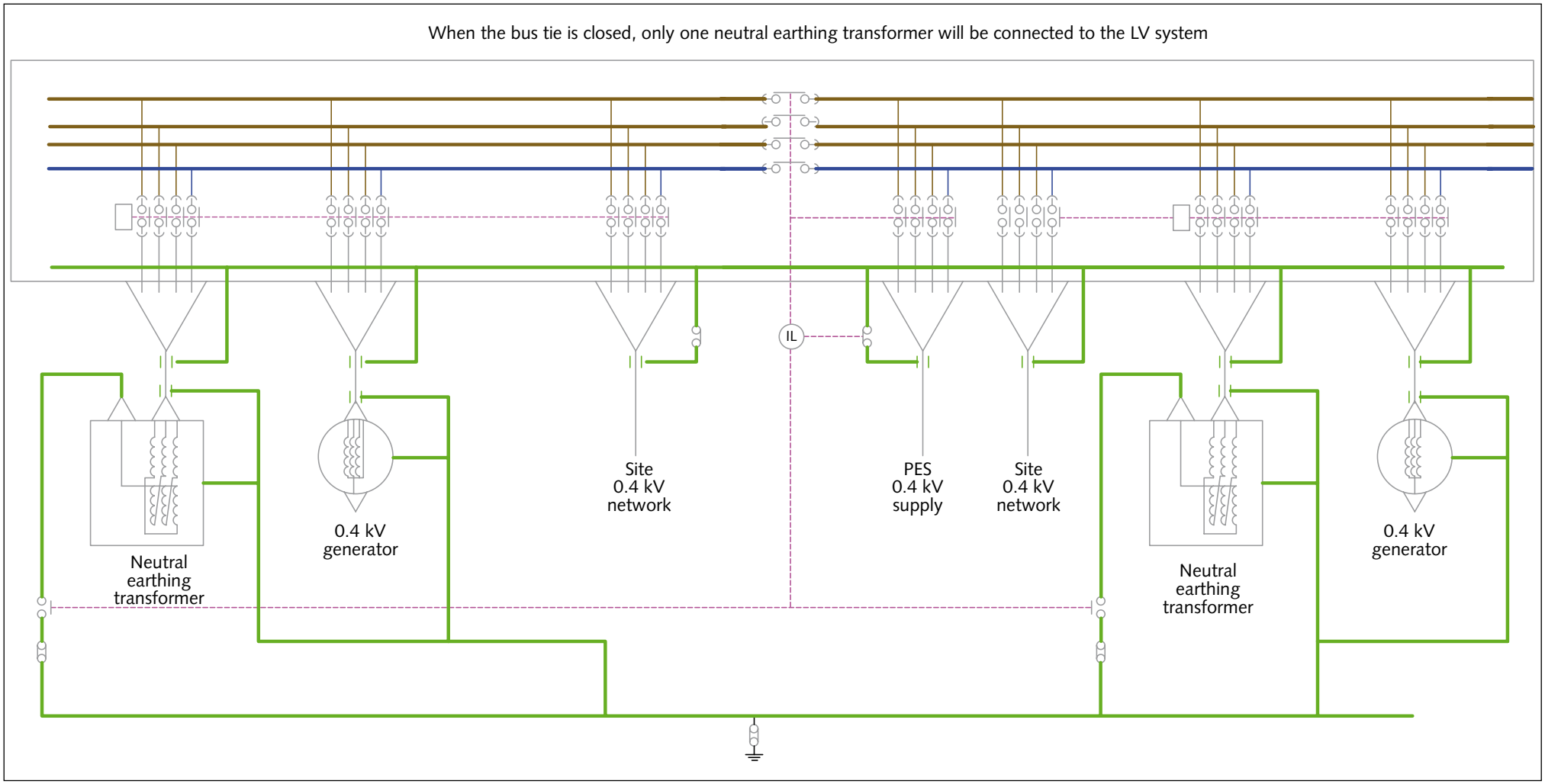
13.24 Isolated power supply (IPS) circuits should have an IT earthing system as defined by BS 7430:1998 and BS 7671:2001.

13.25 In all areas defined as a clinical risk Category 4 or 5, an ERB will be provided adjacent to the local final distribution board of the IPS.

13.26 The IPS circuits will be bonded to a protective earth terminal (PET), which should be easily accessible from the IPS distribution board and IPS isolation transformer housing. An earthing conductor will be directly bonded between the PET and a local ERB. Both the PET and ERB will be visible and accessible by authorised people only. See Health Technical Memorandum 06-02 – 'Electrical safety guidance for low voltage systems'.

13.27 Where the IPS serves a diagnostic room, the PET/ERB should be located within the room (see the MEIGaN).

Figure 37 LV generator earths (TN-S)



Microshock

13.28 Microshock is the passage of a low level of electricity through the body which causes no perceptible sensation. The threshold of sensation is at about the 1 mA level. The subject cannot detect currents below this level. These low-level events are of no consequence unless the current passes through the cardiac muscle, in which case ventricular tachycardia or ventricular fibrillation may be triggered. Currents of the order of 10 μA can be enough to initiate ventricular fibrillation.

13.29 A patient undergoing any procedure which involves the placing of an electrical conductor in the central circulatory system is particularly at risk. In this context, an electrical conductor includes insulated wires such as cardiac pacing electrodes or intracardiac ECG electrodes, or an insulated tube (catheter) filled with conducting fluid inserted into the central circulatory system.

13.30 In order to limit any potential rise due to the effects of leakage current, the voltage between the hard-wired system and the ERB should not be greater than 20 mV. A further voltage of 30 mV is allowed between the exposed conductive parts of the medical equipment and its supply cord (BS EN 60601-1, IEC 60601-1). This means that the maximum obtainable voltage between the exposed conductive parts of the medical equipment and the ERB should not exceed 50 mV. To achieve this low voltage the maximum resistance between the socket-outlet terminals, fixed equipment terminal or extraneous metalwork should be 0.2 Ω (0.1 Ω from any point to the ERB).

13.31 Figure 38 shows a typical earthing arrangement.

Circuit protective conductors

13.32 All parts of the LV distribution including final circuits will have a separate circuit protective conductor (CPC). The size of the conductor will be assessed from the prospective short-circuit current (PSCC) and the current-carrying capacity of the conductor. The assessment will take the form of the calculation:

$$S = \frac{\sqrt{I^2t}}{k}$$

(given in BS 7671:2001)

where

S = the nominal cross-section area of the conductor in mm^2;

I = fault current;

t = the operating time of the disconnecting device in seconds corresponding to the fault current;

k = a factor taking account of the resistivity, temperature coefficient and heat capacity of the conductor material, and the appropriate initial and final temperatures.

13.33 Where circuit cables or conductors have an integral metallic sheath, the sheath will not be used as the sole earth return path. Designers should consider the use of multicore cables with an earth conductor, or where this is not possible, installing a separate CPC.

Functional earth

13.34 Functional earthing systems are a method used to provide a zero reference point or a signalling path for communications equipment. A functional earth does not strictly provide any protection against electric shock or danger. Functional earths should comply with the requirements of Chapter 47 of the IEE Regulations BS 7671:2001.

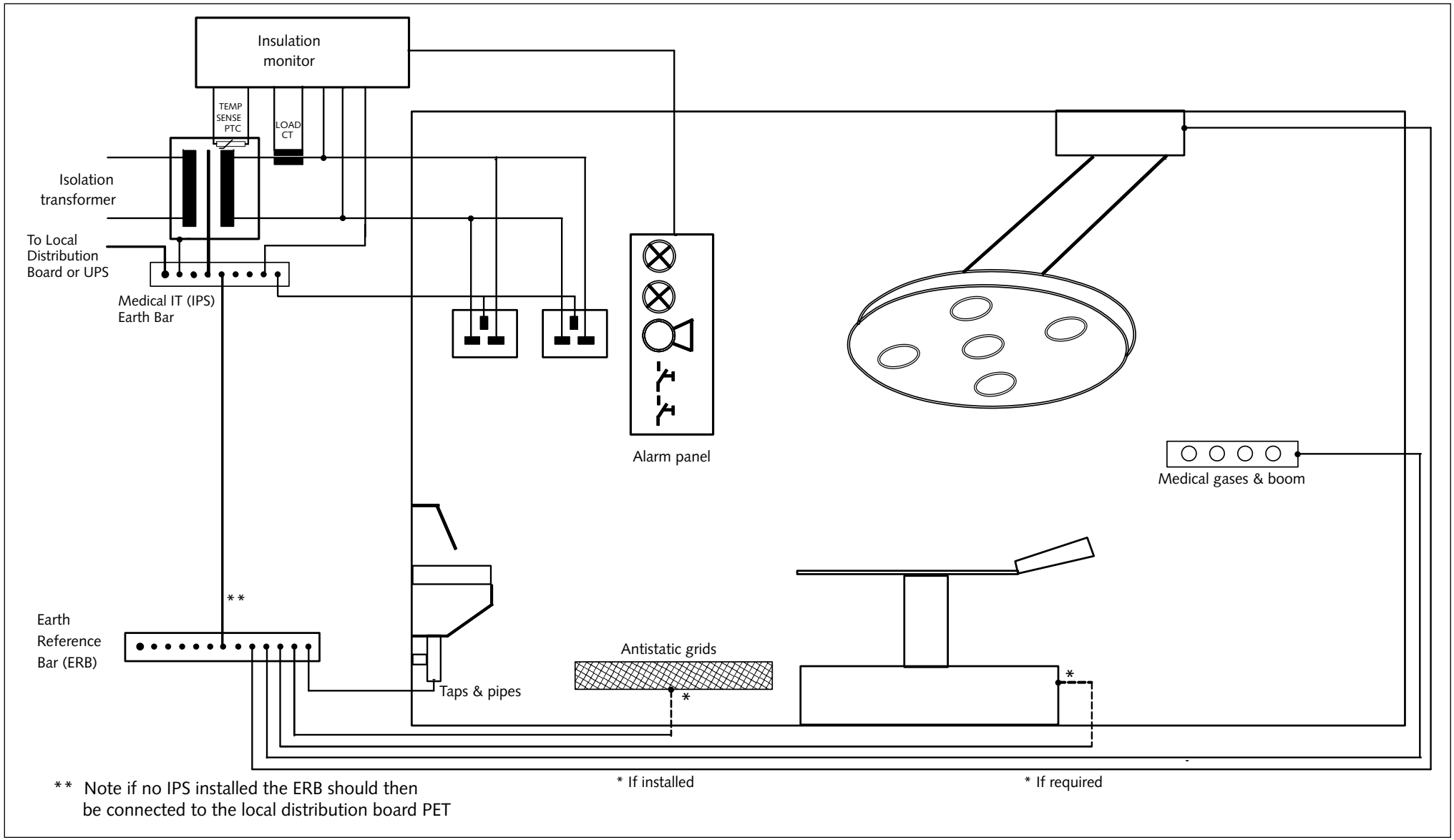
13.35 The functional earth conductor may be connected directly or indirectly to the main earthing terminal (MET) in an installation where earth currents flow due to the normal function of load equipment.

13.36 Functional earths for telecommunication systems should be installed with a cream-coloured sheath. The telecommunications engineer should determine the functional earth conductor size and install it in accordance with BS 6701.

Monitored earthing systems

13.37 Where it is assessed that a high degree of earth integrity is required, an earth monitoring system provides a means of maintaining a high degree of confidence in the impedance level of the protective conductor from the monitoring unit to the remote protected equipment. The monitoring unit may be connected between the source of energy (if accessible) and the equipment to be protected. The source of energy may be, for example, a generator or a transformer. It is therefore essential that any plug, socket and flexible cable provide not only the main protective path but also a return path, which is usually known as the pilot conductor.

Figure 38 IPS theatre earthing arrangement



13.38 The system proves or monitors the protective conductor and pilot conductor loop in a flexible trailing cable supplying transportable or mobile equipment, the proving or monitoring unit being arranged to disconnect the supply to the equipment at the point of connection of the trailing cable to the wiring installation. A wall-mounted protective-conductor proving or monitoring unit is directly connected to a section of the fixed electrical installation and is arranged to feed the flexible trailing cable, which may be connected to the unit either by means of a plug and socket or by a permanent connection. When connected in this manner, both the trailing cable and the equipment will be disconnected when the unit operates in the event of failure of the monitored loop.

Lightning protection

13.39 The energy of a lightning flash can be very high, with typical strikes currents in excess of 20 kA within the UK. The damage from lightning strikes can be very significant and blow electrical components off the wall in the worst case. The damage may not be limited to items that have direct contact to the conducting path of the lightning protection system (LPS). Air (or other conducting materials) are locally ionised around a lightning flash or conducting path, which can induce damaging currents in electrical equipment not directly connected to the LPS. In poorly designed or installed LPSs, flashover of high currents can occur between the LPS conducting path and items not bonded to the LPS. Flashover and/or ionised fields can cause damage to communications systems and electromagnetically stored data.

13.40 BS 6651:1999 provides maps with the statistical frequency of lightning strikes and their energy values throughout the UK.

13.41 Designers should carry out a risk assessment based on the approach given in BS 6651:1999 to determine the need (or otherwise) of an LPS. The risk assessment should consider the location of the healthcare premises (urban/rural, high/low), and the value of the equipment and data stored, as well as any protection afforded by the proximity of taller buildings.

Lightning protection system components

13.42 The LPS consist of three principal components as listed below.

Air terminals – finials

13.43 The air terminals consist of a copper or aluminium tape installed around the roof, and cross-bonded to all exposed metalwork and plant. The air terminals can be insulated with a PVC sheath, or bare. Metal roofs can be used as the air terminals providing that the conductivity and thickness of metal does not impede the discharge of the lightning strike. Air terminals can be laid under a slate roof subject to building regulations and approval of the building control officer.

Down conductors

13.44 The down conductors consist of aluminium or copper tapes clipped down the exterior façade of the healthcare premises at a maximum spacing of 20 m. Each down conductor should be cross-bonded to any exposed metalwork within 1 m of the conductor and installed at least 1 m from any entrance way. Where the down conductor cannot be installed on the external façade, a segregated internal duct (conforming to the requirements of BS 6651:1999) may be utilised. Designers should consider the location of data communications and electromagnetic storage systems before using the steel structure of any healthcare building.

Earth electrodes

13.45 The earth electrode consists of a high-conductive metal rod connecting the down conductor to the mass of earth. The resistance to earth of an LPS network should not be greater than 10 Ω, with the resistance of each individual electrode less than ten times the number of earth electrodes in the LPS. Where the soil resistivity is high, the earth electrode can consist of a high-conductive metal plate or mesh. In very poor soil resistivity areas, the local resistance can be improved by the use of high-conductive concrete, such as bentonite, to provide a bond between the electrode and mass of earth. Each earth electrode should have a test point close to ground level to aid the routine testing of the LPS. See Health Technical Memorandum 06-01, Part B “Operational management”.

Ionised fields

13.46 The effect of a lightning flash can ionise the air surrounding the flash up to several metres. The ionised air can give rise to high transient currents in cables and equipment. Designers should consider the use of "surge arrestors" to mitigate the effects of such transient currents.

13.47 Surge arrestors can be located in one of three locations:

- Type A on all cables as they enter/leave a building;
- Type B on each main distribution switchboard;
- Type C on the equipment itself (or the equipment's supply lead).

13.48 Surge arrestors should be capable of attenuating the induced ionised current such that the transient current is no greater than twice the steady-state normal supply current.

13.49 Further details on the design and installation of an LPS can be found in BS 6651:1999 and BS EN 50164-2:2002.

14 Containment

14.1 Due diligence should be given to the protection of all cable routes throughout the healthcare premises. The various types of cable and busbar system are described in Chapter 15. This section addresses the method of installation. Where the primary distribution cables etc are installed external to any building, the cables should be direct-buried. Where the cable route passes under roadways etc, the cables should be installed in ducts of not less than 100 mm diameter. Appropriate inspection chambers should also be provided. Main cables, where direct buried in open ground, should be initially laid in, covered by sifted soil or sand, and over-covered with reinforced interlocking fibre boards or concrete tiles to BS 2484:1995. Boards or tiles afford protection against hand tools but not against mechanical excavators. Red warning tapes for HV cable routes and yellow warning tapes for LV cable routes should be provided, and placed 300 mm above the tile or cable. Accurately located concrete surface markers should be provided at intervals of approximately 6.5 m (where practicable) in open ground, road crossings etc along the cable route, and at any change of direction or entry to buildings. For information on preventing damage to buried cables, see Appendix 5 in BS 7671:2001.

14.2 Electrical services of any type and/or voltage band installed on or in any containment type should have a current-carrying capacity for the grouping of cables and local environment of the containment system. Advice for de-rating a cable's current-carrying capacity from the nominal values is given in BS 7671 IEE Wiring Regulations. Additional information can be obtained from the cable manufacturer.

14.3 Where single-core cables are used for heavy-current three-phase circuits, the cables of the three phases should be laid in close proximity in trefoil or flat formation, mechanically braced, and tied along the route. Eddy currents should be reduced, for example by the use of non-ferrous clamps, fittings, spacers, non-ferrous gland plates and cable terminations.

14.4 The routing of any containment system should preserve the recommended segregation distances from other services, including other electrical services. General containment routes should not be installed in lift shafts including dumb waiters (see BS EN 81 for more information). Containments should not be routed in laundry shafts.

14.5 Where cable containments pass through a fire compartment wall, a fire-stopping material will be used to make good the opening. A fire barrier should be installed within the containment (close to the fire compartment wall), where the containment has an internal air space (for example trunking systems).

Trenches, service tunnels and ducts

14.6 Where cables of any type and/or voltage band are installed in a trench, service tunnel or duct, they should be installed on other containment types such as ladder rack or tray work. The arrangement of the secondary containment should keep the cables out of any accumulated water and not impede access along the trench/tunnel/duct. Trenches, service tunnels and ducts should be self-draining.

14.7 Where the containment system is used for other services, the space should have natural ventilation. The effect that other services, such as heating pipes, in the same trench or duct may have on the local environment should be taken into account.

14.8 Chapter 11 gives details on how cables should be arranged in voltage-band groups and the respective separation distances to achieve EMC.

14.9 HV cables should not be routed in enclosed areas close to flammable gases such as piped medical oxygen.

14.10 When sizing a trench/tunnel/duct, consideration for maintenance access should be assessed. The recommended minimum clearances are given in Defence Works Functional Standard DMG 08: 'Space requirements for plant access operation and maintenance'. Manholes or access holes should be

provided for entry into cable tunnels and ducts. SELV lighting and a power supply at entrances to trenches and service tunnels should be provided. The provision for portable forced ventilation systems for use of maintenance staff may be required under the Health and Safety at Work etc Regulations.

14.11 On main cable routes where additional cables may subsequently be required, spare cable ducts, trenches or service tunnel space should be provided.

14.12 Where HV cables are installed, they should be identified with "DANGER 11,000 Volts" notices provided at points where access to HV cables can be obtained.

14.13 Open trenches (ha-has) are not a recommended containment system for electrical services. Where such trenches are used, the cables should have additional mechanical protection. Additional safety precautions for the public should also be reviewed.

Ladder rack – tray – basketry

14.14 Steel cable trays and aluminium or steel ladder-rack can simplify installation where several cables are to be installed in close proximity. In damp areas and in order to reduce the risk of corrosion by electrolytic or water action, the containment should have a galvanised finish.

14.15 Such containments should only carry cables of one voltage band. Basketry can be considered for a mixture of cables at low voltage and voltage bands below, provided all such cables are insulated to LV grades.

14.16 Where these types of containment are installed in a common service route, each containment system should preserve the segregation of the various voltage bands. The highest voltage band should be installed on the lowest containment rail. The containments should not be used to support any other services.

14.17 Manufacturers' data should be used to assess the maximum mechanical loading and fixing arrangements of each containment system.

14.18 Such fixings should not be connected to any demountable building element (for example ceiling tiles, wall partitions) or other engineering services.

14.19 Metallic ladder-rack, tray or basketry should be electrically continuous and may be used as a supplementary earth return path. Each length of the containment should be mechanically joined with overlapping fillets on all three sides, and it is recommended that these are supplemented with copper links to ensure earth continuity. Where the installation topology prohibits the mechanical jointing of the containment system, an earth cable (of 6 mm^2 minimum size) should be used to provide the earth continuity.

14.20 In order to limit the effect of electromagnetic radiation and reduce high fault currents, the containment system should not form the only earth return path of any circuit on the containment.

Trunking – conduits

14.21 Steel trunking for cables represents the most satisfactory type of installation where a number of circuits can conveniently follow the same path. Cable trunking is suitable for use in voids, above suspended ceilings, in surface applications and in service risers. Trunking layouts should be predetermined and be dimensionally coordinated with other building components to enable standard prefabricated lengths to be used whenever practicable.

14.22 In installations with segregated essential and non-essential circuits, complete segregation of non-essential and essential subcircuit wiring is desirable, but may not be possible in all instances. Where either the essential or the non-essential wiring is less than, say, 30% of the total wiring, separate containment systems may not be practical or justified. See Chapter 6 for more information.

14.23 Circuits for emergency and escape lighting from a central battery system should always be segregated from both essential and non-essential circuits (guidance is given in BS 5266), and those circuits should be wired in an appropriate fire-resistant cable (see Chapter 15).

14.24 Extra-LV circuits can be installed with LV circuits operating at the mains potential providing that the insulation is equally rated to the maximum circuit voltage present. Wires of mixed service should be suitably screened to reduce inter-circuit electromagnetic interference.

14.25 Small TP & N cables installed in trunking should be tied or clipped together in small convenient

bunches. Groups of four single-core larger cables, comprising a three-phase supply and neutral, should be laid in trefoil, interleaved at suitable intervals and labelled to assist identification of circuits. The number and size of any cable bunch in any trunking should not exceed that allowed in the IEE Wiring Regulations Guidance Note 1 Selection, Appendix A.

14.26 Metal trunking should have a suitable anti-rust finish (for example zinc-coated steel). For damp environments, galvanised trunking will provide suitable protection.

14.27 All equipotential contact surfaces should be free of rust or corrosion or have an anodised finish to ensure electrical continuity to earth and between trunking sections. Tinned copper bonding links should be used across all trunking section joints to complete the equipotential bond and earth connection. The metallic trunking or metal conduits should not be used as the sole earth return path of the circuits within the containment.

14.28 All conduits and trunking systems should be solidly fixed. Such fixings should exclude the use of demountable building elements (for example ceiling tiles, wall partitions) or other engineering services. All fixing systems should be suitable for the mass of the containment and wiring systems.

14.29 Approved non-flammable fire barriers and penetration seals should be inserted in cable trunking where it penetrates floors and partitions which are intended to form fire barriers (that is, fire compartment walls). The outside of the trunking should also be locally fire-insulated on both sides for 500 mm to prevent heat transfer by conduction along the metal trunking and the passage of smoke. Unenclosed cables entering/leaving barriers or seals should also be fire-protected with ready-mixed inert material or fire-resistant paint.

14.30 Fire barriers and penetration seals should be provided for all cable installations entering/leaving switchrooms and plant cubicles where gland plate sealing is not provided. Underfloor trunkings or flush lay-in trunkings are a useful containment system for services to "island" (mid-floor area) equipment such as radiography units and theatre tables, computer hub rooms and laboratory benches. In such locations, it is essential that the manufacturer, structural engineer and architect all be consulted.

14.31 Where large quantities of data and computer equipment are installed, such as hub room and floor-distribution patch cupboards, raised floors with removable square sections to permit sub-floor access for any later cable works are recommended.

14.32 Cables bunched in steel conduit of 20 mm, 25 mm or 32 mm diameter are economical. Conduits less than 20 mm in diameter are not recommended.

14.33 The number and sizes of cables pulled into any trunking and/or conduit should not exceed the circuit-loading guidance in the IEE Wiring Regulations Guidance 1 Selection Appendix A and BS 7671 Chapter 52. The conduit system for each distribution board should be kept separate, and cables from different distribution boards should not be enclosed in the same conduit.

14.34 Conduit should be heavy-gauge quality to BS 31. Enamel finish is satisfactory for indoor dry locations. A passivated, galvanised, Class 4 finish should be specified where damp conditions are likely. The use of only passivated, galvanised, Class 4 finishes may be more cost-effective, as it will negate the need of any retrospective touch-up painting of installed metallic conduits and trunking.

14.35 The effect of electromagnetic interference from non-metallic trunking and conduits should be evaluated before they are used. Electromagnetic energy can be radiated from or absorbed by wiring systems unless they are adequately screened and earthed (see Chapter 11). Electrical containments should be resilient to effects from thermal and/or mechanical impact. The risks may be acceptable in clinical risk category 2 and 3 areas, but is unlikely to be acceptable in clinical risk category 4 and 5 areas (see paragraphs 4.12–4.34 for more information). It is best practice to use metallic trunking and/or conduits.

Preformed wiring containment

14.36 Preformed wiring consists of wiring systems that are manufactured off-site, and the individual circuit conductors are installed in a form of containment. The containment in this case is generally a spiral metallic sheath or interweaved metal-and-paper spiral wrap. The system is delivered with pre-made terminations and in standard lengths (primary runs are 40–50 m while final circuits are 3 m, 4 m and 5 m). Most systems have a range of distribution boxes and fuse boxes

and therefore the installed system becomes a spider's web of cables. The systems allow for lighting and low power. Lighting circuits can have additional control wires for switching and lighting control systems. Low-power circuits can be wired as radial or ring circuits. Preformed wiring systems tend to be sized at 50 mm diameter, while the final runs are typical 20 mm diameter. The number of multi-circuits in any one length of preformed system may be dependent on the installation. However, all conductors of any one circuit should be installed in the same wiring lengths. The system sheath should not be relied on for any part of the earth loop impedance.

Layout considerations

14.37 Designers should consider how to provide for any flexibility and/or spare capacity within the system. As the systems are preformed, it is not possible to cut into an existing length, and the installed routes follow the building room layouts. Designers should therefore consider providing the spare capacity at local distribution points or at the fuse box. A spare capacity of 25% should be made available, partly at the distribution boards and partly at the ends of the primary routes. Alternatively, consideration can be given to all spare capacity being available at one location only.

Fire precautions

14.38 Where preformed wiring systems penetrate floors and partitions which are themselves intended to form fire barriers (that is, fire compartment walls), the outside of the trunking should also be locally fire-insulated on both sides for 500 mm to prevent heat transfer by conduction along the metal trunking, and the passage of smoke. Containments should be treated in such a way as to prevent any smoke that may travel on the inside of containments from linking separate fire compartments.

Remodelling and extensions

14.39 Preformed wiring systems do not provide an easy way for additional circuits to be pulled into existing wiring systems. Hence, any circuits to be added retrospectively will require additional preformed lengths, which in turn erodes the spare capacity. Consideration can be given to providing facilities for re-modelling by allowing other cabling systems to be installed (retrospectively) from a common distribution board used for preformed wiring systems.

Circuit segregation

14.40 Designers should consider the holistic, coordinated installation with all other electrical and non-electrical services within the installation area. Designers should obtain the manufacturer's data on the system's compliance with electromagnetic radiation and absorption, which will need to be specific for the particular environment (see Chapter 11 for additional information).

14.41 All primary preformed wiring systems that may be used should be secured on secondary containments such as tray work. Similarly, all final runs of preformed wiring system should be solidly fixed. Such fixings should exclude the use of demountable building elements (for example ceiling tiles, wall partitions) or other engineering services. Clearly, all fixing systems should be suitable for the mass of the preformed wiring system, and not leave any catenary effect.

14.42 Wiring systems installed within a clinical risk Category 5 area should be exclusive to the use of equipment and fittings in that location.

Access for maintenance

14.43 Designers and stakeholders should consider the risks associated with the installed routes for preformed wiring and the need to provide suitable access for maintenance. (See Health Technical Memorandum 00 and Defence Works Functional Standard DMG 08 'Space Requirements for Plant Access' for additional information).

Suitable locations

14.44 Designers and stakeholders should consider the risk associated with installing the systems in certain locations. Clinical risk Category 1 areas should not be adversely affected by preformed wiring systems. The risks may be acceptable in clinical risk category 2 and 3 areas, but may present a higher risk in clinical risk category 4 and 5 areas.

15 Cable and busbar types

15.1 All current-carrying conductors (cables, busbars etc) should be suitably sized to carry their design load after the application of any de-rating factors generated by their installation environment and in accordance with manufacturers' data. All cables should be of an approved type tested by an external body such as the British Approvals Services for Electrical Cables (BASEC) or CBS ENELEC. The conductor size should limit the volt drop between the network origin and point of use to the values given in BS 7671 IEE Wiring Regulations. Designers may optimise the conductor power dissipation (I^2R losses) by designing the final circuits to carry the majority of the permissible volt drop.

15.2 The environmental protection grades can be found in BS 7671 Chapter 52 and Appendix 5. The electrical properties can be found in BS 7671 Appendix 4.

15.3 Each condition of external influence is designated by a code comprising a group of two capital letters and a number, as follows. The first letter relates to the general category of external influence:

A	Environment
B	Utilisation
C	Construction of buildings

The second letter relates to the nature of the external influence:

. . . A

. . . B

. . . C

The number relates to the class within each external influence:

. 1

. 2

. 3

15.4 For example, the code AA4 signifies:

A =	Environment
AA =	Environment – Ambient temperature
AA4 =	Environment – Ambient temperature – range –5°C to +40°C.

15.5 Further advice should be obtained from cable manufacturers' data sheets to validate the appropriateness of the cable for the intended application.

15.6 Cross-linked polyethylene (XLPE) is well established at higher voltages and is the preferred type of cable construction. XLPE cables have an improved operating temperature (90°C) over PVC, which means that XLPE cables do not require de-rating (for temperature) as much as an equivalent PVC cable. This can be a particular advantage in plantroom and energy-centre locations. Significantly higher symmetrical short-circuit ratings are also possible, corresponding to a conductor temperature of 250°C during fault conditions. This is compared to 150°C for PVC cables. XLPE will ignite and burn readily, but has low smoke and fume-emission characteristics.

15.7 Elastomeric (or thermoset) materials return to their original shape and dimensions after deformation. They tend to have a wider operational temperature range and superior mechanical properties compared with general-purpose thermoplastic materials. This makes them particularly suited to cable sheathing applications, especially in harsh environments. Elastomeric materials are suitable for all cable applications. Ethylene vinyl acetate forms the basis of most modern low-smoke zero-halogen cable sheaths.

15.8 Designers should evaluate whether the cable will be suitable for all normal and fault conditions. The fault calculations should include both overload and short-circuit condition (between live conductors and/or live conductor phase to earth). The fault conditions should be modelled for all circuit conditions, which will vary according to the

number of motors etc running. Cables should be suitable for power supplies from the DNO as well as any secondary power supplies (SPS).

15.9 Where the primary power is supported by parallel-running CHP plant, the fault calculations should reflect various power supply ratios of no CHP, 25% CHP and say 50% CHP.

15.10 Designers should consider the use of computer software applications to simulate all scenarios for fault calculation and cable selection. Any software used for such purposes should have an auditable quality control system such as ISO 9001.

15.11 Where there is large radiographic equipment which derives radiation from short-impulse high voltages, the distribution cables may not be required to be rated at the full load. Designers should liaise with the radiographic equipment suppliers to determine any opportunity to use under-sized cables.

15.12 This chapter addresses the various cable types available for each system within the electrical network of healthcare premises.

High-voltage distribution

15.13 HV cables have a higher power density than the equivalent-sized LV cable; therefore, where an electrical network includes an HV system, the HV system should be made to cover as large an area as is practical (see Chapter 6).

15.14 The grades of cable insulation normally used are XLPE cables complying with BS 6346:1997.

15.15 HV cables may be direct-buried, laid in a trench or, where practical, installed on heavy-duty cable trays.

15.16 HV cable boxes should be made of fabricated steel, and terminations should be air insulated up to 11 kV. Spacing between the terminals must conform to BS 4999-145 or IEC standards requirements for the rated voltage.

15.17 All HV terminations and terminating cable tails should also be encapsulated in heat-shrinkable, voltage-graded plastic insulation, approved and guaranteed by a reputable manufacturer for the rated voltage.

15.18 Steel cable boxes for the HV terminations of rotating machines should be provided with an aluminium foil explosion diaphragm and, as a safety precaution, the boxes should preferably be orientated to face a nearby reinforced concrete vertical surface or 200 mm brick wall. A splash-protected breather hole with an external replaceable silica gel dryer with screwed insert should be provided to prevent the accumulation of condensed water vapour within the cable box.

15.19 All cables should be marked and terminated in an approved manner to indicate phases. The far and near phase cable ends should be checked by a continuity meter to confirm identical phase markings.

Low-voltage distribution

15.20 Multi-core LV distribution cables should have a black outer sheath to denote their voltage rating.

15.21 The core colours should be defined by BS 7671:2001.

15.22 LV distribution conductors are made from copper or aluminium. Aluminium cables as rated are larger, require greater space, are difficult to lay, and require larger glands and cable lugs for terminations. Copper conductors have a better thermal and mechanical impact resistance and are more durable.

Cable identification

15.23 The colour of the conductor sheath of multi-core LV three-phase distribution cables should be as illustrated in Figure 39.

15.24 Where single-core LV distribution cables are installed, the phase colour should be brown with a blue neutral conductor as in Figure 40.

15.25 Note: where single-core cables are installed for LV distribution, all conductors of a common circuit should be enclosed in the same metallic containment such as trunking. In accordance with IEC 60364-7-710 any wiring system within Group 2 locations should be exclusive to the use of equipment and fittings in that location (see BS 7671:2001). The terminations of single-core LV conductors should be identified by the appropriate colour or notation, which may include IPS circuit identification.

15.26 Existing installations may continue to use the pre-April 2004 BS 7671 conductor sheath phase colours (red, yellow and blue), black neutral and yellow-green protective conductors. However, these should be replaced when modifications are undertaken to the electrical system.

Figure 39 LV three-phase multi-core cable identification

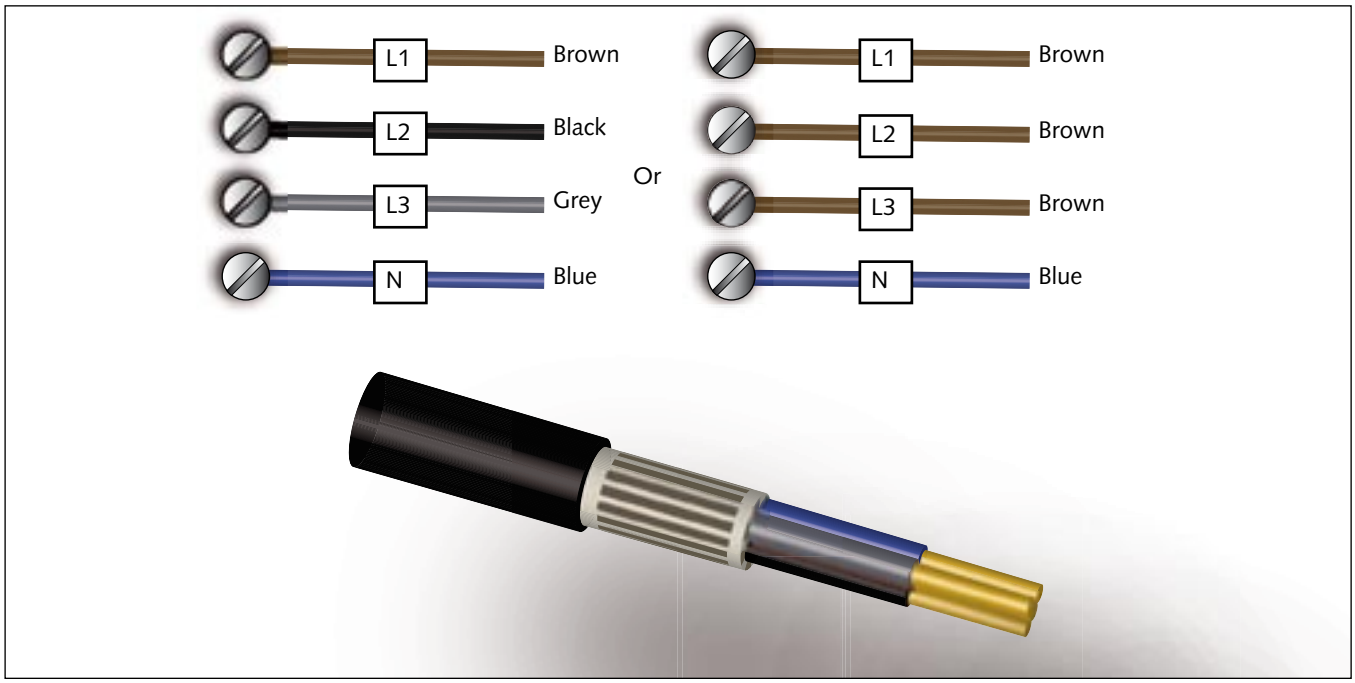
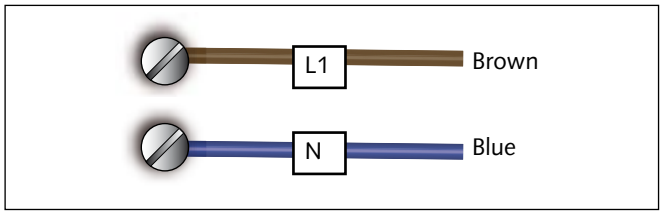


Figure 40 LV single-core cable identification



15.27 Note: where the conductors form an IPS circuit, both conductors should be coloured brown and identified as L1 and L2. In composite cables, conductors can be sleeved brown.

15.28 The LV distribution strategy should focus on the cable size with a view to installing the cable and giving access for maintenance. Designers should allow adequate space for the bending radius of cables (including the respective containment system – see Chapter 14).

15.29 Distribution and sub-main cables above 240 mm^2 are difficult to install, which means either having smaller distribution circuits (which in turn means more switchgear) or installing single-core cables. Where the distribution uses single-core cables, each core should be laid in a trefoil arrangement. In order to limit electromagnetic radiation (see Chapter 11), the group should be 0.75 diameters from a wall or any other distribution cable (cable group), and generally means more space.

Busbar distribution

15.30 LV busbar distribution systems are becoming a cost-effective solution for high-current circuits. LV busbar systems with current ratings from 63 A to 2.5 kA (depending on type) are available, with the insulation being air or cast-resin encapsulation. Some systems provide insulated bars only. The main advantages of LV busbar distribution are the reduced space, and the standard tap-off facility to add additional outgoing circuits later (via fused switches).

Control alarm and communication cables

15.31 There are many types of alarm and communications system in a healthcare facility. This section identifies some of the more common wiring systems used for such circuits. Since the mid 1980s, many communication and alarm systems have moved to digital networks and data highways. As such systems have expanded and their relative speed and bandwidths increased, many data highways are being used to carry a multitude of systems ranging from information technology systems, BEMS, nurse call, blood bank alarms, security and fire alarm signals. Since the mid-1990s, some of the communication and alarm systems have moved to wireless systems.

15.32 This Health Technical Memorandum is only concerned with fixed wiring. However, designers and stakeholders should consider the effects of wireless systems and electromagnetic compatibility (see Chapter 11). The use of any wireless systems in clinical risk Category 3 and above areas should be the subject of a risk assessment. Although the wireless signals may not have any common frequency or side-frequency with electro-biomedical equipment etc, the clinical risk may be high.

Control communication and non-fire-alarm cables

15.33 Designers should liaise with system suppliers before selecting the type of cabling used for general communication and alarm systems.

15.34 The distribution and installation of alarm and communication systems should follow (as far as practical) the general route of containment used for power systems, provided a suitable segregation distance (100 mm to 300 mm depending on voltage screening bands) is maintained.

Information technology cables

15.35 The construction and type of cable used for IT systems fall outside the scope of this Health Technical Memorandum. Designers should liaise with the IT staff at an early stage to coordinate the containment routing for such systems. IT containments should be in separate vertical risers to any other building services containment route. Horizontal containment used for IT should be at least 300 mm to 600 mm from other building services containment, subject to the voltage band of any distributed power cabling system. The IT distribution strategy and separation distance are exclusive of any maintenance access requirements that should also be considered.

Fire alarm cables

15.36 Cables used for any part of a fire alarm system should be an enhanced grade cable as defined by BS 5839-1:2002.

15.37 All fire alarm cables should also satisfy the CWZ rating of BS 6387:1994; that is, the cable should be able to withstand water and impact and be subjected to a temperature of 950°C for three hours.

15.38 Cable systems may be derogated from their respective mechanical cable impact requirements of BS 6387:1994 by installing enhanced-grade fire alarm cable in a continuous containment, which then satisfies the impact requirement of BS 6387:1994.

16 Final circuits

16.1 This section deals with final circuits and point-of-use connections of the PEI that present best-practice configurations for final circuits, UPS and IPS for the emergency protection of final outlets, circuits and equipment. The configurations are presented generally in order of resilience from low to high. The selection of a particular configuration will be dependent on the specific factors of each individual design. The selected configuration should be based on a risk analysis to determine the appropriate level of resilience.

16.2 The configurations presented in this section should not be taken as being definitive, prescriptive, or restrictive of innovation. They are intended as a guide to best practice (see Figure 41).

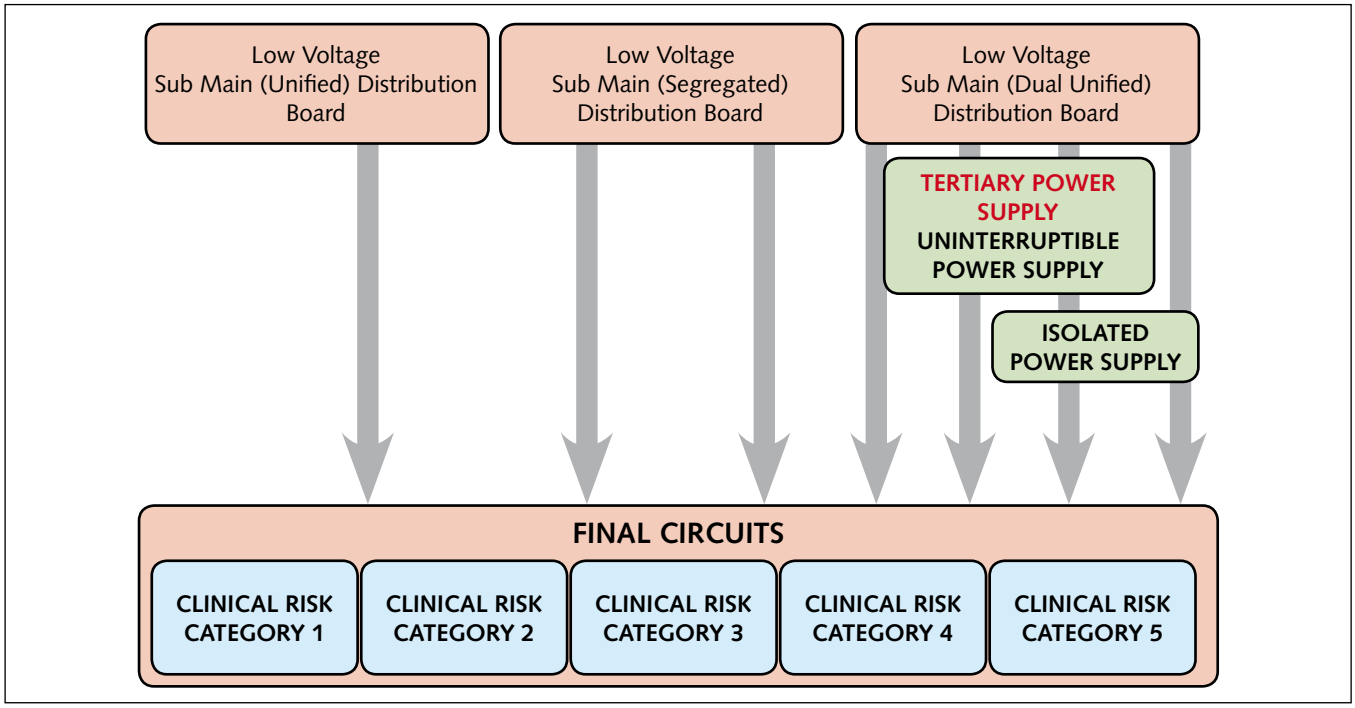
Uninterruptible power supplies

Standards

16.3 UPS systems should be to, but not be limited to, the following design and manufacturing standards:

- BS EN 62040-1-1:2003. 'Uninterruptible power systems (UPS). General and safety requirements for UPS used in operator access areas';
- BS EN 62040-2:2006. 'Uninterruptible power systems (UPS). Electromagnetic compatibility (EMC) requirements';
- BS EN 60146, IEC 60146. 'Semiconductor convertors. General requirements and line commutated convertors';
- BS EN 60439-2, IEC 60439-2. 'LV switchgear and control gear assemblies';
- VDE 0510-2 paragraph 6.5, Ripple current for battery charging systems.

Figure 41 Final circuit connectivity



Rating

16.4 UPS system ratings range from 250 VA up to several hundred kVA; the small units may be single-phase units used to support a single circuit, and the larger UPS systems may be single- or three-phase units for supporting a complete department.

16.5 Central UPS systems may be considered where the need covers several small distributed areas. Where centralised UPS systems are considered, a diesel rotary UPS (DRUPS) may provide an economic solution. The location of DRUPSs should be based on the same environmental criteria used for the standby generators and/or CHP plant.

16.6 Other types of rotary UPS, which use the stored energy of a flywheel under full torque connected to a motor, may also be used. The autonomy of these UPS devices are essentially time-based and largely independent from the actual load. These so-called "silent rotary UPSs" currently have high kVA ratings and are more suited to a centralised system.

UPS environment

16.7 Designers should consider the local space of the UPS, in terms of its access for maintenance and heat generated. Depending on the UPS type, single or double conversion, a UPS will radiate about 3% to 8% of its input power, which will need to be vented. Ideally, the ventilation should be natural. The environmental conditions should control the room space to the limits recommended by the battery manufacture.

UPS description and configurations

16.8 A UPS consists of three principal parts: a rectifier, a battery unit and an inverter. The rectifier converts the ac power supply (single- or three-phase) to a dc supply. The rectifier output maintains the battery in a fully-charged condition. The inverter reconverts the rectifier output (or battery output) to a synthetic sinusoidal waveform output (again either single- or three-phase according to the input). The UPS should include a static bypass, a manual internal bypass and an external bypass; all three bypass switches should be installed. The static bypass will electronically divert the normal supply from the rectifier inverter line through the static switch whenever a fault in the UPS conversion occurs. The static bypass operates at such a high speed that it is considered as a no-break supply switch.

16.9 Single-conversion UPS units are configured so that the supply is normally via the static switch and, on loss of supply or when the supply quality falls, the static switch instantaneously connects the battery output to the load. The battery is held fully charged by a trickle charger supplied from the normal supply. The battery autonomy (see Chapter 10) of single-conversion UPSs working offline is typically up to 15 minutes.

16.10 Double-conversion UPS units are configured so that the supply is normally via the rectifier and inverter line and, on loss of supply (or poor supply quality), the battery output supplies the load via the inverter. The static switch will also bypass the rectifier inverter if the UPS circuit develops a fault. The battery is held fully charged by a trickle charger supplied from the normal supply. The battery autonomy (see Chapter 10) of double-conversion UPSs working online is typically up to 1 hour. The battery autonomy should be assessed to ensure that adequate power can be provided to allow the medical therapies to be concluded safely (within the area of concern). Usually 1 hour will facilitate the closure of any patient in an operating theatre. However, on the most complex of surgeries or medical therapies, periods of up to three hours may be required. Designers and stakeholders should liaise with surgical staff to understand the most appropriate cost-effective strategy.

16.11 The rectifier and bypass may have a common supply connection. The ideal connection should provide separate connections for the rectifier and bypass line (see Figure 42a/b).

UPS fault condition design

16.12 UPS protective devices should be capable of clearing downstream circuit faults in similar fashion to other distribution boards. UPS output-circuit protective devices should discriminate from upstream devices. Designers should consider the effect of overload and short-circuit fault condition. Short-circuits in the UPS load are isolated either by a downstream protective device, or by the insulated-gate bipolar transistor (IGBT) control circuit of the inverter. UPS units may tolerate overloads of 125% for 10 minutes, 150% for 1 minute, or 200% for 100 milliseconds (depending on the manufacturer's selected internal protective device). The actual overload characteristics vary from manufacturer to manufacturer. Designers should verify the

Figure 42a UPS resilient arrangements

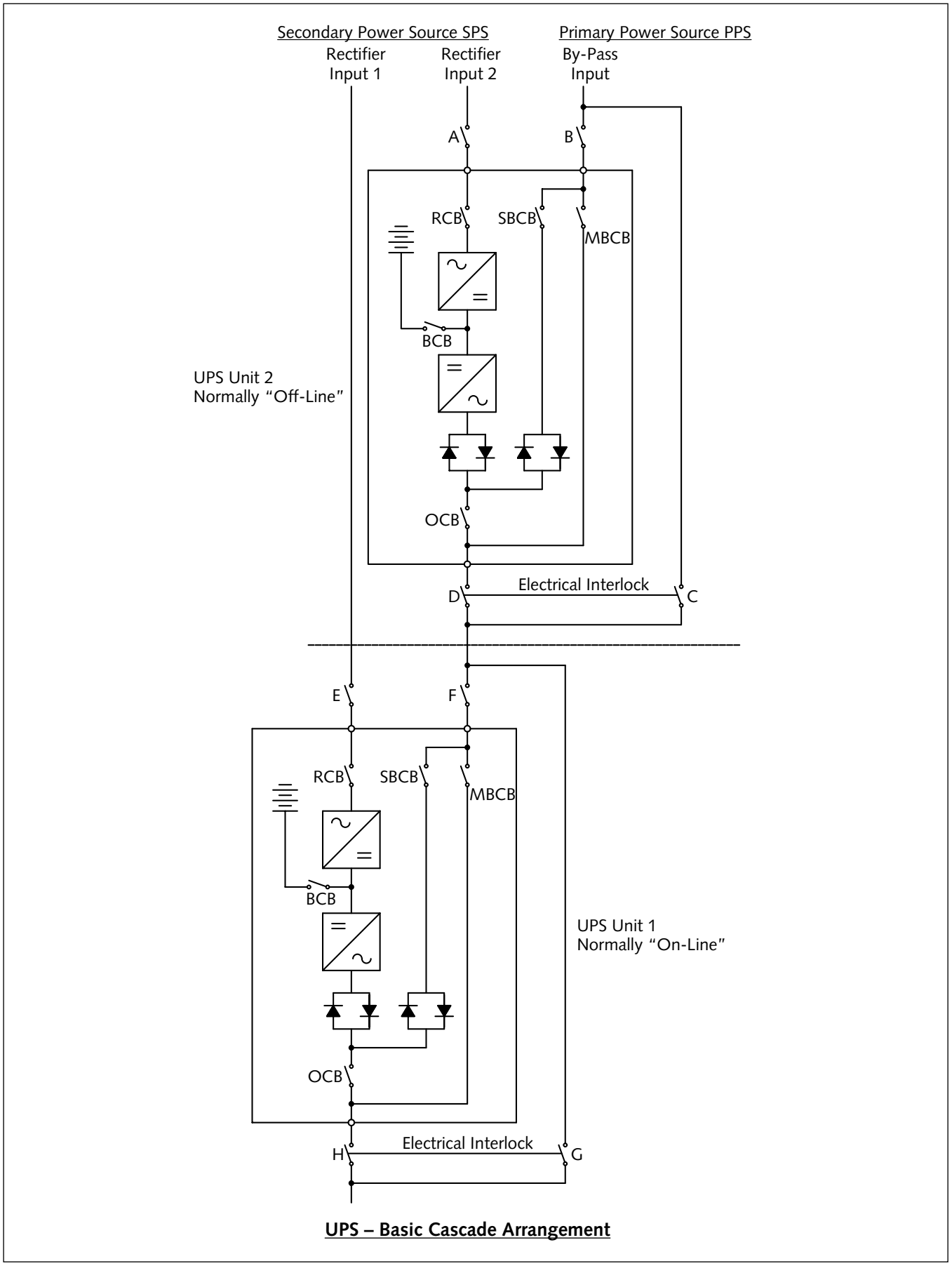
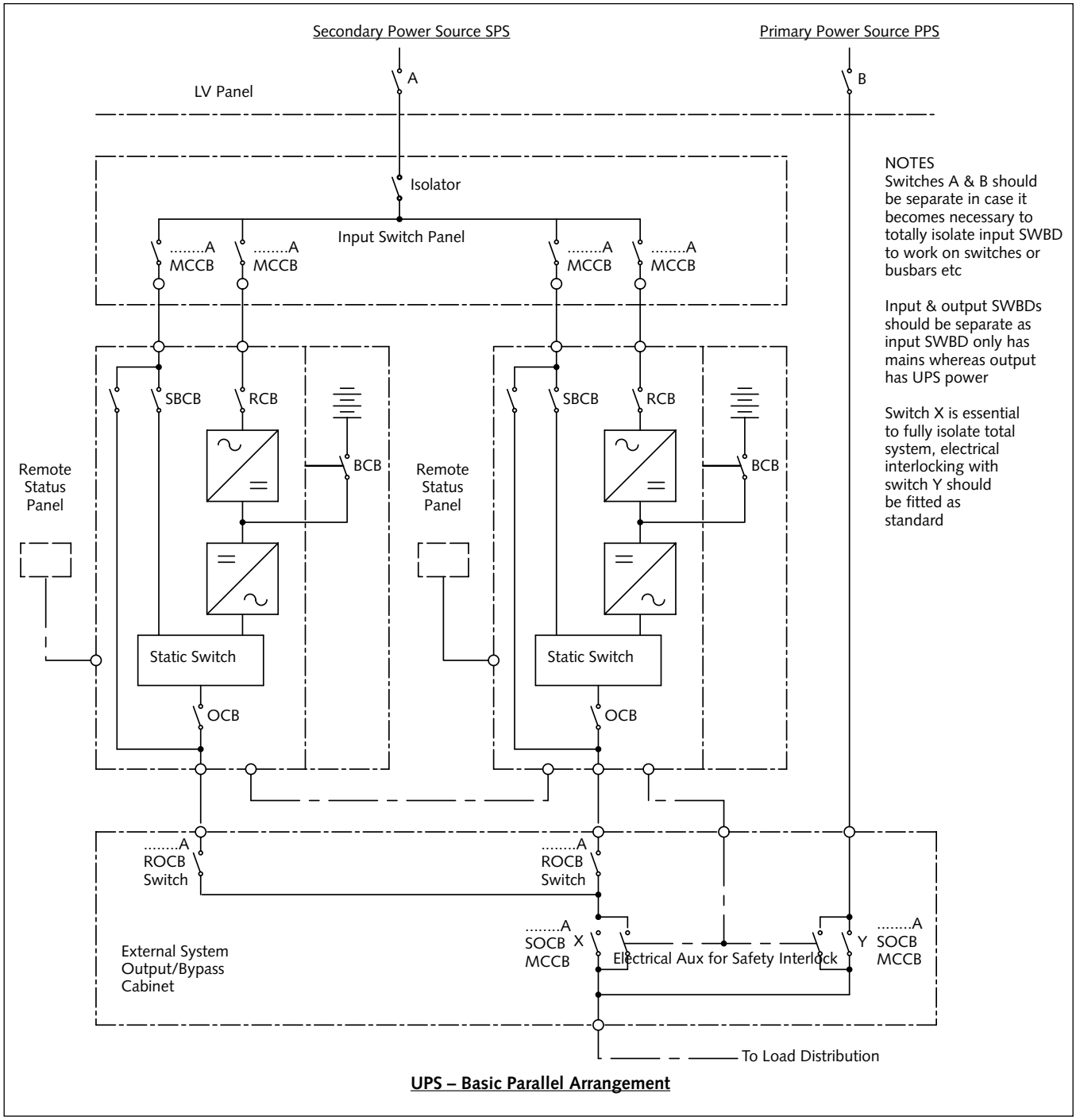


Figure 42b UPS resilient arrangements



coordination of fault conditions when selecting the UPS type.

16.13 Designers need to consider carefully the protection systems used by the UPS. The UPS subcircuit protective devices should provide adequate discrimination with the inverter/static switch protection. If the inverter/static switch protection operates before the subcircuit protection, the UPS may shut down. Clearly, this would then isolate all the subcircuits and not just the faulty circuit.

16.14 With three-phase UPS units, designers may wish to consider the use of a zig-zag transformer on the UPS bypass lines. Such transformers provide a local earth point, may help to ensure that an adequate fault current is developed, and assist in harmonic control.

16.15 Where the UPS is supported by the secondary power supply, a transformer with a double-wound secondary may assist with the limiting of the initial

acceptance load as the harmonic currents have been reduced.

UPS power quality

16.16 UPS systems are a significant non-linear supply. The rectification stage provides a pulsed ripple dc circuit, and the inversion stage provides a synthetic sinusoidal ac circuit. Thought should be given to UPS units which use IGBTs and to the duration and value of any inrush currents.

16.17 The output of the rectifier will be a ripple dc voltage. The ripple effect is normally smoothed by the use of IGBT devices. However, the IGBT circuitry will reflect a harmonic current into the supply line. The level of harmonic currents should be controlled such that the net harmonic current reflected to the DNO connection is in accordance with the Energy Networks Association's Engineering Recommendations G.5/4. See also paragraphs 5.11–5.17.

UPS resilience

16.18 UPS units can be grouped as multiple units connected either in cascade (redundant) or in parallel (see Figure 42a/b). Either arrangement provides N+1 resilience, as described in paragraphs 6.8–6.30. UPSs connected in cascade provide a "redundant" arrangement. With redundant UPS arrangements, each UPS should be able to fully support the full load, that is, be 100% rated. The output of the first cascade-connected UPS should supply the bypass of the second UPS. UPS units connected in parallel are normally all online, but a standby unit (in parallel) may be provided. UPS units connected in parallel may be rated at a percentage of the full load, provided that when one unit is not available, the remaining units can provide the full load. The common point of coupling for parallel UPS units should be downstream of the external bypass of each unit.

16.19 The selected arrangement for UPS resilience should ensure that the internal and external bypass switches provide a safe maintenance strategy.

Inverter units

16.20 The inverter units considered in this Health Technical Memorandum relate to central battery units and stand-alone units used for theatre operating lamps. Inverters used as a self-contained power pack for emergency escape lighting and signage are excluded, as they do not connect to the fixed wiring. However, designers should be mindful of such units when assessing the overall electromagnetic characteristics of the wiring system (see Chapter 11).

Central battery units

16.21 The wiring used in central battery units should be of an enhanced grade as defined by BS 5839-1: 2002.

16.23 Central battery inverter units should be directly connected to the secondary power supply and be so arranged that the output can energise all connected emergency escape lighting and signage within five seconds as required by BS 5266.

16.24 Central battery inverter units should be constructed with maintenance bypass switches. The switch should isolate the battery charging unit and the batteries from the output, but maintain a normal supply to the output. Note: if there were to be an outage of the primary supply during the maintenance of a central battery inverter unit, there would be no output supply until the secondary power supply was available. This period of circa 15 seconds is beyond the 5-second requirement of BS 5266. See paragraphs 10.14–10.16 for details of the battery capacity relating to central battery inverter units.

Rectifier units for theatre operating lamps

16.25 Each separate operating theatre should have its own rectifier battery unit, external to the theatre, exclusively for the operating lamp(s).

16.26 See paragraphs 10.14–10.16 for details of the battery capacity relating to inverter units for theatre operating lamps.

Isolated power supplies (IPS)

16.27 Medical IT systems are IT electrical systems having specified requirements for medical applications. Medical IT systems are commonly termed "isolated power systems", and have monitored circuits. A medical IT system should comply with the following standards:

- IEC 60364-7-710;
- BS 7671 Special Guidance Note 7, Chapter 10;
- BS EN 61558-2;
- BS EN 61557-8.

16.28 It is a basic requirement that an IPS system should be able to sustain power on its subcircuits during and following a first earth fault on the system. This requirement differentiates an IPS from a UPS: the IPS maintains power when an earth fault occurs on the transformer output circuits, while a UPS maintains power output when its source of supply is interrupted. Therefore, these systems may be used to full advantage to complement each other in critical medical locations to improve patient safety.

16.29 For the purpose of this Health Technical Memorandum it may be assumed that any electro-medical equipment used in either a Group 1 or Group 2 location (as defined in the above standards) should be compliant with the requirements of BS EN 60601-1, IEC 60601-1 (as required by the Medicines and Healthcare products Regulatory Agency, MHRA).

16.30 In medical locations, the distribution strategy should be designed to facilitate the automatic changeover from the primary distribution network to the SPS (standby generator feeding essential circuits) when and if the primary supply voltage drops by more than 10%. The LV distribution circuitry, up to the sub-distribution board used to connect the IPS and UPS systems, should be deemed an essential circuit.

16.31 The medical IT system provides a monitored, isolated, floating power supply, which will sustain the first single earth fault. Consequently, IPS systems do not require any overload protection on isolating transformer input or output circuits. An advance warning of potential faults on the medical IT system, which includes the final subcircuitry, is raised by the monitoring of insulation, transformer overcurrent and temperature. The medical staff can unplug medical equipment from the affected circuit and replace or reconnect to a healthy circuit. To enable the transfer of equipment in this manner, sockets at patient locations should be from two interleaved IPS systems. Automatic earth fault location systems (EDS) may be used to advantage in interleaved IPS systems areas and especially in wards, to provide rapid, detailed earth fault location information to clinical staff at the staff base; generally this should be in the form of a simple text message, which for example would state "IPS 1 Earth (Insulation) Fault, ITU bed 4, left side". In addition to the requirements of IEC 60364-7-710 for these locations and BS EN 61557-8 (insulation monitor standards), insulation monitors installed in IPS systems should be capable of correct function (that is, no nuisance alarms) when dc levels (of either polarity) are present on the monitored medical IT systems. Furthermore, insulation monitors should be able to function correctly in systems with capacitive filters such as MRI installations.

16.32 The construction and design of the IPS units should provide adequate access for maintenance. This is especially important in "multiple channel" IPS panels, where it should be possible to safely isolate and maintain each individual IPS channel, without detriment to the operation of the other IPS channels. Where the multi-channel IPS panels also include EDS systems, each channel should be suitable for full EDS function either simultaneously with other IPS channels, or independently, when other IPS channels are isolated for maintenance.

16.33 The installation of IPS systems, together with additional equipotential bonding and other measures described in the standards/guidance referred to above, are necessary to ensure the safety of patients and medical staff in medical locations. However, the increased use of electrical equipment for the purpose of life support and/or complex surgery used in special medical locations requires enhanced reliability and safety of the electrical installation in hospitals to ensure the security of supplies and to minimise incidents of microshock.

16.34 The earth leakage current from the secondary winding of the isolation transformer, when measured in no load condition and in single earth fault condition, should not exceed 0.5 mA. It is essential that this requirement for leakage currents is specified as an additional requirement to IEC 61558-2-15. As it stands, IEC 61558-2-15 specifies these leakage currents to a limit of 3.5 mA; however, there are moves in hand to modify IEC 61558-2-15 to reduce the leakage currents specified to 0.5 mA. This requirement enhances the safety applications of the transformer and brings it in line with BS EN 60601-1, IEC 60601-1.

IPS environment

16.35 Designers should consider the local space of the IPS in terms of its access for maintenance and heat generated. The IPS unit should be located on the same floor and just outside the medical department clinical risk category area it serves. Where this is not practical, derogation may be

given to locating the equipment on the floor immediately above or below, or within 30 m on the same floor as the clinical risk category area. The IPS unit includes an isolating transformer, typically 3.5 kVA–10 kVA radiating about 2–5% of its output power as heat, which should be ventilated. Ideally the ventilation should be natural, unless the forced ventilation power is derived from a standby generator.

IPS communication

16.36 Each IPS system will have audible and visual alarm indication of any first fault in accordance with the requirements of BS EN 61557-8 and IEC 60364-7-710 insulation monitoring devices. Remote indication, where required, will be at the nurse/management station for the medical area covered by the IPS system. Connecting the remote alarm indication to a networked BEMS communication system and terminals within the estates office will have added advantages.

Resilience

16.37 IEC 60364-7-710 and BS 7671 require Group 2 areas to have at least two separate socket-outlet subcircuits at each patient treatment location (for example bedhead or theatre pendant). This applies to Group 1 areas also. This can be achieved from a single IPS unit with an integral single-phase distribution board. The resilience would be further enhanced if the IPS had dual 100%-rated isolation transformers serving different integral distribution boards. Such arrangements would provide an N+1 resilient IPS isolation transformer as defined in paragraphs 6.8–6.14.

16.38 IEC 60364-7-710 and BS 7671 require luminaires and life support equipment used in Group 2 (or occasionally Group 1) locations which need power supply within 0.5 seconds or less, to be restored within 0.5 seconds of a supply failure and other equipment to be restored within 15 seconds. To achieve the safety requirements, IPS units serving life-support equipment should be connected to a UPS supply which has a derived power supply, supported by the standby generator. However, other equipment may not require the same level of UPS/generator support. In order to ensure that the appropriate support is always available to cover a range of treatment options, any IPS used should be supported by a UPS and standby generators. This arrangement will provide greater flexibility in any future remodelling of the clinical risk category 4 and 5 areas.

16.39 Figure 43 shows an IPS arrangement suitable for Group 1 or Group 2 Locations. Figure 38 shows the earthing arrangement for a typical theatre. (Other IPS arrangements that satisfy the requirements of IEC 60364-7-710 and BS 7671 may also be possible.)

The patient environment

16.40 Figure 44 relates to the patient treatment location, where all sockets associated with medical equipment should be connected to the IPS and any other socket (or fixed equipment) connected to the TN-S supply with an RCD/RCBO protective device. Although the figure relates essentially to a theatre location, it should be reasonably clear how the zone would be modified (at the patient head) when used to illustrate an area such as a high-dependency unit (HDU).

16.41 Theatre operating lamps do not require an isolated power supply and should not be connected to IPS circuits.

16.42 In Figure 44 the dark grey area represents the theatre table/bed, while the light grey shows the patient treatment area (exclusion zone). Any exposed or extraneous conductive parts within the exclusion zone, or that could be reached from within the exclusion zone, should be connected to the ERB with an impedance less than 0.1 Ω. The theatre table (or bed) could be moved as illustrated, in which case the exclusion zone would also move. Therefore, any exposed or extraneous conductive parts within the outer boundary (above) should be bonded to the ERB with impedance less than 0.1 Ω. All exposed or extraneous conductive parts within the theatre (or ward) should be bonded as described above. Theatre operating lamps, pendants, beams, equipment gantries etc should be considered as extraneous metalwork and therefore should be bonded to the ERB (see Figure 38).

IPS low-power circuits

16.43 This section refers to sockets in Group 1 or 2 areas as defined by IEC 60364-7-710 (the IEE Guidance Note No 7) and mortuary post-mortem rooms.

16.44 Activity Database (ADB) and the Department of Health's 'Health Building Notes' (HBNs) provide

Figure 43 IPS/UPS high-security supply arrangements

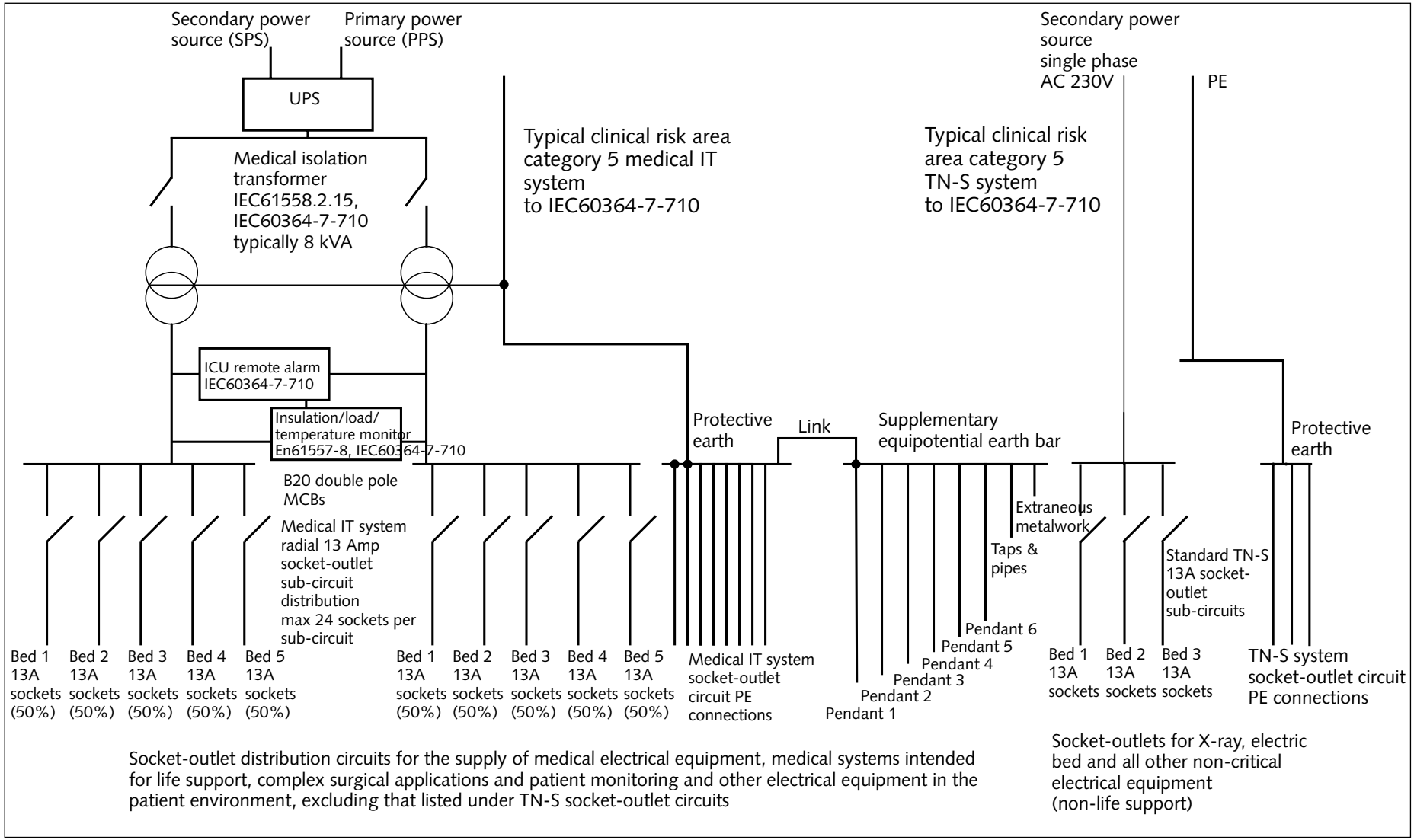
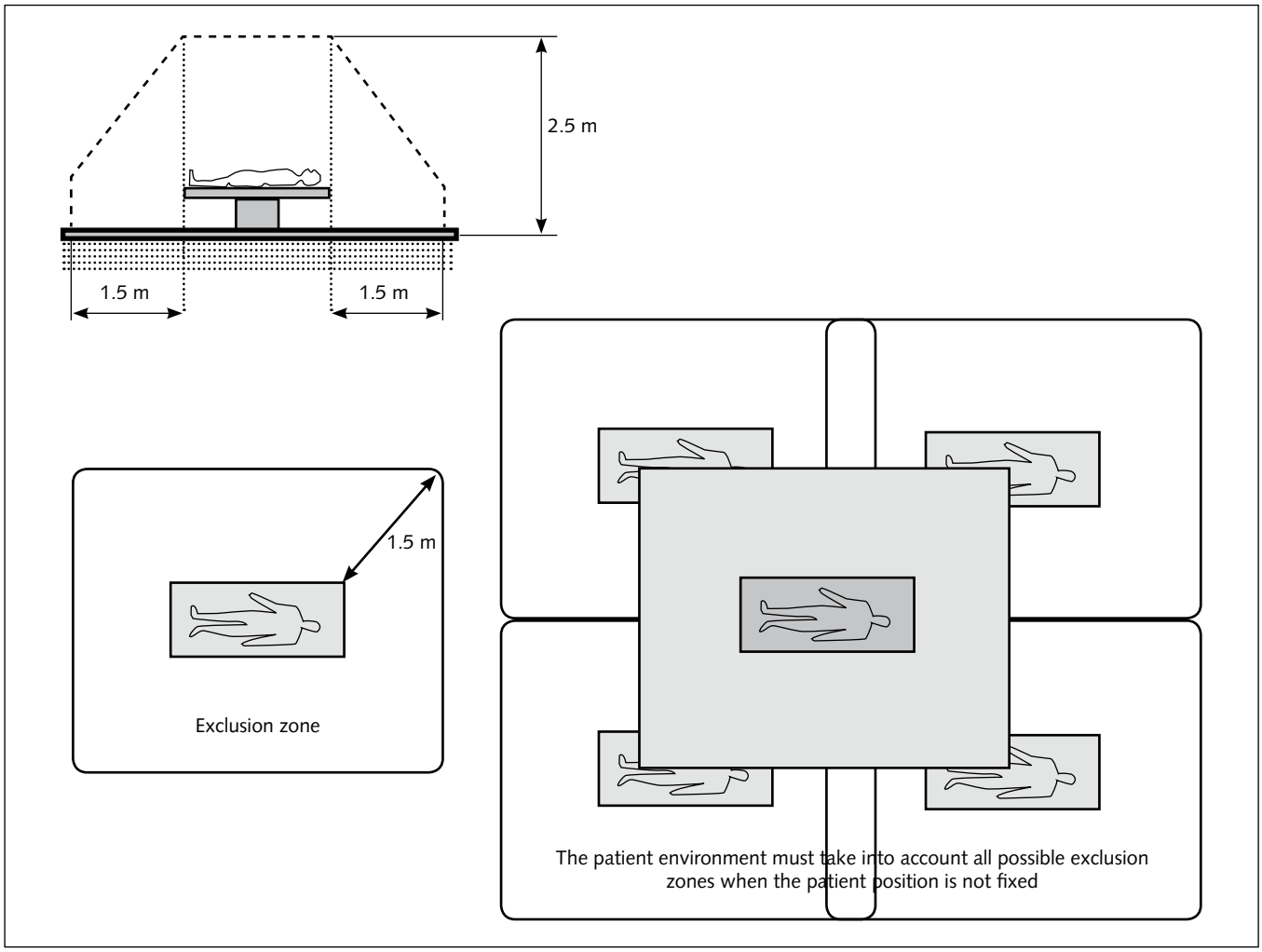


Figure 44 The patient environment



advice on the number of sockets. The number of sockets at the patient location of clinical risk Category 4 and 5 areas will be significantly large. IEC 60364-7-710 recommends that each patient location has two IPS socket circuits and one TN-S circuit. Final circuits of an IPS system may have up to 24 sockets per circuit.

16.45 Socket-outlets in clinical risk category 4 and 5 areas and connected to the medical IT system (IPS circuits) will be connected in a radial format. The protective device for such circuits should be a 20 A MCB with a Type B characteristic. Socket-outlets within clinical risk category 4 and 5 areas not connected to the medical IT supply should be protected by an RCD/RCBO protective device. The RCD/RCBO may be incorporated within the distribution board. The RCD/RCBO will be 30 mA and Type A or B characteristic.

16.46 Sockets-outlets in clinical risk category 4 and 5 areas, and connected to the medical IT system (IPS circuits) may be supplied as unswitched items to prevent accidental switch-off. Where such sockets are supplied as switched items, the switch will be double-pole. A means of identifying individual medical IT circuits should be provided at each socket-outlet. Medical IT socket-outlets should be blue in colour to distinguish them from any TN-S earthed socket within the same vicinity.

16.47 Initial concepts and remodelling of clinical departments will always require an understanding of the intended use of each medical location prior to designing the IPS-UPS configuration.

16.48 Some of the sockets in these areas will be earthed as part of the TN-S system, while others are part of a medical IT system. Sockets earthed by the medical IT method will be connected via the IPS distribution board.

General low-power circuits

16.49 In general, socket-outlets (as defined by BS 7671) will conform to BS 1363 or IEC harmonised standards and be connected to a ring or radial circuit. The protective device for a single-phase socket circuit should be rated no higher than 32 A for a ring circuit and 20 A for a radial circuit.

16.50 All sockets should be suitable for the local environment. While this may appear obvious, it ensures that suitable precautions (IP ratings) are made for sockets in kitchens, laboratories, plantrooms and general circulation spaces. Metal-finished sockets should be installed within a clinical risk Category 3 area and above in order to limit the effect of electromagnetic interference and the increased mechanical protection.

16.51 Socket-outlets and switches, regardless of the location, should be installed at a distance of at least 0.2 m horizontally (centre to centre) from any medical gas outlets. This requirement is specified in BS EN ISO 11197:2004.

Socket-outlets/connection units

16.52 Designers should assess the maximum number of socket-outlets on a final circuit by calculation of the minimum disconnection times given in BS 7671, and the likely simultaneous connected power on the circuit. Designers should consider the distribution strategy and risk ownership when determining whether the socket-outlet circuit should be supported by the SPS. However, for some areas in clinical risk categories 1, 2 or 3, stakeholders may wish to have a different approach. In such areas, consideration can be given to socket-outlets connected to the SPS where the area has standby lighting of Grade B or above. In such cases, designers and stakeholders should be mindful of the implications for the capacity of the essential SPS.

16.53 Socket-outlets (in any location) connected to the essential SPS should be positively identifiable from any non-essential sockets in the same area.

Sockets for special locations

16.54 There may be areas that require special electrical installations, providing safety measures for specific purposes. In general, post-mortem rooms will have medical IT circuits having an earth fault trip for enhanced safety in a wet environment. However, other rooms within the mortuary should be supplied with final circuits protected by RCD/RCBO protective devices. Consideration may be given to the provision of a PELV system within post-mortem rooms.

16.55 Other wet areas, such as hydrotherapy pools, will require all final circuits to be equally protected by RCD/RCBO protective devices. See the IEE Regulations BS 7671 for more details.

16.56 Healthcare premises include engineering workshops for mechanical, electrical and biomedical repairs. The maintenance of electrical equipment and biomedical equipment may require testing with the supply connected, that is, working live. Great care for such working arrangements must be observed for compliance with the Electricity at Work Regulations (regulation 14) and HSE guidelines etc.

16.57 Designers should consider providing a special test room or test bay within the engineering workshops and biomedical workshops. The low-power circuits within the test room and/or test bay should be from an isolating transformer, providing an earth-free environment. These circuits should be very clearly identified, and labels should be provided to alert the occupier to the earth-free environment. The circuits within this area should be protected by a 20 A MCB Type A or B, and require a monitoring system.

Sockets for operating theatre suites

16.58 The patient environment of an operating theatre is a clinical risk Category 5, and hence the sockets may be served from a UPS or IPS circuit. Consideration may be given to connecting the full theatre suite from a UPS supported by the SPS standby generator, or just the SPS standby generator. Other socket-outlets within the operating theatre should be connected to the TN-S wiring system and have an RCBO or RCD with a 30 mA trip.

Socket for mobile X-ray units

16.59 Mobile X-ray units supplied since the mid-1980s do not present any real disturbance to the electrical distribution. However, designers should enquire whether any provision should be made for mobile X-ray units which derive their high ionisation voltage by inductive means, and provide dedicated sockets circuits accordingly.

Spark-proof sockets

16.60 The use of anaesthetic gases with a very low flash point has virtually been eliminated from UK NHS hospitals (see College of Anaesthetic Consultants and the Medicines and Healthcare products Regulatory Agency). However, an assessment by enquiry should evaluate the likelihood of such anaesthetic gases being used, and provide mercury-operated switched sockets (and light switches) accordingly.

Number of outlets per final circuit

16.61 Designers need to consider the potential earth leakage current that may flow on the protective conductor under normal conditions, which should be minimal. For clinical risk categories 4 and 5, the earth leakage current is regulated by cable leakage capacitance, the design of the IPS isolating transformer and associated medical equipment. In other clinical risk areas, the potential earth leakage current will be determined by the medical equipment (assumed to be compliant with BS EN 60601-1, IEC 60601-1), other equipment loads, and cable leakage capacitance.

16.62 The steady-state earth leakage current expected on a TN-S final-circuit protective conductor should not exceed 50% of the sensing element of any RCD or RCBO used as the protective device on the circuit. Designers may therefore wish to consider this statement when designing final circuits as ring mains or radial circuits.

Fixed equipment

16.63 Large fixed equipment such as lifts, compressors, air-handling units, laundries, engineering workshops and radiographic imaging equipment is addressed here. Such items of plant include heavy inductive loads, which may cause disturbances to the distribution network.

16.64 Where the electrical supplies are for high-inductive motors, “soft-start” or “inverter speed drives” should be used. All such inductive loads should have local power factor correction and harmonic filtering. Dedicated earth cables should be provided between the MCC and LV switchpanel ERB, or the main earthing terminal (MET) at the transformer.

16.65 Where the electrical supplies are for radiographic imaging diagnostic and treatment facilities, designers and stakeholders should liaise with the equipment manufacturer/provider and MEIGaN before designing the electrical services to these areas. Dedicated sub-main circuits should be used for these areas. However, the use of dedicated earth cables between the radiography sub-main switchboard and the LV switchpanel ERB or the MET at the transformer is strongly encouraged.

16.66 Designers may wish to consider using a dedicated transformer for the sub-main supplies to large fixed equipment. There are strong positive advantages of such an infrastructure strategy, particularly where the fixed equipment has a very high inductive load, such as vapour compression chillers or radiography departments.

Supplies to external buildings

16.67 Some healthcare premises have small annexes used as stores and/or plantrooms not intended to be occupied for long periods. The standard of electrical installation for these buildings should be the same as for the main healthcare building. Electrical installation standards should reflect the nature of the stores, which may contain medical gases or flammable material. In such cases the electrical equipment, including containments, cabling, luminaires and accessories, may require to be intrinsically safe.

Temporary supplies

16.68 Designs that comply with the guidance given in this Health Technical Memorandum should avoid the need of temporary supplies. Where they are needed, the electrical standards should be as high as for the permanent supply. Derogation may be given on the containment requirement, when a clear understanding of the intended temporary period has been given.

16.69 Designers’ attention is drawn to the application to connect (see paragraphs 3.60–3.62). The site engineer will reserve the right not to connect a temporary installation where the installation does not comply with the guidance given in the Health Technical Memorandums and local electrical safety rules.

Connections for mobile trailer units

16.70 Where mobile Treatment Centre (TC) units (for example MRI scanners), or similar units, are connected to the electrical distribution of the healthcare facility, it is important to maintain a

high degree of electrical safety. This will include suitable protection to any cables and switchgear that might be more readily accessible to unauthorised persons. Suitable solid earthing between the healthcare premises building earth and the mobile unit should be provided.

16.71 Stakeholders should ensure that the internal electrical systems of any mobile TC unit used on healthcare premises could not compromise the safety of patients and/or the electrical system of the healthcare premises.

16.72 The mobile unit should be earthed as a TN-S system, and where the clinical risks are of Category 4 or 5, a suitable IPS system (with medical IT earthing) should be used (see MEIGaN and IEE Guidance Note 7).

16.73 Designers and stakeholders should ensure that the final supply/connection cable to any mobile unit includes a monitored earth as described in BS 4444.

General lighting

16.74 The design of the lighting systems and lighting levels are outside the scope of this Health Technical Memorandum.

16.75 Lighting circuits used should be wired as a radial circuit with a maximum protective device rating of 10 A.

16.76 In any room of clinical risk Category 3 and above, at least two lighting circuits should be provided.

16.77 Lighting circuits within the patient environment should be supported by the standby generator to ensure that Grade A standby lighting is achieved. Consideration may be given to connecting such lighting circuits to a UPS. Connecting lighting circuits to any IPS circuit is not encouraged by this Health Technical Memorandum.

Theatre operating lamps

16.78 All fixed theatre operating lamps, including the main unit and any satellite units, should be connected to a battery inverter unit providing 3-hour autonomy. The connection of the theatre operating lamp (including its battery inverter) to the output of any IPS circuit is not encouraged by this Health Technical Memorandum. However, any exposed conductive part of the operating lamp should be bonded to the ERB.

Examination lamps lighting

16.79 Final circuits used for any fixed examination lamps located within a clinical risk Category 4 or 5 area should be protected by RCD/RCBO protective devices. The connection of the examination lamp to the output of any IPS circuit is not encouraged by this Health Technical Memorandum. However, any exposed conductive part of the examination lamp should be bonded to the ERB.

Emergency escape lighting

16.80 The emergency escape lighting circuits should be designed in accordance with BS 5266 and BS EN 1838. This Health Technical Memorandum considers emergency escape lighting to consist only of escape-route emergency lighting. Emergency lighting circuits should be so arranged as to provide escape-route lighting throughout the healthcare facility. Where the facility has muster points for progressive horizontal evacuation (as defined in the Firecode series), at least two circuits should be provided. Emergency lighting emergency power should be derived from integral battery packs (tertiary power). Consideration can be given to central emergency battery units, but the additional fire-rated cabling cost may make this uneconomic.

Standby lighting

16.81 This Health Technical Memorandum considers standby lighting as a secondary form of emergency lighting (defined by BS 5266 and BS EN 1838). All areas that require standby lighting should also have emergency lighting.

16.82 Standby lighting will derive its power from the SPS. There are two grades of standby lighting: Grade A and Grade B. Grade B standby lighting provides lighting at a reduced level compared to the normal lighting level. Standby lighting to Grade B is best provided by an increased number of emergency light fittings with integral tertiary power battery packs. Grade A standby lighting provides lighting at the same level as normal lighting. Standby lighting to Grade A is best provided by the SPS standby plant.

16.83 Clinical risk Category 3 areas should be provided with Grade B standby lighting, and clinical risk Category 4 and 5 areas with Grade A standby lighting.

16.84 Designers and stakeholders may wish to consider the implication of any additional circuitry required to provide a mixed standby-lighting facility. Consideration may be given to all lighting circuits being connected to the SPS.

16.85 Designers should be mindful that operating theatres, which by definition are clinical risk Category 5, should have an independent tertiary power source (battery inverter unit) for the theatre operating lamp(s) and satellite lamps. The battery autonomy should be at least three hours. In addition to the inverter unit, the electrical distribution supply to the theatre operating lamp(s) should be derived from the secondary emergency power source (SPS).

Fire alarm, security circuits and critical alarms

16.86 Designers should provide an independent tertiary power source (battery inverter unit) for the fire alarm system. The battery autonomy should be compliant with the requirements of BS 5839-1: 2002. The fire alarm systems should be connected to the SPS, where appropriate to the distribution strategy. Consideration may be given to connecting any fire-door detents to the SPS.

16.87 See paragraphs 10.11–10.16 for details of battery inverter capacity.

16.88 All cables associated with the fire alarm system should be of an enhanced grade as defined by BS 5839-1:2002, and should be installed as a Category 3 cable as defined by BS 7671.

16.89 Cables used for security and other alarm systems should be installed as per the manufacturers' requirements.

16.90 Designers should provide an independent tertiary power source (battery inverter unit) for the central head-end of a security system. The system suppliers should specify the battery autonomy. Designers and stakeholders should liaise with all staff, especially security staff, when determining which, if any, security detection and alarm component parts are supported by the SPS. As a minimum, if there is a pharmacy on site with controlled and/or dangerous drugs, the security system should be connected to the standby generators.

16.91 Designers should provide an independent tertiary power source (battery inverter unit) to any blood-bank alarm system. The system suppliers should specify the battery autonomy.

BEMS communication and control wiring systems

16.92 Designers should provide an independent tertiary power source (battery inverter unit) for the central head-end of any system used for these facilities. BEMS outstations should have an integral battery unit to maintain internal software parameters. The BEMS equipment etc should at least operate in the fail-safe position. More critical plant and service (controlled through the BEMS) should be connected to the SPS standby emergency generator.

17 Validation and commissioning

17.1 This chapter describes the recommended level of validation and commissioning required for all new and modified fixed wiring systems. The chapter does not provide a fully comprehensive scope of works, but gives a general overview. Designers and stakeholders may wish to consider acceptance of standard equipment factory or type test certificate items, rather than repeat the test after installation, which in certain circumstances may be difficult to perform.

17.2 Procurement of projects, which includes electrical installations (and others), should include adequate time and organisation to perform the required validation and commissioning programme for any works associated with the fixed wiring of the site. Clearly, for the range of fixed wiring schemes within healthcare premises, it is not possible to provide a general rule of thumb. Design teams should consult with the contractor and planners when allocating resources to the validation and commissioning process. Inappropriate validation and commissioning may lead to failure of the fixed wiring system.

17.3 The CIBSE Commissioning Manual (CCM), which contains very useful data and commissioning techniques for building services in the construction industry, provides valuable guidance in general commissioning strategies. The CCM also describes the design considerations for the construction industry in a similar manner to Chapter 3.

Validation of specific plant

Generators and CHP plant

17.4 Generating plant, including wind turbines, PV cells and CHP, should be tested as a complete system, including the actual equipment control panel and functionality of the controls. Plant should be tested in accordance with the relevant British Standards; see:

- BS 5514;
- BS 4999;
- BS EN 60034-2;
- BS 5000-50:1982, IEC 60681-1:1980; and
- BS 7698.

Factory testing

17.5 The manufacturer should conduct a full set of tests as described for site and dynamic tests below. For verification of dynamic load tests, a reactive and resistive load bank should be used. The project engineer should witness all factory testing. The generator should be located in an environment similar to that of the main site during any factory test.

Site testing

17.6 Before any dynamic tests are carried out on a new engine, the following procedures and static tests should be carried out: all generator lubrication and cooling circulation systems should be fully filtered; after descaling the circulation, systems should be sealed; the oil circulation systems should be filtered; and the filters should be replaced after all tests have been completed and prior to handover. Checks on the engine crankshaft deflection (at the bearings) should be made and recorded for operational maintenance records. Verification of the stator insulation resistance with the manufacturer's type test records should be made. The ratio of the one-minute reading and ten-minute reading (Polarisation Index PI) should be at least 2. The installation resistance of all control circuits should be measured. Verification of the contract documents with installed plant should be made, with all appropriate indications, including fault and control indication lamps and alarms.

Dynamic tests

17.7 The dynamic tests on site should include the following witnessed observations:

a. lubricating oil pressure and pressure trip;

b. lubricating oil and jacket water bypass automatic valves opening during engine warm-up including a series of test starts and checks, as follows:
   - the ability to start up within the specified time;
   - overspeed trip;
   - speed variation within specified limits;
   - voltage regulation and open-circuit characteristic;
   - electrical trips of generator by overcurrent, reverse power protection relays at minimum plug settings with generator below 25% FL (or primary injection);
   - a full-load run of not less than four hours, followed by a one-hour, 10% overload test and full-load protection trip – the test full load should be obtained by either a ballast load bank, or synchronised to the normal supply;
   - fuel-oil inlet pressure;
   - fuel-oil injector settings;
   - temperature rise of jacket cooling water;
   - temperature rise of lubricating oil;
   - temperature rise of charge air across turbocharger, if fitted;
   - temperature of exhaust gases at each cylinder head;
   - 240 V stator winding heater disconnects when circuit breaker closes;
   - ambient conditions;
   - noise acoustic levels, engine/background;
   - verification of the generator voltage rise.

Voltage regulation

17.8 The generator terminal voltage should be verified to be within ±2.5% from no load to 110% load conditions. The voltage regulation should be checked with the applied load varied up and down in the range from no load to 110% load several times, hence simulating actual conditions. The generator terminal voltage on starting should not overshoot the nominal terminal voltage by more than 15%, and return to within 3% of the rated voltage within 0.15 seconds. The generator terminal voltage should not vary by more than 15% following a step load increase from no load to 60% load, and then return to within 3% of the rated voltage within 0.5 seconds.

Multiple generators

17.9 It should be verified that multiple generators, running in parallel (whether with the PES supply or not, G59/1 regulation), share the connected load in equal proportions. The connected load should be varied and a measure of each generator terminal voltage made. The generator engine speeds should also be equal. Excessive differences in generator field currents may lead to the generators drifting out of synchronisation.

Parallel operation with the PES

17.10 Where generators are intended to operate in parallel with the PES, tests to verify that the generator speed varies in conjunction with any change in the PES frequency should be made. When the supply frequency varies, the generator's fuel governor should modulate similarly and adjust the fuel input accordingly. The governor speed characteristic over a speed range of 100%–105% should be at synchronous speed, given a load change from full load to no load respectively. From no load to 110%, the governor should be stable and sensitive, and should respond to prevent overspeed excursions reaching 110%. If a speed of 110% is reached, the governor overspeed protection should close the engine fuel rack, cutting off the fuel supply to the engine.

Power factor correction

17.11 Any installed power factor correction (PFC) units connected to any part of the generator-supplied network should be able to be isolated when the generator is supplying the load. Verification of this control should be demonstrated at commissioning. Where the PFC units continue to be connected across the generator output, a reduced field excitation current may result, making the generator output become unstable. PFC units may be fitted with enhanced modulation control such that the PFC does not produce a leading power factor while the generators are connected to any part of the network.

Operational tests

17.12 After the generator has been fully tested as identified above, an assessment of the actual fuel

consumption should be made, and checks to verify that there is adequate fuel storage (on site) for 200 hours of continuous full-load operation. The manufacturer should hand over all test records and insurance certificates, which should be held in the building logbook and operational maintenance manuals. The generator should be run against the building load, and verification of all phase failure and control devices established. Where the generator is arranged to synchronise with other generators, this should be demonstrated within the required time, voltage and frequency tolerances. Where the generator is designed to operate in parallel with the DNO connection, verification of the G59/1 relay should be established. The commissioning and operational testing of generators will require the DNO's engineer to witness and authorise.

Uninterruptible power supplies

17.13 The uninterruptible power supply (UPS) should provide a no-break supply rated to the load equipment for the required endurance period. The equipment should continue to function normally when the normal supply is disconnected. The battery endurance capacity in ampère-hours should be verified under load conditions.

17.14 Typical commissioning tasks should include:

a. the supply (a UPS) should include a test to verify that the supply changeover occurs within 0.5 seconds;

b. verifications to ensure that the UPS synthetic sinusoidal output is within specification tolerance of the normal mains sinusoidal ac waveform;

c. verification of the total harmonic distortion (THD) should be within the tolerance given in the design specification;

d. the UPS should be operated at a load greater than 50% on battery duty to establish the true battery autonomy.

Environment

17.15 The commissioning of the environment systems of the UPS room should be coordinated with all parties to establish that design conditions have been satisfied. Deviations from the design conditions may be best achieved by changes to the ventilation system, rather than replacing a UPS. This part of commissioning is essential to protect the operational life of the batteries.

Indications and alarms

17.16 All local and remote indications and associated alarm combinations for normal use or failure in operation should be demonstrated and recorded.

Isolated power supplies

17.17 IPSs should be commissioned and validated in accordance with the requirements of IEC 60364-7-710 and manufacturers' recommendations.

17.18 Designs should ensure that the IPS integral distribution board has the correct protective devices and is correctly labelled.

17.19 Verification of alarm indicators, local and remote, should be demonstrated.

17.20 Measurements of all individual circuit insulation resistances should be made as part of the general testing and commissioning stage carried out by the electrical installations contractor and as required by the IEE Regulations. The results should be compared with the reading indicated on the insulation monitoring device (IMD). The IMD should be tested by decreasing the circuit insulation resistance to prove the alarm system.

17.21 The leakage current of the isolation transformer should be tested when the transformer is energised and with the secondary open circuit. The value should be <0.5 mA.

17.22 Where the IPS is connected to a primary supply and secondary supply (generator), a test should verify that the supply changeover (at the point of common coupling) occurs within 0.5 seconds or 15 seconds (depending on the actual circuit intention). This test will require the input of the main electrical contractor and IPS contractor.

Fixed wiring distribution, switchgear and protection

17.23 The fixed wiring system should be verified and commissioned in accordance with BS 7671.

17.24 All testing, verification and commissioning will only be undertaken by suitably competent personnel (that is, having obtained a qualification compatible with the City and Guilds Certificate C&G 2391; see Health Technical Memorandum 06-02).

17.25 The recommended initial test and verification for the fixed wiring systems is given in the IEE Guidance Note No 3 'Inspection and Testing' Sections 1 to 3 inclusive.

17.26 Verification and commissioning of the fixed wiring system should demonstrate that the earthing systems employed comply with the TN-S system as defined in BS 7671. The only exception to such earthing methods will be any IT earthing systems associated with the ISS employed in the patient environment Groups 1 and 2.

17.27 Verification and commissioning should demonstrate that a consistent voltage rise (phase rotation) is employed throughout the electrical infrastructure, including the connection to the PES and any secondary or tertiary power sources.

Records to be kept

17.28 All tests and inspections should be recorded. A collection of sample record sheets covering the more common elements of the fixed wiring is provided in Appendix 2. Designers may wish to adopt other forms put forward by manufacturers or from software design programs. These will be accepted if they cover the minimum information provided on the sample forms.

17.29 The records should include all test certificates relating to electrical test and pressure test as appropriate. Records for all (off-site) manufactured items demonstrating conformity to the European Community legislation (CE marking) should be provided.

17.30 As appropriate, a comprehensive operational maintenance manual for all plant and accessories, including protection and switchgear items, should be provided at project handover or during the validation and commissioning period. The operational maintenance manual should describe how the design satisfies the design strategy and should indicate the intended mode of operation. The operational and maintenance manual should include a section to describe any action required to change the distribution for power supplied from the PES, and/or generator-supplied power.

17.31 The operational maintenance manual should include a full single-line diagram to show all points of isolation (with room name/number references).

As-installed drawings

17.32 The following list provides a minimum acceptable level for the as-installed drawings. Project contract documentation should be written and agreed with the healthcare organisation, and should clearly indicate which drawings are relevant to the particular project and any additional drawings that may be required:

a. HV network – layout and single-line schematic to cover the whole site:

   (i) the drawings should include substation and equipment references;

b. HV switching and transformer schedule to cover the whole site on one drawing:

   (ii) comprehensive equipment details with CT and VT relay ratings settings etc;

c. principal earthing drawing – layout and single-line schematic to cover the whole site on one drawing:

   (i) the layout drawings should use the site general arrangement as a background and show all main earthing points, regardless of being an HV earth, LV earth, generator earth or form the lightning protection systems;

   (ii) the schematic drawing should clearly show the interconnectivity of all earthing systems, and the measured resistances of each earth electrode;

d. LV main distribution – layout and single-line schematic – one drawing per substation:

   (i) the layout drawings should use the building general arrangement as background. The layout drawing should show all containment sizes;

   (ii) the schematic drawing should indicate all cable sizes, protective device rating and setting, switchgear and fault levels at switchboards;

e. LV sub-main distribution – layout and single line schematic per switchroom:

   (i) the layout drawings should use the building general arrangement as background. The layout drawing should show all containment sizes;

(ii) the schematic drawing should indicate all cable sizes, protective device ratings and settings, switchgear and fault levels at switchboards;

f. LV final circuit distribution – layout and single line schematic per distribution board:

(i) the layout drawings should use the building general arrangement as background. The layout drawing should show all containment sizes;

(ii) the schematic drawing should indicate all cable sizes, protective device ratings and settings, switchgear and fault levels at distribution boards;

g. general arrangement drawings of 1:20:

(i) all substation HV rooms;

(ii) all substation transformer rooms;

(iii) all substation LV rooms;

(iv) all generator house/enclosures;

(v) all rooms with CHP or other alternative power sources;

(vi) all LV main distribution switchrooms or rooms with LV distribution equipment;

(vii) all LV sub-distribution switchrooms;

(viii) all electrical risers;

(ix) typical cross-section ceiling voids showing principal routes and areas of high service density;

h. system and control wiring:

(i) where the project includes any associated electrical services (for example fire alarms, nurse-call systems), layout drawings (using the building general arrangement drawing as a background) to show the location of any associated devices and a single-line schematic of the system should be provided, including any associated panel wiring diagrams.

Building logbook

17.33 The building logbook is now a standard requirement for all new buildings throughout the construction industry, and is referenced in the Building Regulations. The items identified throughout Chapter 17 fulfil the requirements of the building logbook. Where the capital project relates to only part of the site or adaptations of existing electrical circuits, the existing building logbook should be updated.

17.34 The purpose of the building logbook is to provide a single collection of all relevant information relating to the architecture and building services at the site. The information should facilitate a source of all data to enable modifications to any part of the building services, and to operate the plant and services in an energy-efficient way homogeneous to the design intent.

17.35 The CIBSE technical memorandum TM31 'Building Logbook' provides a validated guide template for small businesses. The CIBSE Building Logbook, CD-ROM, Logbook Template Standard (LBTS) or Logbook Template Customisable (LBTC) may prove more useful when the project relates to a new build. The CD-ROMs contain electronic templates. LBTSs are the standard templates, which may or may not dovetail into the project, while LBTC contains customisable templates that may be user-adjusted to suit the specific job.

17.36 The building logbook will fulfil some of the designer's duties for compliance with the CDM Regulations.

Appendix 1 – Maximum interruption times to the primary supply

Figure 45 Maximum interruption times – primary supply

Clinical Risk Category	Service	IEC 60364-7-710 Group	Maximum Electrical Supply Interruptions Times (Seconds)		
			< 0 to 0.5 >	< 0.5 seconds to 15 seconds >	< 15 to 10800 >
5	Medical Equipment with IPS	2	←- - -→	←——→	
	General Medical Equipment	0–1		←——→	
	General Electrical Circuits	0	C	←——→	
	Fixed Medical Lighting and Escape Lighting	0	←——→		
	General Lighting	0		←—A—→	
	Mechanical Services	0			←——→
4	Medical Equipment with IPS	2	←- - -→	←——→	
	General Medical Equipment	0–1		←——→	
	General Electrical Circuits	0	C		←——→
	Fixed Medical Lighting and Escape Lighting	0	←——→		
	General Lighting	0		←—A—→	
	Mechanical Services	0			←——→
3	Medical Equipment with IPS	0–1			←——→
	General Medical Equipment	0			←——→
	General Electrical Circuits	0	C		←- - -→
	Fixed Medical Lighting and Escape Lighting	0	←——→		
	General Lighting	0			←—B—→
	Mechanical Services	0			←- - -→
2	Medical Equipment with IPS	0			
	General Medical Equipment	0			←- - -→
	General Electrical Circuits	0	C		
	Fixed Medical Lighting and Escape Lighting	0	←——→		
	General Lighting	0			←—B—→
	Mechanical Services	0			
1	Medical Equipment with IPS	0			
	General Medical Equipment	0			
	General Electrical Circuits	0	C		
	Fixed Medical Lighting and Escape Lighting	0	←——→		
	General Lighting	0			←- - B - -→
	Mechanical Services	0			

NOTES

A Standby Lighting Grade A (Lighting provided to the same, or nearly the same, lighting levels, achieved at normal electrical supply)

B Standby Lighting Grade B (Lighting provided at a reduced lighting level, 33%, of that achieved at normal electrical supply)

C Battery Inverter Unit provided for items such as fire alarms, security, computer network servers, and local computer systems as appropriate.

When the alternative power source has been connected, it should remain connected until the primary power source has been restored and stabilised.

Tertiary power sources (UPS) will be required for periods less than 0.5 seconds (refer to Chapter 14)

Secondary power sources (generators) will be required for periods greater than 0.5 seconds (refer to Chapter 8)

←——→ Indicates that an electrical supply must be available within the specified timeband

←- - -→ Indicates that an electrical supply must be available where equipment requires

Appendix 2 – Sample test record sheets

Figure 46 Test sheet – fixed panels

Plant Item Fixed Panels and Switchboards Inspection Identification/Location Contractor Manufacturer Serial Number			Completed Incomplete PC Address File	
Witness Print Name and Sign			Date	Sheet 1 of
Healthcare Premises Engineer				
Project Engineer				
No	Activity	Witness		Date
		Healthcare Premises Engineer	Project Engineer	
1	Check switchboard for damage or incomplete work			
2	Check all labels warning symbols, switchboard circuit identification labels are correct			
3	Check switch is fixed and mounted correctly			
4	Check switchboard protective earth conductor are connected to the main earth terminal (MET)			
5	Check termination lugs and bolts for tightness			
6	Check VT & CT compartment assembled correctly			
7	Check shutter linkage and the locking facilities			
8	Rack all devices into service position Note: all shutters should have a smooth movement			
9	Check all busbar joints with torque spanner and inspection contact spaces Bolt size Specified torque setting			
10	Isolate VT, remove fuselinks of Voltmeter and CTs Measure (i) IR py/Sy (ii) IR CT Sy (iii) IR busbar and circuit bar phases			
11	Measure total conductance of HV busbar phases along the switchboard by ohmmeter measurement a) between adjoin cubicle busbar phase spouts (BS) b) between circuit spouts (CS) and cable box (BX) Note: Estimate Resistance from 1.0 m of conductor Between Ph1 Ph2 Ph3 Res Spouts BS1 and 2 μΩs BS2 and 3 μΩs BS3 and 4 μΩs 1CS and 1 BX μΩs 2CS and 2 BX μΩs 3CS and 3 BX μΩs 4CS and 4 BX μΩs			

Figure 47 Test sheet – HV switchgear pressure test

Plant Item HV Pressure Test Switchboards Identification/Location Contractor Manufacturer Serial Number			Completed Incomplete PC Address File	
Witness Print Name and Sign			Date	Sheet 1 of
Healthcare Premises Engineer				
Project Engineer				
No	Activity	Witness		Date
		Healthcare Premises Engineer	Project Engineer	
1	Before HV test ensure all covers and fittings are replaced and secure			
2	Check components correctly assembled and fitted			
3	Check free operation of all switch movement etc			
4	Check all earthing facilities and switch positions			
5	Check (i) all instrument fuselinks removed (ii) VT isolated and CT fuselinks removed (iii) IR test busbar before and after pressure test MegΩ Values Ph1-Ph2/Ph2-Ph3/Ph3-Ph1 Ph1-N/Ph2-N/Ph3-N Ph1-E/Ph2-E/Ph3-N			
6	Adhere to the Electrical Safety Rules Health Technical Memorandum 06-02			
7	Pressure test busbars as 0.4 kV system @ 2 kV for one minute 11 kV system @2 kV for one minute Voltage …….. kV Humidity …..… % Temperature ….. °C Phase Ph1-Ph2/Ph2-PH3/Ph3-Ph1 Leakage Current Phase Ph1-N/Ph2-N/Ph3-N Leakage Current Phase Ph1-E/Ph2-E/Ph3-E Leakage Current			
8	Check IR of close, open and control circuits Note: HV Equipment should be energised as soon as practical after test, to ensure faults are checked			
9	Verify switch labels with circuits and record drawings			

Figure 48 Test sheet – Switchboard devices electrical test

Plant Item Switchboard Devices Electrical Test Identification/Location Contractor Manufacturer Serial Number			Completed Incomplete PC Address File	
Witness Print Name and Sign			Date	Sheet 1 of
Healthcare Premises Engineer				
Project Engineer				
No	Activity	Witness		Date
		Healthcare Premises Engineer	Project Engineer	
1	Ensure cubicle busbar/circuit shutter door mechanisms are locked shut, if board energised			
2	Carry out IR test between devices open contacts and when open, closed between phases and frame earth Values Ph1/Ph2/Ph3			
3	Pressure test busbars as 0.4 kV system @ 2 kV for one minute 11 kV system @ 2 kV for one minute Voltage …….. kV Humidity …..… % Temperature ..... °C Phase Ph1-Ph2/Ph2 -PH3/Ph3-Ph1 Leakage Current Phase Ph1-N/Ph2-N/Ph3-N Leakage Current Phase Ph1-E/Ph2-E/Ph3-E Leakage Current			
4	Rack devices into cubicle isolated position for the close open operational test			
5	Check local control, close and trip of device at the rated battery voltage, minimum of ten operations. Check the operation of the close and trip at 80% of the rated applied close battery voltage			
6	Check the trip mechanism at 50% of the rated applied trip battery voltage			
7	Check time of closing mechanism operating spring to recharge, at 80% of rated applied voltage			
8	Check operation of “auto-change” devices used for Emergency Generators and normal DNO supply as appropriate for the distribution strategy			

Figure 49 Test sheet – Transformer mechanical test

<table>
<tr><td colspan="3">Plant Item Transformer Mechanical Test
Identification/Location
Contractor
Manufacturer
Serial Number</td><td colspan="2">Completed
Incomplete
PC Address File</td><td></td></tr>
<tr><td colspan="3">Witness Print Name and Sign</td><td>Date</td><td rowspan="3">Sheet 1 of</td></tr>
<tr><td colspan="3">Healthcare Premises Engineer</td><td></td></tr>
<tr><td colspan="3">Project Engineer</td><td></td></tr>
<tr><td rowspan="2">No</td><td rowspan="2">Activity</td><td colspan="2">Witness</td><td>Date</td></tr>
<tr><td>Healthcare Premises Engineer</td><td>Project Engineer</td><td></td></tr>
<tr><td>1</td><td>Check drawing, general inspection for damage and completeness</td><td rowspan="12"></td><td rowspan="12"></td><td rowspan="12"></td></tr>
<tr><td>2</td><td>Check all components fitted to general arrangement</td></tr>
<tr><td>3</td><td>Prove tightness of all fastenings</td></tr>
<tr><td>4</td><td>Check all labelling to transformer schedule</td></tr>
<tr><td>5</td><td>Check transformer correctly positioned in bay for cable box entries/ bushing connections</td></tr>
<tr><td>6</td><td>Check colour of desiccant crystals (as supplied)</td></tr>
<tr><td>7</td><td>State type of coolant in tank</td></tr>
<tr><td>8</td><td>Check if transformers filled with oil/fluid to operating level yes/no</td></tr>
<tr><td>9</td><td>Check for any coolant leaks</td></tr>
<tr><td>10</td><td>Check cable box details agree with cable details and requirements</td></tr>
<tr><td>11</td><td>Check location of loose CTs, if provided, and method of connection in cable box or to star point neutral</td></tr>
<tr><td>12</td><td>Check position of transformer earth lug and connection to main earth system</td></tr>
</table>

Figure 50 Test sheet – Transformer electrical test part A

Plant Item Transformer Electrical Test Part A Identification/Location Contractor Manufacturer Serial Number			Completed Incomplete PC Address File	
Witness Print Name and Sign			Date	Sheet 1 of 2
Healthcare Premises Engineer				
Project Engineer				
No	Activity	Witness		Date
		Healthcare Premises Engineer	Project Engineer	
1	Check IR of transformer cooling fan motors, and cable terminations (where appropriate)			
2	Check transformer cooling fan motor electrical function in local and remote modes			
3	Check transformer cooling fan motor overload/time by three-phase and single-phase injection			
4	Analyse the tank and Buchholz relay oil for clarity and resistance			
5	Take IR readings of HV and LV windings			
6	Check operation of all protection trips and alarms at initiating and control sections			
7	Check fan controls are operational			
8	Check cable box and bushing connections tight, oil tank free and secure			
9	Transformer enclosure locked and secure			
10	Check marshalling box wiring connections at termination blocks for tightness and correct labelling			
11	Check IR of control wiring using megger (i) Marshalling box control wiring (ii) Buchholz relay (if fitted) (iii) Temperature indicators Coolant Core			
12	Fill transformer with coolant to operational level with new oil complying with BS 148			
13	Check IR of Core insulation to earth before link is covered with coolant, during the fill operation			
14	Check IR when transformer filled with coolant HV LV PPh1–PPh2 / PPh2–PPh3 / PPh3–PPh1 / Sph1–Sph2 / Sph2–Sph3 / Sph3–Sph1 / Ph1–Ph1 / Ph2–Ph2 / Ph3–Ph3 / N–E / All Primary Phases to Earth All Secondary Phases to Earth			

Figure 51 Test sheet – Transformer electrical test Part B

Plant Item Transformer Electrical Test Part B Identification/Location Contractor Manufacturer Serial Number			Completed Incomplete PC Address File	
Witness Print Name and Sign			Date	Sheet 2 of 2
Healthcare Premises Engineer				
Project Engineer				
No	Activity	Witness		Date
		Healthcare Premises Engineer	Project Engineer	
15	Winding ratios at each off-load tap position and the transformer vector group (i) apply 0.4 kV 3-phase ac to HV winding terminals and interconnected Ph1 HV to Ph1 LV (ii) Winding ratio HV Ph1–Ph2, Ph2–Ph3, Ph3–Ph1 LV Ph1–Ph2, Ph2–Ph3, Ph3–Ph1 Tap –10% –5% –2.5% 0% 2.5% 5% 10% (iii) Vector Group Ph1–Ph2 Ph2–Ph3 Ph3–Ph1 Ph1–Ph2 Ph2–Ph3 Ph3–Ph1 PPh2–Sph3 PPh3–Sph2			
16	Check trip/alarm supplies voltages (i) At circuit breaker (ii) At transformer (a) Buchholz (b) coolant temperature (c) Tank pressure (d) cooling fans running			
17	Check IR of Tap changer control pane (if fitted)			

Figure 52 Test sheet – Secondary injection IDMT relay

Plant Item Secondary Injection Test (IDMT Relay) Identifications/Location Contractor Manufacturer Serial Number							Completed Incomplete PC Address File		
Witness Print Name and Sign							Date		Sheet 1 of
Healthcare Premises Engineer									
Project Engineer									
Manufacturer's Description Test							Setting for Test R	Y or N	R
1	General Inspection								
2	Check Contacts close at zero Tm time and follow through								
3	Check Flag operation								
4	Measure time to reset from contacts								
	Close at 1.0 Tm								
5	Check trip isolation contacts								
6	Set 100% Pm, check no creep at 1.0 Psm, and creep commences at/or before 1.25 Psm current values								
7	Check Plug bridge continuity, max Pm setting and with plug out								
8	Check relay, T shorts removed								
	CT ratio ……/…… type		Relay Controls				Relay Operating Times		
	Time/current characteristic at 100%		Pm	Tm	Psm	Amps	R	Y or N	R
	Pm and at applied setting			1.0	1.3				
					2				
			100%	0.5	2				
				1	4				
		Applied setting			2				
	Fag Setting	Final setting applied							
	Remarks								

Note: Settings for electronic IDMT relays are generally software set. Therefore the maintenance test of electronic IDMT relays may be reduced to a check that the commissioning settings have not been changed, or the network (protected by the IDMT relay) has not changed, which would require a re-commissioning of the IDMT relay. The manufacturer's data sheet should be used in all circumstances

Figure 53 Test sheet – secondary injection instantaneous relay

<table>
<tr><td colspan="4">Plant Item Secondary Injection Test Instantaneous Relay
Identification/Location
Contractor
Manufacturer
Serial Number</td><td>Completed</td><td></td></tr>
<tr><td colspan="4"></td><td>Incomplete</td><td></td></tr>
<tr><td colspan="4"></td><td colspan="2">PC Address File</td></tr>
<tr><td colspan="4">Witness Print Name and Sign</td><td>Date</td><td rowspan="3">Sheet 1 of</td></tr>
<tr><td colspan="4">Healthcare Premises Engineer</td><td></td></tr>
<tr><td colspan="4">Project Engineer</td><td></td></tr>
<tr><td colspan="3"></td><td>Witness</td><td></td><td>Date</td></tr>
<tr><td colspan="3"></td><td>Healthcare Premises Engineer</td><td>Project Engineer</td><td></td></tr>
<tr><td colspan="3">Test</td><td>R</td><td>Y or N</td><td>B</td></tr>
<tr><td colspan="3">General Inspection
Check Trip isolation contacts
Check Flag operation
Check CT shorts
Plug bridge continuity (Inst o/c relays)</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">R</td><td colspan="2">Y or N</td><td colspan="2">B</td></tr>
<tr><td>Plug setting</td><td>Op Amps</td><td>Plug setting</td><td>Op Amps</td><td>Plug setting</td><td>Op Amps</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Plug out</td><td></td><td>Plug out</td><td></td><td>Plug out</td><td></td></tr>
<tr><td colspan="2" rowspan="3">With stabilising resistor series and CT in shunt</td><td rowspan="3">Stab resistor value
Applied setting
Operating volts
Operating current</td><td>R</td><td>Y or N</td><td>B</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="2">Flag reset</td><td colspan="4">Final setting applied</td></tr>
<tr><td colspan="6"></td></tr>
</table>

Figure 54 Test sheet – LV final distribution board test results

Description of Works													
Circuit Description	Over- current device Short circuit capacity kA		Wiring conductor		Test Results								
					Continuity			Insulation resistance		Polarity	Earth loop Impedance	Functional Testing	
	Type	Rating in A	Live mm^2	cpc mm^2	R1 + R2 Ω	R2 Ω	Ring	Live/ Live MΩ	Live/Earth MΩ		Zs Ω	RCD Time mS	Other
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Deviations from the Wiring Regulations and Special Notes													

Note the test sheet shown here is a much reduced format of the form provided by the IEE Regulations

Figure 55 Lighting commissioning certificate

LIGHTING COMMISSIONING DETAILS		
Location		
Building		
Areas Covered		
Relevant Distribution Board		
Relevant Controls		
Test Engineer		
Approved Engineer		
Test Date		
Test Commissioning	**Test Result**	**Follow Up Complete**
Groups of luminaires are assigned to the correct positions in grid switch or grid single circuit dimmer		
Emergency lighting complies with recommendations of BS 5266/BS 12464-1		
Luminaires and remote control gear are of the correct make and type		
Fixed luminaires have been installed at the correct orientation		
Fluorescent lamps have the correct phosphor		
Lamps are of the correct colour temperature (Rendering Index Ra **)		
All lamps are the correct wattage and voltage ratings		
Exterior floodlights have been aimed to drawing and according to terms of planning permission		
Horizontal illuminance on horizontal tasks(s) is at specified level		
Vertical illuminance on vertical tasks(s) is at specified level		
PIR detector systems are programmed and operate correctly		
Lighting levels associated with control signals have been chosen		

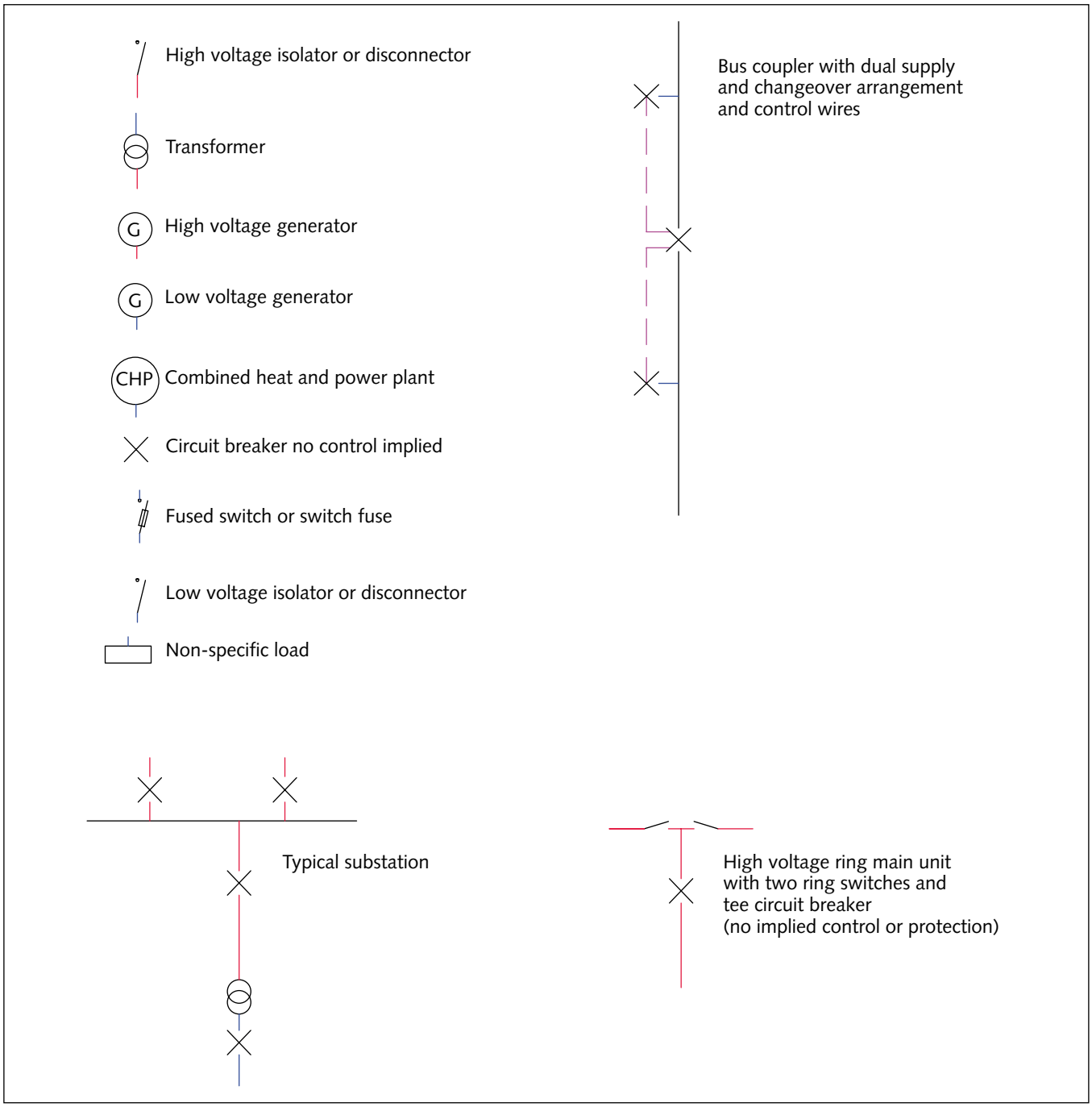
When commissioning lighting installations, grouping rooms with similar functions and lighting designs, for example toilet areas may reduce the number of repeated tests.

A more comprehensive lighting commissioning schedule is available from CIBSE

Appendix 3 – Drawing symbols

Figure 56 Drawing symbols used in this Health Technical Memorandum

The symbols below are all generic versions of the British Standard symbols. In some case where the device type is not specific to the figure in the Health Technical Memorandum text, a symbol representing more than one device type is indicated.



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Note

Only the primary Acts and main Regulations are cited here. Most of these Acts and Regulations have been subjected to amendment subsequent to the date of first becoming law. These amending Acts or Regulations are not included in this list.

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