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Department of Defence  
Defence Support Group

Department of Defence

# Manual of Infrastructure Engineering

## Electrical

2011

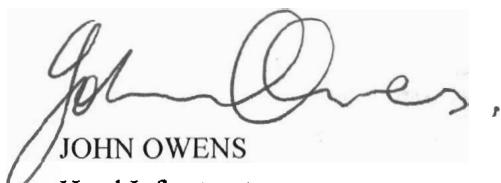
## **FOREWORD**

The *Manual of Infrastructure Engineering - Electrical* (MIEE) is the primary Defence policy document when determining electrical engineering requirements for Defence facilities and infrastructure. Its provisions are mandatory.

This manual can be accessed from the Defence Infrastructure Management System web site on the Defence Intranet. It is also available to the public on the Internet at  
<http://www.defence.gov.au/im/>.

The MIEE nominates *Regulations and Standards* as the minimum construction and maintenance standard for Defence Facilities and Infrastructure, but, recognising the unique nature of some Defence facilities and equipment housed in those facilities, the manual generally nominates additional levels of electrical engineering than those required by *Regulations and Standards*.

All Defence new construction, refurbishment projects and maintenance activities are required to be certified by the designer, contractor or maintainer as meeting the electrical engineering requirements detailed in this manual.



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15<sup>th</sup> September 2010

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# 1 Infrastructure Electrical Engineering

## 1.1 Introduction

The overall electrical engineering philosophy for Defence facilities and infrastructure is the provision of electrical systems that are compliant, safe, functional, energy efficient and offer the best through life performance. Any special Defence capability requirements must be taken into account when determining the electrical engineering requirements for Defence assets.

The respective Commonwealth, State and Territory legislation, regulations, ordinances, codes of practice and Australian and international standards (*regulations and standards*) form the Defence **minimum** construction standard. However, in recognition of the additional Defence capability requirements, this manual generally specifies additional levels of electrical engineering than those required by the *regulations and standards*. In this manual are requirements for:

- General Technical Requirements
- **Internal Electrical Services**
  - Switchboard Labelling and Numbering
  - RCD protection
  - Power Factor Correction
  - Artificial Lighting
  - 400 Hertz Systems
  - Hazardous and Explosive Area Installations
  - Aircraft Earth Reference Points
  - Wharf Services
- **Emergency Power Systems**
  - Uninterruptible Power Systems (UPS)
  - Local Emergency Generators (LEG)
  - Mobile Generator Link Boxes (MGLB)
- **Electrical Reticulation and Power Generation Systems**
  - High and Low Voltage Distribution Systems
  - Central Emergency Power Stations (CEPS), Central Power Stations (CPS) and Central Energy Plant (CEP)
  - Power Control and Monitoring Systems (PCMS)
  - Operation of Power Generations and HV & LV Distribution Systems

Designers and contractors are responsible for ensuring full compliance with this manual unless a dispensation is approved in accordance with Paragraph 6.5 — Alternative Methods and Designs.

## **1.2 Aim**

The aim of this manual is to assist those concerned with formulating requirements for electrical engineering in the construction of new infrastructure and facilities, existing facilities and infrastructure undergoing refurbishment, leased facilities for use or occupation by Defence and maintenance of existing installations.

## **1.3 Application**

The requirements of this manual apply to the design, construction and maintenance of electrical installations. Alterations or additions to an existing installation shall comply with the provisions contained herein in addition to those required by the *regulations and standards*.

It is not intended that the requirements of this document be applied retrospectively to existing installations.

Alterations and additions to an existing installation shall not cause the original installation or the electrical equipment connected thereto to operate or be used in a manner not in accordance with current *regulations and standards*.

When referring to *regulations and standards* in this manual, this is intended to apply to all regulatory requirements and recognised standards including Commonwealth, State and Territory regulations, codes of practice and other subordinate legislation, Australian Standards, Defence standards and recognised overseas standards.

Where any difference is perceived between the requirements described herein and those defined in the *regulations and standards*, the requirements defined in the *regulations and standards* shall take precedence and the matter shall be referred to the Director Estate Engineering Policy.

The content of reference *regulations and standards*, and other publications, have not been repeated in this publication unless necessary for descriptive purposes. Where necessary an appropriate, reference is made to the source of the information.

## **1.4 Electrical Installation Principles**

Electrical installations in Defence establishments and in Defence leased premises shall conform to the requirements of all applicable *regulations and standards* and guidance publications relevant to the State or Territory where the installation or facility is located.

Electrical installations must also comply with the requirements of AS/NZS 3000 and applicable Industry Regulator requirements and the Local Network Service Provider (NSP) requirements such as the Service and Installation Rules or equivalent.

Furthermore, electrical installations and equipment shall comply with all appropriate and relevant Australian standards, for the type of installation or equipment to be used, irrespective of their

status. Where Australian standards are not available, recognised international or overseas national standards shall be used where they are relevant to the type of installation or equipment and to the installation conditions in Australia.

Designs shall be selected, after comparing all design options available, using the most cost effective design solution that will meet the requirements of this manual, the user requirements, those specific requirements to the establishment or facility and the *Regulations and Standards*. Designs shall be performance based and shall be engineered to include equipment and materials complying with the appropriate standards considering current and future use, especially if and when any major refurbishment or change in use is contemplated.

#### **1.4.1 Conflicts between Regulations and Standards and Defence Requirements**

Where a statutory standard conflicts with this manual, the matter must be referred to Director Estate Engineering Policy (DEEP) for resolution.

Where a statutory standard conflicts with another Defence standard, the matter must be referred to the relevant Defence Technical Authority through DEEP for resolution.

Statutory requirements or standards that conflict must be referred to the appropriate regulatory authority for resolution, with an information copy to DEEP. Where compliance with Part 2 of AS/NZS 3000 cannot be achieved and *compliance by specific design and installation* under clause 1.9.4 of AS/NZS 3000 is being applied, formal letters of acknowledgement must be signed and approved by DEEP, refer Paragraph 6.5 — Alternative Methods and Designs.

Conflicting requirements shall be fully documented by the designer or contractor and shall contain a proposed course of action suitably argued with compensating factors clearly identified. Formal written Defence approval of any alternative method and design proposal must be obtained at the earliest stage possible in accordance with the Alternative Methods and Designs approval process provided at Para 6.5 — Alternative Methods and Designs. All regulatory advice and approvals including Defence approval shall be included in the design report, project files by the relevant Defence Project Officer and the operation and maintenance documentation and manuals.

#### **1.4.2 Emergency Power Principles**

Emergency power systems shall be considered on a case by case basis, supported where appropriate by a risk analysis of the hazards involved for the installation. Emergency power systems shall only be considered when:

- a) statutory requirement, standard or Defence policy requirement dictates the provision of emergency power (e.g. ATC Tower, Aircraft Navigation Aids, certain hospitals);
- b) regular critical operations are undertaken at the facility that would be adversely affected by interruption of electricity supply (e.g. Operational Command Centres, Communication and Information System Centres (CISCEN) and critical communications facilities);

- c) an interruption of the electricity supply would result in a severe life safety or environment incident for critical functions such as emergency response facilities and essential engineering services;
- d) the frequency and duration of operations cannot be supported efficiently and cost effectively by mobile or hire generators. Any facility that can tolerate an outage of around 48 hours can, under normal circumstances, be adequately supported by mobile generator;
- e) essential functions and services cannot be transferred to, or catered by, unaffected areas;
- f) site emergency power supplies such as CEPS cannot meet the emergency power requirement; and
- g) the financial losses due to power interruptions, under normal supply availability conditions, would exceed the through life costs of an emergency power system (certain tactical training centres and simulator facilities).

Central Emergency Power Stations shall be suitably justified by the relevant sponsor normally on operational grounds for the establishment.

Guidance on a case by case basis is available from the DEEP in order to determine whether or not emergency power should be provided.

#### **1.4.3 Energy Efficiency**

Electrical installations shall comply with the Defence Energy Efficiency and Ecological Sustainable Development policies and principles and the Building Code of Australia (BCA).

### **1.5 References**

Reference is necessary to current issues of the following documentation:

- a) Commonwealth, State and Territory legislation, regulations, codes of practice and other subordinate legislation
- b) National Electricity Codes
- c) NSP rules.
- d) Australian Standards (AS).
- e) International Standards (ISO, IEC).
- f) Defence and Military Standards
- g) Infrastructure Management System (IM)

#### **Infrastructure Management System (IM)**

The Defence Infrastructure Management system (IM) promulgates policy and procedures for the management of the Defence estate, including the procurement of capital facilities and facilities operations and maintenance. The IM is the prime reference system and documentation for all Infrastructure activities and processes. The provisions of the IM are mandatory. The requirements

relating to ‘as-constructed drawings’ and the Spatial Data Management Plan (SDMP) can be found on the IM at:

<http://www.defence.gov.au/IM/business/spatial/main.htm>

### **National Electricity Code Requirements**

Where applicable, installations shall comply with the requirement of the National Electricity Code. In general this includes, but is not limited to:

- a) Installations that have become contestable in the NEM.
- b) Installations that have electrical power generation that can be run in parallel with the grid.

The designer shall determine if the installation has any obligations under the NEC and if Defence has intent to alter the status of the installation with regards to the NEC.

The new installations shall meet the present obligations and those arising from any proposed change of the NEC status. This shall include, but not be limited to:

- a) The provision of compliant metering;
- b) Power Factor; and
- c) Harmonics.

## **1.6 Dispensations**

Dispensations from the requirements of this manual and alternative design solutions shall be approved in accordance with Para 6.5 — Alternative Methods and Designs.

## **1.7 Responsibilities and Agency Roles**

**Defence Support Group (DSG)** is responsible for the provision of and maintenance of facilities and infrastructure in support of Defence activities and capability. DSG carries the responsibility for the construction and maintenance of fixed electrical installations and infrastructure. DSG responsibilities are summarised as follows:

**Assistant Secretary Estate Policy and Environment (ASEPE)** is the DSG Technical Authority (TA) for the development and promulgation of Infrastructure Engineering policy, DSG Business Rule 11 refers.

**Directorate of Estate Engineering Policy (DEEP)** is the subject matter expert responsible for developing technical engineering design policy, and for providing technical engineering support pertaining to the management and development of Defence estate.

**Directorate of Estate Maintenance Policy (DEMP)** is the subject matter expert responsible for developing technical engineering maintenance policy, and for providing technical engineering support pertaining to the maintenance of Defence estate.

**Regional Directors** are responsible for the implementation of engineering policies at base level for regionally delivered projects and operations and maintenance activities. These are normally delivered through the Comprehensive Maintenance Services (CMS) contract.

**Infrastructure Asset Development (IAD) Branch** is responsible for the implementation of engineering policies for Medium and Major New Works projects. The IAD Branch has Project Directors assigned to major new works. The Project Director may engage a Project Manager/Contract Administrator as part of the procurement and implementation process.

**Public Private Partnerships (PPP) Branch** is responsible for the implementation of engineering policies for PPP Works projects

**Directorate of Ordnance Safety (DOS)** is the Technical Regulator for Explosive Ordnance (EO) Storage and Transport and thus responsible for providing high level policy governing EO storage and maintenance facilities. DOS is the sponsor OPSMAN 3 "*Safety Principles for the Handling of Explosive Ordnance*" which incorporates construction criteria for electrical installations for EO areas and facilities.

**Directorate of Explosive Ordnance Services (DEOS)** is the Defence authority responsible for licensing, safety monitoring and certification of all ADO facilities except Defence Science Technology Organisation (DSTO) where EO is stored and maintained. As part of the licensing role DEOS advises on the applicable standards to be applied to the design and construction of EO facilities and storage areas. DEOS is the sponsor of DEOP 103 *Defence Explosive Ordnance Safety Manual* which details safety requirements for electrical installations and precautions against electrical hazards.

**Navy Platform Systems, Directorate of Power, Propulsion Auxiliary and Control Systems** are the sponsor of the Defence Australian Standard 5000 Volume 5 part 11 Shore Electrical Power Supply for RAN Ships and Submarines.

**Sponsors, Users/Occupier** is responsible for the recognition and advising the use of facilities, equipment specifications and also for classification of hazardous and explosives areas in the workplace. Assistance in the classification can be provided by the designer.

**The Defence Electrical Operating Authority.** The Department of Defence, as the owner and user of electrical systems on its establishments, is responsible for their operation. Defence vests the responsibility for technical control and operational safety for the Base electrical system with the Electrical Operating Authority engaged normally as part of the CMS. The Electrical Operating Authority appoints a Network Controller who is the authority responsible for the operation of Defence reticulation systems.

The Electrical Operating Authority is responsible for the configuration and operation of the Base electrical system at all times to ensure the safety of personnel, the continuity of supply, adequate system documentation and the safety of plant and equipment in accordance with CMS requirement "*Operation of Low and High-Voltage Power Generation and Electrical Reticulation Systems at Defence Establishments*" available through the Regional Manager, refer also Chapter 29. The Electrical Operating Authority is also responsible for regulating access to Defence reticulation systems. The issue of instructions and requirements for the operation of the Base electrical systems is the responsibility of the Regional Directors.

### **Regulatory Authorities**

Regulatory Authorities are responsible for administering the Acts and Regulations promulgated by government bodies. Defence electrical installations shall entirely comply with any requirements administered by, as a minimum, the authorities as listed below:

- a) Energy Networks Association (ENA)
- b) Australian Energy Regulator (AER);
- c) Australian Energy Market Commission (AEMC);
- d) Australian Energy Market Operator (AEMO) and
- e) Network Service Provider (NSP).

### **1.8 Sponsor**

This document is sponsored by DEEP on behalf of the Technical Authority ASEPE. Enquiries may be directed to:

Director Estate Engineering Policy  
Brindabella Park (BP-2-B049),  
Canberra ACT 2600

Tel: (02) 6266 8178      Fax: (02) 6266 8211      Email: [mark.turner2@defence.gov.au](mailto:mark.turner2@defence.gov.au)

## **2 Reserved**

### **3 High Voltage System Master Plans and Project Development Plans**

#### **3.1 High Voltage System Master Planning**

An electrical master plan is a stand-alone document that provides a framework within which the future development of electrical supply infrastructure at a Defence establishment can take place. It is a broad outline addressing the needs of the establishment in the areas of:

- a) Electrical supply into the establishment;
- b) Electrical distribution within the establishment;
- c) The requirements for standby generation, and
- d) The requirements for monitoring and control systems for the electrical systems.

An electrical development plan is similar to an electrical master plan but is generally specific to a project or development activity. Electrical Master Plan and Development Plan reports must carry signature approval from DEEP before they may be circulated.

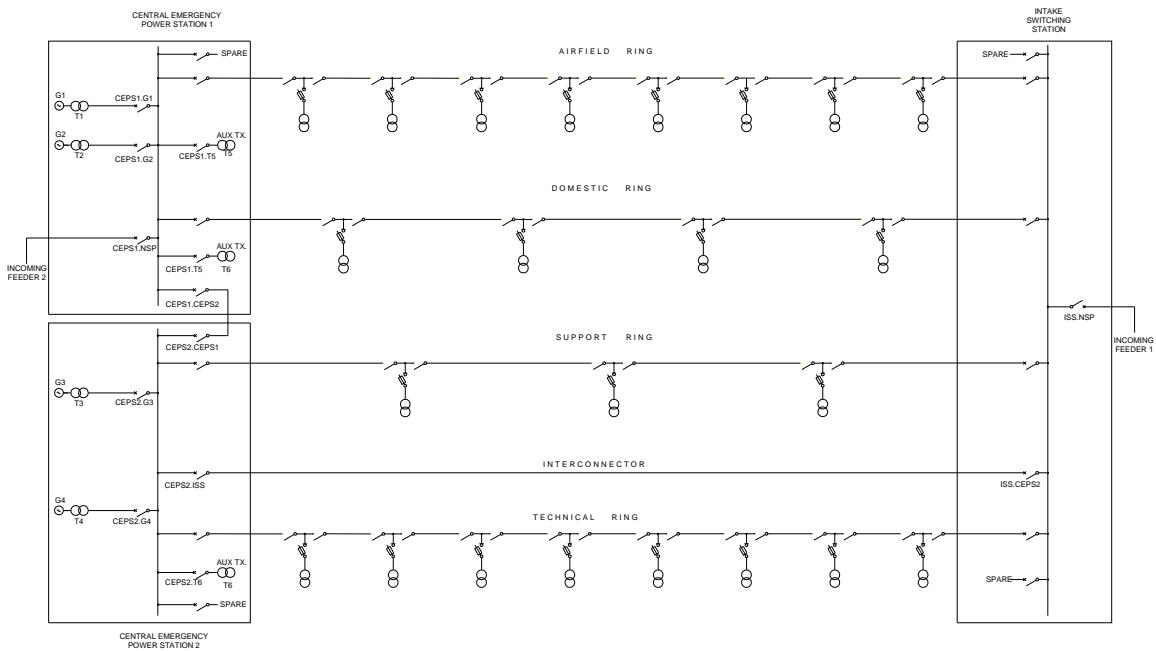
##### **3.1.1 Master Plan Policy Objectives**

The objective of this policy is to provide a strategic framework within which electrical infrastructure works are implemented in a carefully considered way. The purpose of this is to:

- a) Ensure adequate infrastructure capacity is available for new and current developments for a minimum of 15 years;
- b) Minimise redundant or abortive works;
- c) Provide a framework for the planning of longer-term infrastructure projects.

##### **3.1.2 Master Plan Concepts**

The following concepts are used in master planning and development planning as discussed in the following paragraphs and shown in the typical high voltage system diagram, Figure 3.1 below



■ **Figure 3.1: Typical High Voltage System Arrangement**

### Base Load Centres or Zones

Load centres or zones are groupings of load that have a similar function and geographic location. Example load centre types may include:

- Domestic;
- Airfield;
- Technical; and
- Support load types.

They form the most basic level of priority of the electrical system. For this reason, and as far as practical, the loads associated with a particular load centre are normally connected to the same HV ring main. In times of electrical supply shortage this allows HV switching to occur to shed loads of a particular type.

### Intake Switching Stations and Intake Substations (ISS)

Intake Switching Stations and Intake Substations (ISS) form the connection point between the DNSP feeder cables and the Defence reticulations system. ISS are part of the primary distribution system. At establishments with a separate Distribution Network Service Provider (DNSP) intake station provided prior to the ISS, these are referred to as Intake Stations (IS)

### **Primary Distribution**

For the purposes of convenience the electrical distribution is divided into two major components, the primary distribution and secondary distribution.

The primary distribution is that portion of the electrical network that transfers bulk electricity around the establishment. It generally consists of a series of primary nodes that are interconnected by feeder cables, to which no load is connected along their length.

The feeder cables can be either:

- a) Incoming feeders from the DNSP, or
- b) Interconnections that directly connect the primary nodes.

The primary nodes can be either:

- a) Primary Switching Stations – HV switchboards, such as the establishment HV switchboard, at which no voltage transformations occur; or
- b) Primary Substations – Substations at which a transformation occurs from a higher voltage, such as the DNSP's sub transmission voltage, to the HV distribution voltage used at the establishment.

### **Secondary Distribution**

The secondary distribution is that portion of the electrical network associated with conversion of the electrical supply to the final utilisation voltage (400V). It consists of the distribution substations and the ring mains that connect these to the primary nodes.

### **Central Emergency Power Station (CEPS)**

The CEPS is a power station that is used to produce standby power for the entire establishment, or large portions of it, in the event of failure of the mains supply.

In order to distribute this power around the establishment the CEPS is often configured so that it energises the site HV distribution network. Requirements of CEPS systems are described at Chapter 27 —Central Emergency Power Station (CEPS), Central Power Station (CPS) and Central Energy Plant (CEP).

### **Local Emergency Generator (LEG)**

A Local Emergency Generator provides standby power for a specific facility or group of facilities during a power interruption. LEGs are typically smaller than CEPS and can start and supply critical loads quicker than CEPS.

### **Central Energy Plant (CEP)**

A CEP is a power station that can run for extended periods to offset the electrical demand of a Base. CEP installations may also supply energy in other forms, for example waste heat from gas generators being used to run absorption chillers for reticulated cooling.

### **Central Power Station (CPS)**

The CPS is a power station that produces continuous power for the entire establishment. A CPS is typically employed in remote areas where grid connection of the establishment is not feasible.

#### **3.1.3 Master Planning Considerations**

The master plan shall be a stand-alone document that is well justified. It shall include detailed reasoning and the rationales behind each decision, including all relevant supporting documentation, to allow review by the major stakeholders.

The following is a list of key considerations and planning objectives that should be addressed as part of any master planning process.

#### **Incoming Supply**

##### Connection Agreements

The electrical master plan should highlight any issues that might have an impact on the connection agreement for the establishment. This includes such issues as supply tariffs or required increases in authorised demand.

##### NEC Issues

On contestable sites or sites that could become contestable, the master plan shall address compliance with National Electricity Code. Of particular interest at most sites is power factor.

##### Supply Voltage

The electrical master plan shall consider, in terms of potential cost savings and reliability, the voltage at which the establishment takes supply. Where supply is or will be available at more than one voltage, a Nett Present Value (NPV) projection shall be carried out to determine overall cost-effectiveness of each voltage.

##### Redundancy and Reliability Issues

The electrical master plan must consider the reliability of the existing and proposed mains supply with particular emphasis on the frequency and duration of supply interruptions experienced.

A key aspect in the proposed supply arrangement is the degree of redundancy offered in the DNSP network. This shall be examined in terms of the vulnerability of the supply to:

- a) Network events, or
- b) External attack.

Supply reliability is a key input to consideration of the need for on-site emergency power generation, particularly centralised power generation.

## **Loads**

The master plan shall examine the overall master plan for the establishment and any supporting documents such as precinct plans in order to establish:

- a) What new facilities are being constructed and the timeframe, and
- b) What existing facilities are being demolished and the timeframe;

The impact of these works on the overall establishment load over time shall be assessed with respect to:

- a) The magnitude of the load over time;
- b) The changing distribution of the load, and in particular the location of the load zones, over time;

In performing these projections the following methodology shall be adopted:

- a) **Existing Loads:** The electrical demand applicable to an existing facility shall be determined in either of three (3) ways:
  - Actual recorded measurements for the facility from the DESN or other recognised metering device over a continuous period of twelve (12) months. (Note that data from other than the previous twelve months should be incremented at 3% p.a.).
  - Detailed evaluation of the facility loads utilising Appendix C of AS/NZS 3000; or
  - Careful application of recognised W/m<sup>2</sup> rules.
- b) **New Loads:** Unless actual design data is available the maximum demand of new facilities can be estimated by the careful application of W/m<sup>2</sup> rules.
- c) **Load Growth:** In projecting electrical demand on high voltage systems an annual load growth of 3% shall be used unless otherwise approved by DEEP.

The Ultimate Base Load shall include allowance for the above existing load, new load and load growth categories. Ultimate Base Load must be agreed by DEEP.

## **Primary and Secondary Distribution**

### System Configuration

In determining the proposed system configuration the key considerations shall be the reliability and redundancy provided by the arrangement.

For larger establishments the following shall be features of the arrangement:

- a) At least two incoming feeders into the establishment;
- b) Incoming feeders connected to separate distribution nodes consisting of HV switchboards to which the secondary distribution is connected;
- c) Interconnector cables run between the distribution nodes to enable power transfer between them;

- d) Distribution substations connected on ring mains that run from one primary node to another one.
- e) Centralised emergency power generation (if provided) is co-located with one of the distribution nodes, preferably with the standby feeder.

For all configurations, particularly those involving multiple supplies running in parallel a basic load flow study shall be required to confirm viability. The load flow study must confirm a full alternate supply to distribution substations on the failure of any single element of the distribution system.

#### System Capacities

The System components shall generally be sized as follows:

- a) **HV Cables Generally:**
  - Sized for a minimum fault level of 250 MVA for one second;
  - Sized for a minimum capacity of 4 MVA when all derating factors are applied, and
  - Constructed using a minimum 120 mm<sup>2</sup> Cu/XLPE or equivalent aluminium conductor.
- b) **Incoming Feeders and Primary Substation Transformers:** Sized for the Ultimate Base Load. The Second feeder can be a lower capacity feeder; however this is subject to an NPV analysis and will require approval from DEEP. Where incoming supply is by transformers there shall be a minimum of two transformers arranged to maintain full supply in the event of a primary transformer failure.
- c) **Interconnectors:** Sized to accommodate the power transfer that can occur under the worst case condition, including single contingency failure or worst-case configurations, such as when the ring main open points are all shifted to one end.
- d) **Ring mains:** Sized to accommodate the worst-case load and voltage drop that can occur when the open point is shifted to one end. At establishments with a single interconnector this shall also include consideration of through load conditions that may exist if the interconnect has failed. The ring main rating used in the design shall consider the installation method of the cable. In most instances cable will be direct buried but there could be significant lengths installed in conduit under paved surfaces. In general the rating should be for installation in conduit. To allow for uneven loading of the rings and for future loads to be connected, the master planned loading on ring mains should generally not exceed 60% of cable capacity. Any development exceeding this limit requires DEEP approval.

#### Site Selection

Primary substations/switching stations and power stations shall generally be located within the higher security zones of the establishment.

The detailed site of major plant shall be selected in accordance with the site selection criteria given in Chapter 26 —High and Low Voltage Distribution System Requirements.

## **Emergency Power Generation**

### Requirement

Certain loads are provided with standby power in the event that the mains supply fails. In addition, certain operational establishments are provided with a CEPS. The master plan shall consider the operational requirements for standby power generation for the existing and new loads. This shall include:

- a) The types of operations conducted and the consequence of power supply interruptions;
- b) Current practice at the establishment;
- c) Normal Defence practice in providing standby power;
- d) The reliability of the electrical supply.

Depending upon the nature of the loads requiring standby power and their geographic distribution the master plan shall recommend either:

- a) Local power generation using LEGs at each facility;
- b) Centralised power generation using a CEPS, or
- c) A combination of both, with LEGs powering building essential loads and a CEPS providing site power.

### CEPS Capacity

Should a CEPS be proposed the master plan shall recommend a capacity taking into account the availability of load shedding or other load control measures and either:

;

- a) The magnitude of the loads requiring standby power from the Ultimate Base Load calculations, or
- b) A percentage of the total establishment load (e.g.: typically 70% for operational RAAF bases) based on operational experience.

### Site Selection

Centralised power generation should generally be located within the higher security zones of the establishment.

The detailed site of a CEPS major plant shall be selected in accordance with the site selection criteria for switching stations given in Chapter 26 —High and Low Voltage Distribution System Requirements. In any case the CEPS should be located a minimum of 400 metres from the connection point for the primary incoming feeder from the NSP (typically the ISS).

### **3.1.4 Master Plan Report**

For the requirements for the structure and content of Master Plan Reports, refer to Chapter 4 — Documentation Standards.

## **3.2 High Voltage System Development Plans**

### **3.2.1 Development Plan Considerations**

A High Voltage Development Plan is a plan produced either as a precursor to or as part of the Concept Design Report for a particular project that details the extent of work to be executed under that project and demonstrates how this is consistent with the master plan. In this it is similar to detailing the staging of the works under a master plan and so it needs to meet the same requirements but is tailored to a particular development activity.

Where a master plan report does not exist the Development Plans shall indicate how the proposed works will fulfil the infrastructure needs of the current project and not limit future development of the electrical infrastructure needed for possible future developments. In essence it must fulfil the basic master planning principles described above for master plans.

The key considerations in the formulation of a Development Plan are that the proposed works are:

- a) Consistent with the Master Plan;
- b) Meet the immediate electrical supply needs of each project while minimising capital expenditure both for the project and long term;
- c) Minimise redundant work at each stage.

Development plans shall be submitted for DEEP approval prior to their circulation.

### **3.2.2 Development Plan Format**

For formatting requirements for Development Plans, refer to Chapter 4 —Documentation Standards.

# 4 Documentation Standards

## 4.1 Background

This chapter defines the technical standards for documentation of electrical power generation and distribution systems at Defence establishments. This policy includes requirements for:

- a) Electrical Master Plans and Development Plans;
- b) Standard Drawing Arrangements;
- c) System Documentation and Operational Drawings;
- d) Design Reports;
- e) Design Documents;
- f) Shop Drawings and Submissions; and
- g) As Installed Documents and Operation and Maintenance Manuals.

Documentation for the following systems is included:

- a) Site plans and cabling layout drawings;
- b) Equipment layout drawings.
- c) High voltage systems including:
  - Protection systems, including:
    - AC and DC schematics, and
    - Protection schemes;
  - Load Flow and Volt Drop Analysis
- d) Power generation systems, including:
  - Engines;
  - Fuel systems;
  - Cooling systems;
  - Starting systems;
  - Alternators, and
  - Associated control system.

### **Low voltage primary systems;**

- a) Control and instrumentation systems;
- b) Other auxiliary systems, such as On Load Tap Changers;
- c) Auxiliary power systems; and
- d) Earthing systems.

This chapter provides guidance and detailed technical material as necessary to define the Defence documentation requirements and standards to be applied, in addition to the applicable statutory regulations and standards.

## 4.2 Referenced Documents

All documentation shall be of the best standard and shall comply with the relevant Australian Standards, or if such do not exist, with the relevant IEC or International (ISO) Standards.

Irrespective of any requirements shown in this manual the documentation as a whole shall comply with:

- **Australian Standards**

AS/NZS 1102      *Graphical Symbols for Electrotechnical Documentation (series)*

AS/NZS 3000      *Wiring Rules.*

AS 2067            Substations and high voltage installations exceeding 1 kV a.c.

AS 3702            *Item Designation in Electrotechnology.*

- **Other Standards**

The rules and regulations of the relevant NSP.

IEC 61131-3        *Programmable Controllers – Programming Languages*

The requirements of any other Authority having jurisdiction over the installation.

- **Technical References**

No Technical References are utilised.

## 4.3 Documentation Process

### 4.3.1 Requirements of the Designer and Contractor

The designer and contractor are responsible for complying with the requirements of this chapter, the additional requirements outlined in the FDB and the requirements of regulations and standards. This responsibility encompasses documenting the installation and specifying equipment to meet the required standards and also verifying that the final as installed, and operational and maintenance documentation, when completed, complies with these requirements.

The Designer and Contractor must also ensure that the documentation is adequately detailed so that the identified procedures and activities can be undertaken safely and reliably in the facility.

In addition to the requirement for design documentation such as specifications and drawings, the Designer must provide design reports and other reports as outlined in the IM *Design Management* requirement, this manual and any other technical investigations or reports as detailed in the FDB.

### **4.3.2 Requirements of the Electrical Operating Authority/Network Controller**

The Electrical Operating Authority (EOA)/Network Controller (NC) is responsible for maintaining up to date operational drawings as described in Para 4.6 — Requirement for System Documentation and Operational Drawings of this document. This responsibility includes ensuring that the documentation provided by the designer for any alteration or addition complies with these requirements and has been appropriately incorporated into the Base/Establishment records.

## **4.4 Documentation Standards**

Defence attaches considerable importance to the provision of proper documentation of the design (including specification, drawings, datasheets etc) and due regard shall therefore be paid to the detail and completeness of such documents. Documentation shall be clear, concise and precise.

### **4.4.1 Specification of Equipment**

Unless special circumstances exist, equipment and materials shall not be specified by make and model number but shall be selected on the basis of their performance, suitability, availability, maintainability and cost effectiveness. Any proposal to specify equipment by make and model shall be formally documented for approval by Defence.

### **4.4.2 Text Documentation Format**

The format of all text documentation, whether this is for the Functional Design Brief (FDB), Concept Design Report (CDR), design specifications, data sheets, Operation and Maintenance Manuals or any other Design Reports shall be generally as follows:

- a) The page size shall be A4 but may be A3 where drawings are also incorporated.
- b) Shall be provided in both Microsoft Word and PDF formats
- c) New sections shall commence on new pages.
- d) A revision box shall be included at the beginning of each document with:
  - Revision number;
  - Author;
  - Checked;
  - Approved; and
  - Date.

### **4.4.3 Drawings Format**

The drawings shall be clearly legible when printed on A3 size sheets.

All drawings shall be to a professional standard and drawn in accordance with the relevant Australian, IEC or International (ISO) Standards. Drawings shall be provided in both their native format (e.g. DGN, DWG) together with the relevant reference files, colour tables and line styles and also in PDF format.

Where appropriate, the drawing scale must be shown. The drawing shall also include a graphic scale to facilitate scaling when a sheet is reproduced at a different size to the original.

All drawings shall have a revision box containing:

- a) Revision number and status;
- b) Designed;
- c) Drawn;
- d) Checked;
- e) Approved; and
- f) Date.

#### **Non-standard Symbols**

Symbols shall comply with Australian Standards.

Where the use of non-standard symbols is unavoidable, reference to the symbol(s) shall be made in the form of a legend on the drawing, accompanied by explanation and description.

## **4.5 Requirements for Electrical Master Plans and Development Plan Reports and Drawings**

### **4.5.1 Electrical Master Plan**

#### **Introduction**

The Electrical Master Plan report shall document in detail the factors considered in the master planning process. These considerations are listed in detail in Chapter 26 – High and Low Voltage Distribution System requirements.

Electrical Master Plan and Development Plan reports must carry signature acknowledgement from DEEP before they may be circulated.

#### **Report Format**

The Electrical Master Plan shall consist of a written report with drawing attachments as required. The following is a representative outline of the report. This outline is provided for guidance only and all sections might not be applicable in all instances.

#### **Existing Installation**

##### Incoming Supply

- a) Configuration of the incoming supply including its source and voltage;
- b) Any limitation on the capacity of supply as a result of factors in the DNSP's network;
- c) The condition of the DNSP assets;
- d) Factors negatively effecting reliability of the incoming supply;
- e) Redundancy issues, including the alternative mains connections.

### Existing Loads

- a) The types of loads at the establishment;
- b) Magnitude of the load;
- c) Electrical characteristics of the load, such as power factor or load fluctuations;
- d) The distribution of load across the establishment;
- e) The load profile of the load across the day.

### Primary Distribution and PSS

- a) Configuration of the primary distribution;
- b) Feeder/Interconnector capacity including their construction and capacity;
- c) HV switchboard arrangement and capacity;
- d) Space limitations;
- e) Condition and age of the assets;
- f) Reliability and Redundancy issues.

### Secondary Distribution and Distribution Substations

- a) Configuration of the ring mains;
- b) Ring main capacity including their construction and capacity;
- c) Distribution substation arrangement and capacity;
- d) Condition and age of the assets;
- e) Reliability and Redundancy issues.

### Central Emergency Power Station

- a) Configuration of the station:
  - Capacity and connection arrangements of the generators;
  - Physical arrangement of the building and generating halls;
- b) Operation of the control system, including any limitations on automatic operation;
- c) Condition and age of the plant;
- d) Reliability and Redundancy issues.

### Control and Monitoring Systems

- a) Configuration of any control and monitoring systems, in particular systems that:
  - Monitor the status or power flows in the electrical distribution system, or
  - Provide control of load shedding devices;
- b) Capabilities of the systems;
- c) Interfaces to other systems;
- d) Condition and age of the plant.

### Deficiencies

The main deficiencies of the existing systems in:

- a) Meeting the existing loads;
- b) Limiting the future expansion;
- c) Limiting long-term supportability;
- d) Ensuring acceptable reliability of operation.

### Loads and Ultimate Base Load

- a) The types of proposed new loads and demolitions;
- b) Magnitude of the load;
- c) Electrical characteristics of the load, such as power factor or load fluctuations;
- d) The distribution of load across the establishment;
- e) The load profile of the load across the day.

### Drawings

- a) Existing system;
  - SLD;
  - Geographic layout.
- b) Electrical Master Plan
  - Loads and load zoning;
  - SLD;
  - Geographic layout.

An Electrical Master Plan is a stand-alone document that provides a framework within which the future development of electrical supply infrastructure at a Defence establishment can take place. It is a broad outline addressing the needs of the establishment in the areas of:

- a) Electrical supply into the establishment;
- b) Electrical distribution within the establishment
- c) The requirements for standby generation, and
- d) The requirements for monitoring and control systems for the electrical systems.

Electrical Master Plan and Development Plan reports must carry signature acknowledgement from DEEP before they may be circulated.

### **Drawing Requirements**

Drawing Requirements are provided at paragraph 4.5.3—Standard Arrangement Drawings.

## 4.5.2 Electrical Development Plan

### Introduction

An Electrical Development Plan is a plan produced, often as part of the Concept Design Report for a particular project, which details the extent of work to be executed under that project and how this is consistent with the master plan. In this it is similar to detailing the staging of the works under a master plan and so it needs to meet the same requirements.

### Report Format

- a) A report, usually as part of the CDR for the project, that details;
  - The proposed works, including a description of how these conform to the master plan;
  - Estimates for each stage.
- b) Drawings accompanying the report;
  - SLD for each stage;
  - Geographic layout for each stage;
  - Loads and load zoning, where differing from master plan.

Where there is no master plan report the Electrical Development Plan will also need to include the relevant detail as described above for the Electrical Master Plan report.

## 4.5.3 Standard Arrangement Drawings

### High Voltage Master Plan Zone Plan - Load Zoning Diagrams

Zone diagrams are planning documents that detail the location of the various load types in the site. The load types are loads with different functions, such as operational loads, domestic load and support loads. For this purpose it is preferred that the layout occupy a single sheet, using colour for increased clarity. Each load type shall be identified on the plan as a hatched area with a different colour. Sample zone plan diagram drawing is provided at Figure 4.1.

### High voltage Single Line Diagrams

Single line diagrams are planning documents that show the broad configuration of the HV network. For this purpose it is preferred that the SLD occupy a single drawing sheet able to be reproduced in black and white. The SLD shall detail the HV system down to the transformers at distribution substations, including the rating of the distribution transformer. Sample high voltage single line diagrams are provided at Figure 4.2.

### High Voltage Geographic Layouts

Geographic layouts are planning documents that detail in broad terms the physical location of substations and HV cables at a facility. For this purpose it is preferred that the layout occupy a single sheet, using colour for increased clarity. For large networks it might be necessary to separately document the primary and secondary distribution networks.

The high voltage geographic layout shall detail:

- a) The location of Intake Stations, primary switching stations, power stations and distribution substations;
- b) The route of the incoming supply;
- c) The route of primary distribution;
- d) The route of secondary distribution.

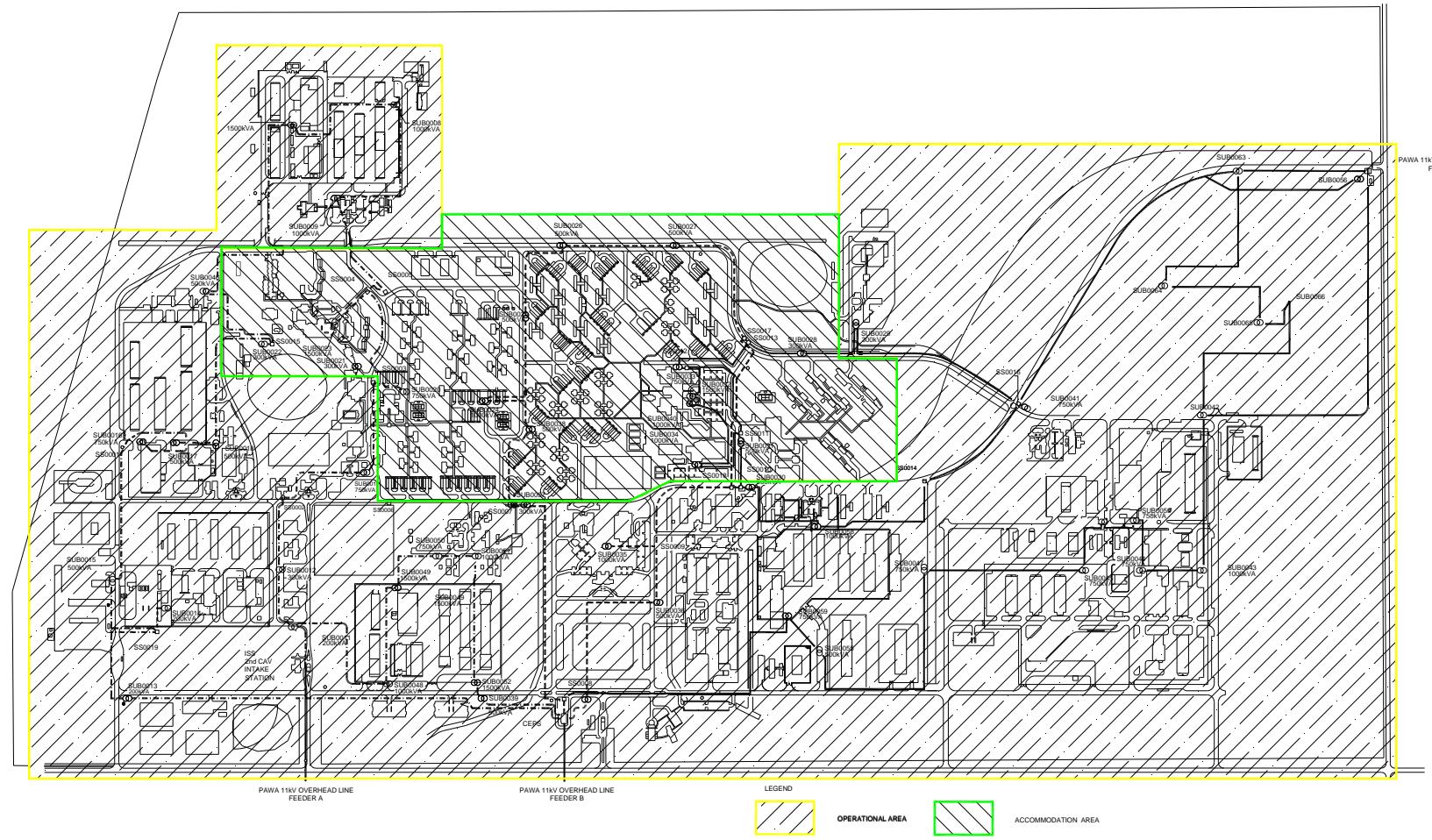
Sample geographic layout drawing is provided at Figure 4.3.

Substation Single Line Diagram is provided at Figure 4.4.

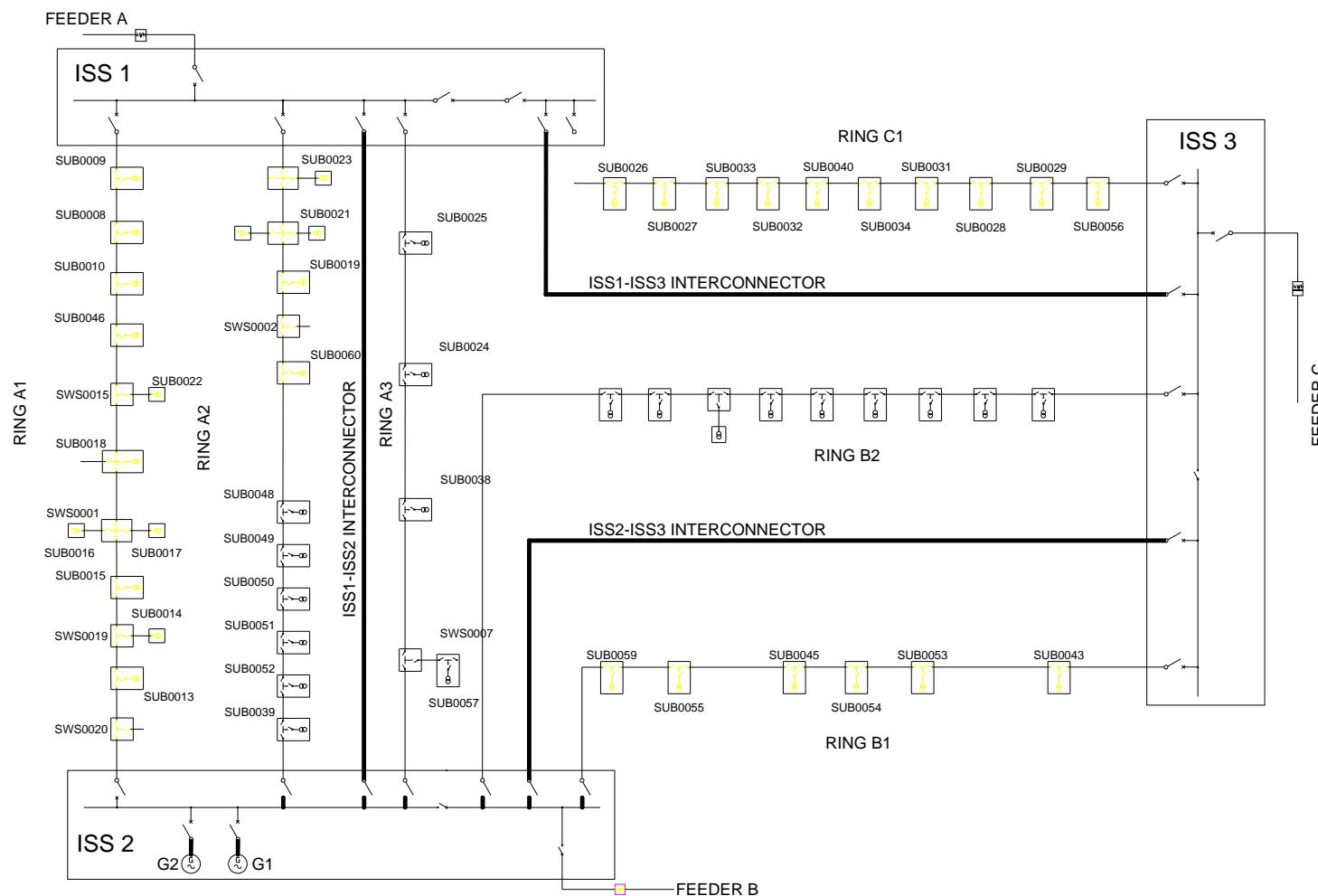
Switching Station Single Line Diagram is provided at Figure 4.5.

Low Voltage Distribution Pillar Schematic is provided at Figure 4.6.

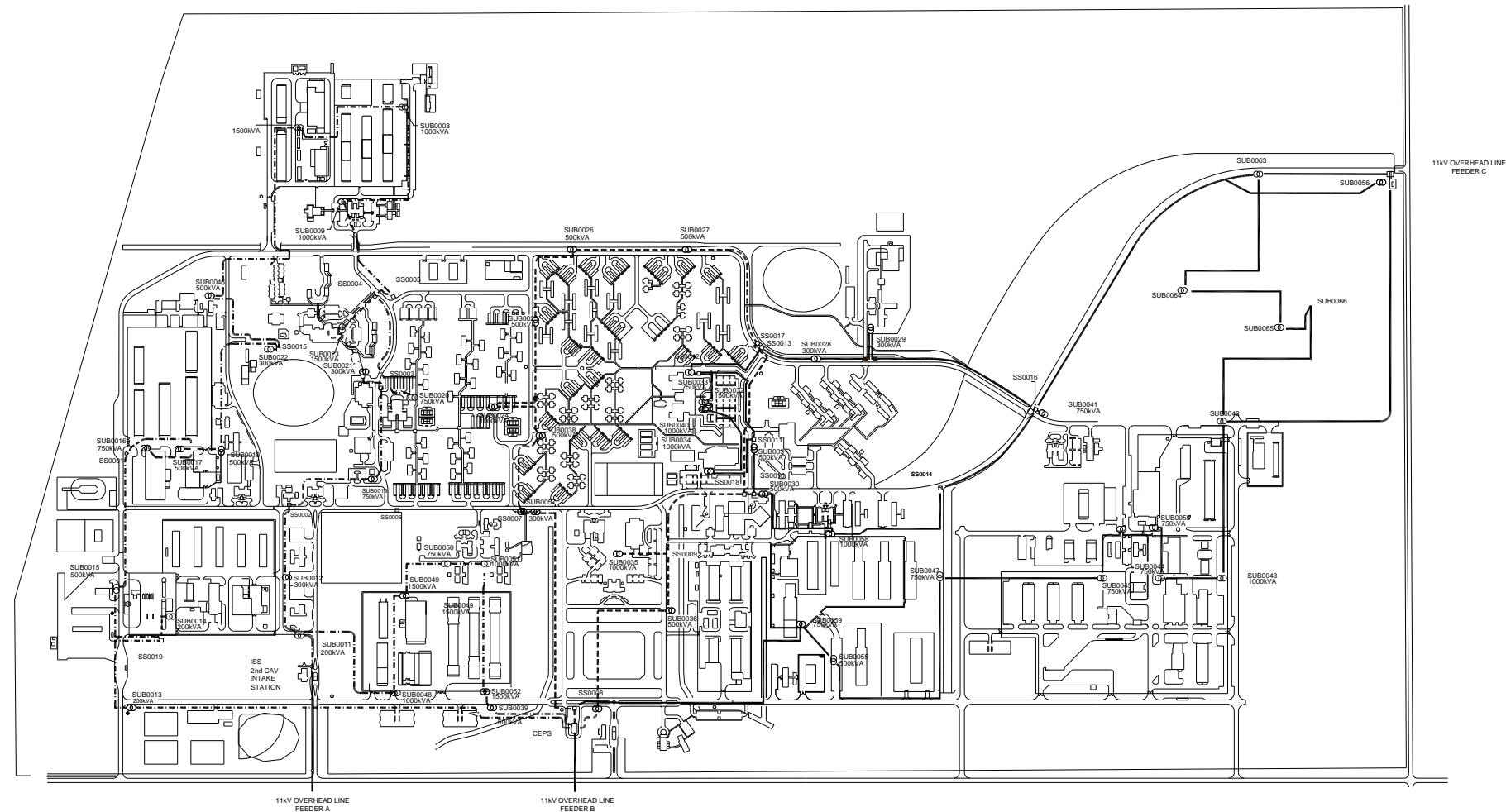
Standard Symbols are provided at Figure 4.7.



#### ■ **Figure 4.1: High Voltage Master Plan Zone Plan**

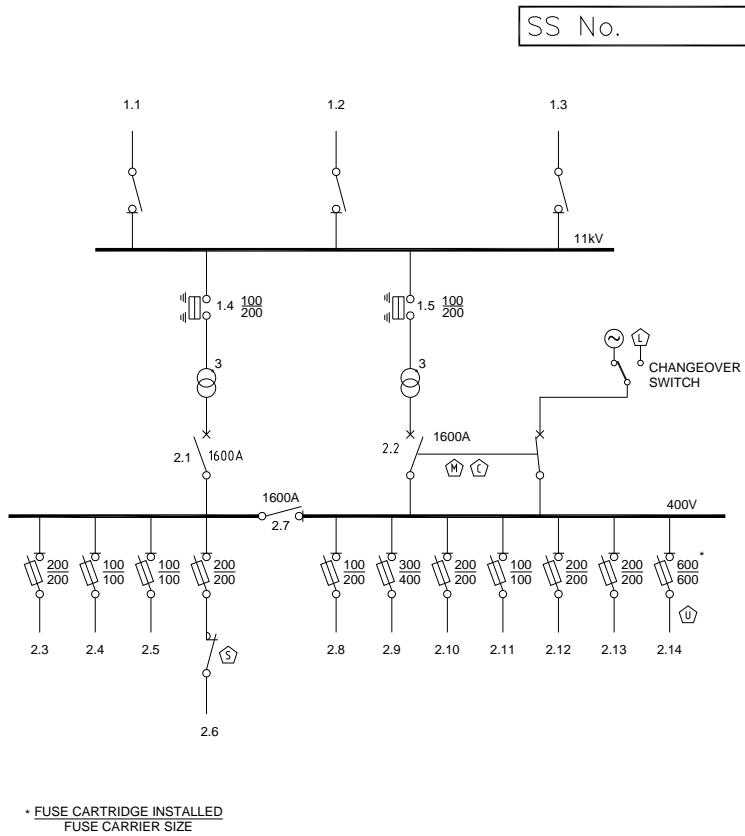


■ **Figure 4.2: High Voltage Single Line Diagram**



■ **Figure 4.3: High Voltage Geographic Layout**

HV SWITCHGEAR	CCT No	HV LABEL	CABLE SIZE/TYPE
MAKE: _____	1.1		
TYPE: _____	1.2		
BUS / SWITCH RATING: _____	1.3		
 HV FUSE	1.4		
TYPE: _____	1.5		
 HV TRANS. TAILS	1.6		
No: _____			
SIZE: _____			
TYPE: _____			
TRANSFORMER	CCT No	LV LABEL	CABLE SIZE/TYPE
MAKE: _____	2.1		
TYPE: _____	2.2		
RATING: _____	2.3		
IMPEDANCE: _____	2.4		
VECTOR GROUP: _____	2.5		
TAPPINGS: _____	2.6		
 LV TRANS. TAILS	2.7		
No: _____	2.8		
SIZE: _____	2.9		
TYPE: _____	2.10		
 LV BOARD	2.11		
MAKE: _____	2.12		
TYPE: _____	2.13		
BUS RATING: _____	2.14		
 NOTES:			
1. PROTECTION SETTINGS SHOWN HERE WHERE POSSIBLE OTHERWISE REFER TO APPROPRIATE H.V. PROTECTION TABLE.			
2. FOR LEGEND REFERTO FIGURE 4.7			



■ Figure 4.4: Substation Single Line Diagram

CCT No.	HV LABEL	CABLE SIZE/TYPE
1.1		
1.2		
1.3		
1.4		
1.5		
1.6		
1.7		
1.8		
1.9		
CCT No.	HV SWITCHGEAR MAKE/TYPE	RATING
1.1		
1.2		
1.3		
1.4		
1.5		
1.6		
1.7		
1.8		
1.9		

NOTES

1. PROTECTION SETTINGS SHOWN HERE WHERE POSSIBLE OTHERWISE REFER TO APPROPRIATE H.V. PROTECTION TABLE.

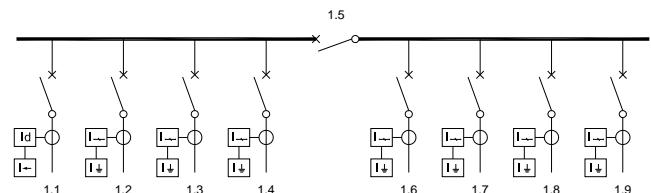
2. FOR LEGEND REFER TO FIGURE 4.7

ISS

NOTE: ALTERNATIVELY, CEPS

1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
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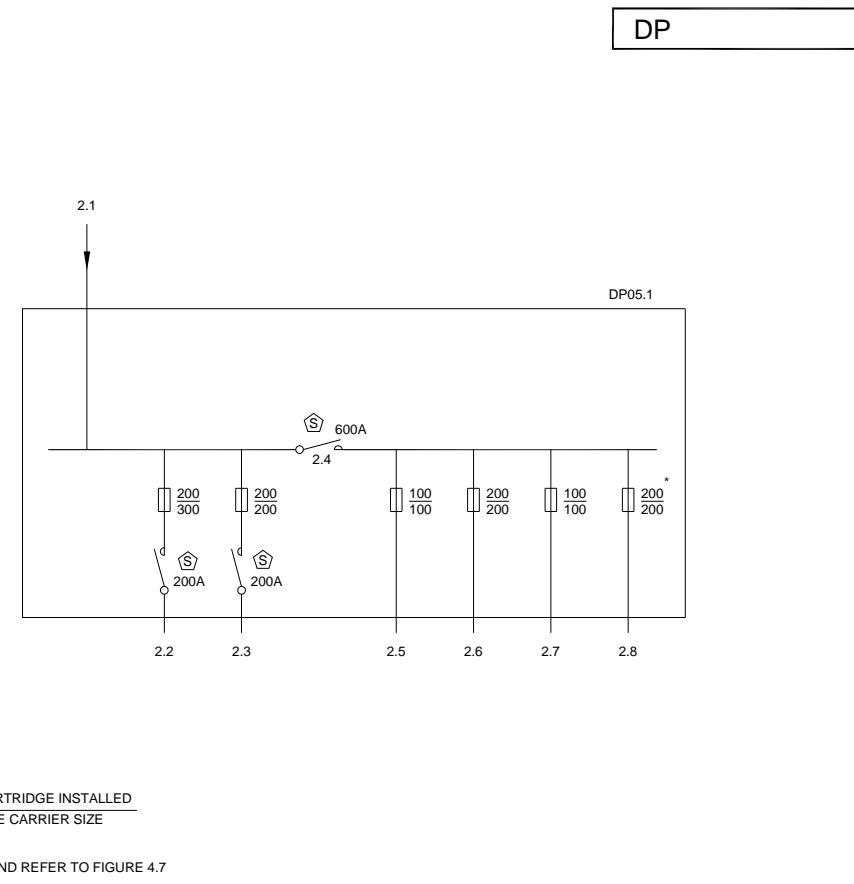
PHYSICAL ARRANGEMENT - ELEVATION  
(VIEWED FROM FRONT)



SINGLE LINE SCHEMATIC DIAGRAM

■ Figure 4.5: Switching Station Single Line Diagram

LV BOARD		
MAKE: TYPE: BUS RATING:		
SWITCHGEAR		
MAKE:	TYPE:	
CCT No	LV LABEL	CABLE SIZE/TYPE
2.1	SUB 05	
2.2		
2.3		
2.4		
2.5		
2.6		
2.7		
2.8		
CCT No	LV SWITCHGEAR MAKE/TYPE	RATING
2.1		
2.2		
2.3		
2.4		
2.5		
2.6		
2.7		
2.8		



■ **Figure 4.6: Low Voltage Distribution Pillar Schematic**

#### ■ **Figure 4.7: Standard Symbols**

## **4.6 Requirement for System Documentation and Operational Drawings**

System Documentation and Operational drawings are those documents and drawings that aid in the operation of the equipment and system. They are used by operators and are also displayed adjacent to equipment as detailed below:

Operational drawings shall be provided as follows:

- a) Within distribution substations:
  - Substation single line diagram (min. A4 size)
- b) Within LV distribution pillars:
  - Pillar single line diagram (min. A4 size)
- c) Within major substations and switching stations:
  - HV switchboard single line diagram (min A1 size)
  - Site HV system single line diagram (min A1 size)
  - Site HV system geographic layout (min A1 size)

The operational drawings shall be securely fixed to the wall.

A4 size drawings can be laminated. All other drawings shall be mounted in heavy-duty metal frames with a glass cover.

Sample drawings showing the expected general standard and layout of the drawings are included in paragraph 4.5.3 —Standard Arrangement Drawings.

### **High Voltage System Configuration Manual**

The High Voltage System Configuration Manual (HVSCM) is an aggregation of system documentation and operating drawings which detail all aspects of the Base HV network as it currently operates. The intent for this document is to centralise information that describes the electrical network so that it is readily available for reference by Defence, the CMS or external parties. It should act as a reference for any switching operations, field inspections or consultation.

The EOA is responsible for developing and maintaining an appropriate HVSCM. Where HVSCM is inadequate or incomplete, the Designer is to produce a HVSCM, which shall incorporate the most recent versions of:

- a) HV Single Line Diagram (refer paragraph 4.5.3 —Standard Arrangement Drawings.);
- b) HV geographic layout (refer paragraph 4.5.3 —Standard Arrangement Drawings.);
- c) Substation / Switching Station schematics (refer paragraph 4.5.3 —Standard Arrangement Drawings.);
- d) LV DP schematics (refer paragraph 4.5.3 —Standard Arrangement Drawings.);

- e) HV protection study report, HV earthing study report and Load flow study report (refer paragraph 4.7.1.1 —Content Requirements for High Voltage Installation Reports); and
- f) Appropriate reference to the O&M manuals and shop drawings.

The Electrical Operating Authority is responsible for maintaining the HV System Configuration Manual and shall hold this document on site. An electronic copy shall be provided to DEEP.

## **4.7 Requirements for Design Reports**

The requirement for documentation varies depending upon which systems are being designed in the project. In general if a system forms part of the project the following levels of detail in the documentation shall be provided at each respective stage.

### **4.7.1 Design Report Requirements**

The Designer shall submit design reports as required by the IM *Design Management* process and in accordance with the respective project requirements. In summary design reports for electrical systems will be required, as a minimum, at the following stages for DEEP review:

- a) Concept Design Stage (Concept Design Report (CDR));
- b) Schematic Design Stage (Schematic Design Report (SDR), and
- c) Depending on the suitability of the above submissions, as further required by DEEP, typically:
  - Detailed Design Stage (Detailed Design Report (DDR));
  - Final Design Stage (Final Design Report (FDR)).

DEEP will advise after reviewing each design report (e.g. CDR and SDR) the need for further design report submissions for review.

It is expected that the design report will be continually developed during the design process in a regular fashion until completion of the design where a Final Design Report (100% design) is provided for inclusion in the Operation and Maintenance information. All design report revisions submitted for review shall have changes clearly tracked within the document to assist review.

The design report shall identify all key design objectives and clearly identify the design intent providing the logic behind design decisions, so that concurrence can be given to such decisions.

The commentary shall fully describe the design intent and parameters that will be provided by the constructed facility. The Design Report shall include sketch plans or drawings of the installation layout in accordance with the requirements below.

The content of electrical design reports shall include:

- a) MIEE Compliance Report as detailed in Chapter 6 —Certification and Verification and Appendix A;
- b) Suitable discussion addressing the Design Considerations at Appendix A and the additional requirements provided below;

- c) Proposed scope of works and detail the system arrangement;
- d) All major regulations and standards, Defence policies and guidance publications and detail their extent and field of application;
- e) Where the design deviates from any of the stated requirements, provide fully justified submissions in accordance with the Alternates Methods and Design process at Chapter 6 — Certification and Verification for Defence agreement and Technical Authority approval.
- f) Detail the proposed point of supply for each facility including the supply capacity/characteristics/condition assessment demonstrating adequate capacity is available at the point of supply, the reticulation system and the NSP supply to the establishment;
- g) Detail any proposed reticulation system modifications;
- h) Facility maximum demand assessment and load characteristics;
- i) Switchboard locations, design fault level, voltage drop allocation, circuiting arrangements, earthing arrangements and protection arrangement;
- j) Basis for sizing of major equipment;
- k) Include layout drawings and single line diagrams for the proposed arrangement;
- l) Detail the system operation where appropriate; and
- m) Certify that the design meets the requirements of the FDB, this manual, the IM and the requirements of the regulations and standards identified above ;

Additional design report content for key subject areas.

#### **Residual Current Devices Reporting Requirements**

- a) All socket outlets not RCD protected are detailed in the design report for agreement and shock risk hazard assessment included with the report

#### **Power Factor Correction Installations Reporting Requirements**

- a) Feasibility assessment and payback period;
- b) Detail the PFC system, location and the basis for sizing/selecting of capacitor steps.

#### **Artificial Lighting Installations Reporting Requirements**

- a) Proposed lighting system performance including operational considerations and levels of illumination for each area;
- b) Financial assessment and cost benefit studies to justify the chosen lighting system;
- c) Detailed description of the control system type and arrangement including justification of the arrangement chosen and detail on the control interfaces (e.g. BMS and SMS);
- d) Detailed description of the energy management and energy efficiency initiatives;
- e) Any specialised maintenance requirements, and
- f) Luminaire types and lamp types where appropriate.

### **400Hz Design Reporting Requirements**

- a) Detail the frequency converter and reticulation system arrangement;
- b) Detailed description of the control system;
- c) Detail the connection arrangement or socket outlet arrangement;
- d) Facility maximum demand assessment and load characteristics;
- e) Detail the supply characteristics/conditions, design fault level and assessment showing the ability to maintain the required supply characteristics for all load conditions;
- f) 400Hz Switchboard locations, voltage drop allocation, circuiting arrangements, earthing arrangements and protection arrangement;
- g) Basis for sizing of major equipment such as converters and transformers, and
- h) Include layout drawing and single line diagram for the proposed arrangement.

### **Hazardous Areas and Explosives Areas Installations Reporting Requirements**

- a) Detail the Hazardous Areas and Explosives area standards being applied;
- b) Detail the competencies of the designers;
- c) Detailed classification description including detail of the processes and hazards;
- d) Hazard analysis report where required by Chapter 15 —Hazardous Area and Explosive Area Electrical Installations;
- e) Design limitations and management practices for the facility impacting on classification or safety;
- f) Any specialised maintenance requirements; and
- g) Include layout drawings, single line diagrams and hazardous area zone plan for the proposed arrangement.

### **UPS Reporting Requirements**

- a) Detail the proposed accommodation for the UPS;
- b) Detail the UPS and critical reticulation system arrangement;
- c) Detail the system operation and control system where appropriate;
- d) Detail the failure recovery strategy, availability and redundancy;
- e) Detail the connection arrangement and impact of NSP rules;
- f) Facility maximum demand assessment and load characteristics;
- g) Detail the supply characteristics/conditions, design fault level and assessment showing the ability to maintain the required supply characteristics for all load conditions;
- h) Critical switchboard locations, voltage drop allocation, circuiting arrangements, earthing arrangements and protection arrangement;
- i) Basis for sizing of major equipment such as UPS and critical power system
- j) Battery capacity and hold up period;

- k) Justification for the chosen system; and
- l) Include layout drawing and single line diagram for the proposed arrangement and control panel layout drawings.

#### **LEG Reporting Requirements**

- a) Detail the generator and essential reticulation system arrangement;
- b) Detailed description of the control system;
- c) Detail the connection arrangement and impact of NSP rules;
- d) Facility maximum demand assessment and load characteristics;
- e) Detail the supply characteristics/conditions, design fault level and assessment showing the ability to maintain the required supply characteristics for all load conditions;
- f) Essential switchboard locations, voltage drop allocation, circuiting arrangements, earthing arrangements and protection arrangement;
- g) Basis for sizing of major equipment such as generator and essential power system, and
- h) Include layout drawing and single line diagram for the proposed arrangement and control panel layout drawings.

#### **Mobile Generator Link Box Reporting Requirements**

- a) Include layout drawing and single line diagram for the proposed arrangement and MGLB switchboard/panel layout drawings.

#### **CEPS Reporting Requirements**

- a) CEPS demand assessment
- b) Building layout;
- c) Detail the generation system including:
  - Generating sets
  - Mechanical systems, including ventilation, fuels system, fuel storage capacity, cooling system,
  - Electrical systems including the earthing arrangements and protection arrangement
  - Control hardware and software
  - Communications networks
  - Operating philosophy
  - Load shedding philosophy
- d) Passive defence
- e) Detail the connection arrangement and impact of NSP rules;
- f) Basis for sizing of major equipment such as generators; and
- g) Include layout drawings and single line diagram for the proposed arrangement and control panel layout drawings.

#### **4.7.1.1 Content Requirements for High Voltage Installation Reports**

##### **Design Reports up to and including CDR**

The following supporting documents for each system shall accompany the report:

- a) Site plans showing cabling layout and the location of the works;
- b) Electrical Development Plan if necessary (refer to Chapter 3 – High Voltage System Master Plans and Project Development Plans, Chapter 26 – High and Low Voltage Distribution System Requirements and Appendix A);
- c) Substation and major plant room layout drawings showing building and all major equipment locations;
- d) Single line diagram of the relevant portions of the establishment HV system putting the works in the context of the network. These drawings should show the general configuration;
- e) Single line diagrams of LV primary systems showing the general configuration of the system;
- f) System Documentation and Operational Drawings described at paragraph 4.6 – Requirements for System Documentation and Operational Drawings;
- g) Control topology drawings where this has been developed sufficiently;
- h) Basic layout drawings showing building and principal equipment locations. Dimensions are not required unless these are critical items;
- i) Preliminary load analysis; and;
- j) Preliminary protection system analysis.

##### **Design Report Drawing Details**

In addition to the requirements above and elsewhere in this Chapter (4) the following applies for high voltage installations:

##### **Substation and Major Plant Room Layout Drawings**

Provide site plan, substation/plant room layout drawing. The substation layout drawings are required for all indoor substations. They shall be 1:50 scale showing the substation arrangement including the layout of the equipment and the arrangement of all pits and conduits.

The drawing shall be fully dimensioned and must show HV switchgear, transformer, LV switchboards, protection panels, batteries and battery chargers, communications panels, SCADA equipment, fire extinguishers, equipment storage and drawing holders. The plans must also detail the ventilation arrangement and also the access and egress paths.

The layout drawing shall incorporate a plan view showing the location, sizes and depths of pits and connecting conduits. This view should indicate the step heights, oil containment arrangement, pit grading and sumps and approximate position of the earthing system. This plan view shall be incorporated as separate views where there is too much information to provide on a single drawing.

##### **Design Reports after CDR**

The following supporting documents for each system shall accompany the report:

- a) Site plans showing cabling layout and the location of the works;
- b) Substation and major plant room layout drawings showing building and all major equipment locations;
- c) Single line diagram of the relevant portions of the establishment HV system putting the works in the context of the network;
- d) Single line diagrams of each major substation, HV switching station and distribution substation showing the general configuration, and protection that is proposed;
- e) Detailed single line diagrams of each HV switchboard panel type showing the detailed configuration, protection and control proposed. These drawings should show details of CTs and VTs, including ratios, classes and burdens;
- f) Single line diagrams, cable schedules etc of LV primary systems showing the detailed configuration of the system, cable sizes, protection ratings etc;
- g) Revised System Documentation and Operational Drawings described at 4.6 – Requirements for System Documentation and Operational Drawings;
- h) Control topology / network drawings;
- i) Single line diagrams of all ancillary electrical supplies, such as DC systems;
- j) Details of any On Load Tap Changing arrangements;
- k) Details of earthing systems, including layout drawings and schematic drawings;
- l) Generating plant auxiliary system schematics, such as those for fuel and compressed air;
- m) Results of load flow analysis for the system under normal operating and worst-case single contingency failure conditions. This must include confirmation of suitable volt regulation/volt drop analysis; and
- n) Results of the protection coordination study and protection system analysis.

#### **Additional Reports Design Reports after CDR**

Generally, unless formally agreed by DEEP otherwise, the following reports shall be prepared. The required timing for the first issue of the reports is concurrent with the issue of the SDR. The final issue of the reports shall occur shortly after comment by DEEP and in no case later than the issue of For Constructed documentation.

#### Earthing Report

An earthing report shall be prepared where the works:

- a) Require the construction of new major substations or switching stations, or
- b) Result in a significant change in HV fault levels.

This report shall be based on on-site measurements of soil resistance and shall detail:

- a) The earth fault levels at each bus;
- b) Earth potential rise in the vicinity of the substation under maximum prospective fault levels;

- c) The step and touch potentials within and in the vicinity of the substation, and
- d) Measures adopted to minimise transfer potentials as part of the design.

#### Protection Report

A review of the HV protection settings is required and a protection report shall be prepared where the works:

- a) Require the construction of new major substations or switching stations;
- b) Require changes to the distribution system that will result in a need to change the protection settings, for example:
- c) Changes to Primary Configuration
- d) Adding a generator, Interconnector, Ring main, etc; or
- e) Result in a significant change in HV fault levels.

The protection report shall include:

- a) A study of the system fault levels to determine the maximum and minimum prospective fault levels at each bus under various system configurations;
- b) A statement of the protection philosophy that has been implemented;
- c) A grading study for IDMT protection under all system configurations;
- d) Setting information for IDMT protection elements;
- e) Setting information for all unit protection schemes, and
- f) Setting information for all other protection elements.

Setting information shall be supported by calculations, that are included as part of the report. Settings shall be provided in engineering terms only.

The results of the protection study shall be implemented in the design.

#### Load Flow Report

The purpose of a load flow report is to predict the areas of poor performance or potential overload at various points in the electrical network under different operating conditions.

A load flow report shall be prepared where the works:

- a) Increase, offset, or otherwise alter electrical load magnitudes and their distribution across the Base; or
- b) Require the construction of new major substations or switching stations;

The load flow report shall be based on a model of the electrical network developed in a known electrical simulation software package suitable for conducting load flow studies. Simulations shall be carried out for both normal operating conditions and single contingency situations and shall include:

- a) Summary of load flows in the network, identifying sections that may be overloaded or operate outside of specification;
- b) Information on voltage drop at each bus; and
- c) Information on current flow at each node in the network.

The outcome of the load flow study shall guide the design.

## **4.8 Requirements for Design Documents**

### **Tender and ‘For Construction’ Documents**

Tender and ‘For Construction’ documents consist of specifications, data sheets, drawings, reports and other documents are required to suit the project.

### **Specifications**

Specifications shall address the following points, as applicable:

- a) Define the scope of works;
- b) General establishment and service conditions data, taking into account data from the Bureau of Meteorology and any special site requirements;
- c) General construction standards, methods and materials;
- d) Details of the works that have not been included on the drawings or elsewhere;
- e) Control philosophies to be implemented.

### **Data Sheets**

Data sheets shall address the following points, as applicable:

- a) Description of the equipment;
- b) Applicable standards;
- c) Equipment characteristics;

### **Drawings**

As a minimum, drawings shall include the following, as applicable:

- a) Site plans showing cabling layout and the location of the works;
- b) HV single line diagram of the relevant portions of the establishment HV system putting the works in the context of the network;
- c) Single line diagrams of each major substation, HV switching station and distribution substation showing the general configuration, and protection that is proposed;
- d) Detailed single line diagrams of each HV switchboard panel type showing the detailed configuration, protection and control proposed. These drawings should show details of CTs and VTs, including ratios, classes and burdens;
- e) LV single line diagrams, cable schedules etc of LV primary systems showing the detailed configuration of the system, cable sizes, protection ratings etc;

- f) Control topology / network drawings;
- g) Loop drawings if considered necessary to describe the system;
- h) Single line diagrams of all ancillary supplies, such as DC systems;
- i) Details of earthing systems, including layout drawings and schematic drawings;
- j) Protection Reports and protection coordination; and
- k) Layout drawings showing building and all major equipment locations. Dimensions are not required unless these are required for coordination purposes.

## **4.9 Requirements for Shop Drawings**

The provision of shop drawings shall be included in the specification covering all aspects of the works. The Designer shall review the shop drawings and any other technical submissions to ensure that the proposed works comply with the design intent and that they are fully compliant with the requirements contained herein and applicable standards.

As a minimum, drawings shall include the following, as applicable:

### **Cabling**

- a) Cable schedules, field wiring diagrams and interconnection cabling diagrams, including cable sizes and constructions.
- b) The final locations of cables, pits, cable joints, cable ladders etc;

### **Electrical Panels and Switchboards Generally**

For all electrical switchboards and panels provide the following shop drawings:

- a) General Assembly drawings showing the arrangement of the switchboard. This shall include details of:
  - Materials;
  - Construction;
  - The location of equipment both externally and internally;
  - Busbar details;
  - Painting;
  - Labelling;
  - Door details;

Include *information to be given regarding the ASSEMBLY* as detailed in AS/NZS 3439.1.

- b) A single line diagram of the entire switchboard;

### **HV Switchboards**

Provide the following additional shop drawings for HV switchboards:

- a) An AC drawing for each panel including a three line diagram showing:
  - The primary system configuration of busbars, circuit breakers and earth switches.
  - All metering, control and protection devices, including model numbers and terminal numbers.
  - The details and arrangement of the CTs and VTs, and the secondary cabling, including wire numbers.
  - Terminals and test link, including terminal numbers.
- b) A DC drawing of each panel showing:
  - All metering, control and protection devices, including terminal numbers.
  - The arrangement of DC cabling, including wire numbers.
  - Details of terminals, including terminal numbers.

**MCCs, Control Panels, DC supplies, etc**

Provide the following additional shop drawings of each MCC, Control Panel and any major component containing control circuitry.

- a) Schematic drawings showing:
  - Details of all equipment, including terminal numbers;
  - Details of control and communications cabling, including wire numbers;
  - Details of terminals, including terminal numbers.
  - Ammeter scales and current transformer ratios;
  - Circuit breaker and fuse current ratings;
  - Ratings of capacitors, resistors and any other electrical devices;
  - A short name description of each relay, timer or control device to describe its operation;
  - A cross-reference system that indicates where each contact for a relay or timer is located. The system may include sheet and line numbers;

**PLC and Instrumentation Systems:**

Provide the following additional shop drawings for systems containing PLCs or instrumentation systems:

- b) Control topology / network drawings;
- c) I/O schedules and drawings;
- d) Loop drawings for instrumentation.

**Major Plant, such as Transformers**

- a) Functional description;
- b) Integral protective devices (Buchultz, vector group);
- c) Cooling arrangement;

- d) OLTC arrangement;
- e) Overall dimensions and mass (including the mass of the heaviest lift for maintenance);
- f) Terminal point details;
- g) Minimum clearances;
- h) Where plant or plant items subject to pressure and temperatures higher than ambient;
  - Design pressures and temperatures;
  - Working pressures and temperatures;
  - Test pressures and temperatures;
- i) Insets, where necessary, to ensure every item of the assembly is clearly shown;
- j) All points of support;
- k) All points of attachment of the plant to piping, conduits or other items supplied by others;
- l) Location of holding-down bolts or other points of support or anchorage.

## **4.10 Requirements for As-Installed Documentation and Operations and Maintenance Manuals**

### **4.10.1 As Installed Documentation and Drawings**

The provision of as-installed documentation shall be included in the specification covering all aspects of the works. At the completion of construction, both the ‘For Construction’ design drawings and Shop Drawings shall be updated to reflect any changes that have occurred during the construction phase. Notwithstanding the requirement for the contractor to provide accurate and adequate documentation, the Designer shall verify that the updates and all as-installed documentation accurately reflect the constructed equipment and installation.

### **4.10.2 Operation and Maintenance Manuals**

Comprehensive Operations and Maintenance (O&M) Manuals shall be provided so as to enable efficient operation and maintenance of the installation. Perform all necessary amendments to the operation and maintenance manuals to ensure formal acceptance by the CMS.

Where existing O&M manuals exist that cover the installation these shall be incorporated into the new manuals, unless the modifications are minor in nature and their amendment is agreed by Defence. Depending upon the scope of works and the condition of the existing manuals this can be done in either of two ways:

- a) The new manuals shall incorporate the relevant sections of the existing manuals, or
- b) The existing manuals shall be updated to reflect the new works.

In any case information on redundant equipment shall not be left in the manuals.

The manuals shall contain short and long form operating instructions and a comprehensive maintenance schedule.

The text of the Operating and Maintenance Manuals, together with all drawings, illustrations and diagrams shall refer specifically to the Equipment being supplied, and shall be specially prepared where necessary. General instructions referring to a range of typical equipment will not be acceptable.

### **Binders**

The Operating and Maintenance Manuals shall be assembled and bound in a four ring A4 binder of the heavy duty, swing hinge, split prong type, of stiff binder board construction designed for rough usage. The binder shall have the title of the project, equipment description and the Contractor's name, imprinted on the spine and front cover.

Binders shall not exceed 75 mm in thickness. If required by the quantity of instruction manual material, multiple volumes shall be supplied, each clearly marked with the volume number. Each volume shall contain a full index for the entire manual and also a detailed index for its own content. A sufficient number of volumes shall be provided so that the material contained in each volume (including drawings, if any) does not use more than 80 percent of the binder capacity.

### **Content**

The instructions shall be fully detailed covering all new equipment supplied. Unless the modifications are minor in nature and the existing manuals are being amended, the manuals shall also incorporate details of any existing equipment that has been retained and the existing manual information can be used for this purpose if suitable. The manuals shall include the following:

- a) Table of contents and index tabs;
- b) Specifications, test data (including all works and site tests), performance and equipment characteristic curves;
- c) Description of the equipment and components. This should include an overview with block diagrams and detail descriptions;
- d) Short form and long form operating procedures;
- e) Comprehensive control system description including control methodology;
- f) Complete and detailed step by step operating instructions, including setting up, start-up, shutdown, emergency, and abnormal operation, as well as steady-state operation. A section shall be devoted to isolation and restoration procedures to be followed when maintenance is required on the various major items of plant;
- g) A full description of all construction and operational testing recommended to ensure proper preparation prior to operation of the equipment;
- h) Comprehensive preventative maintenance schedules outlining each operation and the recommended period at which each item of maintenance should be carried out;
- i) Complete installation and maintenance instructions, including details on preventative, breakdown and trouble-shooting diagnostics for known potential problems. These instructions shall be accompanied by illustrated equipment diagrams (assembly drawings) for use by

maintenance personnel for parts selection and assembly instruction. I.e. Services Manuals, Workshop Manuals and Trouble Shooting Manuals. Instructions recommending the return of the equipment to the supplier for repair are not acceptable;

- j) Recommendations to prevent deterioration during prolonged shutdown periods;
- k) Assembly drawings showing relationship of equipment components (such as sectional views and exploded views of the equipment);
- l) Settings of adjustable parameters, including setpoints of protective devices, such as TOL devices and protection relays;
- m) Comprehensive equipment information, parts list (cross-referenced to assembly drawings). i.e. Parts Manuals;
- n) Where the Equipment manufacturer offers several options for a certain part i.e. the actual part installed shall be stated in the instructions;
- o) Nameplate information, Contact number and Manufacturer's contact address for each item of equipment and component part thereof;
- p) The names and addresses of equipment manufacturers and suppliers together with the type, model reference, serial number, duty rating and the order number and date. The manufacturer's data shall include all necessary supplementary descriptions and instructions to ensure clarity.
- q) List of all special maintenance tools required and supplied by the Contractor;
- r) Listing of any programmable logic or other program including the ability to reinstall programming after a CPU/PC hard disk or PLC failure;
- s) Software maintenance requirements;
- t) Settings files for protection relays;
- u) All test and verification results, and
- v) As-constructed drawings and information.

The information shall be arranged in such a manner as to permit insertion of amendments and additional material. The instructions shall be cross-referenced for ease of use in maintenance and such reference number shall cross-reference to all drawing numbers, item numbers, part numbers and catalogue references necessary to ensuring identification and understanding of systems.

Before manuals officially enter circulation, the Designer is required to verify their contents and their suitability for use by Defence staff.

### **Format**

As-constructed drawings shall comply with the Spatial Management Plan (SDMP) available from the web site at:

<http://www.defence.gov.au/IM/business/spatial/main.htm>

Provide metadata files of each drawing, compiled as described in the SDMP. Details of metafiles are also available from the IM website at:

<http://www.defence.gov.au/IM/business/spatial/main.htm#FAQ5>

Metadata files are necessary for plans to be loaded and catalogued in the National Spatial Information Management System (NSIMS).

Manuals shall include a Remote Data Module that describes any new or additional structures, plant or equipment. This is loaded directly into the Defence Estate Management System (DEMS). RDM's are available from the Regional Information Manager through the Project Officer.

Provide an update of the existing ‘Master As-Constructed’ site plan of the base that incorporates the existing services and the new work. This update is to show the geographic detail described in the As-Constructed requirements including any redundant services left in situ, the location of capped services and any services that were removed.

The Operation and Maintenance Mmanuals shall be provided in both electronic and paper formats. The electronic format shall be suitable for inclusion on DEMS-FM; the paper format shall be suitable for the environment in which the manuals are used with all pages in plastic sleeves or similar.

The format of the manuals shall be generally as follows:

- a) The page size shall be A4.
- b) All pages shall have reinforced binding margins.
- c) Preferred drawing size is A4. A3 drawing size may be used where clarity of drawing will be lost with reductions. Existing larger drawings to be bound in clear plastic packets.
- d) Pages are to be numbered by section rather than consecutively so that additional pages can be readily inserted without affecting the existing page numbering.
- e) New sections are to commence on new pages separated by tabulator dividers.

There should be provision for noting revisions on each page with amendment list in front of each manual.

#### **Number of Copies and Submission Timing**

The Defence Project Director and Regional Manager Technical Services will advise the number of copies required, or a minimum of four copies (whichever the greater) of the manuals in each format, plus one additional copy in electronic format, shall be provided prior to handover of the installation to Defence.

## **5 Reserved**

# **6 Certification and Verification**

## **6.1 Certification and Verification of Designs, Construction and Maintenance**

Certification and verification is defined as the authoritative act of documenting and demonstrating compliance with the requirements of *standards and regulations* and Defence requirements. It is one of the key elements within the technical regulatory system, and a fundamental principle of facilities and infrastructure engineering and maintenance and the allocation of accountability and responsibility for engineering and maintenance decisions and actions. It assures that facilities and infrastructure conform to specified engineering standards.

Certification and verification is achieved through formal confirmation that the engineering processes undertaken in the design, construction and/or maintenance of the system or equipment are affirmed as having been correctly undertaken and adequately supervised by competent personnel.

All facilities and infrastructure are to be certified as fit for service, safe and environmentally compliant prior to their acceptance into service and ongoing use within Defence.

## **6.2 Conflicts between Regulations and Standards and Defence Requirements**

There are three prime principles for addressing any conflicting requirements as outlined below:

- a) Where a statutory standard conflicts with this manual, the matter must be referred to DEEP for resolution. DEEP will advise the need for a formal Alternate Methods and Design submission as outlined below.
- b) Where a statutory standard conflicts with a Defence standard, the matter must be referred to the relevant Defence Technical Authority through DEEP for resolution.
- c) Statutory requirements or standards that conflict must be referred to the appropriate regulatory authority for resolution, with an information copy to DEEP.

Conflicting requirements shall be fully documented by the designer or contractor and shall contain a proposed course of action suitably argued with compensating factors clearly identified. Formal written Defence approval of any alternative method and design proposal must be obtained at the earliest stage possible in accordance with the Alternative Methods and Designs approval process provided at paragraph 6.5 – Alternative Methods and Designs. All regulatory advice and approvals including Defence approval shall be included in the design report, project files and the operation and maintenance documentation and manuals.

## **6.3 Certification**

Certification provides formal confirmation that the engineering or maintenance processes undertaken in the design and/or maintenance are affirmed as being correctly undertaken, and

adequately supervised by competent and proficient personnel. The elements of certification are determined, agreed and documented at the earliest stages of a project. Within facilities and infrastructure, certification is provided to:

- a) designs;
- b) construction, after commissioning; and
- c) after completion of a maintenance or modification activity.

### **6.3.1 Design and Construction Certification**

Design certification is provided by the responsible designer to confirm that specified requirements have been met by the design agency. The certification must establish the responsibility for the quality of the design, and provide a warrant to the effect that the design meets the defined requirements as reflected by the *standards and regulations*, specification and, as appropriate, the contract or agreement. All facilities and infrastructure are to be certified as meeting the electrical engineering requirements detailed in this manual, fit for service, safe and environmentally compliant prior to their initial and ongoing use within Defence.

The method of certification may vary depending on the size and circumstances of the design effort. Certification may involve a number of signatories and may be provided in stages to enable the release of the facilities and infrastructure. Such interim certifications must show full compliance with the *regulations and standards* and establish a baseline for the necessary maintenance and user documentation upon which interim release can be based.

Final certification, or construction certification is provided after the test and evaluation activities have provided the appropriate level of confidence that the constructed solution derived from the approved design is verified against the specifications and traceable back to the endorsed user requirements in the FDB. These include compliance with mandatory *standards and regulations*.

#### **6.3.1.1 Consultant and Sub-Consultant Design Certificate**

Defence contracts require the designer to provide Consultant Design Certificates or Sub-Consultant Design Certificate, whichever appropriate, to certify that (refer to the contracts for the actual definitions):

- a) The design documentation complies with the requirements of the Contract and all statutory requirements; and
- b) The works comply with the design documentation.

Statutory requirements are defined as:

- a) any law applicable to the carrying out of the services, including Acts, ordinances, regulation, by-laws and other subordinate legislation;
- b) Approvals (including any conditions or requirements under them);
- c) Defence Requirements; and

d) Environmental Requirements

Defence Requirements include all policies, plans, manuals, guidelines, instructions (including departmental procurement policy instructions) and other Commonwealth or Department of Defence requirements which are, or may become, available to the Site, the Works or the Services.

### **6.3.2 Maintenance or Modification Certification**

*Standards and Regulations* require certification of the appropriate completion of maintenance and modification activity. Maintenance and modification are to be conducted in accordance with procedures and schedules promulgated in authorised technical instructions and the *Standards and Regulations*. At the completion of maintenance or modification actions, the tradesperson responsible for the task is to certify task completion. Records of certification are subsequently retained in the maintenance management system.

Maintenance certification may be subject to regular and ongoing technical inspection in accordance with advised programs, criteria and intervals as required by this manual or the *standards and regulation* to maintain technical integrity.

#### **6.3.2.1 Comprehensive Maintenance Services (CMS) Certification**

The maintenance agent is required to provide routine (normally monthly) compliance certificates certifying that all statutory requirements have been undertaken. The CMS contractor must also provide or attain design certificates in accordance with paragraph 6.3.1.1 Consultant and Sub-Consultant Design Certificate above when undertaking new construction or refurbishment works.

### **6.3.3 Certification of Electrical Installations**

Without limitation, and as required by the respective electrical regulations, all electrical work shall be certified by the licensed electrical contractor. This is achieved through the issue of Electrical Safety Certificates or similar (depending on the State/Territory) as required by the respective Regulatory Authority.

Where required by the regulations and standards, this shall also include all relevant equipment certifications.

In addition, the electrical contractor shall certify that the installation has been completed in accordance with the requirements of project electrical design drawings and specifications.

#### **6.3.3.1 High Voltage Systems**

Accredited Auditors Certification for the purposes of this policy is meant to include all certification or inspections required by regulations, such as the requirement for High Voltage work in Queensland to be inspected by an accredited auditor registered under the Register of Professional Engineers Queensland (RPEQ).

Accredited Auditors Certification and verification must be completed before connection to electricity supply and energising the installation. All certification, compliance and verification documents must be provided in the Operations and Maintenance manuals and the High Voltage Compliance Statement provided to DEEP.

### **6.3.3.2 Hazardous Area and Explosives Area**

The designer is to certify all electrical installations in hazardous areas and explosives areas in accordance with the applicable regulations and standards the Defence Explosive Ordnance licensing agencies requirements.

Certification involves all statutory obligations as required by the regulations such as the Notification of Electrical Works/Certificate of Electrical Safety or equivalent and accredited certifier's certificates where required. Accredited certifiers certification for the purposes of this publication is meant to include all certification or inspections required by regulations such as the requirement for hazardous area prescribed work to be inspected by suitable inspector for example in Victoria and by an accredited auditor for example in Queensland.

Certification must be completed before connection to electricity supply and energising the installation. All certification documents must be provided in the verification dossier.

#### **6.3.3.2.1 Equipment Certification**

All electrical equipment installed in hazardous areas and explosives area must have suitable AS/NZEx/IECEx classification. All certification should be carried out by the equipment manufacturers and all items must be properly labelled. Ensure overhaul and repair of electrical equipment used in hazardous and explosives areas is in accordance with AS/NZS 3800. Any non-complying equipment in an area being altered or refurbished should be replaced.

## **6.4 Verification**

Verification is the process of adequately documenting and demonstrating compliance. Verification is in addition to the certification described above and comprises various elements such as compliance reports, verification reports and design reports in accordance with the IM Design Management process. These are further described below.

### **6.4.1 Manual of Infrastructure Engineering Electrical Compliance Report**

Manual of Infrastructure Engineering (MIEE) compliance report is provided to supplement design report submissions. Its purpose is to clearly demonstrate compliance to this manual and to the *Regulations and Standards* or any departure from these. The MIEE Compliance Report template is provided at Appendix A.

The MIEE Compliance Report is to be provided with every Design Report submission, including the final design report.

## **6.4.2 Compliance Statements**

At the completion of works involving:

- a) high voltage and power generation installations; and/or
- b) hazardous area and explosive area installations.

The designer must provide a Compliance Statement in accordance with the requirements outlined hereafter.

The Compliance Statement is to be in the form of a minute as outlined at Annex A identifying the particulars of the installation and confirming that the installation has been thoroughly inspected, tested and verified. The minute must be suitably endorsed by the designer and must identify any exceptions and the course of corrective action.

The Designer shall verify in the Compliance Statement that the design and construction meets all statutory requirements, the requirements of the FDB and this manual. The Designer shall also confirm that the system has been fully commissioned and is functioning correctly, that all required training is complete and that the required manuals and documentation have been provided and verified for suitability.

The Compliance Statement must be completed for all new works or any alteration or addition to an existing installation.

### **6.4.2.1 HV Compliance Statement**

The designer is to provide written confirmation in the form of a Compliance Statement for all high voltage electrical installations. The report is to certify that the installation has met the requirements of the applicable regulations and standards and this manual. Requirements for the HV Compliance Statement are provided at Appendix A.

### **6.4.2.2 Hazardous Area and Explosives Area Compliance Statement**

In addition to any statutory requirements, provide a Defence Hazardous Area/Explosives Area Electrical Compliance Statement, prepared by the designer (or electrical contractor where minor and no designer is involved), covering the electrical installation works. The requirements for Hazardous Area and Explosives Area Compliance Statement are outlined at Appendix A.

#### **6.4.2.2.1 Hazardous Area and Explosives Area Verification Dossier**

A Verification Dossier fully describing the installation and the nature and extent of the hazardous areas must be provided and must make note of any special requirements or limitations in use of the facility. The verification dossier shall be in accordance with AS 2381.1 and shall be provided in suitable digital format for inclusion in the operating and maintenance manuals for the facility and also DEMS-FM. Verification dossier must also be maintained on site with the person in charge of the facility.

Where an existing hazardous area electrical installation is modified the designer shall ensure that the facility meets the above requirements and where necessary develops an up to date verification dossier in accordance with AS 2381.1.

#### **6.4.3 General Electrical Works Verification**

Testing and verification shall include all mandatory and optional tests as identified by AS/NZS 3000 and other relevant standards such as AS/NZS 2381.1. AS/NZS 3017 provides a description of the methods of carrying out inspections and testing for general electrical installations.

The designer must ensure that a copy of all required equipment certificates and safety certificates (e.g. "Electrical Safety Certificate, Notification of Electrical Works" or similar) are provided and that these are included in the documentation handed over to the Region for inclusion on DEMS-FM. To facilitate inclusion on DEMS-FM all documentation should be in a suitable electronic format.

Any tests and/or verifications stipulated in the applicable Australian Standards as optional shall be deemed to be mandatory.

### **6.5 Alternative Methods and Designs**

This manual details the minimum requirements for electrical installations and infrastructure. There are a number of reasons why a project may find it difficult to implement all requirements and under certain circumstances it may be unnecessary or impractical to comply with the full requirements of this manual. Any alternative methods and designs that do not comply with the specific policy requirements of this manual, but give equivalent results to those specified, are not necessarily prohibited. Requests for Technical Authority approval of alternate methods and design must be supported by appropriate tests, solutions or other supporting evidence to ensure that the proposal still affords an equivalent level of safety, functionality and reliability.

The Defence alternative methods and designs approval process does not replace or supersede any statutory requirements that must also be satisfied. This process is primarily intended to address the additional Defence engineering and functional requirements specified herein.

#### **6.5.1 AS/NZS 3000 Wiring Rules Alternate Methods and Designs**

AS/NZS 3000 specifies at clause 1.9 the means for demonstrating compliance. Where electrical installations, due to their unusual requirements, cannot meet the relevant requirements of Part 2 of AS/NZS 3000, compliance by specific design is permitted for Defence electrical installations. The Assistant Secretary Estate Policy and Environment (ASEPE) is the only authorised Defence authority to endorse formal letters of acknowledgement as required by the standard, for fixed electrical installations. Such letters of acknowledgement are to be supported by a suitable Alternative Methods and Designs Proposals as detailed below.

### **6.5.2 Approval of Alternative Methods and Designs Proposals**

Areas of a project that would not comply with the requirements of this manual or would seek to utilise alternatives would normally be identified at the Functional Design Brief (FDB) or initial design stages of a project.

Formal written Defence approval of the alternative must be obtained as early as possible in the design stage. The formal process would normally commence with a Defence Project Officer or a design consultant employed by that officer, identifying an aspect of a proposed project, that, for reasons identified earlier, form the basis of the alternative proposed to those prescriptive requirements of this manual.

The Project Director should then forward a formal request for alternative methods and designs to ASEPE for approval, through the Director of Estate Engineering Policy (DEEP). ASEPE has the responsibility as Technical Authority and for managing the provision of Electrical Engineering Policy for Defence. ASEPE would seek a technical assessment and recommendation from DEEP and either approve or reject the alternative proposal.

The request for alternative methods and designs should take the form of a minute, with provision for the various levels of review, recommendation and approval. The minute should be staffed through DEEP to ASEPE and it shall clearly identify:

- a) the alternative proposed (with specific reference to the appropriate section of the compliance document);
- b) the reason for the alternative proposal;
- c) technical assessment of the request including suitable argument of the compensating factors and the deem to satisfy provisions; and
- d) cost implications, where relevant, by comparison of the initial and through life costs.

Copies of the design report and any technical opinions or reports sought should be enclosed with the minute. The design consultant should provide sufficient detail to allow the Project Officer to complete the request and should include a certification statement to accompany the request.

Copies of finalised requests (approved or disapproved) shall be forwarded to the design consultant and Project Officer/Project Director. The original request should be held on the Defence project file.

A sample request for dispensation is provided at Appendix B.

# 7 Design Requirements

## 7.1 Design Process

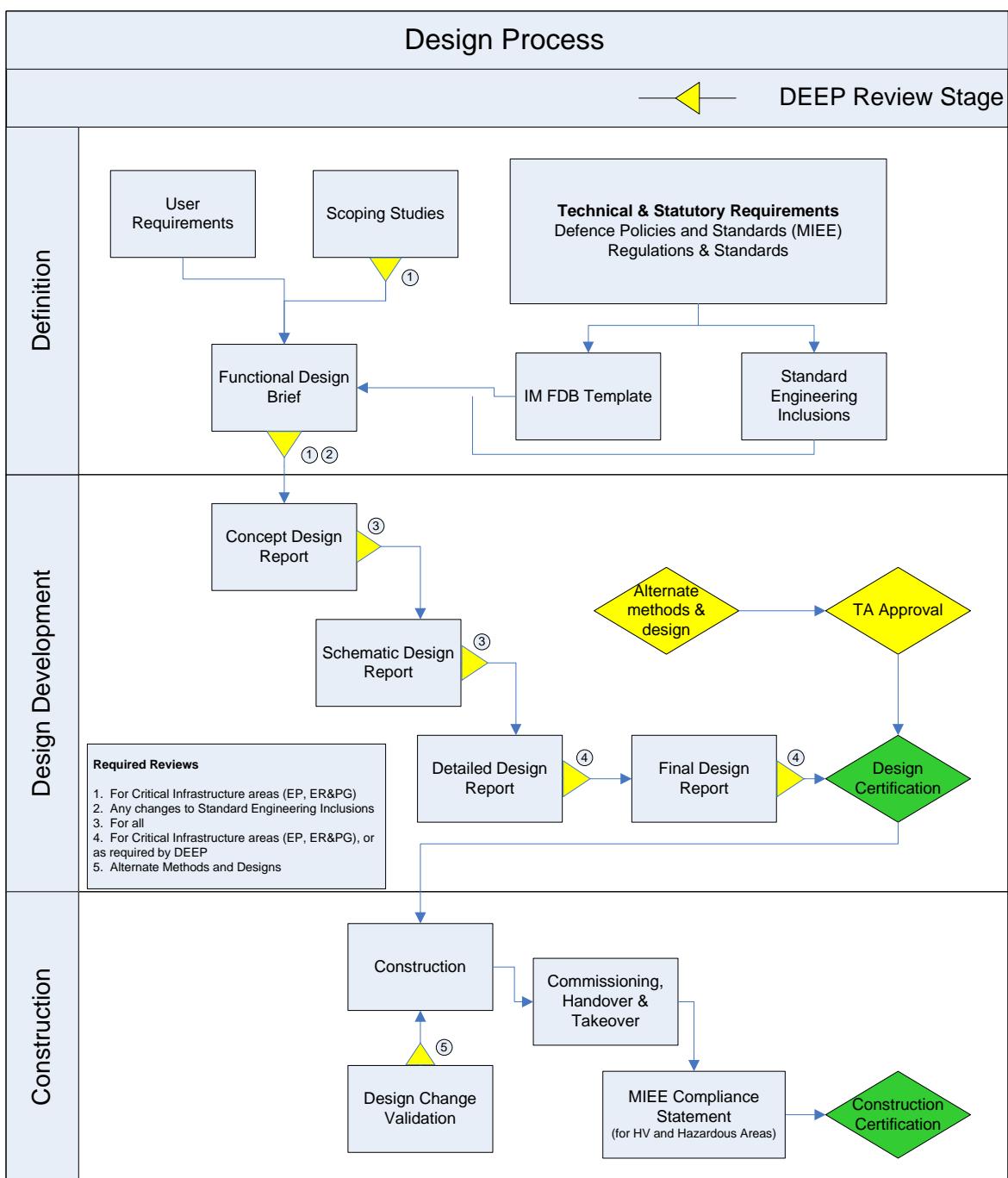
The most suitable solution for any single project will depend on the particular requirements and use of the facility. It is not intended that designers would follow any of the example or previous installations absolutely, but rather that they would use their judgement, experience, knowledge and local conditions as a guide during design to suit the particular installation requirements.

The design shall be undertaken in accordance with the IM *Design Management* process and must provide a compliant system that includes meeting the design requirements as detailed in this manual, those additional requirements specified in the FDB and any other requirement of applicable regulations and standards. The design process is depicted at Figure 7.1 below. The design shall also consider:

- a) the economics of the design;
- b) the availability of proven technology;
- c) the integration and compatibility with existing equipment, and
- d) equipment and installation compliance.

Designs shall be performance based and shall be engineered to include equipment and materials complying with the appropriate standards. Unless under special circumstances, equipment and materials shall not be specified by make and model number but shall be selected on the basis of their performance, suitability, maintainability and cost effectiveness. Any proposal to specify equipment by make and model shall be formally documented for approval by relevant Defence Project Director.

Prior to undertaking the design, the designer shall prepare a detailed design plan. During the design, it shall be regularly updated to reflect any changes. The design plan shall conform to the requirements of the designers' Quality Manual but shall also incorporate Defence requirements. Refer to Appendix A for the minimum required content of the design plan.



#### ■ Figure 7.1: Design Process

## 7.2 Requirements of the Designer

The Design Consultant (called designer hereafter) is responsible for complying with the requirements of this manual, the additional requirements outlined in the FDB and the requirements of the *regulations and standards*. This responsibility encompasses designing the installation and specifying equipment to meet the required standards and also verifying that the installation, when

completed, complies with the design (refer to Chapter 8 – Construction Requirements and Project Controls in this manual) for commissioning requirements.

The designer must ensure that the design adequately addresses the user requirements and that the identified procedures and activities can be undertaken safely and reliably in the facility. The design of the electrical installation shall achieve the following design objectives:

- a) safety and reliability
- b) properly designed and appropriately sized to allow the full and proper functioning of all equipment, plant and fittings
- c) facilitates the operational requirements of the specific equipment, materials, processes and functions in the building or facility
- d) sized with adequate capacity for expansion
- e) arranged and routed in an organised and systematic manner and be accessible for operations and maintenance
- f) provided with necessary flexibility and versatility to allow isolation, shutdown and removal of equipment and systems as required for maintenance and extension
- g) compatibility with existing services and systems on the establishment and in the facility
- h) labelled and colour coded for ease of identification and operation, to suit semi-skilled operation
- i) compatibility with the electricity distribution system both Defence on-Base and Network Service Provider (NSP) distribution
- j) meet the design and functional requirements of the Defence functional design brief and also in be in accordance with DSG local and central requirements
- k) designed and installed to all relevant legislation, standards, codes and guidance that are appropriate and relevant to the type of electrical installation or equipment

The designer shall also follow the principles and guidance provided in HB 300 *Electrical Installations Guide to Using the Wiring Rules* and HB 301 *Electrical Installations Designing to the Wiring Rules*. The electrical installation shall be documented in the format of these handbooks, or similar suitable format, for future reference or design changes if required.

In addition to the requirement for design documentation such as specifications and drawings, the designer must provide design reports as outlined in the IM *Design Management* process and any other technical investigations or reports as detailed in the FDB. Further guidance on design reports requirements specific to this manual are provided in paragraph 7.4 – Design Reporting Requirements below.

### **7.2.1 Hazardous Area and Explosives Area Installations.**

The designer shall follow the principles and guidance provided in HB 13 *Electrical Equipment for Hazardous Areas*. The designer must also assist with the correct classification of the hazardous and

explosives areas and be responsible for ensuring the installation is certified and verified in accordance with the requirements of this manual.

### **7.2.2 Feasibility Assessment, Financial Assessment & Technical Investigations**

When required by the FDB or by this manual, designers shall be responsible for undertaking cost benefit studies to determine viability, detailed technical investigations of identified problems and for making recommendations on solutions to new requirements or particular activities or processes. The resulting reports shall be included in the Design Report or as a separate report.

## **7.3 Functional Design Brief (FDB)**

The FDB must be developed in accordance with the IM *Design Management* process. In summary, the FDB template from the IM is the starting point and is combined with the user requirements, scoping studies, specific project requirements and the relevant elements from the Electrical Standard Engineering Inclusions to form the project FDB. Refer to Figure 7.1 above which depicts the design process.

The following additional requirements shall be included in the FDB:

- a) Electrical Standard Engineering Inclusions at Appendix C, tailored to suit the specific project requirements;
- b) General site and service conditions data, taking into account data from the Bureau of Meteorology and any special site requirements;
- c) Findings and subsequent requirements due to a Threat Assessment Analysis and Post-Disaster Functionality requirements;
- d) The requirements for passive defence measures or investigations;
- e) The various options available (or not available) for configuration and/or equipment;
- f) Facility functional requirements;
- g) Details of any investigations to be carried out as part of the design process;
- h) Any specific requirements for the installation including any regional requirements;
- i) Any additional processes which must be followed as part of the design; and
- j) Reference to any relevant studies, Master Planning documentation, or other reference documentation.

### **7.3.1 Standard Engineering Inclusions**

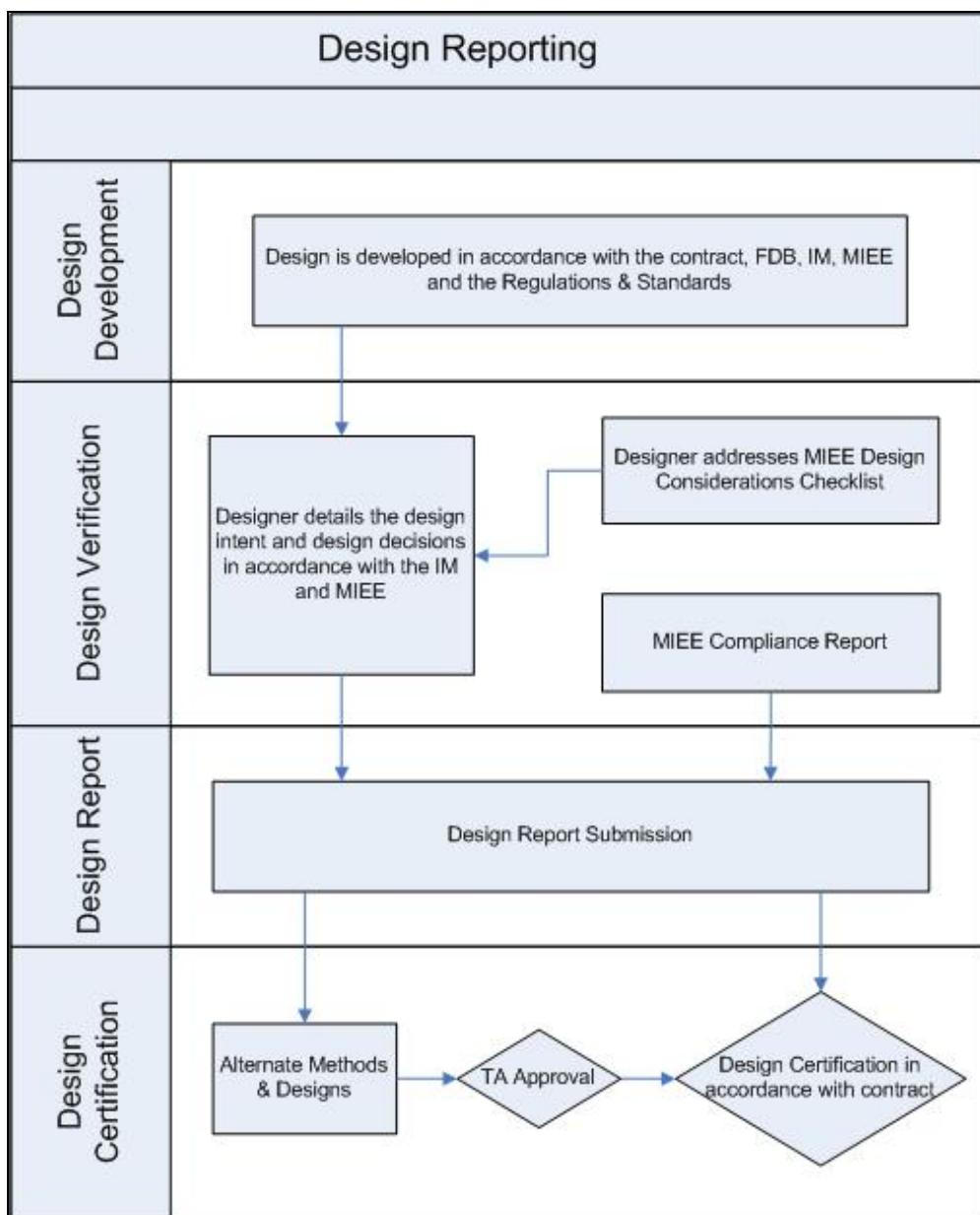
The Electrical Standard Engineering Inclusions are provided at Appendix C. The Standard Engineering Inclusions are to be tailored to the specific project and included in the project FDB. Any modifications to the requirements to the Electrical Standard Engineering Inclusions required DEEP agreement as part of the FDB review process.

### **7.3.2 Justification of Emergency Power Installations**

Emergency power installations (i.e. CEPS, LEG and UPS) shall only proceed if their respective sponsors have successfully argued for their justification. The sponsor shall also detail the loads or portions of the building to be supported by LEG/UPS, as well as the equipment requirements and/or other special requirements that shall be incorporated or referenced in the functional design brief for the project. Guidance on the justification process and the associated risk assessment is included in the respective policy Chapter; refer to Chapters 20 – Uninterruptible Power Systems (UPS) and 21 – Local Emergency Generator (LEG) Requirements.

## **7.4 Design Reporting Requirements**

The design report requirements are provided in the IM Design Management process and Chapter 4 – Documentation Standards of this manual. The Design Report shall include commentary on the design considerations and include a MIEE Compliance Report as detailed in Chapter 6 – Certification and Verification and Appendix A. An overview of the design report process is depicted at Figure 7.2 below.



■ **Figure 7.2: Design Reporting**

The designer shall, in the design report, identify all standards and legislation, including Defence policy, standards and guidance, adopted together with clear indication of the extent and field of application. The designer shall certify in the design report that the design meets these requirements and the requirements of the brief. Where the design deviates from any of the above requirements, the designer shall provide fully justified submissions in the design report for Defence agreement in accordance with the alternate methods and designs at Chapter 6 – Certification and Verification.

#### **7.4.1 Design Considerations and Compliance Checklists**

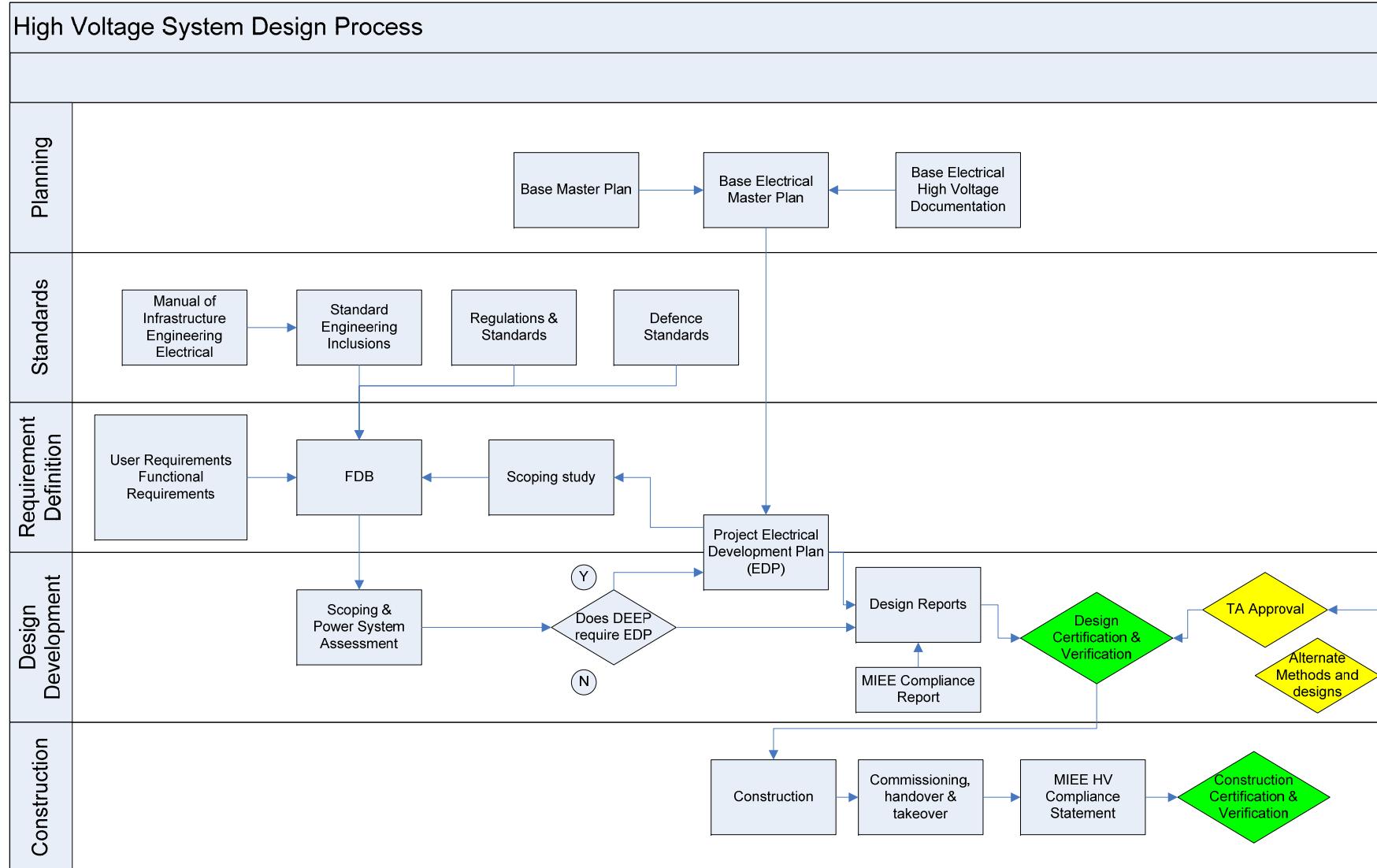
Provided at Annex A are Defence design considerations which are a checklist of items that require consideration during the design phase. The designer shall ensure that, in addition to demonstrating in the design report that the design has met all applicable requirements, that all elements of the checklists have been adequately addressed and documented in the design report.

#### **7.4.2 Electrical Reticulation Works**

It is important that the designer assess the implications of new works or additional load on the electrical infrastructure network and document the finding of the assessment in the design report for agreement.

The power supply assessment must include the NSP feeders to the establishment and the on-base electrical infrastructure. This also includes any impact on Defence electricity retail contracts or the NSP connection agreements.

It is important that this be done as early as possible so that DEEP can determine the need for a project High Voltage Development Plan in accordance with Chapter 3—and provide agreement to the proposed electrical reticulation system augmentations and avoid project delays. The design process for high voltage systems is outlined in Figure 7.3 below.



■ **Figure 7.3: High Voltage System Design Process**

# **8 Construction Requirements and Project Controls**

## **8.1 Construction**

The designer shall acquaint himself with the Base or establishment reticulation system procedures for access and operating requirements and make all necessary allowances in the design. In particular the designer must ensure that appropriate requirements are included for the following:

- a) access permits, vicinity permits, dig permits, etc
- b) requirement for the contractor to have all necessary skills and training such as recipient training
- c) requirement for standard keying arrangements
- d) access to the high voltage systems including method of works and constraints in opening the high voltage system or any configurational changes effecting continuity of supply either directly or by subsequent fault
- e) required commissioning and acceptance procedures for new installations including the completion of all required tests and proving the system is safe to the requirements of the operating authority before connection
- f) requirement in certain States/Territories for certified inspections prior to connection

## **8.2 Procurement**

### **8.2.1 High Voltage Equipment**

High voltage switchgear is standardised at each Defence establishment. This high voltage switchgear standardisation must be maintained unless the designer has gained written approval to introduce a new standard for the Base from DEEP. Where a new standard is to be introduced it will be by suitable performance specification in accordance with paragraph 4.4.1 – Specification of Equipment and paragraph 4.8 – Requirements for Design Documents. Otherwise the switchgear must be specified by make and model to match the existing switchgear at the establishment, noting that the designer must consider the suitability of maintaining the existing switchgear standards as part of the design considerations.

### **8.2.2 Tender Assessment**

The designer must undertake detailed technical assessment of electrical tender submissions to confirm suitability and compliance and provide a detailed *Technical Assessment Report* where required by this manual and the FDB or as otherwise required by DEEP. The technical assessment report is a detail report which confirms compliance or otherwise to the specified requirements and provides through life assessment of the offered systems.

## **8.3 Inspections, Testing and Commissioning**

The designer must ensure that all tests and commissioning activities necessary to prove the safety and correct operation of the system are included in the specification. The designer must also participate in the testing and commissioning activities to ensure and confirm the design intent has been met and complete suitable certification, compliance reports and compliance statements for Defence at the end of the commissioning phase. Guidance on the certification verification requirements is given in Chapter 6 – Certification and Verification.

Testing will require full functional testing to prove performance. The designer must ensure all possible safeguards are put in place to protect systems and equipment as part of any such tests. Full functional tests are required for the following systems as a minimum:

- a) Power Factor Correction Systems. Harmonic analysis shall be undertaken as part of commissioning. The harmonic analysis must be undertaken in all operating modes and configurations including with other equipment such as UPS and LEG.
- b) Aircraft power supply systems and the connection to the aircraft. Precautions shall be put in place to prevent damage to the aircraft.
- c) Hazardous Area and Explosive Area Installations: Visual inspections should be carried out to check labelling, stopping plugs, guards, glands, seals, earthing, etc. and to check for equipment damage and illegal penetrations. A commissioning plan must be prepared by the electrical contractor and each item checked by the designer. HB13 provides guidance relevant to this process.
- d) Emergency power systems. Initial testing and commissioning shall ensure that the functionality of the LEG and that of the other emergency systems elements (e.g. UPS, air-conditioning and building services) are fully tested in all prospective operating and failure modes as a complete emergency system. Where appropriate, load banks and heat loads for the air-conditioning shall be used to replicate the actual connected load, to ensure the relevance of the test carried out and to prove that the LEG is able to supply the expected design load.
- e) Power Generation Systems. Full functional tests in all operating modes. Outages required during testing will need to be coordinated with the Base Services Manager.

Typically, the designer will also be responsible for periodic inspections of work in progress during the construction phase. In any case, the designer will be responsible for the integrity of the design and provide additional information and advice as required to assist the contractor in meeting the specification details.

### **8.3.1 Testing**

Testing shall be conducted in accordance with the relevant Australian, IEC, Defence or other appropriate standard and to the requirements of DSG.

Perform all necessary testing:

- a) At the factory for major items of plant and equipment;

- b) Factory Acceptance Testing of the Control System. For CEPS this shall include full functional simulation not just PLC forcing;
- c) Site Acceptance Testing of the emergency power system and CEPS; and
- d) At completion of individual systems or groups of systems.

At the minimum, the following testing shall be conducted:

- a) All tests required by AS/NZS 3000 and other required standards;
- b) Suitable performance measurements of all optical fibre communications cables;
- c) Earth resistance tests for HV & LV Requirements at each earth stake and of the entire interconnected system.
- d) Insulation and continuity testing for HV & LV Requirements.
- e) High voltage power frequency withstand for HV & LV Requirements.
- f) Correct operation of protection relays and other protective devices.
- g) Instrument configuration and calibration.
- h) Full functional tests.
- i) Full harmonic analysis for power factor correction installations including:
  - Measure & record the harmonic content of the three (3) phases and neutral with the all mains supplies. Measure at all critical locations including at the PFC with the PFC both online and off line to confirm suitable performance. This will become a point of comparison for the future harmonic analysis of the system.
  - Measure & record the harmonic content with the PFC equipment on and off line in all operating modes with the standby Generator and UPS (where applicable).
  - Measure & record the harmonic content of the PFC cabling and stepping through each capacitive stage.

Copies of the test records shall be incorporated in the Operations and Maintenance Manual.

### **8.3.2 Commissioning**

Perform commissioning to place the completed installation into service. The designer will need to ensure that an appropriate commissioning plan is provided, either by the designer or the Contractor, to ensure that the system is adequately proven with minimum disruption to the Base or establishment operations.

Commissioning shall verify the correct operation of the entire installation against the project requirements. Commissioning shall be undertaken in accordance with the IM *Commissioning and Handover* process. The IM Commissioning and Handover policy defines the processes to be undertaken for commissioning and the level of consultation and communication that must occur. The Designer will not deviate from this process unless prior Defence approval has been provided.

Where required by the other Defence Technical Authorities, there shall be adequate tests to confirm compliance with their nominated standards. Consult with the Technical Authority to arrange as the appropriate commissioning.

### **8.3.2.1 Checklist for Commissioning & Verification**

Review the following checklist prior to sign-off of works as complete:

- a) Correct functioning equipment and systems, fully proven in all operating modes
- b) Suitable indication and control
- c) Correct performance of both individual systems and total installation, full functional tests
- d) Compliance with this manual, regulation & standards and NSP requirements
- e) All tests have been undertaken to prove safety
- f) Signage and labelling complete
- g) All required training complete
- h) Operation & Maintenance Manuals and as constructed information verified as complete
- i) MIEE Compliance Statement has been provided where required by the MIEE

## **8.4 Handover**

### **8.4.1 High Voltage Systems**

In addition to the IM handover requirements, the following applies.

Before the Network Controller can accept any new equipment for connection to the high voltage system the following minimum requirements shall be achieved:

- a) All required tests have been undertaken and are provided to the Network Controller such as, but not limited to earth mat resistance tests, high voltage withstand tests, secondary injection tests and polarity tests;
- b) All necessary compliance certificates are provided;
- c) All switchgear and equipment is correctly labelled and that the new labels for the existing reticulation are ready for change or changed as required by the Network Controller;
- d) All required safety equipment is provided, including all signs and barriers;
- e) Operator training has been conducted to the level that the operators are qualified to operate the installation;
- f) All appropriate operating and maintenance information is provided;
- g) Revised documentation, acceptable to the Network controller reflecting the new system arrangement; and
- h) Certification has been received that the new installation meets the requirements of all appropriate legislation and standards and the requirements of the FDB.

The Network Controller has the right to refuse any connection where in his opinion it could compromise safety or the above requirements have not been met. Failure to achieve the above may result in the Network Controller abandoning the commissioning process and not connecting the new equipment.

The designer must ensure that the specification includes the above requirements and any additional Network Controller requirements. Any limitation on the contractor's part is not the responsibility of the Network Controller. It is imperative that contractors with suitable experience in high voltage installation works be selected and the designer should ensure that the specifications adequately address this matter

## **8.5 Spare Parts**

The Designer shall assess the need for key or essential spares to meet the requirements of the installation based upon:

- a) The consequences of failure of the particular item of equipment; and
- b) The location of the site with respect to availability of spares and service.

Provide all necessary spare parts as determined above.

## **8.6 High Voltage System Outages**

The staging of the works shall ensure that where the high voltage system is opened, that the duration of the outage is as short as practical. Under no circumstances shall the reticulation system be left with an open ring, or unmovable open point, for greater than three days and all such works require prior approval from the Base Commander and Regional Manager.

The Network Controller has the right to refuse any connection where in his opinion it could compromise safety. The designer must ensure that the specification includes appropriate requirements and any additional Network Controller requirements.

## **8.7 Installation, Operating and Maintenance Manuals**

Provide comprehensive Operations and Maintenance Manuals so as to enable efficient operation and maintenance of the installation in accordance with Chapter 4— Documentation Standards. The manuals shall be provided in both electronic and paper formats. The electronic format shall be suitable for inclusion on DEMS-FM; the paper format shall be suitable for the work environment with all pages in plastic sleeves or similar.

## **8.8 Software**

All programmable controllers shall be supplied with licensed programming software and soft copies of the final installed site specific code.

## **8.9 Training**

Immediately following the completion or as part of commissioning of the installation, the users and maintainers are to be fully trained in the nature, extent and use of the systems. Training is to include any special precautions and operational procedures in the location and operation of user equipment.

Training should also be provided in the ongoing maintenance of the systems. CMS and, where appropriate, the user's nominated maintenance personnel are to be trained.

## **8.10 Post Occupancy Adjustment**

Prior to completion of the project, nearing the end of defects liability, the Designer may be required to review the performance of the electrical system and controls and arrange for all necessary adjustments. The FDB will identify when this is required.

The designer when undertaking this task must liaise with the users and the local regional staff to determine the need to optimise the installation performance. Guidance on how to implement the changes will be given by the respective Project Director on a project by project basis.

## **9 Reserved**

# **10 General Technical Requirements**

## **10.1 Introduction**

Electrical installations in Defence establishments and in Defence leased premises shall conform to the requirements of all applicable legislation, codes of practice and guidance documents relevant to the State or Territory where the installation or facility is located.

Electrical installations must also comply with the requirements of AS/NZS 3000 and applicable Industry Regulator requirements and the Local Network Service Provider (NSP) requirements such as the Service and Installation Rules or equivalent.

Furthermore, electrical installations and equipment shall comply with all appropriate and relevant Australian standards, for the type of installation or equipment to be used, irrespective of their status. Where Australian standards are not available, recognised international or overseas national standards shall be used where they are relevant to the type of installation or equipment and to the installation conditions in Australia.

Designs shall be selected, after comparing all design options available, using the most cost effective design solution that will meet the requirements of this manual, the user requirements, those specific requirements to the establishment or facility and the Regulations and Standards. Designs shall be performance based and shall be engineered to include equipment and materials complying with the appropriate standards considering current and future use, particularly if and when any major refurbishment or change in use is contemplated.

The works shall use the cost effective solution that will meet the requirements of this manual, the FDB and those specific to the establishment or facility identified by the DSG regional office.

## **10.2 Design Life**

All equipment shall be designed and installed to operate continuously at full load for 24 hours per day, 7 days per week at the extremes of temperature, humidity and environmental conditions (e.g. corrosive atmospheres) applicable for the installation location with a realistic economic life of:

- a) 50 years for electrical equipment/systems and building elements;
- b) 15 years for converters and other electronic equipment/systems;
- c) 5 to 10 years for batteries depending on their type and application.

without the need for excessive maintenance regimes.

Maintenance of the electrical systems shall be in accordance with the relevant standards such as AS 2467 and the manufacturers recommendations.

### **10.2.1 Corrosion Protection**

All equipment and fixings shall be selected and installed so that it is suitable for the corrosive effect of the environment in which it is installed. The equipment shall give an economic service life of at least 50 years without excessive maintenance

## **10.3 Equipment Selection**

### **10.3.1 Standardisation**

Electrical equipment shall, as far as practicable, be standardised on a site-by-site basis to:

- a) Maximise interchangeability;
- b) Minimise necessary spare holdings; and
- c) Maintain any existing standards wherever appropriate.

Standardised electrical reticulation systems are to be adopted to allow the application of consistent design and operating practices across each Defence establishment and, where appropriate, across a Defence Region. Consideration of the locally available equipment and support from outside organisations such as the local NSP is important when establishing standardised arrangements and equipment.

The DSG region will provide the current standard equipment requirements for each establishment. This will entail a particular switchgear type, mainly high voltage and transformer characteristics. The designer when arranging for a new, or augmenting an existing substation, is to ensure this equipment is current and adequately supported. Where current standard equipment becomes discontinued, obsolescent or is no longer considered cost effective, new standard equipment is to be arranged for the establishment. DEEP agreement is required before changing or when establishing appropriate substation requirements.

New standard equipment is to be provided for the establishment/Region through an appropriate performance specification with the selected equipment becoming the standard equipment for that establishment/Region from that point onwards. Performance specifications are to be referred to DEEP for comment prior to issue for tender and the selected equipment is to be reviewed by DEEP prior to placing an order. Design reports, Tender Evaluation Board reports and technical evaluation reports are to be used for this purpose.

### **10.3.2 Supportability**

All equipment shall be selected from product ranges that are current and likely to be supported well into the future. Product ranges that are dated or likely to be at the end of the product cycle shall be avoided.

All equipment shall be readily and adequately supported in Australia and preferably in the local region. Adequate spares for important equipment shall be available in Australia and all equipment shall be fully supported by the equipment manufacturers and suppliers.

Generating sets shall only be sourced from manufacturers with prominent factory support within Australia and preferably within the region where the sets are installed. The set shall be of a model with a large installed user base in the local region.

For major equipment, a Statement of Supportability shall be obtained from the Supplier addressing their commitment to support the equipment through the prospective life of the equipment and equipment guarantees/warranties. This Statement of Supportability is to be assessed as part of the tender assessment and is to be included in the operation and maintenance manuals.

### **10.3.3 Maintainability**

Electrical installations and plant room layouts shall allow for appropriate and easy access for the purpose of operations, maintenance, repair, and replacement of major components.

Consider the maintenance requirements when determining the most appropriate equipment performance specifications and electrical system arrangement. This shall be based on the required performance, maintenance, reliability and the availability of comprehensive manufacturer's product support locally.

The designer shall assess the need for key or essential spares to meet the required availability and shall also include the requirement for the supplier to nominate essential recommended spares. These key spares shall be provided as part of the installation contract and shall be provided to the Comprehensive Maintenance Services (CMS) but remain the property of Defence.

## **10.4 Safety**

The Designer shall acquaint himself with the Site procedures for access and operating requirements and make all necessary allowances in the design. In particular, ensure that appropriate requirements are included as required by Chapter 8 –Construction Requirements and Project Controls.

### **10.4.1 Step and Touch Potential**

Earthing systems shall be provided at all high voltage power stations, substations and switching stations. The design of the earthing system shall ensure that step and touch potentials inside and surrounding the installation are kept within safe limits for all prospective faults. Refer to Chapter 26 – High and Low Voltage Distribution System Requirements.

The design of metallic service connections and adjacent metallic structures shall incorporate electrical isolation or other measures to prevent dangerous potentials being transferred to other locations.

### **10.4.2 Equipment Safety**

All items of equipment shall inherently be designed and installed for safety of operation and the plant layout shall be designed such that the plant may be operated in a safe manner.

Guards shall be provided for protecting personnel against exposed moving parts, hot surfaces and dangerous voltages. Guards shall be removable for maintenance access.

#### **10.4.3 Personnel Safety**

All switchboards and equipment shall be metal enclosed dead front type so as to increase operator safety. All exposed metalwork shall be bonded to earth via appropriate methods and it shall not be possible to access or come in contact with live conductors without removing guards or other barriers.

All Contractor personnel shall be inducted with any applicable OH&S procedures and be experienced with the equipment being utilised.

#### **10.4.4 Fire Safety**

Particular attention shall be paid to fire safety and the potential spread of fire shall be inhibited by sealing off all openings and penetrations using appropriate materials and methods at the completion of the erection phase.

### **10.5 Labelling and Signage**

Provide all necessary signage as required by any Codes and/or legislation to ensure safety. Labels shall be provided on equipment to:

- a) Advise of safety hazards;
- b) Act as an aid to prevent mis-operation of equipment, and
- c) Act as an aid to identification.

Generally unless otherwise agreed, all equipment shall be labelled using engraved laminated plastic labels, which are clearly visible after the installation of all equipment and wiring. This shall not preclude the use of other systems tailored for specific applications that provide an equivalent functionality and durability.

General equipment labels shall be black lettering on white background. Warning labels shall be white lettering on red background. Engraving on labels shall be of minimum height 6 mm unless otherwise approved. Fixing shall be permanent. Do not fix labels to removable duct covers.

Refer to AS/NZS 2381.1 for requirements relating to identification of equipment certification in hazardous areas.

#### **10.5.1 Equipment Labelling**

Control Panels and other equipment shall be labelled such that it is clear as to which system the panel controls relate to. Where necessary, include suitable short form operating instructions shall be provided on the front of equipment in the form of an etched panel or durable laminated sheet.

### **10.5.2 Pipework**

All pipework systems shall be labelled as to the fluid contained within and the direction of flow.

### **10.5.3 Plant Rooms**

All electrical plant rooms shall be labelled clearly so as to identify it as a plant room and also clearly designate the name or type of plant room as per the documentation.

### **10.5.4 LV Switchboards**

Switchboards shall be labelled in accordance with Chapter 11 – Low Voltage Distribution Pillars and Switchboards Labelling and Numbering.

Existing framed copies of the SLD shall be replaced with amended drawings.

### **10.5.5 RCD Labelling**

All socket outlets are to be suitably labelled to show the circuit designation and distribution switchboard supplied from for resetting purposes. In addition, each socket outlet protected by a RCD shall be adequately labelled (e.g. RCD-PROTECTED) to identify that it is provided with RCD protection.

Labels shall be legible and indelible and shall be made either on the socket outlet or equipment itself or on a plate securely fixed on or immediately adjacent to the socket outlet or equipment. The marking shall be sufficiently durable for the intended purpose and location where it will not lead to deterioration of the marking. Metallic labels shall not readily touch live parts or bridge insulation if they become detached.

Socket outlet labelling may be standardised for an establishment or region. The Regional Manager (RM) will advise the designer of the standard labelling requirements, if they exist.

Socket outlets not provided with RCD protection, having a specific equipment function, are to be suitably labelled (e.g. TACAN EQUIPMENT ONLY) to show the intended use in addition to circuit designation and distribution switchboard labels.

Socket outlets protected by electrical separation are to be suitably labelled (e.g. ISOLATING TRANSFORMER PROTECTED).

### **10.5.6 Artificial Lighting**

All switches shall be suitably arranged to clearly identify the associated lighting controlled. Where this is not achievable or where switches are grouped suitable marking or signage shall be provided to clearly indicate the area controlled. The control shall be arranged to suit semi skilled operation by the building occupants.

For complex arrangements provide an anodised sheet metal drawing showing each light group and how the lighting corresponds to the switching or similar.

The labelling schedules shall be submitted for review for suitability prior to manufacture to the DSG region.

The fixing of labels shall be by means of escutcheon pins or non-corrosive tapped screws. Adhesive fixing may only be used when it can be demonstrated that the method is permanent.

### **10.5.7 Hazardous Area and Explosives Area Signage**

In addition to the requirements of the applicable standards and regulations, all facilities with hazardous areas or explosives areas are to be provided with a permanent, clearly legible, etched panel showing a 3 dimensional hazardous area zone plan, conditions relevant to the hazardous area classification certification, key dates and the applicable contact persons. Contact persons are to include the person in charge of the facility, the maintenance agent contact details.

The panel is to include the date of verification, and the date of re-verification in a manner which allows these dates to be updated without renewing the entire panel (use a separately fixed section). Include any limitations on the use of the facility and any important factors that may effect the certification of the installation and extent of hazardous areas.

Mount the etched panel in a suitable prominent location at the entry to the building or in an area readily visible by the users. Provide additional panels as required in larger or more complex buildings.

### **10.5.8 UPS labelling and Signage**

All UPS shall be labelled clearly so as to identify it with the designated name as per the systems drawings.

#### **10.5.8.1 UPS Socket Outlets**

Socket outlets and switches connected to critical circuits shall use blue plates where colour is used to mark socket outlets.

#### **10.5.8.2 UPS Equipment Labelling**

In addition to the descriptive marking of switchgear, control gear and the distribution boards, indelibly and conspicuously mark the UPS and critical power supply installation. Where colour is used for marking the critical parts of an installation the standard colour shall be blue. Where labels are prepared they shall be blue lettering on a white background.

#### **10.5.8.3 UPS Switchboards**

Critical switchboards shall be labelled in accordance with the Chapter 11 – Low Voltage Distribution Pillars and Switchboards Labelling and Numbering.

Framed single line diagrams defining the upstream isolation and downstream distribution of the critical supply associated with the UPS installation shall be provided in the UPS room. Any existing copies of the SLD shall be replaced with amended drawings as required.

All switchgear shall be clearly labelled to show the source of supply and the normal and emergency operating positions. In addition, transfer switches shall have short form operating instructions showing the required operating procedures and the correct operating positions clearly identifying the source of supply. The short form operating instructions shall be an engraved two colour laminated panel traffolyte or similar and shall be suitable fixed on or adjacent the transfer switch.

### **10.5.9 LEG Labelling and Signage**

#### **10.5.9.1 LEG Supported LV Switchboards**

Frame mounted as-installed single line diagram of the essential distribution system shall be suitably fixed on or adjacent to the LEG control panel. The single line diagram need not be provided where already adequately catered for as part of the main switchboard single line diagram. The single line diagram shall be laminated for durability and the size of the diagram shall ensure legibility.

Essential switchboards shall be labelled and numbered in accordance with Chapter 11 – Low Voltage Distribution Pillars and Switchboards Labelling and Numbering.

All switchgear shall be clearly labelled to show the source of supply and the normal and emergency operating positions. In addition, transfer switches shall have short form operating instructions showing the required operating procedures and the correct operating positions clearly identifying the sources of supply. The short form operating instructions shall be an engraved two colour laminated traffolyte or similar and suitably fixed on or adjacent the transfer switch.

#### **10.5.9.2 LEG Equipment Labelling**

In addition to the descriptive marking of switchgear, control gear and distribution boards, indelibly and conspicuously mark the essential installation. Where colour is used for marking the essential and critical parts of an installation, the standard colour shall be red for essential services and dark blue for critical services. Where labels are prepared they shall be red lettering on a white background for essential services and dark blue lettering on a white background for critical services.

#### **10.5.9.3 LEG Supported Socket Outlets**

Socket outlets and switches which are connected to essential circuits shall use red plates, where colour is used for these.

### **10.5.10 HV & LV System Labelling**

All substations shall be labelled clearly so as to identify it as a substation and also clearly designate the name of the substation as per the site HV single line diagram.

### **10.5.10.1 HV Cable Labelling**

Provide a durable plastic tag at each end of each HV cable that indicates:

- a) The cable source and destination.
- b) The cable size and construction.
- c) The date installed (new cables only).

The labels shall be a proprietary system with the lettering printed in black and letters at least 5 mm high. Hand written labels are not acceptable.

### **10.5.10.2 Substation Signage**

All substations shall be clearly identified externally with suitable substation designation signage and warning signs. Substation designation signage shall be consistent with the respective Base building signage showing the designated name of the substation as per the site HV single line diagram (e.g. Substation XX, Switching Station XX, Intake Switching Station).

Substations numbers shall be allocated as follows:

- a) New substation numbers shall be two digit numeric (e.g. 01, 02, etc) unless otherwise agreed in writing by DEEP. Existing establishments with alpha or alpha-numeric numbering can remain until major upgrade of the electrical reticulation system;
- b) For new substations the substation number will be provided by the respective DSG Region;
- c) For a substation rebuild or upgrading within the existing substation building, the existing substation number shall be retained;
- d) For the total replacement of a substation or immediately adjacent sites using the same form of construction (e.g. kiosk substation replacing kiosk substation), the existing substation number shall be retained;
- e) For a total replacement of substations on adjacent sites using different forms of construction (e.g. Indoor substation replacing a kiosk substation), a new substation number is required.

### **HV Switchboards**

HV switchgear in new substations and the adjacent substations are to be labelled, or relabelled as appropriate, in accordance with the Defence numbering philosophy. See Chapter 26 – High and Low Voltage Distribution System Requirements, which provides the numbering requirements for high voltage systems.

The High Voltage Mimic Panel (usually in the CEPS) is to be amended to incorporate any new substation/s. Existing framed copies of the SLD shall be replaced with amended drawings.

## **10.6 Electromagnetic Radiation (EMR)/Electromagnetic Compatibility (EMC)/Disturbances**

The Design shall consider and prevent the effects of EMR/EMC on the performance of equipment or adjacent areas so as to ensure that under normal operating or fault circumstances, the effects of EMR/EMC do not adversely affect operation.

The Design shall limit interference in accordance with the requirements of MIL-STD-461, AS/NZS CISPR and AS 61000.

## **10.7 Fire Protection Systems (Indoor Substations and other Indoor Installations)**

Provide fire protection as required by and in fully conformance with the requirements of the Manual of Fire Protection Engineering (MFPE) and the Building Code of Australia (BCA). This includes the provision of:

- a) Signs;
- b) Extinguishers; and
- c) Detectors (if required).

## **10.8 Environmental Issues**

Defence places importance of specifying and utilising materials that are not harmful to the environment either during manufacture, installation, use or disposal. Hence, biodegradable materials shall be given preference where possible.

The use of sprays or other equipment which utilises hydrocarbons is discouraged.

Due consideration shall be given to the collection and proper disposal of all trade/industrial wastes.

### **10.8.1 Fuel**

All tanks, tank filling facilities and fuel system shall meet the requirements of AS 1940 and also Australian Institute of Petroleum (AIP) Code of Practice 4 (CP4) The Design, Installation and Operation of Underground Petroleum Storage Systems. Particular care needs to be taken with the tank filling point spill control which shall be meet the requirements for tank vehicle loading facilities in accordance with AS 1940. See Chapter 21 – Local Emergency Generator (LEG) Requirements and Chapter 27 – Central Emergency Power Station (CEPS), Central Power Stations (CPS) and Central Energy Plant (CEP) for further requirements.

### **10.8.2 Asbestos and Polychlorinated Biphenyls**

All equipment supplied under the Contract shall be entirely free of asbestos and polychlorinated biphenyls. Test certificates shall be supplied for all second-hand equipment.

If asbestos or polychlorinated biphenyls are encountered during design or construction DSG shall be immediately notified.

### **10.8.3 Insulation Oil**

The finished installation shall comply with all requirements of AS/NZS 3000 with regards to the containment of insulating oils.

In any case insulating oils shall be prevented from leakage into soils and waterways in the event of a spillage.

### **10.9 Keying**

Entry or access into substations and high voltage switch rooms by unauthorised personnel is not permitted. Doors must be fitted with suitable locks and all locks supplied shall be master keyed to Defence requirements.

All Electrical plant room shall be fitted with suitable locks to Regional requirements.

All equipment of similar nature and type shall be keyed alike to suit the Base arrangements.

### **10.10 Interface with Existing Services**

Where new works are to interface with existing services the Designer shall arrange for pre-design surveys of the existing services, where necessary, to ensure the accuracy of existing documentation and the coordination of design. All details Defence retains on the existing engineering services will be made available to the Designer by DSG Region.

### **10.11 Operation and Maintenance**

Electrical equipment and plant rooms; where possible these rooms should be accessed from areas requiring a lower security clearance or where the need for a security escort may be minimised. Ensure that all equipment and the sighting of all equipment gives priority to the ease of erection, operation and maintenance of the equipment. This includes:

- a) Suitable access around all equipment;
- b) Adequate access panels and doors on equipment;
- c) The careful orientation and location of equipment within panels; and
- d) Indicators and instrumentation in easy to read locations.

Major equipment items shall not be located in such a manner that would prevent the safe removal and replacement of any major item of the installation.

### **10.12 Voltage Drop**

In accordance with AS/NZS 3000, the maximum permissible voltage range at any point in an electrical installation under normal service conditions, excluding voltage transients such as those

due to system switching, shall be 400/230V +10% –11%. This is based on the nominal supply voltage of 400/230V +10% –6% and the maximum permissible voltage drop between the point of supply and any point of an electrical installation of 5%.

The designer must determine the supply voltage characteristics which shall be accounted for in the electrical distribution system design to ensure the voltage is maintained within the above voltage range.

In determining the voltage drop, a minimum 25 percent load growth allowance or suitable master planned load allowance, whichever the greater, shall be used in addition to the estimated maximum demand.

Transient voltage performance where outside the above voltage range needs to be checked against the facility or equipment requirements to ensure the correct operation of the installation and equipment. Where equipment is susceptible to voltage transients the designer must ensure that the electrical installation is designed to meet the equipment requirements.

In determining the voltage drop the designer shall consider:

- a) Use of the electrical installation
- b) Any special equipment requirements
- c) Location and distribution of the load. Location and arrangement of the loads dictate the requirement for additional distribution boards.
- d) Characteristics of the load such as the effect of motors and effect of fluorescent or discharge lighting. Adequate allowance is required to cater for transient performance. The effect of low power factor and switching transients and impact of high current draw need to be adequately catered for and may require dedicated submains and distribution boards.

### **10.13 Circuit Arrangements and Spare Capacity**

The designer is to review all equipment and user requirements in determining the most appropriate and cost effective electrical distribution layout. Adequate spare capacity is required as follows:

■ **Table 10.1: Circuit Arrangements and Capacity**

Circuit Arrangement	Capacity
Switchboards	25 percent spare capacity 25 percent space for additional switchgear
Consumers Mains and submains	25 percent spare capacity
Power circuits	Maximum 8 double socket outlets per circuit (minimum 30% spare capacity)
Lighting circuits	Maximum 66% utilisation (i.e. 33% spare capacity)
Cable trays and ducts	50 percent spare capacity

Note that the capacity of lighting circuits may be limited by allowable leakage current to earth rather than rated active current carrying capacity or voltage drop.

Dedicated power circuits shall be provided for equipment loads. Where appropriate the designer shall consider the installation of distribution boards for the connection of the equipment. As a general rule dedicated circuits shall be provided for the following:

- a) each communication equipment racks
- b) lighting
- c) general power
- d) electrical equipment
- e) HVAC/mechanical services

Care shall be taken to limit the number of points on a circuit and to distribute the points with leakage current in order to avoid nuisance tripping.

Power requirements are provided in the respective room data schedules.

## 10.14 Switchboards

The location of the main switchboard shall be readily accessible from the entry of the building. Main switchboards require special consideration as in an emergency situation such as a fire, the switchboard will need to be located and operated by persons unfamiliar with the installation and the disposition of the equipment on the switchboard. This requires the main switchboard for a building to be located within easy access to the entrance of a building with its location clearly indicated at the main entrance, by a sign if necessary, and at the fire indicator panel.

All switchboards shall comply with AS/NZS 3000 and AS 3439 series of standards. Main switchboards provided for important facilities shall be at least Form 3 construction. Main Essential and Critical distribution boards shall be Form 4 construction.

The finish of switchboards shall be in accordance with Regional requirements. In harsh environments consideration shall be given to using marine grade aluminium or stainless steel enclosures. All switchboards shall be provided with locks wherever possible and all switchboards shall be dead front type and provided with doors. Lift off escutcheon panels are permitted.

All cabling in switchboards shall be provided with suitable identifying labels. Mains and submains shall have two colour engraved durable laminate or similar suitably fixed on the cable showing the cable size and type as well as the origin/destination of the cable. All other cabling shall be identified by slip on ferrules or other suitable means.

## **10.15 Emergency Power Distribution**

Emergency power, when required, is to be provided with critical and essential power distribution throughout the facility as required to meet the defined performance and equipment requirements of the FDB. Defence power supply classifications are provided in Table 7.3 below

■ **Table 10.2 Classification of Defence Power Supplies**

<b>Power Distribution Classification</b>	<b>Type of Support</b>
Critical	UPS supported
Essential	LEG supported
Normal or Non-essential	No UPS or LEG support May be supported by CEPS or mobile generator

Emergency power distribution shall also meet the requirements of relevant standards below:  
Defence Chief Information Officer Group (CIOG) UPS system requirements for small UPS systems associated with the communications systems will be provided by CIOG.

Defence UPS system and LEG requirements provided in Chapter 20 – Uninterruptible Power Systems and Chapter 21 – Local Emergency Generator (LEG) Requirements.

Emergency power supplies shall be suitably marked or colour coded. Refer to the labelling and signage requirements above.

## **10.16 Earthing and Bonding Systems**

Separate earthing systems or earth reference points, where required in buildings, are to be bonded in accordance with AS/NZS 3000, AS 1020 and AS/NZS 1768. In meeting this requirement the designer is to ensure that the design does not compromise the engineering requirements of the earthing systems and that the potential for earth loops in the facility are eliminated.

## **10.17 Lightning Protection**

The designer shall investigate the requirement for lightning protection. Lightning protection, where provided, shall be designed and installed in accordance with AS/NZS 1768. The following facilities shall be provided with lightning protection irrespective of the assessment.

- a) oxygen workshops, storage facilities;
- b) explosive ordnance facilities and hazardous area facilities; and
- c) where the facility type of construction allows lighting protection to be installed or incorporated at little cost (e.g. fully metallic construction).

All computer accommodation and other sensitive equipment shall be provided with suitable surge and transient protection.

## **10.18 Metering**

An intelligent metering system incorporating MDIs, voltmeter, ammeter, power factor, kW, kVA and kWh functions shall be provided at every substation on the output of the transformer.

Intelligent meters shall also be provided for each significant facility in accordance with the Defence Energy Efficiency and Ecologically Sustainable Development requirements. The preferred location for this metering is at the substation to minimise control cabling, however for large facilities with multiple meters install the meters at the facility.

All intelligent meters shall be interfaced to the Power Control and Monitoring System (PCMS) or equivalent monitoring system such as Site Utility Metering System (SUMS) and Regional Utility Management System (RUMS) to monitor the following minimum parameters:

### **Monitoring Requirements**

- a) Volts phase to neutral for LV (phase to phase for HV) and average 4 off
- b) Amps each phase and average 4 off
- c) Thermal amps each phase and average 4 off
- d) Average power factor each phase and average 4 off
- e) watts, kVA, kWh

Where the SCADA cannot adequately calculate the minimums and maximums all of the above needs to be monitored for maximums and minimums for Volts and power factor as above.

The meters need to be configured to suit the communications environment they are to be installed and this depends on the number of meters and the ability to install in conjunction with other systems such as PCMS and BMS. Generally the meters shall be based on open protocols and various communication capabilities.

Where incorporated on the DESN/PCMS Modbus communications and 485 connectivity are required. Meters can also be ETHERNET capable which may be required to suit certain topology (i.e. where there is no PLC/RTU or other similar device), but this places importance on the SCADA software to attain and store accurate data. This is normally overcome by providing meters that hold the required data and the SCADA extracting and storing it for later use.

The metering systems must provide two main streams of data, the first being the energy management data and the other demand management data. The later is used to undertake electrical master planning and to determine adequacy of the distribution system to cater for existing and new loads. The metering connected to the PCMS is for a different purpose to the other metered networks. The preference is to keep the PCMS metering network on Defence Bases independent of other metering systems and for this purpose, it may be more practical to use separate meters for the PCMS.

When a new facility is incorporated into the site metering system the designer shall also include all necessary amendments to the SCADA systems and reporting requirements. Where the facility also has energy efficiency measures or ESD applications that are being measured by the metering, incorporate a separate energy efficiency or ESD report as part of the SCADA to report directly on the achievement of the ESD objectives or performance requirement.

# **Internal Electrical Services Requirements**

- 11 Low voltage distribution pillars and Switchboards Labelling and numbering
- 12 Installation of Residual Current Devices in the Workplace - New and Refurbished Facilities
- 13 Artificial Lighting
- 14 Power Factor Correction
- 15 Hazardous Area and Explosive Area Electrical Installations
- 16 Other Requirements
  - Aircraft Earth Reference Points
  - Wharf Services
  - Liquid Dry Breathing Oxygen (LDBO)/Cryogenic Facilities
  - Battery Rooms
- 17 Reserved
- 18 Reserved
- 19 Reserved

# 11 Low Voltage Distribution Pillars and Switchboards Labelling and Numbering

## 11.1 Background

This Chapter sets out the requirements for labelling and numbering of low voltage distribution pillars and low voltage switchboards for all Defence establishments and facilities. The purpose of this Chapter is to ensure uniform presentation of essential information at each distribution pillar and switchboard location throughout Defence.

**Distribution Pillars** are typically provided as part of the low voltage trunk cabling and are a convenient means for distributing power from substations. They can be either free standing or fixed to building structures. Distribution pillars are primarily used to distribute power throughout an establishment and are not used for energising final sub circuits or submains within buildings.

**Main switchboards and distribution switchboards** are those switchboards from which a building's submains or final sub circuits originate.

## 11.2 Distribution Pillar Numbering and Labelling Requirements

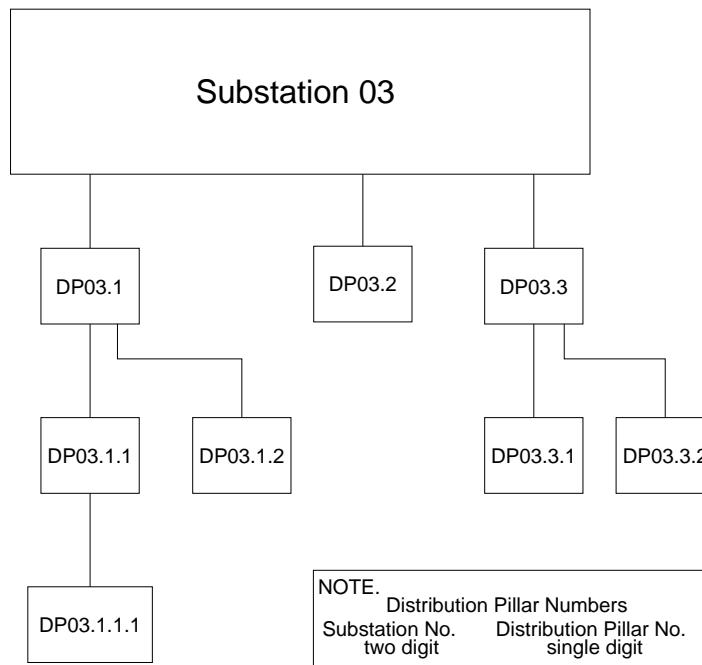
Distribution pillars shall be numbered in accordance with Figure 11.1. The numbering system is based on the origin of supply starting at the substation. The numbering system shall clearly indicate the source of supply cascading with upstream distribution pillars. For example, distribution pillar number 03.2.1 indicates that the pillar is fed from distribution pillar 03.2 which in turn is fed from substation 03.

The distribution pillar number shall be two digit substation number followed by the single digit distribution pillar number (e.g. (substation number), (distribution pillar number)). Where a distribution pillar is supplied from another pillar the number shall be the substation number followed by upstream distribution pillar number and then the distribution pillar number (e.g. (substation number), (distribution pillar number), (distribution pillar number)).

Distribution pillars with two sources of supply (e.g. two substations are connected to the pillar) shall be numbered based on the normal or predominant point of supply.

The distribution pillar number is to be clearly and indelibly labelled on the pillar in a similar manner to the substation numbering consistent with the region labelling requirements. The nomenclature used shall be "**DISTRIBUTION PILLAR** (number)" (e.g. **DISTRIBUTION PILLAR 03.2.1**).

Distribution pillars shall be provided with a circuit schedule, single line diagram and switchboard label in accordance with the low voltage switchboard requirements inside the pillar. The switchboard designation is not required to be 25mm or 15mm character height as required for the switchboard labels.



■ **Figure 11.1: Distribution Pillar Designations**

### 11.3 Switchboard Numbering and Labelling Requirements

#### Circuit Schedule

Switchboards shall be provided with typewritten circuit schedule cards. The cards are to be suitably sized showing:

- submain / subcircuit designation/description and area supplied;
- cable size and type; and
- rating of the submain / subcircuit protective device.

The circuit schedule card shall be kept in a fixed holder prominently mounted inside the switchboard cupboard or on the door inside the switchboard. The circuit schedule card shall be protected by a hard transparent perspex cover or similar. An example circuit schedule card is shown in Figure 11.2.

DB No			Installed By Date				
Fed from				Main size			
No.	Amps	Description	Cable	No.	Amps	Description	Cable
1	20	Power - Skirting sockets West	4mm Cu PVC/PVC	16			
2	15	Lights - West	2.5mm Cu PVC/PVC	17			
3				18			
4				19			
5				20			
6				21			
7				22			
8				23			
9				24			
10				25			
11				26			
12				27			
13				28			
14				29			
15				30			

■ **Figure 11.2: Example Circuit Schedule**

### **Single Line Diagrams**

Frame mounted as-installed single line diagrams shall be suitably fixed in or adjacent to each switchboard assembly. The single line diagram shall be laminated for durability and the size of the single line diagram shall ensure legibility.

### **Switchboard Label**

A suitable switchboard label shall be provided on all switchboards. The label shall be securely fixed in a prominent location on the front door or external cover of the switchboard assembly. The label shall be an engraved two colour durable laminate or similar. The label requirements are detailed below:

**Example Switchboard Label**

# **MAIN SWITCHBOARD 173/1**

**FED FROM: DP03.2**

**MAINS SIZE: 120 mm<sup>2</sup> cu PVC/PVC**

**MAIN EARTH: 35 mm<sup>2</sup> cu PVC/PVC**

**Location: SW corner of building**

**FAULT CURRENT: 40kA**

**MANUFACTURED BY: XX Switchboards May 2003**

**Engraving**

**"A (Switchboard designation)"**

**FED FROM: "B"**

**MAINS SIZE: "C" mm<sup>2</sup> "F"**

**MAIN EARTH: "D" mm<sup>2</sup> "F"**

**Location:**

**FAULT CURRENT: "E" kA**

**MANUFACTURED BY:**

**Letter Size**

The minimum letter height for switchboard designations shall be 25mm for Main Switchboards (MSB) and 15mm for all other switchboards. All other engraving shall be minimum 6mm height.

**"A" - Switchboard designation**

The switchboard designation shall be shown as follows:

MSB        "MAIN SWITCHBOARD (structure number)/1"

(e.g. "MAIN SWITCHBOARD 173/1" for structure 173 MSB)

DB        "(Structure number)/(MSB number)/(DB number)"  
(e.g. "**173/1.1**" for DB 1 fed from the MSB in structure 173)  
(e.g. "**173/1.1.1**" for DB fed from DB1 in structure 173)

Where the switchboard is supplied from a Local Emergency Generator or an Uninterruptible Power Supply (UPS) additional wording of "**Essential**" or "**Critical**" respectively is to be added (e.g. "**Essential Switchboard 173/1.1**" or "**Critical Switchboard 173/1.1.1**")

Where the switchboard is supplied from a frequency converter additional wording showing the frequency of supply is to be added (e.g. "**400 Hertz switchboard 173/1.2.1**")

Guidance in the application of switchboard designations is provided in Figure 11.3.

#### **"B" - Source of supply**

The source of supply shall be shown as follows:

External supply.      Source of supply (e.g. "**DP03.2**" or "**SUB 03**" for a supply from distribution pillar 03.2 or from substation 03 respectively).

In some cases the structure MSB may be supplied from another structure. These shall be shown as for an internal supply below.

Internal supply.      Switchboard supplied from (e.g. "**MSB173/1**" for a DB supplied from main switchboard in structure 173). Where supplied from an UPS, frequency converter or other similar device the label shall also include the UPS or frequency converter in the description (e.g. "**DB173/1.1 via UPS**").

#### **"C" - Mains cable size**

The main cable size (e.g. "**120mm<sup>2</sup>**")

#### **"D" - Main earth size and location**

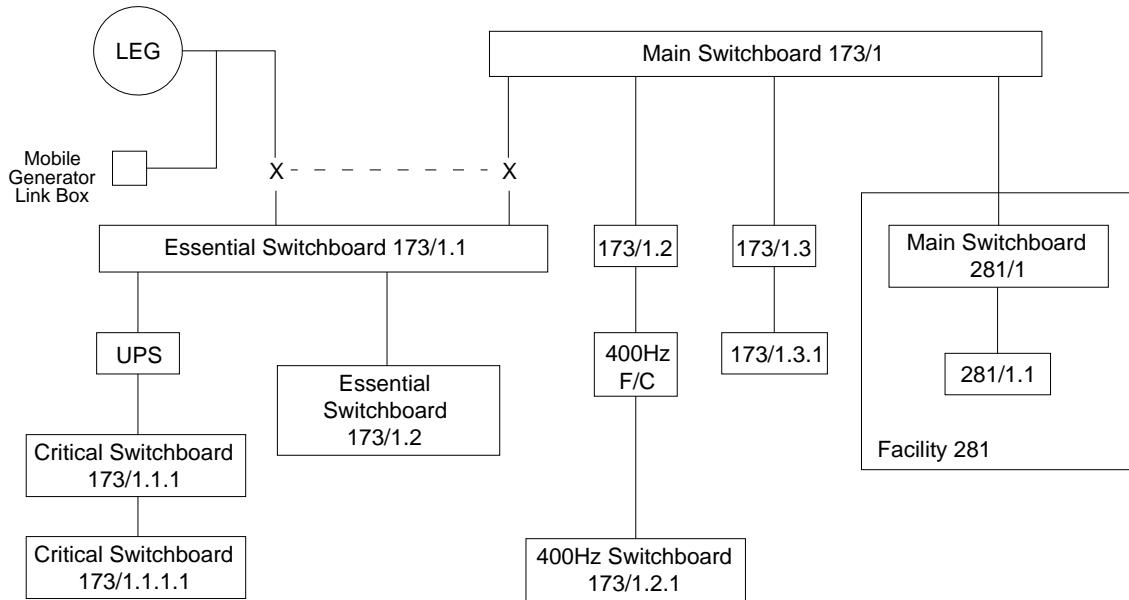
The main earth size and location (e.g. "35mm<sup>2</sup>"; "Location: SW corner of building")

#### **"E" - Fault rating of the switchboard**

The fault rating of the switchboard shall be shown in kA (e.g. 40kA). Note this is the switchboard fault rating not the circuit protective device fault rating.

#### **"F" - Cable type**

The cable type (e.g. "Cu PVC/PVC")



■ **Figure 11.3: Switchboard Designations**

# **12 Residual Current Devices Protection**

## **12.1 Background**

Commonwealth, State and Territory legislation and Australian Standards (AS) require Residual Current Devices (RCDs) to protect electrical installations. These requirements are mandatory, however, they are not consistent, and not all adequately address Defence's duty of care responsibilities.

The legislation and standards are intended to increase personnel protection from electric shock and physical injury hazards that may arise from an electrical installation that is used with reasonable care and due regard to the intended purpose of the electrical installation.

It is important to note that a RCD does not ensure safety. It is designed to disconnect the electricity supply when there is a leakage of electricity to ground, as may occur during an electric shock. It is important to remember that if a person is in contact with both the active and neutral or between two active leads of an electricity supply, the RCD may not operate and an electric shock would be received. This shock can kill.

## **12.2 Reference Documents**

AS/NZS 2243 - Safety in laboratories

AS/NZS 3000 - SAA Wiring Rules

AS 3001 - Electrical Installations - Movable premises and their site installation (includes commercial vans and construction huts)

AS 3002 - Electrical Installations - Shows and Carnivals

AS/NZS 3003 - Electrical Installations - Patient Treatment Areas of Hospitals and Medical and Dental Practices

AS/NZS 3012 - Electrical Installations - Construction and Demolition Sites

AS/NZS 3175 - Approval and test specification - Residual current-operated circuit breakers without integral overcurrent protection for household or similar uses.

AS 3190 - Approval and Test Specification - Residual Current Devices (current operated earth-leakage devices)

AS 3760 - In-service Safety Inspection and Testing of Electrical Equipment

AS/NZS 61009 - Residual current-operated circuit breakers with integral overcurrent protection for household or similar uses

### **12.2.1 Requirements of Legislation**

The ADO is required under Section 4 of the Occupational Health and Safety (Commonwealth Employment) Act 1991 (OHS (CE)) to comply with a State/Territory regulation on a safety subject where there is no OHS (CE) regulation. At this point in time the OHS (CE) Act does not have a regulation on electrical safety.

In addition, OHS (CE) Act 1991 places a duty of care on employers to provide a safe environment for employees. The courts have found that under Common Law, a building owner can be held liable for not providing or upgrading a building to reflect current accepted community safety standards. These expectations and requirements are not limited to new building works.

Retrospective installation of fixed RCD protection to existing electrical installations in buildings is required either directly, as in the case with Western Australia Regulations, or indirectly through duty of care and Common Law.

These requirements clearly confirm fixed RCD protection in electrical installations as the accepted means to protect personnel against the risk of electric shock.

### **12.2.2 Requirements of Australian Standards**

State and Territory legislation mandates a number of AS that require or recommend RCD protection, such as the standards listed below. Other AS that require or recommend RCD protection also need to be adopted to ensure ADO's duty of care responsibility is met, particularly, where they reflect current accepted community safety standards.

The Wiring Rules AS/NZS 3000 requires RCD protection of socket outlets in all types of electrical installations such as domestic, residential, commercial and industrial installations.

Other AS that require or recommend RCD protection include:

- a) AS/NZS 2243 - Safety in laboratories
- b) AS 3001 Electrical Installations - Movable premises and their site installation (includes commercial vans and construction huts)
- c) AS 3002 Electrical Installations - Shows and Carnivals
- d) AS/NZS 3003 Electrical Installations - Patient treatment areas of hospitals and medical and dental practices
- e) AS 3012 Electrical Installations - Construction and demolition sites

## **12.3 Defence RCD Policy Requirement**

Electrical installations are to comply with the requirements of respective State, Territory or Commonwealth legislation, regulations and guidance notes and AS. RCDs shall therefore be provided in all facilities as required or recommended by such legislation, regulations and guidance notes and AS.

In addition to legislative and AS requirements, Defence electrical installations are to have RCDs installed to protect **all socket outlets** wherever practicable, irrespective of rating or location.

Therefore, all socket outlets are to be RCD protected unless:

- a) The proposed equipment or electrical installation is unsuitable for RCD protection;
- b) The electrical installation is in low risk area, where it is not practicable to install RCD protection and electrical safety is effectively achieved by an alternate method; and
- c) The electrical installation supplies an area of high importance where it could be detrimental if connected to a RCD.

Socket outlets provided for general use, for unspecified equipment or purpose or where the socket outlet could reasonably be used for a purpose, other than intended, that represents an *increased risk of electric shock* (e.g. desk top socket outlets that could be used for cleaning) are to be protected by RCDs.

Examples of equipment or installations NOT intended for RCD protection are:

- a) Electromedical equipment where it could be detrimental to the health of a patient if connected to a RCD (note the requirements of AS/NZS 3003 apply);
- b) Equipment or installations not suitable or compatible with RCD protection like essential imported test equipment having internal neutral earth bonds or equipment that has inherent current imbalance. Consideration should be given to modifying this type of equipment to achieve compatibility in the first instance, if possible;
- c) Socket outlets, other than domestic installations, installed at a height in excess of 2.3m above the ground, floor or platform specifically set aside for the connection of fixed or stationary appliances or luminaires in an area not considered to be an *increased risk of electric shock*;
- d) Equipment supplied from socket outlets that represent a low risk and where it would be detrimental to an important function or requirement such as uninterruptible power supply, aircraft safety (e.g. NAVIADS/VISAIDS), particular computing systems and communications equipment; and
- e) Socket outlets for 400 Hertz (Hz) installations such as used in aircraft power supplies and avionics workshops. These installations are not suitable for Type I (10mA) or Type II (30mA) RCD protection and currently there is no known manufacturer of RCDs for this application. Electrical safety for these installations is to be achieved by complying with one of the other protection techniques of AS/NZS 3000, in particular *Clause 1.7.4 Protection Against Indirect Contact* (e.g. Protection by automatic disconnection of supply, Protection by electrical separation or by the use of Class II equipment).

In addition to protecting socket outlets, consideration is also to be given to protecting fixed electrical equipment and appliances with RCDs in areas of *increased risk of electric shock*. This would particularly apply for Class 1 equipment where automatic disconnection of supply could not be assured by the overcurrent protective device in accordance with Clause 1.7.4.3 of AS/NZS 3000. The purpose of this requirement is to provide RCD protection of fixed equipment in areas of

increased risk such as laundries, ablutions and kitchens where it is practical (i.e. the equipment is suitable for RCD protection) and where the degree of risk posed to personnel warrants RCD protection.

## 12.4 RCD Installation

The design objective is to install, as far as practical, RCDs protection for all socket outlets, and RCD protection for fixed equipment installed in accordance with the requirements of the Australian Standards and in areas of *increased risk of electric shock*. The designer, in consultation with the users, is to ensure that all electric shock hazards are identified and that the electrical systems are designed to reduce or eliminate these electric shock hazards. All socket outlets not provided with RCD protection are to be the subject of an electric shock risk hazard assessment, with the results of this assessment provided in the Design Report, or similar, for DEEP agreement.

RCDs are to be permanently installed as part of the electrical installation at the distribution switchboard. RCDs can be arranged to protect a number of circuits, several socket outlets on a circuit or even the entire electrical installation with the one RCD. However, the number of circuits or socket outlets that can be connected to one RCD is influenced by the likelihood of a faulty piece of equipment tripping several other circuits or socket outlets.

To minimise this impact, RCDs are to be installed on an individual circuit by circuit basis. RCD protection and circuit design are to be arranged to prevent any adverse or harmful effect between equipment, circuits or socket outlets. This is to be achieved by separating RCD protection for important functions within each facility or area (e.g. one circuit per test bench, circuits arranged by function or area, no general purpose socket outlets on the same circuit as important equipment and separate circuits for cleaner's outlets and kitchenettes in office areas).

Intermixing of RCD protected equipment and non-RCD protected equipment on the same circuit is not permitted.

Except where otherwise required by Legislation or Australian Standards, RCDs shall be Type (II) (i.e. maximum 30mA tripping characteristic) in accordance with AS 3190, AS/NZS 3175 or AS/NZS 61009.1.

Socket outlets provided for equipment that is unsuitable for type (II) RCD protection, in areas that may represent an *increased risk of electric shock*, are to comply with the one of the remaining protection techniques/requirements of AS/NZS 3000, particularly *Protection Against Indirect Contact* to ensure personnel safety.

Socket outlets provided for equipment or systems unsuitable for RCD protection should be configured to prevent general use where possible, such as non-standard patterns (i.e. not three flat pin plug), and shall be suitably labelled for the intended use to prevent general use.

Equipment characteristics are to be reviewed by the designer when determining the most appropriate configuration for RCD protection.

#### **12.4.1 RCD Testing and Record Keeping**

RCDs are to be regularly tested by *competent persons* and such tests are to be recorded and made available for safety audit purposes.

The electrical contractor responsible for the electrical installation works shall undertake monthly pushbutton tests during defects liability period and shall test the operation of each RCD at the time of commissioning and at the end of defects liability period.

After the defects liability period, testing is to be undertaken by the Regional Managers through the CMS contracts in accordance with Table 12.1. Record keeping requirements, including the requirement for log books, are also provided at paragraph 12.4.3 below.

Provide a means of recording the most recent operational test date by an electrician and the verifier's signature. This register can be in the form of a label at each RCD or switchboard housing the RCDs or as a central register similar to a circuit schedule at the switchboard.

#### **12.4.2 RCD Training**

Notwithstanding the potential for RCDs to protect persons and equipment, RCDs do not provide unequivocal protection against electric shock or even electrocution. Due diligence and care must always be afforded by all users of electrical equipment and appliances irrespective of the level of protection provided. It is important that the in-service application of these devices be managed with the knowledge of their limitations.

The assumption that RCD protection provides absolute protection may in turn lead to some users taking unnecessary risks when using electrical equipment/appliances that they otherwise would not if they knew RCD protection was not installed. Where there is sufficient potential for users to take such unnecessary risks, personnel awareness program for users of Defence buildings will need to be conducted. Such programs are the responsibility of the user unit, however, where necessary, ID can assist in defining the training requirements.

#### **12.4.3 RCD Testing and Documentation Requirements**

Testing requirements for portable Residual Current Devices (RCDs) are provided in legislation and AS 3760 and are the responsibility of the user.

Testing of fixed RCD installations shall be in accordance with the respective State or Territory legislation, as recommended by Australian Standards (AS) or in accordance with Table 12.1, whichever is the more frequent.

### **Maintenance Documentation**

A detailed maintenance program shall be implemented and shall include procedures and a recording system. The recording system shall include the maintenance schedule, a log and as-installed diagrams of the installation. The information shall be current and be readily available. The Regional Manager (RM) is responsible for this through the Defence maintenance contractor (i.e. Comprehensive Maintenance Services Contractor (CMS) or similar).

The log shall contain records of all formal inspections, test results (not push button tests) and RCD history including any repairs or modifications. The log shall be dated and include the verifier's identification. The log may be an electronic form of record keeping.

Where a log book is used, it shall be provided with a suitable holder at each distribution switchboard. Log books may be standardised for each establishment, the RM will provide these standard requirements when advising if a log book is required. Log books are to be substantially bound (not in loose leaf format) and contain the following information as a minimum:

- a) page numbered
- b) description of the inspections, tests, repairs or modifications
- c) test results
- d) the log shall be dated and include the verifier's identification for each entry
- e) where testing due to presence of a fault, identification of faulty equipment and action taken to repair and remove it from service

■ **Table 12.1 Residual Current Devices Testing Schedule**

ENVIRONMENT	TEST INTERVAL IN MONTHS (see note 1)			
	Push-button test (see note 2)	Responsibility (see notes 2 and 3)	Test for operation (see note 4)	Responsibility
Workshops and places of repair, assembly maintenance or fabrication	3	User	12	ID
Commercial environments such as laboratories, kitchens and gymsnasiums.	3	User	24	ID
Office environment	3	User	24	ID
Accommodation environment	3	User	24	ID

Notes:

- 1) Frequency of testing depends on the environment in which the device and equipment is being used, with more frequent testing required for harsher environments or higher risk areas. In all cases, the electrical contractor responsible for the electrical installation shall test the operation of each RCD at the time of commissioning and monthly pushbutton test during the defects liability period and a final test for operation at the end of defects liability. After the defects liability period, Defence personnel or the Defence maintenance contractor shall regularly test RCDs in accordance with the schedule above.
- 2) Infrastructure Division (ID) is not responsible for ongoing push button tests. The detail provided above for these tests is provided as information only and typically representative of State and Territory OHS guidelines. Unless operated from time to time, a RCD may mechanically freeze and not trip when required. RMs are responsible for referral of the user requirements to the regional or establishment OHS committee.
- 3) Users are defined as the unit or units normally occupying the facility. Users will need to ensure that an appropriate responsibility (ies) is identified and suitably trained to perform push button tests. For facilities with no single user (e.g. transient accommodation), the unit managing the accommodation will need to arrange an appropriate responsibility for the push button tests.
- 4) The test for operation shall ensure that the RCD operates within the maximum tripping times and current levels as required by AS 3190, AS/NZS 3175 or AS/NZS 61009.1.

# **13 Artificial Lighting**

## **13.1 Background**

Artificial lighting accounts for a considerable portion of the energy consumption in Defence. It is imperative that lighting systems and their associated controls meet the engineering performance requirements and achieve optimal energy usage and that high efficiency lighting systems and robust control strategies be realised.

Emphasis is on the provision of the best through life performance and this policy addresses both the lighting systems and lighting control applications. For the purposes of this policy, lighting systems encompasses the entire lighting system including luminaires, fixtures, fittings and control systems.

The areas of application covered by this policy include:

- a) Interior Lighting;
- b) Exterior Lighting such as flood, apron, road & car park;
- c) Security Lighting;
- d) Cleaning Lighting;
- e) Emergency Lighting; and
- f) Lighting Control.

## **13.2 Performance Objective**

The objective of this policy is to:

- a) facilitate the suitable performance of lighting installations;
- b) facilitate optimal lighting control strategies;
- c) facilitate optimal energy efficiency, and
- d) ensure the economics of the design on a through life basis.

## **13.3 Referenced Documents**

### **13.3.1 Standards and Codes**

All materials and workmanship shall be of the best standard and shall comply with the relevant legislation and Australian Standards, or if such do not exist with relevant International Electrotechnical Committee (IEC), International Standards (ISO) and International Commission on Illumination (CIE) standards.

Irrespective of status and any requirements shown in these documents the installation as a whole shall comply with:

### **Australian Standards**

- AS/NZS 1158 *Road Lighting series*
- AS/NZS 1680 *Interior Lighting series*
- AS/NZS 2293 *Emergency evacuation lighting for buildings series*
- AS 2467 *Maintenance of Electrical Switchgear*
- AS 2560 *Sports Lighting series*
- AS 3595 *Energy Management Programs - Guidelines for financial evaluation of a project*
- AS/NZS 3827 *Lighting System Performance*
- AS/NZS 61000 *Electromagnetic capability series*
- AS/NZS CISPR *Electromagnetic compatibility - Requirements for household appliances electric tools and similar apparatus - Immunity - Product family standard*
- HB 49.1 *Sports Lighting*
- HB 264 *Power Quality*

### **International Standards**

- International Commission on Illumination (CIE) 129 *Guide to the lighting of exterior work areas*

### **Defence Requirements and Standards**

- Australian Defence Force Publication - 602 (ADFP-602) Joint Services Works and Administration Aerodrome Design Criterion.
- Defence Energy Management Strategy. Promulgates Defence energy management policy guidance.

### **Other Standards**

Building Code of Australia (BCA)

Civil Aviation Safety Authority (CASA) Manual of Standards Part 139 (MOS Part 139)

International Civil Aviation Organisation (ICAO) Annex 14 Aerodrome Design and Operations and Design Manuals

Regulatory Authority requirements in each state

### **Technical References**

Australian Greenhouse Office Best Practice Guidelines

Green Building Council of Australia, Green Star rating tool and Best Practice Guidelines

Department of Industry, Tourism and Resources - Energy Use in Commonwealth Operations' & 'Measures for Improving Energy Efficiency in Commonwealth Operations.

### **13.4 Other Agency Guidance**

Adequate consideration is required on the policy and guidance published by other government agencies and other recognised organisations. Where the provisions containing the guidance published by these agencies cannot be implemented or where it is found impracticable the matter is to be raised in the design report for Defence agreement. Some of these agencies and their policy and guidance are listed below.

#### **Australian Greenhouse Office**

The Australian Greenhouse Office (AGO) is a government agency responsible for government energy management that provides policy and guidelines on reducing power consumption and greenhouse gas emissions. The policy requirements are to be implemented for all Defence installations.

#### **Green Building Council of Australia**

The Green Building Council of Australia has developed a new rating tool for commercial office buildings. The tool, known as Green Star, evaluates new and refurbished office design based on a number of environmental criteria including energy and water efficiency, indoor environment quality, waste avoidance and resource conservation. There are also additional tools available such as as-build and interiors.

#### **Department of Industry, Tourism & Resources**

The Department of Industry, Tourism & Resources is a government Department that encourages the efficient use of energy. To this end, the Department monitors and produces a report on the 'Energy Use in Commonwealth Operations' & 'Measures for Improving Energy Efficiency in Commonwealth Operations'.

### **13.5 Financial Assessment**

Financial assessment is required to justify the selection and economic basis for the chosen design solution. Financial assessment is also required when considering the merit of upgrading an existing installation or implementing energy efficiency measures in existing facilities.

Financial assessment must be undertaken on a through life basis and must include the lighting system installation costs and all recurring costs such as energy usage, energy impacts to other services such as HVAC and the ongoing operating and maintenance costs.

Financial assessment must demonstrate:

- a) Payback period for the works is within 5 years:

- b) Chosen solution offers the lowest through life costs;
- c) Best environmental and/or ESD performance;
- d) Through life costs including SCADA maintenance, energy costs, lamp replacement, luminaire cleaning and control system management;
- e) Compliance with current Standards; and
- f) Operational considerations that overrides the economic consideration.

### **13.5.1 Economic Analysis**

The payback period is the time required for the lighting installation to redeem the cost of installation. The cost benefit analysis needs to consider the through life costs of the PFC installation against the reduced energy costs or savings in the reticulation system construction costs.

There are two fundamental methods accepted:

- a) **Simple Payback:** this doesn't normally take into account future value of monies today but can be used as a basic check of the feasibility of a project.
- b) **Net Present Value (NPV):** this does take into account future value of monies today. NPV is very useful in comparing options over the time frame considered.

### **13.5.2 Energy Performance Contracting (EPC)**

EPC can be considered to minimise the cost of installation to Defence by using the energy savings. EPC is a form of contracting for energy efficiency services. The contractor guarantees a level of energy consumption savings, upgrades the facility using equipment at its own expense to achieve the consumption targets and is repaid over a number of years from the resulting stream of energy cost savings.

Energy Performance Contracting provides access to private sector capital, technology and technical expertise at minimal up-front cost to the Commonwealth.

Any EPC proposal must be formally agreed by Director Engineering Services and Technical Regulation (DESTR).

### **13.5.3 New lighting System Assessments**

Financial assessment is required to confirm the selection of the most suitable lighting design and lighting control system. The financial assessment is to consider the through life cost of the lighting system (including energy usage for both the lighting and impacts to other services such as HVAC and the ongoing management and maintenance costs).

New lighting systems when comparing the merit of suitable options must use NPV.

#### **13.5.4 Existing Lighting Systems**

The purpose of replacing older lighting systems or installing new lighting control systems is to improve the energy efficiency of the building in which it is applied. If this isn't achieved through the proposed modifications, justification will be difficult unless it is required to bring the installation into conformance with the required lighting levels

Financial assessment is necessary to determine the merit of replacing existing lighting systems on the basis of energy savings or through life savings.

#### **13.5.5 Energy Audit: Watts/m<sup>2</sup> lighting consumption**

To establish a base line for existing energy/power consumption, a preliminary load profile can be established for an installation by one/all of the following methods:

- a) Power Measurement where a suitable temporary three phase power recorder should be installed at the switchboard supplying the floor(s) to be upgraded;
- b) Electricity accounts can be reviewed to determine the electricity consumption, and
- c) Building Management System can be investigated to determine the availability of data from the Defence Building Management System or Digital Power Analyser on the Main Switchboard (MSB) to determine power consumed.

Following these preliminary investigations, a watts/m<sup>2</sup> can be determined for each area and can be compared against the anticipated design watts/m<sup>2</sup>. The difference can be used to calculate the cost savings.

### **13.6 Energy Efficiency**

Defence energy performance requirements are provided below. Where a lighting system cannot achieve these requirements or it is considered impractical to comply, the reasons need to be justified as an alternate design solution as detailed in Chapter 6 – Certification and Verification.

- a) The target power densities for Defence all indoor lighting applications is 10 watts/m<sup>2</sup>.
- b) Electric lighting levels must not be over designed. Maintain levels for office applications at not more than 400 lux for 95% of the net floor area.

#### **Fluorescent Lighting Ballasts - Minimum Energy Performance Standard (MEPS)**

AS/NZS 4783.2 specifies the MEPS requirements for lighting ballasts (e.g. Class A1 to Class B2). The designer is to determine the most appropriate ballast based on merit, cost effectiveness and energy efficiencies. Detail in the design report suitable justification of the chosen solution showing the option considered and the basis for selection.

## **13.7 Developing and identifying specific project lighting requirements**

Generally, lighting system performance requirements are adequately defined by the required standards; however, in some instances there may be unique Defence requirements where alternate lighting systems solutions are needed. Examples include rooms used for night vision training and simulator complexes.

Normally, specific project requirements will be identified in the FDB or other project requirement documentation together with the performance requirement. However, where the FDB does not include the performance requirement the designer will be required to investigate and make recommendations on suitable lighting installations as part of the design process.

### **13.7.1 Maintenance and Lamp Replacement**

When determining the lighting system maintenance requirements and light loss factors, the designer shall consider AS/NZS 1680.4, the anticipated lamp life and the required CMS cleaning intervals in deciding on the most cost effective design solution. The designer shall detail the design basis including the required lamp replacement and cleaning intervals in the design report.

Where the designer proposes an alternate maintenance regime to current CMS requirements this shall be clearly detailed in the design report together with justification for the alternate arrangement.

Where no CMS maintenance requirements are available, the designer shall base the maintenance cycles on the recommendations of AS/NZS 1680.4 using bulk lamp replacement, manufacturers published lumen output/lamp life and allowing for luminaires to be cleaned at the same time as the replacement of lamps (e.g. for T5 luminaires: not less than 80% of manufacturers published lumen output and allowing for luminaires to be cleaned not more regularly than 5 yearly intervals).

All new luminaires shall be constructed for ease of maintenance and cleaning and to suit the ceiling system. Attention is drawn to AS 2946 for luminaire and ceiling compatibility.

### **13.7.2 Lighting Circuitry**

New lighting circuits shall be designed to a maximum circuit utilisation of 66 percent (i.e. 33 percent spare capacity). The capacity of lighting circuits may be determined by factors other than normal current rating. RCD protected lighting circuits may have a much lower limit to the number of light fittings which may be reliably connected to the same circuit, due to the leakage current to earth inherent in electronic ballasts within the light fittings.

### **13.7.3 Power Factor**

All fluorescent and high intensity discharge lighting systems are to be power factor corrected (to at least 0.9pf). The Designer shall consider both individual equipment/luminaire correction and centralised correction based on the best through life performance.

### **13.7.4 Equipment**

In industrial or commercial areas the designer is to ensure that the colour rendition of the lighting system is suitable for the tasks performed. Where lights are installed in areas that could be exposed to mechanical damage (e.g. plant rooms) the fittings shall be provided with suitable wire guards or impact resistant lens.

Discharge lighting installed in hangars or other sensitive areas shall have fail safe type control gear that will automatically de-energise the igniters' circuit in the event of lamp failure to prevent any failure condition from causing a potential fire hazard.

All fluorescent lights are to have electronic starters or electronic ballasts. Electronic ballasts shall be selected with the operating conditions and design life in mind. Longer design life types will generally provide a whole of life cost benefit.

### **13.7.5 Luminaire Standards**

The base or region may have lighting standards which will need to be addressed by the designer in the development of new works. The designer will need to consider these and adopt them where they comply with the requirements outlined in this policy and offer practical and cost effective solutions.

Where a regional standard is identified but is not proposed for adoption the reasons why is to be addressed in the design report for Defence agreement.

### **13.7.6 Lamps Selection**

Lamp choice shall take account of whole of life cost as well as operational requirements.

### **13.7.7 Harmful Effects of Lamps**

Where lamps pose a hazard in normal/failed operation or when damaged, the designer must ensure suitable safeguards are applied. To this effect suitable UV filter or similar should be installed with the fittings that emit UV radiation. The designer must address, in the design report, any lighting system that has the potential for harmful effect and the proposed treatment strategies.

## **13.8 Lighting Design Criteria**

The following requirements are provided to further define Defence requirements. The main objective is to ensure lighting system designs achieve the required performance whilst also achieving optimum energy efficiency.

### **13.8.1 Interior Lighting**

The levels of artificial lighting shall accord with the recommendations of AS/NZS 1680 series for the various tasks to be undertaken in the facility. The lighting installation shall comply with the energy limitation requirements of Section J of the BCA regardless of the State or Territory in which the installation resides. Lighting layouts and switching patterns are to be arranged to make best use of the available daylight and the tasks being undertaken in the facility.

Consideration shall be given to intelligent automatic daylight compensation where appropriate and cost effective. The preferred method of daylight compensation is by automatic perimeter dimming using individual sensors per luminaire, particularly the lighting installed adjacent to window areas. Where implemented adjacent window areas, the daylight compensation dimming system shall only control the first row of luminaires.

Existing lighting systems to be modified as part of building refurbishment shall be assessed for compliance with current standards and suitability for retention. The existing lighting shall only be retained where justified by a business case against modern energy efficient lighting systems.

Luminaires in office areas shall generally incorporate fluorescent lamp sources. High efficiency lamp types and luminaires are to be specified and the selected light arrangement and lamp type shall be on the basis of achieving the best through life performance.

### **13.8.2 Daylighting**

The use of daylighting within a building can increase the occupant's amenity. This needs to be balanced against the potential for increased glare from daylighting.

Daylighting is to be used with the appropriate use of sun shading or internal to prevent the entry of direct sunlight and control glare. The fundamental measure of the quantity of daylight at a point indoors (the daylight factor), is the ratio of the inside daylight horizontal illuminance to the horizontal illuminance simultaneously existing under an unobstructed sky and expressed as a percentage. The daylight factor is approx 2-5% of the externally available light. AS/NZS 1680.1 – 1990 table 9.1 provides a table of the illuminance available from the sky for major Australian cities. From this table, illuminance within a space can be determined.

### **13.8.3 Artificial**

Artificial lighting is lighting required to illuminate the interior of a building if no daylight was available. The provision of artificial lighting comes in many forms and is further detailed below.

#### **13.8.4 Task**

Task lighting is local illumination related to a workstation or specific task. It can be used as secondary lighting, where the primary lighting is provided by lights from the ceiling and task lighting provided by a local luminaire that can be moved by the occupant. This will provide higher levels of light than the primary lighting. For example office lighting is generally 320 lux but task lighting can increase the local illumination to 600-1000 lux. Task lighting is a more cost effective alternative than trying to increase the office illumination from the primary lighting source to 600-1000 lux.

The disadvantage with task lighting is that it cannot be easily controlled by an automated system and therefore has the possibility of increasing the lighting energy consumption for the building. This aspect will need to be addressed in any proposed task lighting application.

#### **13.8.5 Perimeter**

Perimeter lighting are the luminaires adjacent the external windows of a building. Light sensors built into each luminaire can reduce the level of light when there is adequate daylighting. At night, the sensors drive the luminaire to full brightness.

#### **13.8.6 Cleaning Lighting**

Building cleaning can be conducted after hours at night. Where cleaning is undertaken at night, there must be a system where the cleaner can activate egress path lights and suitable limited office space lighting to enable for them to carry out their cleaning duties without the need to energise entire lighting system. This can be a key system or other suitable arrangement at the entrance to the building or each area. When the cleaner leaves, they de-energised the lights through the key again or by time control.

#### **13.8.7 Security Patrol Lighting**

Where a building is routinely patrolled by security staff, a similar lighting system to the cleaning lighting above is required to enable the security patrols to be undertaken without the need to energise the entire lighting system. Security lighting can be achieved by movement sensor, by a key system or other suitable arrangement.

#### **13.8.8 Emergency Lighting and Exit Signs**

Emergency lighting and illuminated exit signs shall comply with the requirements of AS/NZS 2293 and be provided in the areas as required under the BCA.

Emergency luminaires shall be connected to a computerised automatic testing system, consisting of a central control unit located in a suitable location. The computerised testing system shall be incorporated onto the site wide or regional monitoring, where existing. Please note that Defence intends to implement centralised site/regional monitoring at all establishments and therefore consideration is required on standardising equipment to achieve this requirement, whether such a system is already installed or not.

Luminaires for emergency lighting should incorporate the following general features:

- a) Plant areas and switchboards – Non maintained lamp, integral with general lighting luminaire;
- b) General floor areas – Recessed non-maintained type;
- c) Exit signs – Two (2) lamp with one lamp being non maintained; and
- d) Install emergency lights over Fire and Security Alarm panels.

Existing emergency lighting and illuminated exit signs in buildings to be refurbished or modified are to be upgraded as necessary to comply with AS/NZS 2293 and provided in the areas as required under the BCA. Where the expense of the above requirements for monitoring and lighting types cannot be justified, additional or relocated emergency lighting and illuminated exit signs shall comply with AS/NZS 2293 and can be single point, self-contained, battery operated type. The newly configured system should satisfy the following criteria:

- a) install single point emergency luminaries and illuminated exit signs at locations in accordance with the BCA,
  - b) emergency luminaries shall generally be non-maintained type and recessed mounted,
  - c) illuminated EXIT signs shall operate in a dual-lamped sustained mode, and
  - d) install emergency lights over Fire and Security Alarm panels.
- e) Where there is no computer monitoring, lights shall be provided with a test facility at the local distribution board complying with the requirements of AS/NZS 2293.

### **13.8.9 Building Exterior Lighting**

External lighting is to be provided to suit the tasks involved and to allow safe access and usage of the building particularly after hours. The design of the external lighting shall be suitable for the purpose and meet all applicable OH&S requirements. The luminaires shall be of robust construction, weatherproof and high efficiency lamp sources (preferably either sodium, metal halide or fluorescent lamp sources).

### **13.8.10 Building Security Lighting**

The requirement for security lighting is to be investigated by the Design Consultant after consultation with the Base Security Agency to meet Operation Safe Base (OPSB) passive defence augmentation requirements. Generally in the majority of instances, only building perimeter lighting is required and the requirements for this lighting system follow. Where an alternate security lighting system is required such as perimeter fence lighting seek DEEP guidance for the additional engineering requirements for these lighting systems.

Building perimeter security lighting shall be designed to illuminate an area sufficient to detect an intruder. This area will depend on the surroundings of the site and the category of the area to be protected but should be at least an area of 3m from the building extremity. The distance to be illuminated will be provided by the Base Security Agency. The lighting shall be designed to achieve the following requirements:

- a) Minimum vertical illuminance of 1 lux;
- b) Uniformity of 5:1 (maximum: minimum);
- c) Maintenance factor of at least 20 percent; and
- d) Restrike and achieve 80 percent illuminance within 60 seconds after outage.

### **13.8.11 CCTV Security Lighting**

Where camera security monitoring systems (e.g. CCTV) are installed, the designer of the security lighting system shall ensure that the performance of the system is appropriate for the type of monitoring system installed.

The illuminance requirements for security lighting installations can be compared with those for roads in so far as they are both designed for detection at night.

If closed-circuit TV cameras are used, higher levels of illumination may be required depending on the choice and sensitivity of the camera. Below is a guide:

■ **Table 13.1: Illumination Levels for CCTV Systems**

Illuminance	Comments
1 lux	Minimum for security lighting
5 lux	Recommended average
10 lux	Recommended for areas adjacent roads
10 lux horizontal 3 lux vertical	For CCTV camera's.

The CCTV levels are as a guide and reference is needed with the manufacturer of the cameras to determine their recommended levels of light for human face recognition.

### **13.8.12 Road, Car Park & Pedestrian Lighting**

The FDB will identify the outdoor areas to be lit. Where required the following shall apply.

Road, carpark, pedestrian, outdoor and street lighting where required is to be designed in accordance AS/NZS 1158. The design report is to detail the selected category and the proposed lighting system arrangement including a through life cost benefit analysis.

The luminaires shall be of robust construction, weatherproof and high efficiency lamp sources. The luminaires may be standardised on each site and the designer shall liaise with the Region to determine the required lighting system and incorporate the Regions Requirements.

All road lighting systems installed at or near aerodromes shall use aeroscreen type luminaires with zero tilt.

### **13.8.13 Flood lighting**

Flood lighting requirements are to be developed by the designer in consultation with Defence using all applicable standards. Attention is drawn to CIE 129-1998 Guide to the Lighting of Exterior Work Areas. Where no applicable standards exist, either Australian or international, the designer shall make suitable recommendations based on the activities proposed for the facility. The lighting should be designed with appropriate illuminance for the activities to be undertaken and shall be arranged to meet the specific objectives sought. The design arrangement and objectives are to be detailed in the design report.

### **13.8.14 Sports Lighting**

Sports lighting shall comply with the requirements and recommendations of AS/NZS 2560 series of standards.

### **13.8.15 Military Apron Floodlighting**

Aircraft apron floodlighting shall comply with Civil Aviation Safety Authority (CASA) Manual of Standards Part 139 (MOS Part 139), International Civil Aviation Organisation (ICAO) Annex 14 and ICAO Design Manual 4. The lighting systems shall be designed with appropriate cut offs to prevent any spill light affecting aircraft operations.

### **13.8.16 Extraneous Lighting Control for External Lighting**

All outdoor lighting shall comply with AS 4282.

Where any proposed outdoor or external lighting falls within the controlled areas as detailed in MOS Part 139 the lighting design shall comply with the requirements of MOS Part 139 Section 9.21.

Lighting installations complying with these requirements will in most instances be acceptable to aircraft operations. However, the suitability for aircraft operations cannot be ascertained without flight survey and ground survey that includes survey from the ATC Tower. The designer shall ensure that the necessary assessments and verification is included as part of the facility commissioning. If it is found during these assessments that the proposed lights endanger the safety of aircraft operations, the lighting shall be suitably modified.

On Defence airfields, all street lighting shall be provided by luminaires with no upward light component (e.g. aeroscreen type) to minimise potential conflict with aircraft operations irrespective of whether the lighting falls within the controlled areas. Consideration of no upward lighting component is required for all outdoor lighting on or near the aerodrome.

## **13.9 Lighting Control**

After a decision has been made on the types of lighting to be used and in what applications, decisions need to be made on the method of control.

The design must consider the facility usage and determine the most appropriate control strategy. The performance of the control system must achieve the defined functionality and also optimise the energy usage, minimising wastage.

Consideration needs to be given to ongoing management of the lighting control systems. Aspects such as the ability to implement control changes, modifying or tuning operation may dictate the type of control system arrangement. Complex computer based control systems offer significant through life advantages for applications with high accommodation churn rates or where control changes are likely.

Guidance is provided in the following paragraphs on the Defence lighting control objectives. The designer must consider these objectives and detail the chosen control arrangement in the design report. The designer must demonstrate the chosen strategy offers Defence the best through life performance with minimal reliance on manual intervention.

### **13.9.1 Control Strategies**

Manual switching alone is not acceptable because of the risk associated with users leaving lighting on. Consideration shall be given to a complete automated building lighting control system similar to ECS, Clipsal CBUS or BMS controlled system based on through life performance and cost effectiveness.

Additionally, where the light loss factors dictate that the initial lighting levels significantly exceed the required performance, consideration may be given to lighting controls incorporating dimming functions to minimise energy usage particularly where electronic ballasts have been incorporated into the design. Any such dimming shall be controlled in a manner so as not to cause premature lamp failure due to the lamps being dimmed prior to the manufacturer's lamp burn in time.

The control system shall be suitable for unskilled operation and shall not require training to achieve effective operation of the system. There shall be sufficient manual overrides and after hours initiation provided for each area to ensure that the lighting is available for extended occupations and also to allow occupant to turn off lighting in unoccupied areas. After hours lighting shall be regularly switched off to suit the intended use to prevent excessive unnecessary usage.

Areas shall be segregated into logical user defined work areas and the control switches shall be readily accessible to the users as they enter the work area. The control switches shall be clearly labelled to assist operation of the system and prevent unnecessary turning on of unoccupied areas. Where necessary include engraved two colour laminated traffolyte labels to clearly show the control.

Further guidance on control strategy application is provided in Table 13.2: Schedule of Lighting Control Applications Summary below.

■ **Table 13.2: Schedule of Lighting Control Applications Summary**

<b>Control Type</b>	<b>Conference</b>	<b>Meeting</b>	<b>Training</b>	<b>Single Occupant</b>	<b>Office Open Plan</b>	<b>Locker/change room</b>	<b>Exercise/ weights</b>	<b>Lunch/tea</b>	<b>Toilets</b>	<b>Transit Corridors</b>	<b>Stores (small)</b>	<b>Warehouse</b>	<b>External</b>
Manual Switch	X	X	X	X	X			X	X				X*
Time delay													
PIR		X		X		X	X	X	X	X			
Ultrasonic	X	X	X								X		
PE Cells												X	X
BMS	X	X	X	X	X	X	X			X		X	X
Lighting Control	X	X	X	X	X	X		X	X	X	X	X	X
Dimming	X	X	X	X	X		X			X		X	
DALI	X	X	X	X	X		X			X		X	

Note: X\* manual override switch at the main switchboard or substation as appropriate

### **13.9.1.1 Meeting & Conference Rooms**

All meeting and conference rooms shall be provided with separate on/off and dimming facilities. Dimming shall achieve 10 to 100 percent luminous output.

### **13.9.1.2 Building External Lighting**

External lighting is to be controlled by photoelectric cell with a manual override provided at the building MSB. This may also be achieved through the BMS system or site wide control system such as DESN, however there must be a manual switch provided at the building main switchboard.

All external lighting is to be connected to the Base "Black Out" system where applicable.

### **13.9.1.3 Building Security Lighting**

The building security lighting is to be controlled by photoelectric cell with a manual override provided at the building MSB. This switch shall be separate to any other external lighting control and the switch shall be suitably labelled "Perimeter Security Lighting". Security lighting can be controlled through BMS system or site wide control system such as DESN where agreed by the Base Security Agency.

### **13.9.1.4 Carpark, Street & Outdoor Lighting**

Carpark, street and all other outdoor lighting systems are to be controlled by the site wide control system such as DESN where available otherwise by photo-electric cell with a manual override at

the relevant substation. BMS system can also be used where no site wide system exists. Control for this lighting is generally to be separate to building service controls.

### **13.9.1.5 Flood Lighting**

Control of the flood lighting needs to be specified as a particular to project requirement that will generally involve local on/off switching. For aircraft apron flood lighting, this may need to be achieved at a number of locations such as the flight line, ATC tower and local manual control to suit the operations at the airfield.

### **13.9.2 Methods of Control**

There are a number of methods available to control a luminaire. **The designer shall liaise with the users to determine the most suitable control arrangement where not adequately covered by the design brief.** Control methods include:

**Manual switching.** Simplest form of control of a luminaire and comprises an on/off switch adjacent the entry to the room/building.

**Time based switching.** Timer functions are used that has pre-set times for turning luminaires on/off. Changes of times are manually done through DESN, BMS, specific lighting control systems or other suitable system.

**Occupancy Sensors.** Two main types, passive infrared and ultrasonic. They rely on movement of the building occupants. They are very effective in reducing power consumption for the capital installation cost.

**BMS Control.** Consists of time based control through the BMS. The BMS can also provide after hours operations and may allow global changes making modification easier to implement.

**Lighting Control.** Proprietary lighting control system incorporating similar controls to the BMS described above and possibly also the dimming or DALI functionality.

**Dimming.** Dimming control reduces the output from the luminaires depending on the level of available light. Dimming control requires the luminaires to have electronic ballasts for either 0-10 volt analogue or Digital Serial Interfacing (DSI) control. Electronic ballast provides better control and increases the life of the lamp.

**Digital Addressable Lighting Interface (DALI).** System which communicates with each luminaire individually. Most expensive and flexible form of luminaire control. If the space to be considered requires continual changes to the floor/workstation layout due to employee movements, this system can be considered as luminaires can be switched in any configuration through software changes avoiding expensive rewiring. Control can be from a single luminaire or any luminaire combination.

### **13.9.3 Location and Arrangement of Control Systems**

The location of the control system varies depending on the type of control system employed and the user requirements. Generally a more sophisticated control system should be located in readily accessible areas for the responsible persons and, if possible, in the same location as other control systems such as the BMS. The designer is to liaise with the DSG Region Energy and Sustainability Manager and the user to determine the most suitable location and arrangement.

All manual switching is to be located adjacent entrances to the room/buildings.

#### **13.9.3.1 Control System Application**

##### **Manual Switching**

As a minimum, building lighting systems should have separately switched zones so that unoccupied parts of floors can be switched off. Switches should be placed at obvious positions at the entrance(s) to each zone. The use of a single switch to control multiple zones is not acceptable.

Consideration needs to be given to a convenient way to turn all lights through a suitable lighting control solution to turn light off after hours. Neither the last user out nor the cleaners can be relied upon to walk around and switch off multiple switches for lighting zones that will be invariably left on. A master off switch may be considered where automatic controls are not justified, linked to a control relay should be located in an obvious position near the main exit door. It should be clearly labelled.

##### **Manual Time Delay Switches**

These switches are typically wall mounted push button timers. They have application in certain installations such as accommodation facility communal areas.

The timing is usually preset in the range of 5-30 minutes, and a 15 minute setting should suit most applications. Appropriate applications include spaces subject to short-term occupancy where there is no access to natural light or transit areas such as corridors. It may not be economical to retrofit timers if the total controlled load (including ballasts) is less than 400VA. Such timers must not be used to control HID lamps.

Safety is an issue and the situation where occupants can be suddenly plunged into darkness needs to be avoided. For larger spaces and corridors this can be achieved by installing a minimum of lighting on 24 hour operation. For specific smaller, infrequently used spaces installing an occupancy sensor with a 10 minute delay that keeps the lights on until the space has been safely vacated should provide the necessary safety without inefficient 24 hour operation.

##### **Automatic Time Switches**

Automatic time switches turn lights on and off at manually preset times. They are generally inflexible and not preferred. They are prone to get out of time due to such events as extended power failures, holidays, and day light saving. Their resetting requires manual intervention that all

too often fails to occur as time switches are generally out of sight. As a result, lights come on when they shouldn't or do not go off when they should.

In some cases, the manual override function is used as an easy way to overcome the inconvenience of the lights not functioning correctly. Consequently the device may be left in override mode and this negates the value of the original capital investment in controls. Therefore, time switch controls should be considered as a last resort for one-off cases where it is too costly or the load controlled too small to justify other better control methods. If used, they should be installed in or near switchboards or electrical distribution rooms so as to be accessible and not hidden away.

### **Occupancy Sensors**

There are several types of movement sensors including:

- a) Passive Infrared (PIR)
- b) Ultrasonic
- c) Microwave
- d) Combinations of PIR and ultrasonic.

The purpose of these devices is to turn lights on/off as occupants enter/leave the room or as they access common areas such as corridors. These devices can be used alone or together with other control devices in a coordinated manner and are very effective in reducing energy consumption by approximately 30%. The units are available with photo-electric cells where there is ample natural light.

#### Passive Infrared (PIR)

PIR devices work on the principle of heat detection by detecting the difference between the human body and the ambient temperature. PIR devices are not as sensitive as the Ultrasonic devices.

#### Ultrasonic/Microwave

Ultrasonic detectors are more sensitive than PIR devices and are for short to medium range applications such as cellular offices or open plan where lights are controlled in linked groups which can be easily reconfigured to suit changes in office layouts. With greater sensitivity comes the chance of spurious operation of the sensor, especially if there are large air movements from air conditioning registers in the ceiling.

Microwave devices are for long range applications and can be used for virtually any internal space. They are generally more expensive than the other types, so are only economical for larger areas.

## **Dimming**

Dimming of a luminaire occurs when there are more than adequate levels of light (dimmed by PE cell) or where there is no occupant movement for a period of time (dimmed by occupant sensors). Dimming requires electronic control gear within the luminaire.

Individual Light Dimming. This is used in perimeter lighting as described above in Perimeter lighting. Photocells are installed in each luminaire that measure the illumination in that area and dims the light from the luminaire. The required levels of light after dimming are still to remain within the Australian Standards for levels of workspace illumination.

PE cells can be individually clipped to any existing luminaire that will sense the amount of natural light and adjust the luminaire light output accordingly. A sensor can be added to each light so as to provide local control. Changes in light conditions in one area will not effect the operation of lights in another area.

The existing luminaire is required to have an electronic dimming ballast (0-10V analogue) installed already for PE cells to work. If the existing fitting doesn't have an electronic ballast, retrofit kits are available that consists of an electronic ballast, wiring, lamps holders and light sensor if required.

Zone Dimming. Zone dimming is the dimming of a number of luminaires in an area or zone.

## **DSI**

Digital Serial Interface (DSI) is a digital protocol used for the control of high frequency ballasted luminaires. This gives the ability to control/dim a group of luminaires and requires a communication cable and power cable to be installed.

## **DALI**

Digital Addressable Lighting Interface (DALI) is a common platform that enables equipment from different manufacturers to be connected together.

DALI is the most advanced method for controlling high frequency ballasted luminaires as each individual luminaire has an 'address' and can be controlled separately from every other luminaire. Both the 0-10Volt analogue or DSI method of control for high frequency ballasts cannot achieve this level of control.

The luminaires can also be grouped with any other luminaire on a floor to provide maximum flexibility (max of 64 devices). This also means that any DALI motion sensor or PE cell or similar DALI device can be used to switch any light and up to 64 DALI devices can be on one communications cable.

Of the 64 devices, 16 groups can be formed and in each group, 16 lighting scenes can be set. A lighting scene is preset levels of light: for example: 50% light in a room for an audiovisual projector presentation. A site requiring more than 64 devices is implemented by having multiple

separate DALI networks, each having 64 devices. These separate networks are then linked together with DALI gateways and a data backbone running a high level protocol.

This system also requires a communications cable and power cable to be connected to all the luminaires increasing the wiring costs.

Reconfiguring of the system is a software reconfiguration and is quick and inexpensive as no re-wiring is required. If an area has a history of changing workstations/ room boundaries, this system should be considered.

Where replacement of ballasts is required under maintenance, there will be an extra cost of configuring the new ballast to have an address similar to the ballast to be removed.

▪ **Table 13.3: Dimmable high frequency ballast comparison**

Control type for HF ballast	Control cable	Polarity dependent	Individually addressable
DALI	2 wire	No	Yes
DSI	2 wire	No	No
0-10Volt	2 wire	Yes	No

### **Lighting Controller and BMS Control**

The proprietary lighting controllers and BMS or similar system can provide a range of control options to turn lights on or off and to optimised lighting performance in conjunction with occupancy sensors, PE cells, DALI and dimming. This method of luminaire control could be considered for a retrofit situation.

The benefit of this control is the flexibility, occupants can press a manual switch adjacent their office/workstation to control light. The flexibility comes at a cost and where it can be demonstrated as a cost effective means, particularly for high churn rates, it should be installed.

### **Energy saving devices**

Energy saving devices are available that operates by reducing the voltage to a luminaire and thereby reduces the power consumption by 30% for a 15% reduction in light output. These devices can be used in commercial, educational and warehousing.

The principle of operation is an autotransformer that can switch from full supply volts to 70, 80 and 85 % (user selectable) after 5 minutes of operation.

# **14 Power Factor Correction**

## **14.1 Background**

Power factor is an important consideration to ensure the efficient and effective use of electricity and also in meeting the Network Service Provider (NSP) requirements. When undertaking construction or refurbishments works, the building power factor must be considered and where it will not naturally meet the requirements of this policy, Power Factor Correction (PFC) must be installed.

This policy defines the technical requirements and feasibility assessment criteria for Power Factor Correction (PFC) installations in existing, refurbished and new buildings.

### **Benefits of PFC**

Benefits achieved by the installation of PFC include:

- a) Electricity tariff savings;
- b) Avoidance of Network Service Provider (NSP) penalties for low power factor, including restricted access to more suitable tariffs (minimum of 0.9 for large and high voltage supply establishments in most states);
- c) Reduced losses;
- d) Reduce power drawn from distribution systems, optimum sizing of electrical infrastructure, and
- e) Stabilised site voltage levels by reducing the inductive effect of the connected load.

The payback for PFC installations can be very reasonable and should not be overlooked when considering PFC for existing installations.

## **14.2 Performance Objective**

The objective of this policy is to:

- a) facilitate suitable power factor at Defence facilities and establishments, meeting the requirements of the industry regulator and Network Service Provider (NSP) and ensuring the efficient and effective use of electricity;
- b) manage the impact of PFC installation to ensure no harmful effect or interaction with other installed equipment, or from other equipment to the PFC;
- c) facilitate the suitable performance of PFC installations;
- d) provide suitable basis for assessing the viability of installing PFC, and
- e) ensure the economics of the design on a through life basis.

## **14.3 Reference Documents**

All materials and workmanship shall be of the best standard and shall comply with the relevant legislation and Australian Standards, or if such do not exist, with the relevant IEC or International (ISO) Standards.

Irrespective of any requirements shown in this document the installation as a whole shall comply with:

### **Australian Standards**

AS 1013-1971	Shunt Capacitors for connection to power frequency systems
AS/NZS 3000	<i>Wiring Rules</i>
AS/NZS 3947	Low Voltage Switchgear and Control gear
AS/NZS 61000	Electromagnetic Compatibility

## **14.4 Defence Requirement For Power Factor Correction**

### **14.4.1 New Works, Upgrades and Refurbishments**

Power factor correction shall be provided under the following circumstances for new, upgraded or refurbished buildings:

- a) To meet the NSP requirements for minimum power factor and not to interfere with the NSP's ripple control on the rest of their network
- b) At Defence establishments with a high voltage tariff, any new, refurbished or upgraded building with a power factor less than 0.9.

Where assessment of the power factor cannot confirm suitability, the PFC equipment may be omitted provided adequate space is allowed in the design of the building to incorporate PFC equipment as a future requirement. This would also apply to buildings where it would be reasonable to assume that PFC may be required at a later stage.

When allowing for future PFC installations the designer shall make all practical provisions for the installation and connection of the future PFC equipment.

Comprehensive Maintenance Services (CMS) contractor or design consultant shall monitor buildings not provided with PFC during the defects liability period to confirm suitable power factor performance. Where the performance is found to be unsuitable during the defects liability period, PFC shall be installed and commissioned prior to completion of the project.

#### **14.4.2 Existing Installations**

PFC shall be considered for existing buildings to comply with the NSP requirements for minimum power factor to avoid disconnection of supply, costly penalties, and tariff restrictions or where the feasibility assessment determines a worthwhile cost benefit.

The funding of power factor correction works for existing buildings shall be in accordance with regional funding and prioritising arrangements.

#### **14.4.3 New Equipment**

Equipment performance, both individual performance and the cumulative effect of non PFC equipment needs to be considered as part of the design and also for equipment specifications.

Ensure that all equipment meets appropriate standards for harmonic content and that the equipment power factor performance is considered to avoid the need for PFC or expensive filtering in the first instance.

### **14.5 Feasibility Assessment**

Feasibility assessment is to primarily address the suitability for PFC and the development of a business case to determine the financial viability.

Feasibility assessments must consider capital and through life costs of the PFC installation against the reduction in energy costs.

It is important to remember that poor power factor due to an inductive or capacitive load can be improved by the addition of PFC. However, poor power factor due to distorted current waveform can require a change in equipment design or expensive harmonic filters.

#### **14.5.1 Assessment Procedure**

The designer needs to determine the need and suitability for PFC. Consideration of the following should be included in the assessment:

- a) What are the consequences of poor power factor in terms of energy costs and non-compliance with NSP
- b) Determine if any special conditions exist and the suitability for PFC such as existence of distortion due to electronic loads, UPS systems, power generation facilities or complex electronic loads
- c) Determining the load profile and the nature of the load in all operating modes and with all possible sources of supply
- d) Determine any power supply quality issues in terms of voltage and frequency stability
- e) Determine the nominal location, sizing and arrangement
- f) Complete the Financial Assessment

- g) For HV connection check any possible interference with the NPA's ripple control and if necessary use series reactors to detune from these frequencies.

#### **14.5.1.1 PFC Viability Checklist**

Provided below is a basic checklist for determining PFC feasibility:

- a) Is there a kVA Demand Charge Tariff from the Network Provider against which savings can be made?
- b) Will the installation of PFC achieve construction cost savings?
- c) Is the payback period less than 5 yrs?
- d) Is there a suitable location for the installation of the PFC equipment?
- e) Is the installation suitable for PFC?
- f) Is there an operational or commercial reason to install PFC that overrides the economic reasons?

#### **14.5.1.2 Review Existing for PFC implementation.**

Consideration of previous Defence installations can provide valuable insight into the strategies and design principles of PFC that could be used to undertake the feasibility assessment. General aspects to consider include:

- a) Location and type of PFC equipment
- b) Previous supplier of PFC equipment and preferred configurations
- c) Performance of existing PFC equipment including maintenance issues and downtime.
- d) Equipment compatibility/suitability

#### **14.5.1.3 Load Profile and Energy Costs**

A preliminary load profile needs to be established to consider the required PFC arrangement providing the basis for determining size (kVAR). This assessment is used to determine viability, not detailed design criterion, and can be achieved through any of the following:

##### **Electricity Accounts**

Review existing electricity accounts to determine the electricity tariff. There must be a kVA Demand component charge to which savings will be made or a cost penalty or tariff restriction for low power factor. If this isn't the case, PFC should not be considered unless there are operational reasons for doing so.

The electricity accounts will provide a base line to determine the kVA Demand consumption and the electricity charges. Improving the PF to unity will reduce this charge and provide monetary savings for Defence.

### **Base Power Monitoring**

Investigate the availability of data from the Defence power monitoring systems such as Defence Engineering Services Network (DESN), Power Control and Monitoring System (PCMS), Building Management System (BMS), Regional Utility Management Systems (RUMS) or other permanent Digital Power Analyser typically installed at Main Switchboards (MSB's).

### **Maximum Demand Indicator**

The Maximum Demand Indicator on a MSB can provide a guideline to the maximum current drawn but rarely will this provide sufficient information to adequately assess the PFC installation.

### **Measurement**

The maximum demand and load profile can be measured by the use of a data logger that measures in 15 minute intervals over a 7 day period.

### **Assessment**

For new buildings and facilities it may be found impractical to measure the maximum demand and load profile. Assessment can be made by calculation using a square metre rate of VA consumption for a building. This will give an approximate PFC Unit size.

### **Location and Preliminary PFC Configuration**

To complete the feasibility assessment the anticipated cost of installing the PFC needs to be determined. This will involve determining the preliminary location and arrangement for the PFC including the number of load steps as this could have a significant cost impact.

### **Financial Assessment**

The payback period is the time required for the PFC installation to redeem the cost of installation. The cost benefit analysis needs to consider the through life costs of the PFC installation against the reduced energy costs or savings in the reticulation system construction costs.

The financial assessment must confirm a simple payback is achieved within five years and must take into consideration the through life costs of the installation.

## **14.6 Technical Requirements**

### **14.6.1 Objectives of PFC Design**

To provide an automatically controlled PFC unit that will bring the power factor to as near to unity as practical (typically 0.97) and have sufficient capacity for future PFC requirements or expansion. The PFC shall be designed with suitable safeguards to prevent harm to the PFC from outside influences or from the PFC to the distribution system or the building services and its equipment. All power factor correction units shall have series reactors to detune the capacitance away from the harmonic frequencies and protect the capacitors from excessive harmonic currents.

It is intended that proven commercially available units be used arranged to suit semi-skilled operators.

### **14.6.2 Design Analysis**

Suitable analysis must be undertaken as part of the design process. The minimum requirement includes detailed analysis of the load profile and harmonic analysis.

Where the installation is a new establishment and it is not possible to undertake measurement, the designer must assess the installation requirements and constraints before specifying each project element. The designer must incorporate all assumptions and assessment outcomes in the design report and must ensure that the PFC will not cause any harmful effect to the building, its equipment or the supply system.

#### **Determination of the Load Profile**

Suitable load profile assessment must be undertaken. This will normally involve three phase power recorder installed at all relevant locations but as a minimum the same location as the proposed PFC equipment. The recorder should sample VA and W every 15 minutes for at least 7 days. This will provide the load profile for the site to allow the PFC configuration to be determined.

Wherever possible, the load profile should be taken as close as possible to the critical demand periods, however, where this is not possible the results will need to be adjusted to cater for seasonal variations.

#### **Consideration of Load Types**

Generally load falls into two (2) categories:

- **Load that creates lagging PF.** A lagging PF load will consist of magnetic devices that cause inductance like motors, magnetic ballasts in lights and cables.
- **Load that creates leading PF.** A leading PF load will consist of capacitive devices. Increasingly, installations containing data centres are causing a leading power factor and the PFC equipment needs to be matched to this noting that traditional capacitive PFC systems will not be able to cope with leading power factor. An alternative is the synchronous motor but this has its limitations due to de-rating under leading power factors. It is noted that a leading PF may offset the lagging PF of the rest of the site.

#### **Harmonic Analysis Before Construction**

The purpose of harmonic analysis is to provide a base line for existing harmonic levels within the installation and to identify where special precautions may be necessary.

This will be used for comparison against the post installation measurement of harmonic levels and ensure that the PFC is not increasing the existing harmonic levels.

It will also provide the design basis for the installation of harmonic filters to reduce harmonics to below 5% Total Harmonic Distortion (THD) and to ensure that no harmful effect or interference to any other element of the building. The harmonic analysis shall be undertaken in all operating modes and particularly with both normal and emergency power supply systems.

### **Resonance**

The use of PF correcting capacitors in combination with an inherently inductive circuit can result in either series or parallel resonance or a combination of both depending on the system configuration. Usually parallel resonance occurs more often because capacitor banks act in parallel with system impedance (inductive). This can be a matter of concern if the resonant frequency happens to be close to one of the frequencies generated by the harmonic sources in the system. The result is that excessive harmonic voltages can be generated in the circuits containing PF correction units. Therefore the designer must take all necessary measures to ensure that the resonant and harmonic frequencies don't occur at the same frequency. This will involve both design calculations and onsite assessment as part of commissioning. Due to the possible changing nature of the load over time however, all power factor correction units shall be fitted with optional series reactors to detune the capacitors away from the main harmonic frequencies. The voltage rating of the capacitors shall also be increased appropriately (normally 525 Volt minimum for low voltage installations).

## **14.7 PFC Requirements**

### **14.7.1 Unit Size and Arrangement**

The required size in kVAR and arrangement of the PFC steps shall be based on the load profile and the known future requirements where applicable. To allow for future increases in demand, space shall be provided to allow the incorporation of additional capacitors/inductors.

The designer shall consider the merit of installing smaller distributed units against installing one larger unit where large distances are involved between the point of connection of the PFC equipment and the load to be corrected.

It is generally preferred that PFC be installed on the low voltage system near the load to be corrected.

### **14.7.2 Steps/Sizing**

The smaller the kVAR rating of each inductor or capacitor switched in stages, the better will be the control of the PF. This will be offset against the increase in space required for more capacitors and the cost for additional contactors. The only variation to this is for fixed duty loads (e.g. particular motor) where a single PFC step used in conjunction with the equipment is justified or more practicable.

The number and arrangement of the steps shall be to suit the profile and characteristics of the load. There shall be sufficient adequately sized steps to ensure smooth correction of power factor with

minimum cycling under normal load conditions. There shall also be sufficient provision to prevent cycling of the load steps within the control system.

Unless single step arrangement for fixed load is used, load steps shall be arranged with at least one suitable half step and minimum of four steps, unless direct-coupled PFC is used for specific equipment application such as a single large motor. As a guide, for low voltage installations 25/12kVAr capacitive steps can be used below PFC units of 200kVAr and 50/25kVAr capacitive steps above PFC units of 200kVAr.

#### **14.7.3 Location and Accommodation**

An essential requirement for the positioning of PFC is that it be located near to the load to be corrected. Typically this will be at the MSB, however, where the load is more than 100 metres from the MSB or where the load is large consideration must be given to locating the PFC at the load. Distances beyond 100m will need to be checked with the PFC manufacturer to confirm suitability of the PFC as voltage performance may become a significant consideration.

Additionally, if the load is distributed over a large area consideration should be given to locating PFC at the equipment locations meaning installing smaller PFC units closer to the load to be corrected instead of a single larger unit at the source of incoming power.

Where it is impractical to install the PFC at the building, installation at the substation may be allowed subject to DEEP agreement.

It is preferable that the power factor correction equipment only correct the building load when the mains is connected and not correct the load when the local emergency generator is connected.

Allowance also needs to be made for access and maintenance activities. There shall be a minimum of 600mm clearance provided from open enclosure doors to adjacent walls or equipment. The layout of the PFC and its accommodation shall be arranged such that a failed component, such as a capacitor unit can be replaced without dismantling the unit or impacting on other components of the PFC.

The space required around PFC equipment varies depending on size and the ventilation requirements, but as a guide generally a 500kVAr unit will be 2m Wide X 2 m Height X 0.6m Deep.

Ensure adequate ventilation is provided in the room containing the PFC equipment.

#### **14.7.4 Fire Integrity**

The PFC and switchboard rooms must have fire integrity to MFPE/BCA. If the PFC equipment is installed in a switchboard room that has an emergency mode operation (e.g.: smoke exhaust equipment), the arrangement of the PFC shall be such that on failure it cannot interfere with the emergency operation of the facility.

Where necessary, this shall include suitable fire separation of the PFC from the emergency services. Any penetrations through fire compartments will need to be suitably sealed to maintain the fire integrity of that compartment as per the MFPE/BCA.

Also ensure that the PFC equipment is not mounted near critical infrastructure where a fire could cause excessive damage to these building elements.

### **Other Requirements**

The room containing PFC equipment shall be provided with:

- a) An appropriate fire detection system suitable for the environment (normally some form of smoke detection)
- b) Emergency and Exit Lighting in accordance with MFPE/BCA
- c) Lighting levels to AS/NZS 1680
- d) A means of adequately rejecting the heat generated by the power factor correction capacitors and reactors. It should be noted that the heat generated by the reactors can be significant and some rooms may require air conditioning to achieve this.

### **14.7.5 PFC Configurations**

There are two (2) types of PFC equipment to consider:

- **Static PFC.** Static PFC is the use of staged capacitors or inductors to adjust the Power Factor as determined by a Power Factor Controlling device. Capacitors or inductors are switched in and out to compensate for various lagging or leading PF conditions. This is generally the system of choice for correcting PF but the use of a rotary PFC may be more practical in certain situations.
- **Rotary PFC.** A synchronous motor can be used as PFC given the right power factor control. The synchronous motor would be connected to a continuous mechanical load and the motor provided with a three (3) phase supply. As the motor runs, the excitation on the motor can be varied to provide leading or lagging PFC on the electrical supply to which it is connected. This would provide PFC at the source and would be located away from the Main Switchboard, possibly in a plant room.

### **14.7.6 Static PFC Construction**

Static PFC construction shall be dead front metal clad equipment cubicle minimum Form 1 construction. The cubicle shall be suitable dust and vermin proof and shall contain:

- a) Controls section housing the controller, transducers, metering and control and indicating devices;
- b) Switchgear section housing the contactors and fuses; and
- c) Capacitor/inductor compartment. The arrangement shall be such that the heat from the reactors does not unduly elevate the operating temperature of the capacitors, controls or switchgear.

#### **14.7.7 Harmonic Performance**

Harmonic loads cause additional power losses in the power supply and in severe cases the distortion can cause over heating of switchgear, transformers and motors, malfunction of voltage regulators and drop out of phase failure relays. Depending on the natural frequency of the power supply and its connected load, the system can actually resonate causing high voltage peaks and equipment damage.

Particular care needs to be taken with PFC equipment is connected to the systems with harmonic content because the capacitors can suffer from over heating due to the passage of harmonic current through them, or can suffer insulation damage due to voltage notching in the power supply caused by commutation of semi-conductors. As a precaution use “reactive” capacitors for power factor correction equipment. These have series reactors designed to impede harmonic currents and “detune” the capacitor circuit away from the main problem causing harmonic frequencies.

The PFC must be installed in a coordinated manner considering the environment the PFC will be connected and to the level of harmonics present. The designer shall ensure that the PFC design achieves the required harmonic performance and where necessary incorporates suitable harmonic filtering to protect the PFC and also to ensure no harmful effect to the installation and equipment. The harmonic filters are to detune the capacitors away from the harmonics present.

The best way to handle harmonic distortion is to treat it at the source of the harmonics and reduce the magnitude. If the background level of harmonics is already high, then consideration may need to be given to providing harmonic filters at the main sources of the harmonic distortion to lower the background harmonic distortion sufficiently. Make the PFC supplier aware of the background harmonics as part of any specification.

#### **14.7.8 Resonant Performance**

Parallel resonance only causes problems if a source of harmonics exists at the same frequencies as the resonance frequency. To avoid this a frequency scan and harmonic resonance evaluation with calculations are required to determine the possibility of the harmonic and resonant frequency occurring at the same frequency. If this does occur, the solution is to either apply tuned harmonic filters to each offensive harmonic frequency or an appropriately sized capacitor to avoid harmonic resonance.

It should be noted that the harmonics generated, and the resonance point in the system may be different when the load is connected to a local emergency generator. Generators are generally rated to adequately supply the kVAR required by the load. It is therefore preferable not to connect the power factor correction equipment whilst the load is being supplied by the local emergency generator.

#### **14.7.9 Transient Performance**

Capacitor switching causes voltages and current transients. The size of a transient is determined by the size of the capacitor and this is a proportional relationship. To overcome transients, a series

inductor needs to be installed which will decrease the rate of change of the current transient and thereby reduce the resulting voltage transient.

#### **14.7.10 Capacitors**

**Wet Type.** Wet type capacitors are oil-impregnated capacitors. Wet type capacitors shall not be used in PFC equipment as the rupture of this type of capacitor under fault conditions may endanger the safety of Defence personnel or equipment.

**Dry Type.** Dry type capacitors don't contain fluids and are a reduced risk under capacitor rupture. The capacitor should also have a discharge resistor to allow for discharging the capacitor when the PFC unit is turned off for maintenance reasons.

The following general capacitor performance requirements should be considered:

- a) Minimum voltage of 525 V r.m.s. phase-to-phase in a single three (3) phase unit.
- b) Ratings from 25kVAr to 50kVar
- c) Self healing type
- d) Protection against internal rupture
- e) Life expectancy of 10 years
- f) Temperature operation range from -10°C to 50°C

#### **14.7.11 Inductors**

The primary functions of inductors are to:

- a) Reduce the effects of harmonic currents on the PFC system
- b) Reduce the possibility of resonance occurring in the system
- c) Reduce the interference to and from possible utility supplied metering signals.
- d) Life expectancy of 10 years
- e) Temperature operation range from -10°C to 50°C.

#### **14.7.12 PFC Controller**

Solid state controllers shall be used to automatically control the PFC to maintain the optimum system power factor. The controller shall have automatic and manual modes. Under manual mode it shall be possible for an operator to manually select the required operation and the manual controls shall only be operable in manual mode.

The automatic mode shall be site configurable without the need to change software or hardware configurations. Appropriate hysteresis loops are to be incorporated to avoid hunting and the controller should also cycle capacitor/inductor duty.

Control and indication is required to suit semi skilled operators and there shall be sufficient indicators and meters to easily and accurately portray the state and condition of the PFC equipment.

The PFC shall share the duty between capacitors and inductors as appropriate.

#### **14.7.13 Defence Engineering Services Network (DESN) & Building Management System (BMS) Interface**

The PFC controller shall incorporate sufficient monitoring and alarm outputs to allow interfacing with the DESN and/or BMS systems. The monitoring and alarms interface shall be voltage free contacts from the PFC controller. Generally monitoring shall include Auto/Manual indication, common alarm and common fault indications and power factor out of range indication.

### **14.8 Contactors**

Contactors shall be adequately rated to switch the capacitor or inductor loads. The contactors shall be rated for an electrical endurance to give 20 years life based on the anticipated switching duty. The designer must ensure a suitable duty category is specified for all switchgear to meet the above requirement.

#### **14.8.1 Protection**

The PFC equipment shall be appropriately protected and shall be fail safe in operation (i.e. PFC component failure will not effect the power supply to the facility).

Each capacitive/inductor device shall be protected by appropriately rated HRC fuses and the HRC fuses are to be co-coordinated with the upstream circuit breaker. Notification of HRC fuse rupture is to be interfaced with the DESN/BMS as a common fault alarm.

The PFC shall automatically disconnect on controller failure.

The PFC shall be designed to suit the electrical system fault levels and shall include suitable harmonic drop out relays where appropriate. Harmonic drop out relays must be configured to trip and require manual reset by operator. Any alarm or fault including out of range alarm shall be suitably monitored as a common fault on the DESN or similar where present at an establishment.

The PFC shall automatically disconnect on loss of supply and when supply return the PFC shall resume normal operation.

The provision of automatically disconnecting the PFC equipment on an inappropriate power factor is required (e.g. leading power factor for capacitor bank) and alarmed appropriately.

#### **14.8.2 Provision for Maintenance**

The PFC shall be configured to allow maintenance to be easily performed. There shall be suitable facilities to discharge the capacitors, labelling of equipment to indicate the presence of high voltages, and ease of access to the rear of the panel.

Consider the maintenance requirements when determining the most appropriate equipment performance specifications and system arrangement. This shall be based on the required

performance, maintenance, reliability and the availability of comprehensive manufacturer's product support locally.

# **15 Hazardous Area and Explosive Area Electrical Installations**

## **15.1 Background**

This policy provides requirements for the design, construction and maintenance of electrical installations in Defence hazardous areas and explosives areas. The requirements are intended to outline the minimum Defence standards and the formal standards and statutory requirements applicable to hazardous and explosives area installations.

**Hazardous Areas.** A hazardous area is defined in the applicable standards as an area in which an explosive atmosphere is present, or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of potential ignition sources. The explosive atmosphere is caused by the presence of a flammable liquid, gas or vapour or by the presence of combustible dust in suspension or in layers or a combination of gas and dust atmospheres.

**Explosives Areas.** An explosives area is defined as an area in which explosives are present. Similar to hazardous areas, an explosives atmosphere is where, due to the presence of explosives, a flammable or combustible atmosphere is present, or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of potential ignition sources. The explosive atmosphere is caused by the presence of explosives in a liquid, gas or vapour form or by the presence of explosives dust in suspension or in layers or a combination of explosives gas and dust atmospheres.

**Explosives Ordnance Areas.** An explosives ordnance area is an area used for the handling, processing and storing of explosive ordnance. Where there is no fence, it is taken as being the area within a radius of 50m from any building or stack containing explosive ordnance. For the purposes of this document an Explosive Ordnance Area includes Explosives Areas, Explosive Ordnance Workshops and Explosive Ordnance Storehouses (see DEOP103 for definitions)

## **15.2 Performance Objective**

The objective of this policy is to:

- a) facilitate compliance with the respective hazardous and Defence explosives installation standards
- b) safeguard hazardous and explosives area installations by facilitating suitable performance of electrical installations, and
- c) ensure the economics of the design on a through life basis.

## **15.3 Reference Documents**

The following list of regulations and standards is identified as minimum guidance only and is not meant to represent a comprehensive list of all applicable regulations and standards.

### **State and Territory Regulations**

Guidance on the relevant State and Territory regulations is given in Standards Australia Handbook 13 *Electrical Equipment for Hazardous Areas* (HB13).

### **Australian Standards**

AS/NZS 3000	<i>Wiring Rules</i> , including referenced standards some of which are listed below.
AS 1020	<i>The control of undesirable static electricity</i>
AS/NZS 1768	<i>Lightning protection</i>
AS/NZS 2381	<i>Electrical equipment for explosive atmospheres</i>
AS/NZS 2243.7	<i>Safety in laboratories – Electrical aspects</i>
AS/NZS 2430	<i>Classification of hazardous areas (series)</i>
AS/NZS 3800	<i>Electrical equipment for explosive atmospheres – overhaul &amp; repair</i>
AS/NZS 3931	<i>Risk analysis of technological systems – application guide</i>
AS/NZS 4114	<i>Spray painting booths</i>
AS/NZS 61241	<i>Electrical apparatus for use in the presence of combustible dust</i>
AS IEC 61882	<i>Hazard and operability studies (HAZOP studies) – Application guide</i>

A comprehensive list of standards is given in Appendix B & Appendix C of HB13

### **Defence Regulations and Standards**

*Safety Principles for the Handling of Explosive Ordnance (OPSMAN 3)*

*Defence Explosive Ordnance Safety Manual (DEOP-103)*

*RAN Explosive Ordnance Safety Manual, Australian Book of Reference 862 (ABR 862)*

*Operational Safety Committee (Explosives) OSC(E)81/1 Safety Conditions for Electrical Installations and Equipment for Explosives Buildings and Areas* (referenced by the OPSMAN 3)

*Draft Code of practice Electrical Installations For Hazardous Areas (EIHA) (E) 1001 Int:2004 - Electrical Installations For Hazardous Areas at Explosives Manufacturing, Research,*

*Development and Storage Facilities - Classification, selection, installation and maintenance requirements*

*Manual of Fire Protection Engineering (MFPE)* The Manual of Fire Protection Engineering (MFPE) is the primary policy document when determining fire safety requirements for Defence facilities and its provisions are mandatory.

#### **Reference Publication**

Standards Australia *Handbook 13 Electrical Equipment for Hazardous Areas* (HB13). This handbook is to be used a guide, but does not replace the requirements of relevant regulations and standards.

### **15.4 Application of the Regulations and Standards**

Hazardous area and explosives area electrical installations shall meet all appropriate and relevant legislation and Australian standards for the type of installation or equipment to be used, irrespective of their status. In addition, hazardous area and explosives area installations must also comply with applicable Defence standards.

Where Australian standards are not available, recognised international or overseas national standards may be used where they are relevant to the type of installation or equipment and to the installation conditions in Australia. The designer shall detail in the design report all legislation and standards adopted together with clear indication of the extent and field of application.

Refer to the principles provided in Chapter 1 – Infrastructure Electrical Engineering in relation to conflicts between standards and regulations.

#### **Hazardous Areas**

All works in and around hazardous areas must be carried out in accordance with the applicable regulations and standards relevant to the state or territory in which the installation is being undertaken. Compliance with the standards and procedures specified in this policy does not absolve the obligation in respect of the standards prescribed by other government or statutory authorities.

#### **Explosive Ordnance Areas**

All works in and around Explosive Ordnance (EO) areas must be carried out in accordance with the applicable Defence regulations and standards as determined by the licensing agency, DEOS or DSTO (DSTO have their own separate licensing agent). The application of these regulations and standards is supplementary to and not alternative to any of the requirements given above for hazardous areas, AS/NZS 3000 and the applicable regulations which would apply to electrical installations and equipment in explosives areas.

Explosives area installations utilise the same protection techniques as hazardous area installations and are based on similar safety principles and practices and therefore must also comply with all relevant hazardous area regulations and standards.

OPSMAN 3 is the main reference document normally used. The *DEOP-103* is subordinate to the *OPSMAN 3*, and is intended to replace the former documents published by the single services (incorporating much of RAAF's *AAP 7039.001*, Navy's *ABR 862*, and Army's *ALI-POL 9-1*).

In case of insufficient information from OPSMAN3 and DEOP-103, the single services documents like RAAF's *AAP 7039.001*, Navy's *ABR 862*, and Army's *ALI-POL 9-1*, could be referred after consultation with DMOS and DEEP.

## **15.5 Certification of Hazardous Areas and Explosives Area Installations**

A competent person is to certify all electrical installations in hazardous areas and explosives areas as meeting the requirements of the applicable regulations and standards in accordance with Chapter 6 – Certification and Verification. This includes certification of explosives area installations to the Defence licensing agencies requirements and any relevant regulations and standards.

Certification involves all statutory obligations as required by the regulations such as the Notification of Electrical Works/Certificate of Electrical Safety or equivalent and accredited certifier's certificates where required. In addition, a Defence Hazardous/Explosives Area Compliance Statement is required as outlined in Chapter 6 – Certification and Verification.

Accredited certifiers certification for the purposes of this publication is meant to include all certification or inspections required by regulations such as the requirement for hazardous area prescribed work to be inspected by suitable inspector in Victoria and by an accredited auditor in Queensland.

Certification must be completed before connection to electricity supply and energising the installation. All certification documents must be provided in the verification dossier.

### **15.5.1 Defence Hazardous/Explosives Area Compliance Statement**

The Defence Hazardous/Explosives Area Compliance Statement is in addition to statutory requirements and is required to confirm the design, construction, commissioning and the satisfactory completion of the works. The requirements for Compliance Statements are provided at Appendix A and Chapter 6 – Certification and Verification.

### **15.5.2 Equipment Certification**

All electrical equipment installed in hazardous areas and explosives area must have suitable ANZEx/IECEx. All certification should be carried out by the equipment manufacturers and all items must be properly labelled. Ensure overhaul and repair of electrical equipment used in hazardous and explosives areas is in accordance with AS/NZS 3800.

## **15.6 Classification of Hazardous Areas and Explosives Areas**

Classification of hazardous or explosives areas is an important first step in determining the correct design approach. The classification is necessary to determine the type and extent of any hazard, possible hazard reduction measures, correct protection techniques and the necessary management practices required to ensure the safety of the facility and its occupants. Guidance on the classification process is given in HB13 at Chapter 4.

The user/occupier retains the responsibility for the recognition and classification of hazardous areas. However, it is the designer's responsibility to gather the required information from the client and users and to then determine the appropriate classification in conjunction with the user. The designer plays a key role in the classification and delineation of the hazardous and explosives areas and is normally the competent responsibility in this area.

### **15.6.1 Hazard Analysis**

Hazard analysis is a planning process used to identify and quantify hazards. It must include detailed assessment of the risks and safety implications that affect the occupancy and operation of the facility and the process intended to be undertaken therein.

The objective of the analysis in the context of this policy is to identify and quantify all hazards and uncertainties so that the appropriate area classification and treatment strategies can be determined. This is in addition to the normal classification and delineation of the hazardous and explosives areas.

Key outcomes of the hazard analysis must include identification of the hazardous materials and processes, the required standards and their application and consideration facility construction requirements in a holistic manner to ensure electrical safety is achieved.

Formal hazard analysis in the form of Hazard Operability Studies (HAZOP), Hazard Analysis (HAZAN) or Preliminary Hazard Analysis (PHA) is required under the following circumstances:

- a) All explosives facilities where an explosives atmosphere is or is expected to be present;
- b) All explosives facilities where explosive ordnance containing Electro-Explosive Devices (EED) are handled, maintained or tested;
- c) Complex hazardous areas (i.e. multiple hazards, or outside the specific occupancies identified by the standard); and
- d) As otherwise required by DEEP.

Any uncertainty as to the need for hazard analysis should be referred to DEEP. Guidance on hazard analysis assessment is given in AS/NZS 3931 and AS/IEC 61882.

The designer must liaise with users to identify particular activities and processes and identify all areas that may require special treatment and, where necessary, initiate suitable hazard analysis to establish the correct design approach and the appropriate installation requirements.

### **15.6.2 Explosives Areas (EA)**

The designer will need to liaise closely with the users and particularly the certifiers for areas involving EO. It is essential that the designer clearly determines the nature of the activities and degree of hazard before contemplating the design. The designer must adequately identify the specific hazards of the installation and ensure that the proposed electrical installation has addressed these hazards and ensures safety.

Whilst Australian Standards relevant to classification and delineation of hazardous areas specifically exclude application to the manufacture and handling of explosives, the processes contained therein are relevant and are to be applied in conjunction with the nominated Defence standards.

Another issue the designer needs to consider is the suitability of the proposed protection technique is to address the specific risks imposed by the EO. This may necessitate the performance testing of particular protection techniques where the relevant equipment test standard does not adequately represent the EO hazard.

All buildings that contain explosive ordnance incorporating EED or which can give rise to flammable or combustible vapours or dusts must undertake a hazard analysis as detailed in paragraph 15.6.1 above as part of the classification process.

## **15.7 Selection of Equipment and Protection Techniques**

The designer when selecting particular protection techniques must ensure that the protection technique is suitable for the installation taking into consideration the way in which the users intend to operate the facility and equipment, the agreed management practices and the nature of the hazards.

### **Explosives Areas**

Designers must assess the suitability of protection technique against the properties of the hazard. An example is the use of flameproof equipment where the equipment must be able to withstand the ignition of the intended gas air mixture. The designer must ensure that the type of gas air mixture correlates to the test gas groups for aspects such as explosion severity.

Designers must also determine the precautions necessary to protect facilities incorporating EED. Explosive ordnance incorporating EED will be susceptible to a variety of threats including those presented by radio frequency electromagnetic radiation, electrostatic energy, electrical transient discharge and also potential earth loops.

Particularly for explosives areas, the electrical equipment and installation must be deemed suitable for the conditions expected in service. The designer must therefore determine if additional equipment testing/certification is required to confirm suitability for the particular hazards anticipated in service.

## **15.8 Installation Requirements**

### **15.8.1 Materials**

Only new materials in accordance with the relevant standards shall be used unless otherwise specified by the FDB. The materials chosen shall be suitable for the particular application and shall not be incompatible with the materials and processes used within the facility.

### **15.8.2 Earthing and Bonding**

Earthing and bonding shall be in accordance with the respective requirements of the applicable standards. Care shall be taken to ensure earth loops are eliminated and wherever possible earthing systems are equipotential bonded.

All non-current carrying conductive components in hazardous areas are to be equipotential bonded including Zone 2 areas.

EO areas will have special earthing requirements detailed in the applicable standards or in the FDB. Depending on the EO regulation used these may be specified as separate earthing systems. Some EO devices incorporating EED may have a very high sensitivity to electrostatic discharge which must be considered in determining the most appropriate earthing system. The designer when considering the facility earthing system requirements must ensure the earthing systems and ordnance earthing system are considered in a holistic manner and must ensure that the activities and processes do not create earth loops or give rise to any condition that will result in hazardous or unsafe condition.

### **15.8.3 Electrostatic Protection**

Electrostatic protection requirements for EO incorporating EED are detailed in the applicable EO standards.

Electrostatic precautions for areas in which flammable or combustible atmosphere may be present must meet the requirements of AS 1020.

### **15.8.4 Radio Frequency Interference and Electromagnetic Compatibility**

The designer must ensure that the electrical installation does not give rise to any harmful emissions that could compromise the safety of the operations in the facility. For particularly sensitive facilities or equipment the designer must also ensure that appropriate measures are incorporated in the facility design to prevent any harmful internal or external influence to the facility (e.g. shielding).

Suitable safety signage and procedures shall be provided at the facility where appropriate, to prevent unauthorised equipment entry or to enforce suitable safety perimeters.

Facilities or areas containing EO incorporating EED and/or electronic circuits must have a suitable risk hazard assessment for all electromagnetic radiation hazards, cognisant of the radio frequency

electromagnetic radiation susceptibility of the EO or EED. Refer further to OPSMAN 3 for electromagnetic radiation assessment and requirements.

### **15.8.5 Lightning Protection**

Lightning protection must be installed for all hazardous area and explosives facilities. The lightning protection design shall meet the requirements of AS/NZS 1768.

### **15.8.6 Signage**

Refer to Chapter 10 – General Technical requirements for signage requirements.

### **15.8.7 Specific Installation Requirements for Fuel Farm Laboratories**

Fuel Farm laboratories, also known as Fuel Quality Control Centre (FQCC) require special consideration due to the nature of activities undertaken therein. The main issue is that the electrically powered test equipment must be located in the defined hazardous area and this equipment cannot be certified as required by Australian Standards due to the inherent nature of the equipment. Whilst the electrical installation can and should be installed outside the defined hazardous area (by AS 2430), the installation must be protected by ventilation (Ex V) to overcome the test equipment limitations. Guidance on the FQCC requirements is given in (*draft standard - no numbering at present*).

## **15.9 Routine Inspection and Maintenance**

Routine inspection and maintenance requirements are detailed in the applicable standards. Where insufficient guidance is provided in current Australian standards, IEC 60079-17 shall be used.

In summary, the minimum maintenance requirements are provided below and must include annual visual inspections and thermographic test of the switchboards, cabling and electrical equipment under normal operating conditions. It is not intended that electrical equipment within the hazardous or explosives area need to be dismantled for thermographic tests. Please note that any discrepancy between the table below and those of the regulations and standards, the standards and regulations shall take precedence.

■ **Table 15.1: Inspection Maintenance**

<b>Inspection</b>	<b>Standard</b>	<b>Interval</b>
Initial installation or after modification - Detailed Inspection	AS 1020, AS/NZS 2381 AS/NZS 3000, HB13 and IEC60079-17	Before connection
Visual Inspection	as above	Yearly
Close and Detailed Inspection	as above	Max 4 yearly. Varies, as required by the standards
Thermographic Test		Yearly
Lightning Protection	AS/NZS 1768	Yearly

Hazardous and explosives area routine inspection and test reports shall be completed for each inspection and recorded in the verification dossier and DEMS-FM. These reports shall record the results of the inspections required above.

Modify the re-verification date on the facility hazardous area sign as appropriate after the completion of the routine inspections and testing.

# **16 Power Systems for Aircraft Servicing and other 400Hz Applications**

## **16.1 Background**

Power systems for aircraft servicing and other 400Hz applications are specialised installations with important considerations. The aircraft servicing supplies need to be compatible with the on-board aircraft systems they serve and also ensure safety of the equipment and personnel. This policy defines the minimum engineering requirements technical requirements of fixed 400Hz power supplies for aircraft servicing in hangers, workshops and other areas.

## **16.2 Performance Objective**

The objective of this policy is to:

- a) facilitate compliance with the respective installation standards;
- b) safeguard aircraft electrical systems;
- c) facilitate the suitable performance of 400Hz installations
- d) provide a consistent operator interface for Defence operators, and
- e) ensure the economics of the design on a through life basis.

## **16.3 Reference Documents**

### **Standards/Codes**

All materials and workmanship shall be of the best standard and shall comply with the relevant legislation and Australian Standards, or if such do not exist, with the relevant IEC or International (ISO) Standards.

Irrespective of any requirements shown in these documents the installation as a whole shall comply with:

#### **Australian Standards**

AS 1020	<i>The control of undesirable static electricity.</i>
AS 1055	<i>Acoustics. (Series).</i>
AS/NZS CISPR 14.2	<i>Electromagnetic compatibility - Requirements for household appliances electric tools and similar apparatus - Immunity - Product family standard</i>
AS 1243	<i>Voltage Transformers for Measurement and Protection.</i>
AS 1307	<i>Surge Arrestors.</i>
AS 1627	<i>Metal Finishing – Preparation and pre-treatment of surfaces.</i>

AS 1675	<i>Current Transformers - Measurement and Protection.</i>
AS 1767	<i>Insulating Liquids. (Series).</i>
AS/NZS 1768	<i>Lightning Protection.</i>
AS 1939	<i>Degrees of Protection Provided by Enclosures for Electrical Equipment.</i>
AS 2374	<i>Power Transformers. (Series).</i>
AS 2381	<i>Electrical Equipment for Explosive Atmospheres. (Series)</i>
AS 2467	<i>Maintenance of Electrical Switchgear</i>
AS 2650	<i>High Voltage AC Switchgear and Controlgear - Common Requirements.</i>
AS/NZS 3000	<i>Wiring Rules.</i>
AS 3702	<i>Item Designation in Electrotechnology.</i>
AS 3013	<i>Electrical Installations – Wiring Systems for Specific Applications.</i>
AS 4070	<i>Recommended Practices for protection of low voltage electrical installations and equipment in MEN systems from transient voltages.</i>
AS 61000	<i>Electromagnetic Compatibility (series).</i>

#### **400Hz Standards**

MIL-STD-704	<i>Aircraft Electrical Power Characteristics</i>
MIL-STD-1399-300	<i>Interface Standard for Shipboard Systems</i>
DEF (AUST) 290	<i>Electrical Power Supply Systems Below 600 Volts</i>
ASCC 25/19A	<i>Connectors for 115/200 Volt 400Hz 3-Phase AC Servicing Power</i>
DI(AF)AAP 7600.500-14M	<i>GSE Handling Procedures General Maintenance and Safety Precautions</i>
STANAG 1008	<i>Characteristics of Shipboard Electrical Power Systems in Warships of the North Atlantic Treaty Navies.</i>

## **Other Standards**

Any requirements as per the applicable IEEE, ISO and IEC Standards, including:

ISO 6858	<i>Aircraft - Ground Support Electrical Supplies- General Requirements</i>
BS 2G 219	<i>Specification for General Requirements for Ground Support Electrical Supplies for Aircraft</i>
MIL-STD-461	<i>Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment.</i>
MIL-HDBK-217	<i>Reliability prediction of Electronic Equipment</i>

The rules and regulations of the relevant DNSP.

The Building Code of Australia (BCA).

The requirements of any other Authority having jurisdiction over the installation.

## **16.4 Technical Requirements**

400Hz systems shall generally be based on 200/115V four wire systems and are required for a number of applications as follows:

- a) Aircraft Hangers, Shelters and Aprons (including OLAs): To power aircraft systems without the need to run the aircraft engines
- b) Workshops: To power electrical systems on electronic and weapons systems

### **Technical Considerations**

Distribution of electrical power at 400Hz offers a number of technical challenges when compared with 50Hz. These apply largely to the impedances and losses within the distribution system, principally the cabling. Compounding the challenges associated with increased distribution losses is the quite close tolerances on both voltage drop and no-load to full-load voltage regulation required of the supply.

The nature of aircraft static earthing, and its interaction with the fixed 400Hz system is also an important consideration when determining protection system requirements.

#### **16.4.1 Output Characteristics**

The 400Hz system shall provide a sine wave output with characteristics and tolerances in accordance with the applicable standard(s) defined by the respective aircraft Systems Project Office (SPO) when measured at the following locations:

- a) For aircraft power: At the 200/115v 400Hz aircraft connection,
- b) For workshop power: At the 200/115v 400Hz outlet,

For certain aircraft this may require confirming the aircraft power supply meets both the current and earlier version of the standard (e.g. F111 requires compliance with MIL-STD-704A, the current standard is 704F, the design must comply with both).

Where the installation may support a number of aircraft types or loads the installation shall be designed to comply with all standards using the most demanding criteria. Conflicts between standards shall be dealt with as detailed in Chapter 1 – Infrastructure Electrical Engineering. Alternative solutions must be addressed as detailed in Chapter 6 – Certification and Verification.

Frequency converters shall comply with the above characteristics for both linear and non-linear loads as specified.

The designer must ensure that the output characteristics are maintained within prescribed limits and for aircraft ground power, to the aircraft input receptacle. The designer must also ensure suitable transient and surge performance of the frequency converters and the supply system.

The Tables and Classes contained in DEF(AUST)290 ELECTRICAL POWER SUPPLY SYSTEMS BELOW 600 VOLTS shall be modified as detailed below.

DEF(AUST)290 Table IV Class D modified as follows:

■ **Table 16.1: DEF(AUST)290 Table IV Class D**

Ref.	Item	Parameter	
Line 4	Transient surge component	Para. 4.12.1(i) - Low Limit:	16%
Line 5	Transient surge component	Para. 4.12.1(i) - Recovery Time:	1 sec
Line 6	Transient surge component	Para. 4.12.1(i) - High Limit:	16%
Line 7	Transient surge component	Para. 4.12.1(i) - Recovery Time:	1 sec
Line 17	Divergence	Para. 4.16:	5%

In addition all standards must include the following performance requirements:

- Voltage spike (peak value) at the point of entry to the converter building must be at least 6000V.
- Minimum Over Load Capacity of 200% for 250 mSec

#### **16.4.2 System Configuration**

Two types of basic configurations can be adopted in the design of fixed 400Hz system. The choice of which system is adopted needs to be made on the basis of capital/recurrent costs on a through-life basis, together with operational considerations.

The designer will need to confirm the most appropriate arrangement via a through-life assessment.

### **Distributed Systems**

This configuration uses individual frequency converters for each individual location. An example is an isolated OLA where the outlets at the OLA are supplied from a single frequency converter.

Distributed systems have advantages in terms of reduced 400Hz distribution cabling as the converter is close to the end user. However for larger installations the increased number of converters can increase both capital and ongoing maintenance costs.

### **Centralised Systems**

This configuration uses a centralised converter or bank of converters to supply a number of different locations. An example is a group of OLAs where the converter/s can be located adjacent to the substation.

In order to allow the 400Hz power to be distributed across larger distances higher distribution voltages are often used in centralised systems. The typical higher voltage used in this situation is 960V. This is still LV and therefore avoids the need to apply high voltage equipment/installation standards. This arrangement does however require the installation of step-down transformers near to the point of utilisation.

The lower number of converters can offer advantages in terms of capital and ongoing maintenance and energy efficiency. However this needs to be balanced against the increased complexity of control and reduced redundancy. End of line voltage monitoring may be required as an input to the voltage regulator.

#### **16.4.3 System Capacity**

Aircraft and workshop loads vary greatly depending upon the type of installation and how it is operated. Aircraft loads in particular exhibit large peaks, especially when pumps and control surfaces are operated.

Note that these and other special applications may require a higher short time peak load than standard. For these special loads, the required load profile should be specified so that the appropriate characteristics can be designed into the inverter. For static systems, this may require customising the rating of reactive compensators which is more efficient than over rating the entire unit.

The following loads are offered as a guide, however the Designer shall determine the actual loads to be used in the design and confirm these in the CDR.

#### **■ Table 16.2 Aircraft Power Requirements**

<b>Operating Condition</b>	<b>P3C</b>	<b>C130J</b>	<b>F/A-18</b>	<b>F111</b>
Steady State	55kVA	50kVA, 15 minute av.	30kVA	60kW max
Peak	Extra 130A/phase on	54kVA,	72kVA on Start-	N/A

start-up	5 second av.	up
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#### **16.4.4 Housing of Equipment**

The housing of equipment, particularly the frequency converters shall consider the following factors:

- a) Environmental conditions;
- b) The pattern of usage of the equipment;
- c) Passive defence, and
- d) Post disaster functionality.

##### **Environmental Conditions**

The housing of 400Hz system components shall consider the relative sensitivity of electronic equipment and rotating machinery to environmental conditions. In areas subject to atmospheric contamination or areas subject to high relative humidity consideration should be given to housing equipment indoors.

Where equipment is located indoors suitable means shall be provided to remove heat generated from the space so that the room temperature under worst case conditions does not exceed the maximum permissible ambient temperature for the equipment.

##### **Pattern of Usage**

In certain locations fixed 400Hz systems are subject to infrequent usage. The design shall incorporate measures to ensure that environmental conditions do not result in excessive degradation of the equipment under these circumstances. The following measures shall be considered:

- a) Suitable weather protection for externally mounted equipment;
- b) Anti-condensation heaters; and
- c) Air conditioning of indoor equipment to reduce relative humidity. Note: A cost effective solution might be to provide air conditioning when the unit is not running and provide ventilation only, at a high rate, to remove losses when the unit is running. This will of course depend upon any atmospheric pollutants.

Even when operated continuously the system might be required to operate at no load for extended periods. The system shall be constructed to withstand such usage.

##### **Passive Defence**

Auxiliary power for aircraft is an important service. The nature of much commercial equipment is such that the equipment does not survive physical attack well. For that reason additional protection will be required when Defence nominates defined passive defence requirements. These requirements will normally be identified in the FDB.

### **Post Disaster Functionality**

Facilities that have a post disaster function require consideration to ensure a certain amount of survivability in the event of natural disaster. For example, cyclonic events and in certain circumstances the fixed 400Hz system may be required to support aircraft operations following a cyclone. In such an instance the housing of the 400Hz installation should consider means to limit damage to the system from the cyclone including flying debris and water ingress.

## **16.5 System Operation**

### **Overview (Refer to paragraph 16.14 – Standard Arrangement Drawings.)**

The operator is required to manually start the system. This generally occurs at the Remote Control Panel within the facility. A Control Panel is to be provided at the converter but this is largely for maintenance purposes.

The operator connects the aircraft to the 400Hz system using an umbilical lead from the wall socket to the aircraft inlet connection. The supply is energised for a period by pressing the Connect button adjacent to the wall socket.

The supply shall remain energised only if the aircraft connects, and remains connected, within the time period. Failure to do so shall automatically de-energise the supply system. Once connected, any disconnection of umbilical lead or supply shall automatically de-energise supply.

The aircraft is disconnected from the 400Hz system by pressing the Disconnect button adjacent to the wall socket and removing the umbilical lead.

The control system runs the required converters to suit the load profile of the facility. The converters remain running until the system automatically shuts down at which point it shall automatically disconnect and stop. Automatic shutdown shall be initiated if no aircraft are connected for a period of 15 minutes (adjustable from 10 min to 1 hour).

### **Multiple Converter Systems**

Where multiple converters are provided to feed a common bus they shall be staged on and off in response to changes in electrical demand. Appropriate hysteresis shall be incorporated to optimise the utilisation of the converters and to achieve efficiency. As an example for a two converter systems this shall consist of:

- a) When the running (first) converter reaches 60% load for a period exceeding 10 seconds the second converter shall start, synchronise and connect to the load.
- b) When the combined load on both converters falls below 70% capacity of one converter for a period exceeding 5 minutes one converter shall disconnect and stop.

## **Other Facilities**

The operator shall manual start and stop the system. This generally occurs at the Remote Control Panel within the facility. A Control Panel is provided at the converter but this is largely for maintenance usage.

## **16.6 Earthing**

### **200/115V Systems**

Prior to operations beginning on an aircraft a static earth is applied to the airframe to discharge any static electricity. Also note that from an electrical viewpoint the area immediately surrounding the fuel storage areas of aircraft are hazardous areas.

There is no earth cable in the aircraft lead and the 400Hz neutral within the aircraft is connected to the airframe. If the 400Hz system were earth referenced at the point of supply a fault within the aircraft could result in fault currents flowing in the static earthing system and possibly resulting in a spark within the hazardous area. For this reason 115V 400Hz systems are not solidly earthed. Instead protection shall be provided to detect earth faults to minimise risk to personnel and property.

### **960/555V Systems**

960V systems are 3 wire 3 phase systems that are solidly earthed.

A separate earth cable shall be run from the converter to the step-down transformer. The earth shall not form part of the power cable where it will adversely impact of the cable asymmetry (i.e. impacting on the cable losses).

## **16.7 Protection**

### **16.7.1 Fault Clearance**

The fault clearance capacity of 400Hz sources can be relatively low. As a result it can be difficult to achieve mandatory fault clearance times. Considerable attention shall be given to system protection to ensure that the fault clearance requirements of AS/NZS 3000 are met.

### **16.7.2 Protection Equipment**

All protection equipment shall be certified by the manufacturer as being suitable for use in 400Hz systems and at the applicable voltage level.

### **200/115V Systems**

Overcurrent and fault protection shall be provided by means of circuit breaker(s).

Earth fault detection consisting of neutral displacement detection shall be provided to detect earth faults in the system. An acceptable solution is a voltage relay between neutral and earth at the source of supply. The earth fault protection shall shunt trip the circuit breaker using a 230V supply. The tripping supply shall be monitored to raise an alarm on failure.

### **960/555V Systems**

Overcurrent and fault protection shall be provided by means of appropriately rated circuit breakers.

Where required to meet earth fault clearance times earth fault protection shall be provided. An acceptable solution is a residual current device with a definite time element that shunt trips the circuit breaker using a 230V supply. The tripping supply shall be monitored and raise an alarm on failure.

### **Transient Overvoltage**

Transient overvoltage protection shall be used to protect equipment from lightning induced transients on long cable runs or on sensitive equipment.

Where suitable equipment is commercially available the condition of the protective elements shall be monitored to raise an alarm on failure.

## **16.8 Frequency Converters**

### **Technologies**

Two frequency converter technologies are presently in widespread use:

- a) Static Converters – Use solid-state inverters to generate 400Hz.
- b) Rotary Converters – Use rotating machinery, in effect a motor and alternator to generate 400Hz.

Each type has certain advantages and disadvantages and this policy is not biased in favour of one or the other technology. Instead the technical requirements shall be specified after due consideration of such factors as the operating cycle and technical considerations such as fault clearance capacity.

For continuous operations operating costs and efficiency become more important.

### **Protection**

The frequency converter shall have in-built protection against:

- a) Over and under voltage disturbances on the incoming mains supply including surges caused by lightning;
- b) Overcurrent and short circuit at the output terminals (for phase-to-phase and phase-to-earth faults);
- c) Load switching and circuit breaker operation in the supplied distribution system;
- d) Sudden changes in output load, and
- e) Over-temperature.

The frequency converter shall have built-in protection for the prevention of permanent damage to itself or the connected load in the event of a fault within the frequency converter.

## **Control**

Each converter shall be fitted with the following:

- a) Emergency stop pushbutton
- b) Control switch - Local/Remote: In the Local mode the converter shall be operated from the local panel with any control from the Remote Control Stations inhibited. In the Remote mode the controls on the local panel shall be inhibited (with the exception of the Emergency Stop), with control of the converter only from the Remote Control Stations. Local mode disables automatic shutdown of the converter.
- c) Converter Start pushbutton
- d) Converter Stop pushbutton (Disconnect and Stop)
- e) Converter On-line pushbutton (only if starting and connecting are a two stage process)
- f) Lamp test pushbutton
- g) Converter Running indicator (White)
- h) Converter On-line indicator (White)
- i) Converter Fault indicator (Amber)
- j) Fault Reset pushbutton

## **Instrumentation and Indication**

The frequency converter shall have an integral control and indicating panel, housing all instrumentation required for the efficient operation of the system. Instrumentation shall include but shall not be limited to:

- a) Voltmeters or LCD to display both input and output phase to neutral voltages.
- b) Ammeters or LCD to display both input and output line current.
- c) Frequency meter or LCD to measure input and output frequency.
- d) Hours run indicator to indicate the operating time in hours - operating time shall be taken when frequency converter is supplying load.

Indicators shall be provided for all status, fault and warning conditions such that the condition of the converter is immediately obvious to an operator who is not familiar with the equipment.

## **Efficiency**

The efficiency of each converter at full load shall not be less than 85%.

## **Availability**

Each frequency converter shall have a Mean Time Between Maintenance (including scheduled and unscheduled maintenance where maintenance requires a discontinuity to service) of not less than 50,000 hours when operated under the following ambient conditions:

- a) Temperature of 50 °C
- b) Relative humidity up to 99%.

Reliability calculations shall be performed in accordance with MIL-HDBK-217D to demonstrate compliance. These calculations shall be the basis for these calculations and the source of failure rate data.

The Mean Time To Repair shall be 2 hours with a Maximum Time To Repair of 12 hours.

#### **Standby Power Supply**

The converters shall be suitable for operation from the standby generators, where these are provided.

### **16.9 Remote Control Panels**

Provide a Remote Control Panel at a convenient location within each facility. For larger facilities supplied from a single converter multiple Remote Control Panels might be required.

The control station shall provide the following functions and status indications:

- a) Converter Start pushbutton
- b) Converter Stop pushbutton (not for aircraft supplies)
- c) Lamp Test pushbutton
- d) Mute pushbutton
- e) Converter Online indicator (White): Indicates that a converter is running and connected
- f) Converter Fault indicator (Amber)
- g) Converter Fault audible indicator

Instrumentation to display analogue information such as volts amps etc is not required at the Remote Control Station.

## 16.10 Transformers

The transformer shall have the following basic construction:

■ **Table 16.3: Transformer Characteristics**

Type:	Dry type - Fully enclosed
Cooling:	Air, Natural Convection
Overloading:	10% for 1 hr
Rated voltages:	
- Primary voltage windings:	960/560V
- Secondary voltage windings:	200/115 V
Insulation grade:	B to AS 2768
Insulation level:	5 kV peak
Neutral terminal impulse withstand:	3 kV peak
Losses:	
- No load:	To suit the system
- Load:	To suit the system
Parallel operation:	None

## 16.11 400Hz Outlets

### 16.11.1 Aircraft Outlet Location

The outlets should generally be wall mounted at approximately 1.2 m above floor level wherever possible.

Where wall mounting is not practical the outlets can be either fixed to the end of a cable reel suspended from the roof structure or in-ground mounted. The use of in-ground outlets shall generally be avoided.

**Provide prominent warning label adjacent to outlets to state the voltage and frequency.**

### 16.11.2 Outlet Type

The type of outlets will depend upon the installation method as follows:

a) Wall Mounted Outlets:

400 Hz outlets shall consist of 200A 9 pin de-contactor type modified so that one of the 200A pins is converted into a multiple control pin allowing for interlocking arrangement and for provision of 28VDC "feedback" from the aircraft. The interlock should be such that power outlet cannot be energised without a plug being inserted into the outlet and an attempt of pulling out the plug will disconnect power supply to the outlet before the active and neutral pins of the plug and the socket are decoupled.

Adequate capacity 9-pin outlets (200A for “active” and “neutral” pins, and control pins capable of accepting a minimum of 2.5mm<sup>2</sup> control cables), with provisions for interlocking circuit and 28VDC control form the aircraft will be considered if submitted in accordance with specified procedures for alternatives.

b) Cable Reel Outlets:

A separate outlet is not required. The aircraft plug shall be directly affixed to the end of the trailing cable.

c) In-ground Outlets:

The Designer shall investigate alternatives and advise the selected solution.

All pins at the outlet and the plug shall be labelled. It is acceptable to have power supply earthing conductor connected directly to the body of the socket outlet. The earthing conductor does not need to be extended to the aircraft.

#### **16.11.3 Aircraft Connected Indication**

When 400Hz supply is connected to an aircraft it returns a 28VDC signal. This signal is used to determine if an aircraft is connected to the supply.

#### **16.11.4 Aircraft Outlet Control**

A stainless steel control box housing the following shall be located adjacent to the outlet:

- a) Connect pushbutton
- b) Disconnect pushbutton
- c) Connected indicator
- d) Power contactor
- e) Associated control equipment.

The power contactor shall control the energisation of the outlet as follows:

- a) The contactor shall be disabled if a plug is not inserted into the outlet.
- b) When the Connect pushbutton is pressed the contactor shall close and remain closed for an adjustable period (1 – 60 seconds, default 20 seconds). During this time the Connected indicator shall flash.
- c) If an aircraft does not connect during this time period the outlet shall de-energise.
- d) If the aircraft connects while the outlet is energized the contactor shall latch closed and the Connected indicator shall stop flashing and illuminate.
- e) If the umbilical is removed from either the outlet or the aircraft the outlet shall de-energise.
- f) The outlet shall de-energise if the Disconnect pushbutton is pressed.

### **16.11.5 Aircraft Connection Configuration**

Aircraft connectors shall comply with ASCC 25/19A and are to be configured to meet the aircraft requirements.

Generally the configuration of the socket on the aircraft is as follows:

▪ **Table 16.4: Socket Configuration on Aircraft**

Pin	Function
A	A Phase, 400Hz,
B	B Phase, 400Hz,
C	C Phase, 400Hz,
N	Neutral, 400Hz. Connected to airframe
F	28VDC Aircraft Connected signal from aircraft. This signal goes 'Hi' if the external supply has been connected to the aircraft connector
E	28VDC Enable External Power signal to the aircraft. If this signal goes 'Hi' the aircraft will connect the external supply to the aircraft systems, provided other checks, e.g. phase rotation, are also satisfactory.

For the aircraft to connect the external supply the aircraft plug must therefore have an internal bridge between pins E and F.

The sequence of operations for connection is as follows:

- a) The umbilical lead is attached to the aircraft, connecting the neutral to the airframe.
- b) 400Hz supply is made available. The aircraft returns a 28VDC signal on Pin F.
- c) 28VDC is returned to the aircraft on Pin E.
- d) If checks within the aircraft on the quality of the 400Hz supply are satisfactory the 400Hz supply is connected to the aircraft systems.

### **16.11.6 Workshop Outlets**

Workshop outlets shall comply with the requirements of DI(AF)AAP 7600.500-14M.

Workshop outlets shall be energised whenever the converter is running and connected.

## **16.12 Cabling**

The performance of cabling systems at 400Hz differs from that at 50Hz and in particular:

- a) The influence of cable reactance increases with frequency. This increases voltage drop.
- b) Resistance increases marginally as a result of skin effect.
- c) Reactance of the individual phase conductors is a function of the physical arrangement of the conductors. Asymmetrical phase conductor arrangements can result in different reactance's for each of the three phases. For longer cabling runs this can have an effect on voltage balance.

### **200/115V Systems**

For short runs, where the conductor reactance is a small component of the overall system impedance, standard 4 core cables can be utilised.

For longer runs specialist low-reactance 400Hz cables should be used to maintain phase voltage balance.

The earth should be run as a separate cable as its inclusion with the phase conductors will result in further asymmetry.

### **960/555V Systems**

1000V rated three core cables are generally acceptable for most situations.

The earth should be run as a separate cable as its inclusion with the phase conductors will result in a degree of asymmetry.

### **Umbilical**

Special configuration (Copper 7-core for power, 2 core per phase and one neutral, and 2-cores for control) low reactance cables (LRC) minimum 200A per phase capacity shall be provided for 400Hz umbilical's.

Suitable cable storage facilities shall also be provided.

### **Shielding**

Shielding should be considered where there is a potential for induction into adjacent systems.

### **Termite Protection**

Termite protection (comprising a Nylon jacket and sacrificial over sheath) shall be provided to all underground cabling in regions subject to high termite activity. For those special types of cables that are not available with termite protection, double insulated cables may be used without Nylon termite protection provided they are enclosed in uPVC conduit.

### **Cable Enclosures**

Cable enclosures and supports should preferably be non-ferrous.

Care shall be exercised when penetrating ferrous enclosures or building elements to minimise the effects of eddy currents.

## **16.13 Defence Engineering Services Network (DESN) Monitoring Requirements**

Provide voltage free contacts to allow monitoring of the status of the system as follows:

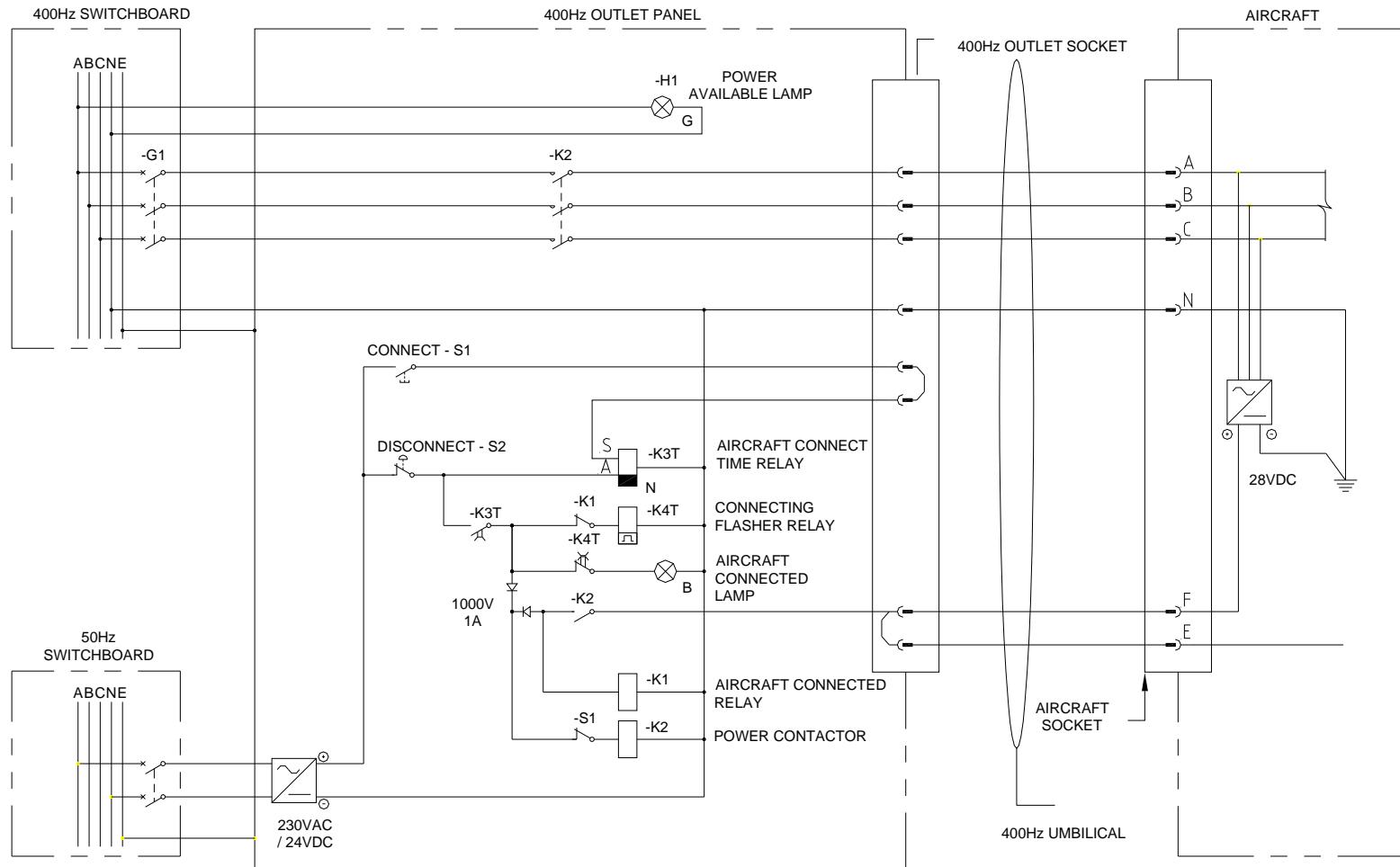
- a) Run, On-line, Fault status of each converter
- b) The status of surge diverters

Where required by the FDB, the DESN will be required to monitor the frequency converter operation and provide exception reports when the frequency converters are being run excessively or not automatically shutting down.

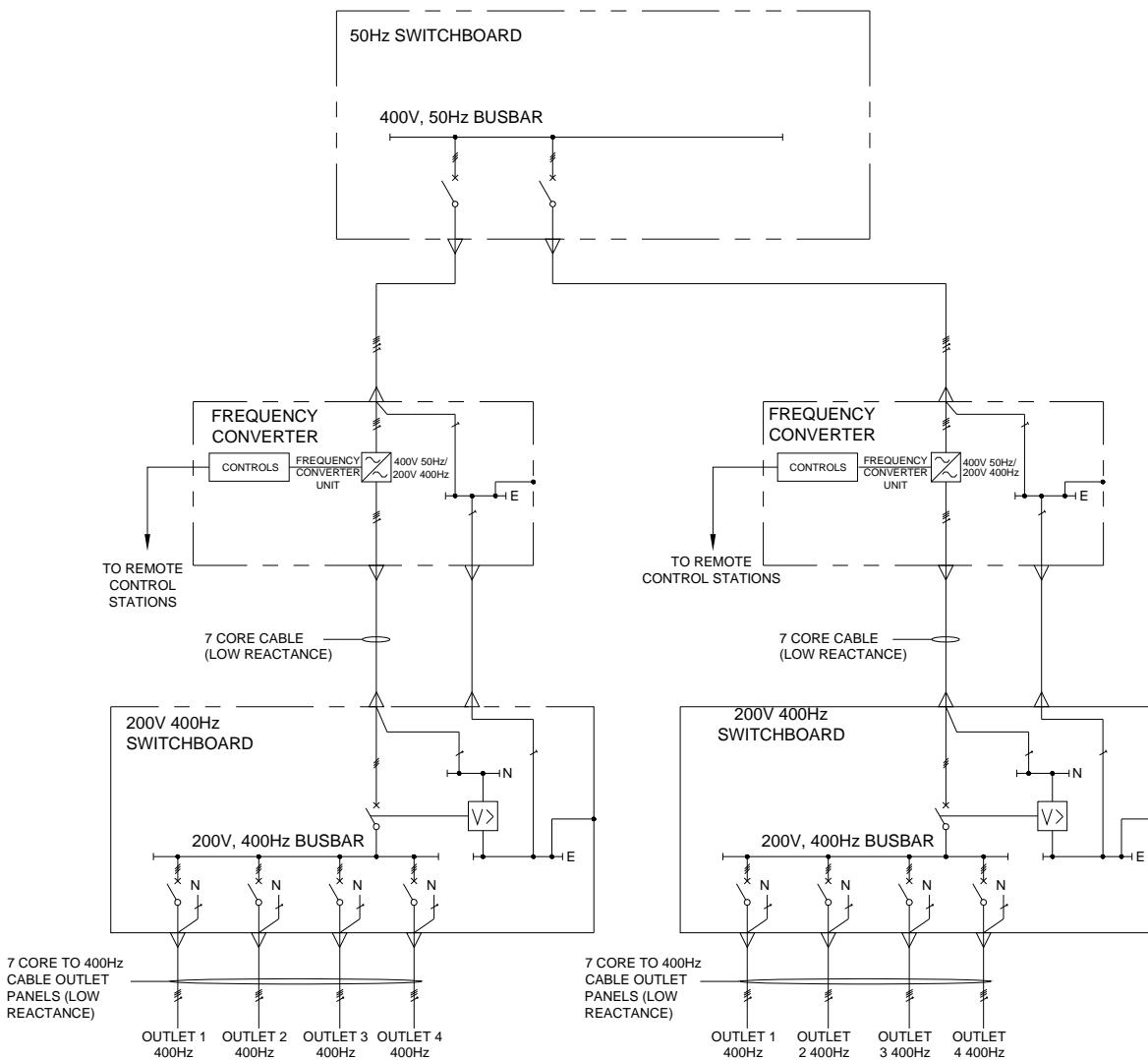
#### **Load Shedding**

Where centralised 400Hz systems are supplied directly from substations separate load shedding and metering is generally required. Distributed 400Hz systems are usually supplied from the associated facility switchboard and are therefore load shed as part of the facility.

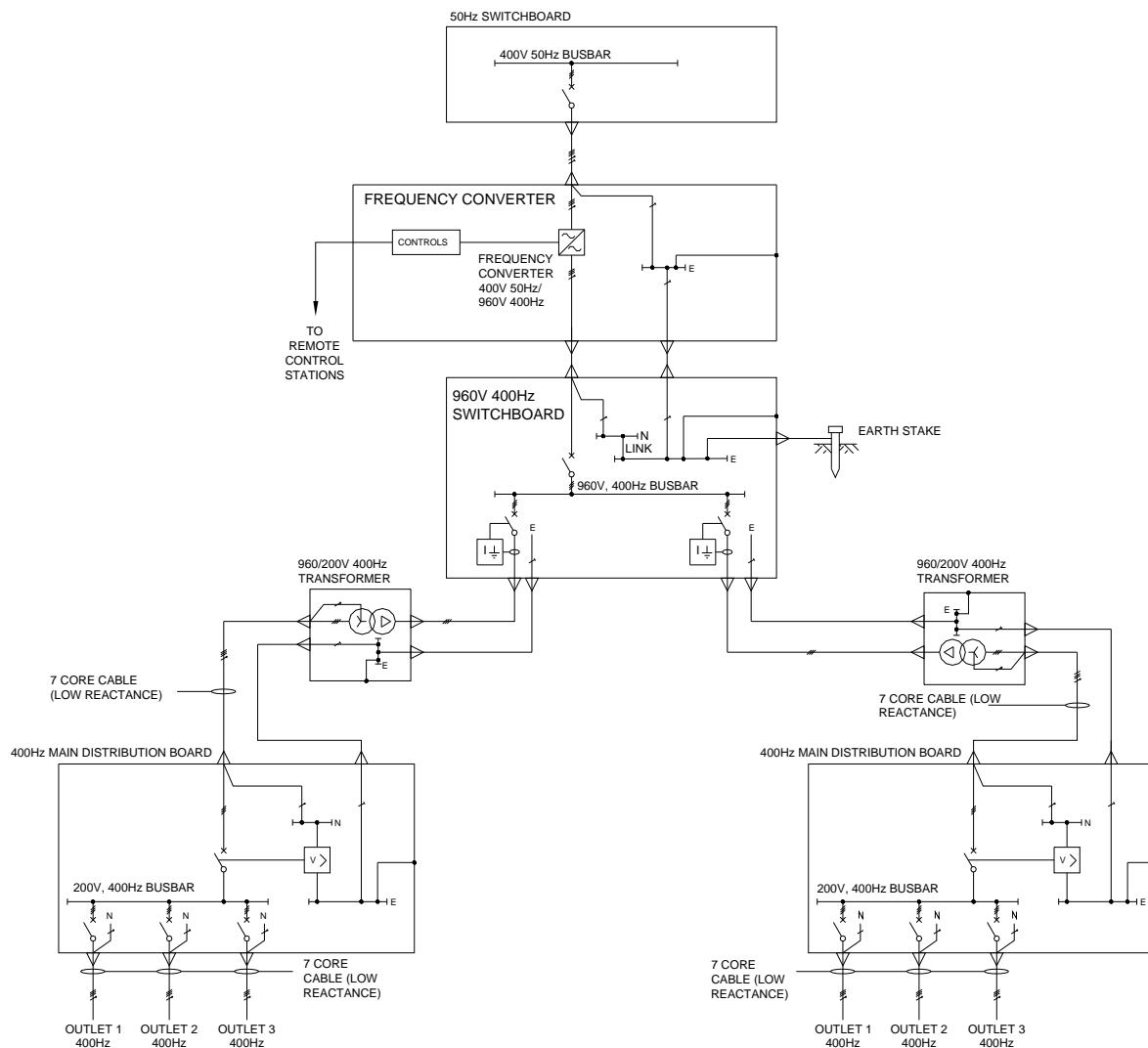
### **16.14 Standard Arrangement Drawings**



■ Figure 16.1: Typical 400Hz Outlet Schematic



■ **Figure 16.2: Typical 400Hz Distributed System Configuration**



■ **Figure 16.3: Typical 400Hz Centralised System Configuration**

# **17 Other Requirements**

## **17.1 Aircraft Earth Reference Points**

Aircraft earth reference points shall comply with the requirements of Australian Air Publications (AAP) 7045.002-01 Chapter 14. Where associated with a facility or future facility they shall be equipotentially bonded in accordance with AS/NZS 3000, AS1020 and AS1768. Note the FDB needs to specify the required location of the aircraft earth reference points.

## **17.2 Wharf Services**

Shore electrical power for Royal Australian Navy (RAN) ships and submarines shall meet the requirements of Navy Standard DEF AUST 5000 Vol 05 Pt 11.

## **17.3 Liquid Dry Breathing Oxygen (LDBO)/Cryogenic Facilities**

Liquid Dry Breathing Oxygen and Cryogenic facility electrical installations shall comply with DI AF AAP 7002.023 and the relevant standards.

## **17.4 Battery Rooms**

Battery installations shall comply with AS 2676 Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings and AS 3011 Electrical Installations - Secondary batteries installed in buildings.

Please note for Battery Workshops, Defence currently has a preference for discrete battery chargers for battery charging in lieu of large battery charger/reticulated systems.

## **18 Reserved**

## **19 Reserved**

# **Emergency Power Systems Requirements**

- 20        Uninterruptible Power Systems
- 21        Local Emergency Generator (LEG) Requirements
- 22        Mobile Generator Link Boxes (MGLB)
- 23        Reserved
- 24        Reserved
- 25        Reserved

# **20 Uninterruptible Power Systems (UPS)**

## **20.1 Background**

An Uninterruptible Power System (UPS) is equipment that maintains power to critical equipment load continuously. To achieve this, a UPS has an associated energy storage device (e.g. battery, flywheel); the capacity of which determines the maximum duration supply is maintained to the load whilst power is absent from the input side of the UPS. Normally this capacity is sufficient to allow a generator to start and come online or to allow orderly shutdown of equipment.

This standard contains policy, guidance and detailed technical material as necessary to define the Defence performance requirements and standards to be applied, in addition to the applicable statutory regulations and standards.

### **Types of System**

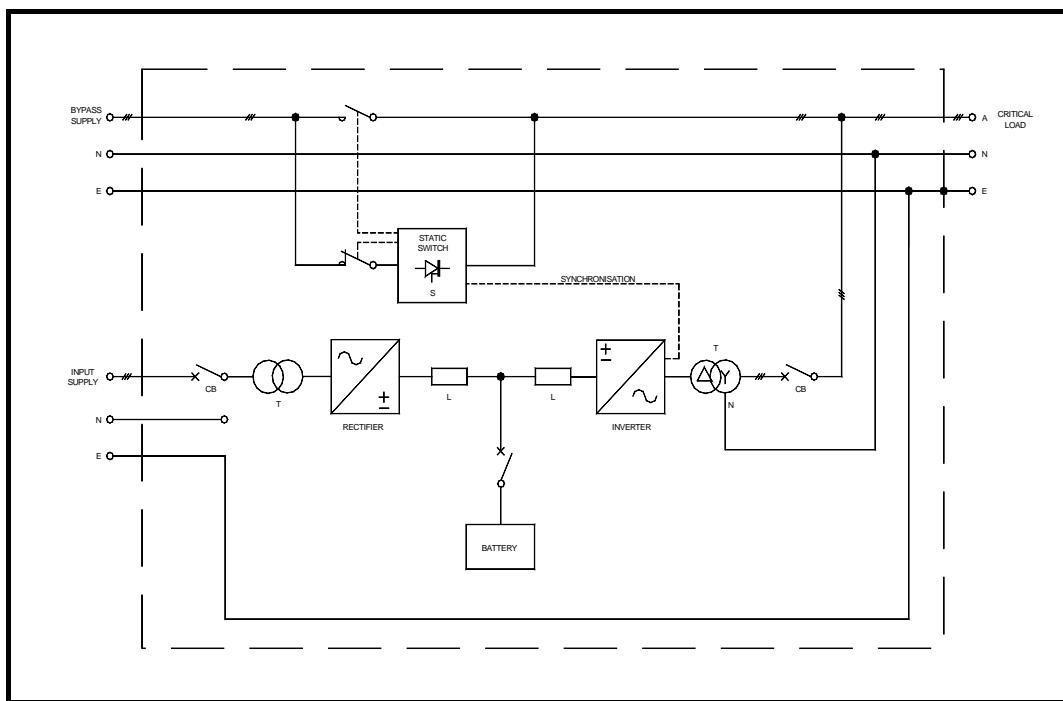
An UPS provides uninterrupted power for critical loads catering for failure of the normal mains power supply. The UPS can also provide protection for loads against line frequency variations, voltage excursions, and elimination of power line noise and voltage transients, however, these need to be treated carefully as the UPS can go into bypass and therefore separate additional protection may also be required.

An UPS can provide continuous support where associated with a Local Emergency Generator (LEG) or Central Emergency Power Station (CEPS) or they can be provided alone to allow orderly shut down.

### Static UPS

A static UPS is a solid-state system relying typically on battery power as an emergency source. A static UPS consists of a rectifier, inverter, an energy storage device (i.e. one or more batteries) and normally a static by-pass. Defence installations also require a separate maintenance by-pass to allow the UPS to be removed. The inverter in the static UPS also typically includes components for power conditioning.

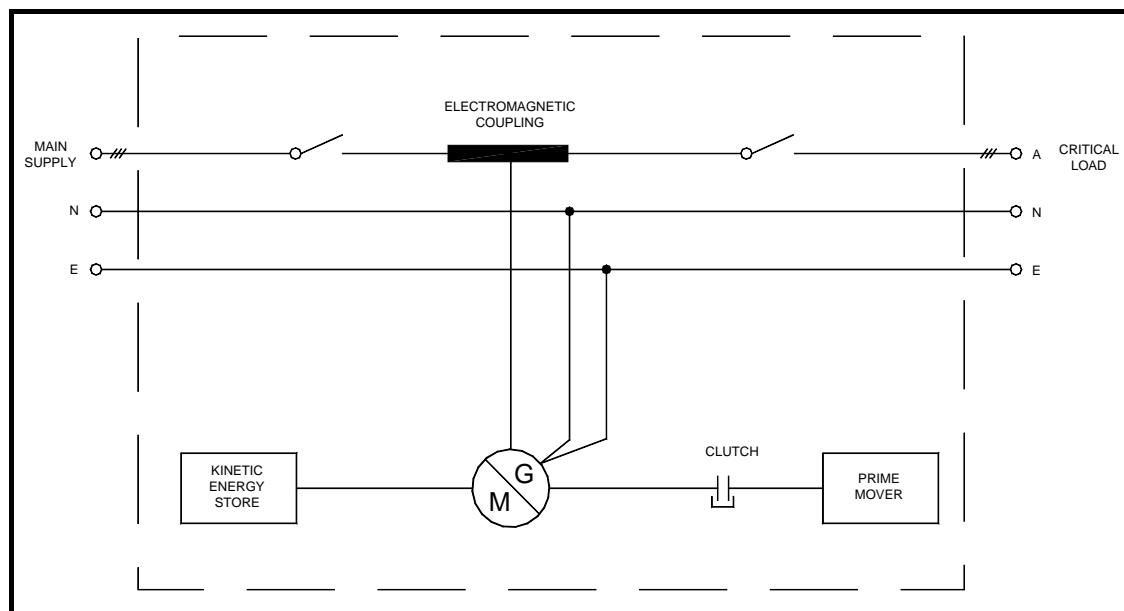
Maintenance bypass shall be interlocked and/or provided with a sync check function with the UPS output isolation device to prevent paralleling of unsynchronised supplies. Modern static UPS systems are constructed with ratings ranging from about 250 VA to over 1 MVA. Figure 20.1 below shows a simple static UPS.



■ **Figure 20.1: Simplified Static UPS, does not show the Maintenance Bypass**

### Rotary UPS

A rotary UPS is a system that uses a motor-generator (M-G) set in its design. Unlike static units, the basic parts may vary between manufacturers for rotary units and typically rotary units are mainly designed for large applications, 125 kVA or higher. Figure 20.2 below illustrates a simple rotary UPS.



- **Figure 20.2: Simplified Rotary UPS, does not show the Maintenance Bypass or Optional Essential Supply**

## 20.2 Power Distribution System Classification

Defence power distribution systems are classified as follows:

- **Table 20.1: Power Distribution Classification**

Power Distribution Classification	Type of Support
Critical	UPS supported
Essential	LEG supported
Normal or Non-Essential	No UPS or LEG support May be supported by CEPS (prioritised via the load shedding system) or mobile generator

LEGs are used to support essential loads to prevent loss of key facilities during periods of failure of the normal supply. The LEG supplies the essential loads through the essential power distribution system, whilst the UPS supplies the critical loads through the critical power distribution system. The CEPS distribution system is through the normal high voltage reticulation and supports the

normal, essential and critical power supply systems. The term 'essential' or 'critical' is not to be taken to apply to facilities supported by CEPS or mobile generators alone.

### **20.3 Performance Objective**

The objective of this policy is to:

- a) facilitate high reliability electrical systems;
- b) facilitate compliance with the respective installation standards;
- c) facilitate the suitable performance of UPS installations;
- d) manage the impact of UPS installations to ensure no harmful effect or interaction with other installed equipment, or from other equipment to the UPS;
- e) provide suitable control and monitoring of UPS installations;
- f) provide suitable basis for assessing the viability of installing UPS, and
- g) ensure the economics of the design on a through life basis.

### **20.4 Referenced Documents**

#### Standards/Codes

All materials and workmanship shall be of the best standard and shall comply with the relevant legislation and Australian Standards, or if such do not exist, with the relevant IEC or International (ISO) Standards.

Irrespective of any requirements shown in these documents the installation as a whole shall comply with:

#### **Australian Standards**

AS 1020	The control of undesirable static electricity
AS 1028	Power reactors and earthing transformers
AS 1307	Surge Arrestors
AS 2005 (All parts)	Low voltage fuses
AS 2064	Limits and methods of measurement of electromagnetic disturbance characteristics of industrial, scientific and medical (ISM) radiofrequency equipment
AS 2067	Switchgear Assemblies and Ancillary Equipment for Alternating Voltages Above 1 kV.
AS 2184	Moulded case circuit breakers for rated voltages up to and including 600Vac and 250Vdc

AS 2374 (All parts)	Power transformers
AS 2467	Maintenance of Electrical Switchgear
AS 2529	Collection or reliability, availability and maintainability data for electronics and similar engineering use
AS 2676 (All parts)	Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings
AS/NZS 3000	Wiring Rules
AS/NZS 3008.1.1	Cables for alternating voltages up to and including 0.6/1 kV
AS 3011 (All parts)	Electrical installations – Secondary batteries installed in buildings
AS 3100	Approval and test specification - General requirements for electrical equipment
AS 3111	Approval and test specification. Miniature over current circuit breakers
AS 3439 (All parts)	Type tested and partially type tested assemblies
AS 3947 (All parts)	Low voltage switchgear and control gear
AS 4070	Recommended practices for protection of low voltage electrical installations and equipment in MEN systems from transient over voltages
AS 4029 (All parts)	Stationary Batteries
AS 4044	Battery Chargers for stationary batteries
AS 4251	Electromagnetic compatibility - Generic emission standard
AS 4252	Electromagnetic compatibility - Generic immunity standard
AS 61000 (All parts)	Electromagnetic compatibility limits
AS62040 (All parts)	Uninterruptible Power Systems (UPS)
AS/NZS ISO 9001	Quality Systems – Model for quality assurance in design, development, production installation and servicing.
AS/NZS CISPR 14.2	Electromagnetic compatibility - Requirements for household appliances electric tools and similar apparatus - Immunity - Product family standard

<b>Other Standards</b>	
MIL-HDBK-217	Military Handbook – Reliability prediction of Electronic Equipment
ANSI/TIA-942	Telecommunications Infrastructure Standard for Data Centres

## **20.5 Feasibility Assessment**

UPS installations shall only proceed if their respective sponsors have successfully argued for their justification. This shall normally occur in consultation with the Project Director as part of developing the FDB, or if necessary later in the design report.

The sponsor shall also detail the loads or portions of the building to be supported by UPS, as well as the equipment requirements and/or other special requirements that need to be incorporated or referenced in the functional design brief for the project.

### **20.5.1 Policy**

UPS shall be provided to support key Defence operational facilities such as critical communications facilities, critical computing facilities and Air Traffic Control (ATC) facilities, where power supply disruption would have a significant adverse impact to the capability of the Services. UPS may also be considered when, based on the availability of the normal supply, the costs of down time or disruption exceed the through life costs of a UPS.

### **20.5.2 Justification**

This policy does not prescribe the type of facility or area that requires the installation of UPS. Instead, it identifies those areas or functions which are normally UPS supported and establishes the basis on which project staff, sponsors and consultants may evaluate the need and type of system required.

#### **Assessment Criteria**

The determination as to whether an UPS is required shall be by assessment, on a case by case basis, supported where appropriate by an analysis of the risks involved; this activity shall be undertaken by the sponsor and the project staff, or alternatively where required by the FDB, by the design consultant on behalf of and in conjunction with the sponsor and project staff.

The risk analysis shall be undertaken in accordance with AS 4360 and shall consider the impact of the all possible opportunities and/or detrimental outcomes in the Defence context inclusive, but not limited to, the following:

- a) statutory requirements, standards and Defence policy requirements for UPS
- b) consequences of power supply interruption in terms of:
  - loss of function
  - loss of data or erroneous data
  - disruption of process

- damage to equipment
  - time and cost to recover
- c) frequency and duration of power outages
- d) can the load tolerate a break in power of 100 milliseconds, 50 milliseconds, 10 milliseconds or none
- e) would power line conditioning or surge and transient protection be more cost effective
- f) quality of the power supply in terms of voltage and frequency stability and ability to meet the equipment requirements
- g) area or equipment to be supported
- h) ability of any site emergency power supply (e.g. LEG or CEPS) to meet the emergency power requirements

#### **Basis for Justification**

UPS shall only be considered when:

- a) statutory requirement, standard or Defence policy requirement dictates the provision of a UPS (e.g. ATC Tower, certain Aircraft Navigation Aids , certain hospitals);
- b) regular critical operations are undertaken at the facility that would be adversely affected by interruption of electricity supply (e.g. Communication and Information System Centres (CISCEN) and critical communication/computing facilities);
- c) any interruption of the electricity supply would result in a severe life safety or environment incident for critical functions such as in a hospital with an operating theatre;
- d) the financial losses due to power interruptions, under normal supply availability conditions, would exceed the through life costs of a UPS (certain tactical training centres and simulator facilities);
- e) the frequency and duration of operations cannot be supported efficiently and cost effectively by generators. Any facility that can tolerate an outage can, under normal circumstances, be adequately supported by generator;
- f) site emergency power supplies such as LEG and CEPS cannot meet the emergency power requirement; and
- g) power line conditioners or other similar devices cannot meet the emergency power and/or power quality requirements.

Guidance on a case by case basis is available from the DEEP in order to determine whether or not a UPS should be provided.

## **20.6 Technical Requirements**

UPS are specialised systems that can be configured in many ways and can significantly impact on the immediate environment. Therefore, due consideration shall be given to the issues of compatibility with, and impact on, other services and the building environment respectively.

The capabilities and limitations of UPS shall be considered to ensure their suitability for supplying equipment and loads whose requirements and operational characteristics shall be adequately defined. This places an important emphasis on defining the equipment requirements and the responses under failure conditions.

Selection of UPSs shall achieve best value for money on whole of life basis and shall also take cognisance of the level of product support provided in Australia and locally in the region installed.

The UPS system shall be fully compatible with the building power reticulation system and its connected loads to ensure harmonious and non-detrimental interfacing between the UPS and the generating equipment if provided and the building connected loads. The designer shall ensure that appropriate analysis is undertaken to determine the UPS configuration required.

#### **20.6.1 Characteristics of the Critical Load**

When specifying the UPS, the supplier should be made aware of the characteristics of the critical load to be supplied. The designer must adequately determine the characteristics of the load and the environment in which the UPS will be installed and make all necessary provisions to ensure suitability.

Specifically, the designer must specify:

- a) The nominal output voltage and allowable voltage limits (including steady state and transient limits). Transient limits may be different to take into account large step changes in the load and the short duration of a resulting output voltage change.
- b) The desired full load output power rating and power factor.
- c) The expected harmonic content of the load. An idea of the likely harmonic content of the load can be obtained from measuring the harmonic content of the existing or similar load, or by consulting the equipment load suppliers.
- d) The presence of power factor correction.
- e) The presence and characteristics of other key items such as LEGs.
- f) Any loads with characteristics not covered above such as regeneration.

Make the UPS supplier aware of any intermediate isolation or step-down transformers that will be connected between the UPS output supply and the load, because these can act in a non-linear manner to transform the harmonic content of the load or negate any harmonic compensation built into the UPS system.

#### **20.6.2 Availability and Mean Time Between Failures (MTBF)**

UPS shall have a mean time between failures (MTBF) of at least 20,000 hours as calculated for the installed arrangement with the UPS operating at 40 degrees C. Availability shall be at least 99.99 percent or as required by the equipment load/users, whichever the higher. Mean Time to Repair (MTTR) shall be less than one hour and Maximum Time to Repair (MAXTTR) shall be less than

twelve hours, these times do not include travel time which must be assessed separately when considering supportability and maintainability.

The availability and MTBF shall be determined based on the installed arrangement and conditions addressing the following:

- a) The mains failure conditions. Based on actual failures or an average of one failure of 30 minutes duration per year and 10 outages of less than one minute per year, whichever the greater.
- b) Automatic start diesel alternator can be expected to restore power supply within 10 minutes.
- c) Change back to mains supply from diesel alternator supply will introduce a short break in supply since paralleling of supplies is not permitted.
- d) Availability calculations shall be in accordance with American MIL-HDBK-217E.
- e) Failure rate data for individual items of equipment may be based on actual field experience provided adequate supporting evidence is demonstrated.

The designer shall ensure that suitable reliability calculations are submitted by tenderers, together with the bases for these calculations and the sources of failure rate data.

### **Availability**

The availability of the selected UPS must be acceptable to the particular installation requirements. The criticality of the loads will determine the necessary availability of the UPS. The availability of an UPS may be improved by using different configurations to provide redundancy.

#### **20.6.3 Energy Efficiency**

Due consideration shall be provided to specifying efficient design solutions that minimise energy usage. UPS must achieve at least 75% efficiency at all loads in the specified power factor range from 50% load to rated output with the battery on float charge. Efficiency at full load shall be a least 85%.

#### **20.6.4 Determination of the Required Support Time**

The required support time to maintain output supply in the event of a primary supply failure, if known, will be specified in the FDB, however, the designer may need to determine the required support time in consultation with the facility users or sponsors. This time may be that required by standards or a requirement of the equipment or operations to support. The support time is specified as the time required for the equipment to be supported by UPS and shall include the full operation specified including consideration of the time required for the LEG or CEPS to come online.

Whilst static systems incorporate batteries, kinetic energy storage devices in rotary systems are typically sized to allow the immediate start and transfer of the M-G set to a diesel engine or generator and typically only maintain supply for 15 – 30 seconds. The required support time for rotary systems will therefore have separate consideration.

Where necessary, ensure the building services required to support the equipment are also adequately supported during the support time period (e.g. suitable cooling to continue equipment operation).

### **20.6.5 Battery Systems**

UPS system costs are very sensitive to support time, so careful consideration needs to be given to the minimum battery reserve time specified. The minimum required time may often correspond to the time needed to notify remote connections that a service is about to go down and then carry out an orderly shutdown. It should also be noted that the actual support time will increase greater than in proportion should the actual load be less than the full load rating. This matter shall be validated with reference to the battery manufacturer's data sheets with a summary included in the design report.

The usual support time specified for battery backed systems is 10 – 15 minutes. In most cases 10 minutes is adequate time to allow an orderly shutdown should the standby generator supply not be available due to equipment failure or due to non-installation of a standby power source. Increasing the support time from 10 minutes to 15 minutes has a large impact on battery size and costs. Support time may extend to 15 minutes in some cases, but longer support time must be suitably justified in the design report for Defence agreement.

It is important to note that the longer support times cause other complications such as how to keep the load and UPS systems within operating temperature limits for that period.

Batteries can be installed either in cabinets or on racks, whichever the more appropriate. If cabinets are provided, consider the implications on ease of maintenance, temperature build up and ventilation.

#### **Connection of Battery Banks**

Batteries can be configured as parallel strings and this may be necessary to achieve the desired support time in larger ratings or to meet specified redundancy requirements.

Notwithstanding this, where cost effective, any UPS incorporating battery storage is to be provided with redundant battery strings so that in the event of failure of one string there is a reduced level of support available from the remaining string(s) of batteries. Redundant battery strings in the context of this general policy requirement means providing two parallel battery strings that are of sufficient combined capacity to meet the required support duration. Failure of a string reduces the available support time until both strings are returned to service. This is particularly important for a single UPS that supports a key capability such as an ATC tower.

Redundant battery strings must have appropriate protection to eliminate any single point of failure and isolation in the form of links and/or circuit breakers. Rating of switchgear shall take into account the greater difficulty in interrupting DC current. It must be possible for a healthy string(s) to remain in service, in the event of a fault in the other battery string(s), supplying the critical load

with a reduced support time (unless Defence specifies total redundancy). It must also be possible for repairs to be undertaken to one or several cells on the same string without disconnecting all of the available battery supply.

It should be noted, that having parallel battery strings increases the component count and reduces the availability (i.e. the probability of full battery capacity being available).

### **Battery Requirements**

The preferred type of battery selected will depend on a number of considerations. Battery technology and ratings available in different forms is constantly changing. The designer must make recommendations to Defence, including through life assessment, on the most suitable battery technology and arrangement which must consider the following discussion.

Depending on the application and rating any of the following types may be suitable:

- a) Valve-regulated sealed lead-acid to AS 4029.2.
- b) Pure lead Positive pasted plate type to AS 4029.3

It is unlikely that Nickel-cadmium batteries will be a practical choice for UPS systems. Their high cost has restricted them mainly to applications where improved low temperature performance or high discharge rate characteristics have offset the cost disadvantages. The future disposal of such batteries shall also be considered in any evaluation recommending this type of battery.

It is important to note that a battery's performance will be specified for a given temperature and given safe minimum cell end voltage. The ratings at either anticipated ambient temperature extreme should be checked to determine whether acceptable performance is maintained. Keep in mind the large thermal inertia of some batteries and the likelihood of the cells following an average daily ambient temperature rather than short term extremes.

At high ambient temperatures, heavy discharge currents may heat the cells to an electrolyte temperature where they will not accept recharge efficiently and must not be boost charged to stay within the manufacturer's recommended limits. Overheating batteries can cause cell damage and shortening of battery life.

A condition called thermal runaway can render a battery completely unserviceable within a short space of time. Thermal runaway can occur due to the interaction of battery and charger. As lead acid cells temperature rise, the terminal voltage decreases. Also as batteries age the terminal voltage decreases. A battery towards its end of life will be subjected to a greater float charge current for most constant potential charging systems. A fully charged battery is unable to utilise this charge current which is converted to heat. Should a battery have a combination of low output voltage due to age, high ambient and/or high internal temperature, cell voltage can become unstable and keep decreasing. The more the voltage decreases, the more current the battery charger provides causing more internal heat and lower cell voltage and so on. Within a period of 12 hours or so the

internal cell temperature is so great that damage occurs. The excess gassing in these situations causes generation of corrosive and explosive fumes.

The situation can be avoided by a number of measures either manually or automatically. These include:

- a) Monitoring cell temperature
- b) Monitoring float current when the battery should be fully charged
- c) Monitoring the change in battery voltage

More sophisticated charging systems are capable of preventing thermal runaway by only allowing high charge current while the battery voltage increases over time. Voltage readings are stored every 20 minutes or so and compared with the previous reading. A no change or negative change in terminal voltage results in the battery being considered as fully charged and charging current limited appropriately.

Regular battery “maintenance” is important to ensure reliable UPS operation. Regular checks on cell voltage, electrolyte specific gravity and temperature are a good way to confirm the health of vented lead acid battery banks. This can be tedious but valuable. Other less tedious options available include the installation of automatic cell voltage systems that can provide rapid measurement and printout of every cell voltage during different conditions of charge and discharge. These have a fairly high capital cost.

It is important that during a battery discharge, that the cell voltage is not allowed to drop below a certain threshold beyond which the cells may be damaged or may not be able to recover from a normal charging process. The limit set for the average cell voltage will depend on the battery type and the discharge rate. Guidance should be taken from the battery manufacturer. The UPS system should automatically shutdown and open the battery connection prior to this occurring.

A common misconception is that sealed lead-acid batteries are “maintenance free”. Although these batteries do not require topping up with distilled water, they are more susceptible to not being equalised in charge and are more difficult to equalise. If cells fail to equalise it means that the cell voltage is greater or lesser than the average cell voltage in one or more cells. In the extreme case it can mean that during a battery discharge, some cells will be discharged below their minimum allowable cell voltage from which they may never recover.

### **Battery sizing**

In order to properly size the battery, required discharge rate in kilowatt (kW)/cell, required protection time, end of discharge voltage, and ambient temperature must be determined.

### Discharge rate

For an UPS system battery, the discharge rate should correspond to the highest inverter input power required to produce rated output at minimum input dc voltage. The end of discharge voltage should

be equal to or higher than the minimum dc input voltage required by the inverter to maintain rated performance. The minimum dc voltage required by the inverter is normally published by the manufacturer. The maximum dc power required by the inverter can be obtained from the manufacturer or can be calculated. In addition, it is recommended to include a suitable margin for the required capacity to account for battery aging.

#### Lifetime

The expected lifetime of batteries on UPS duty is usually stated in terms of years of service on continuous charge to an end of life defined as the failure to be able to deliver a certain percentage of rated capacity. Initial capacity (unless specified as 100 percent capacity) is usually in the range of 90 to 95 percent of rated capacity. This will rise to 100 percent capacity in normal service after several charge-discharge cycles. IEEE Industry recommendations are that a battery be replaced when its actual capacity drops to 80 percent of rated capacity; however, some manufacturers rate "end-of-life" at 50 percent of rated capacity. Obviously, the designer needs to check the initial capacity rating, the service life period, and the aging characteristics given in the battery guarantee so as not to be unpleasantly surprised.

#### DC voltage Ripple

The rectified AC wave form is "rippled" and would cause a similar rippled current to flow into the battery if measures were not taken to reduce this. The rectified AC has a peak voltage significantly higher than the average, and the battery is highly capacitive in nature, allowing higher than desirable current surges into the cells if a smoothing choke were not provided. The maximum ripple voltage shall meet the battery manufacturer's requirements or 3 percent, whichever the lower.

#### End of discharge voltage

UPS batteries are not sized on so many ampere-hours of capacity for an 8-hour period. Battery voltage is not constant, so if the load requires a constant power output, which most UPS applications do, the current must increase as the voltage decreases. Consequently, the battery is sized to supply a specific kW rate (usually the maximum inverter kW requirement without recharging) for a specific period of time (usually 5 to 15 minutes) to a minimum specific end voltage and, for lead-acid types, at a maximum specific gravity (measured at 25°C).

- a) Lead-acid cells. A nominal system design may utilise minimum end voltage of 1.67 to 1.75 volts per cell and a maximum specific gravity of 1.215 at 25°C. The actual end voltage should be the voltage which the UPS manufacturer, battery manufacturer, or the system design requires, whichever is higher. In some cases, designs provide higher end voltages to meet design concerns. A higher specific gravity may result in a battery installation needing less space, but results in shorter life spans and higher cell losses and float voltages. The lower end voltage that manufacturers recommend may cause the UPS to go to static bypass or, by overstressing battery plates, shorten the life of the battery.

- b) Nickel-cadmium (ni-cad) cells. A nominal system design for ni-cad units will be to a minimum end voltage of 1.14 volts at 25°C with the actual end voltage to meet both manufacturers' and system design requirements. The specific gravity of a new cell will vary between 1.160 and 1.190 at 25°C, depending upon the manufacturer. Lower specific gravities are generally used in cells with larger electrolyte reserves. Higher specific gravities are typically used for low-temperature applications. The specific gravity will decrease slowly over the years because of evaporation and other effects, even though the surface of the electrolyte is probably covered with a protective layer of oil. Renewal will be necessary if the specific gravity decreases to 1.130 to 1.160, depending upon the manufacturer's instructions.
- c) Temperature correction. Ratings are at 25°C. Therefore, to determine specific gravity, which is temperature sensitive, a temperature correction factor must be applied. For both lead-acid and ni-cad batteries, add one point (.001) to the hydrometer reading for every 3°F above 25°C and subtract one point for every 3°F below 25°C.

Ambient temperature.

Consideration shall be given to providing a stable environment (temperature and humidity) for the batteries to ensure that their maximum life is achieved. Many batteries that have a warranty associated with a nominal life expectancy require an environment of 25°C to prevent voiding such a warrantee.

#### **20.6.6 The Effect of Static UPS on the Mains and Generator Supply**

The controlled rectifiers of UPS systems can be a major source of harmonics which can produce distortions of the voltage and current waveforms and may have a detrimental effect on a variety of electrical equipment both upstream and downstream of the UPS system.

The designer shall ensure compliance with relevant requirements in accordance with Chapter 10 – General Technical Requirements and Australian Standards AS/NZS 61000 Electromagnetic Capability (EMC) and AS 62040 Uninterruptible Power Systems (UPS) to minimise the effects of harmonics on electrical equipment.

The designer shall ensure that the UPS is suitable for operation with any intended generator including LEGs. Depending on the magnitude of the rectifier load as a percentage of an alternator's load, measures may need to be taken to ensure reliable alternator operation when a diesel alternator is used as a standby power source. As a guide, there will be problems unless special measures are taken when the rectifier rating is more than 50% of the alternator rating. These measures may include:

- a) Using a three phase voltage regulator;
- b) Using permanent magnet field excitation;
- c) Using an electronic governor;
- d) Using a 2/3 pitch in the generator winding
- e) Over sizing the alternator compared to the kW rating required; and

- f) Specifying the UPS with filtering or 12 pulse rectifiers to limit the amount of harmonic distortion, where possible.

The UPS can represent a significant load on an emergency power supply. A technique that can be used to prevent overload to a stretched standby power supply is to inhibit or reduce battery boost charging to the UPS whilst on standby power. This requires some interface relay connection between the standby power supply control panel and the UPS system. Use of this arrangement must have DEEP agreement.

#### **20.6.7 Harmonics Distortion**

Harmonic loads cause additional power losses in the power supply and in connected motor loads. In severe cases the distortion caused to the supply can cause over heating of switchgear, transformers and motors, malfunction of voltage regulators and drop out of phase failure relays. Depending on the natural frequency of the power supply and its connected load, the system can actually resonate causing high voltage peaks and equipment damage.

Particular care needs to be taken when bulk power factor correction equipment is connected to the same low voltage power supply as the UPS. The capacitors can suffer from over heating due to the passage of harmonic current through them, or can suffer insulation damage due to voltage notching in the power supply caused by commutation of semi-conductors. It is advisable to use “reactive” capacitors for power factor correction equipment. These have series reactors designed to impede harmonic currents and “detune” the capacitor circuit away from the main problem casing harmonic frequencies. They will also be more immune from other harmonic sources such as electric motor variable speed drives.

The best way to handle harmonic distortion is to treat it at the source of the harmonics and reduce the magnitude.

For static UPS systems, consideration should be given to using 12 pulse rectifiers instead of 6 pulse rectifiers when necessary to limit the amount of harmonic distortion to the mains supply. An alternative or supplementary measure that can be used is to add harmonic filters to the system. These add extra losses to the system, work best only at their design load and can interact with other harmonic load connected to the same supply.

The design and rating of harmonic filters needs to take into account other background harmonics caused by other loads on the same supply. This may mean that a harmonic analysis of the system is required by either measurement or computer modelling. Other common loads that contribute to harmonic distortion include variable frequency drives, soft starters for motors, electronic loads and power factor correction.

If the background level of harmonics is already high, then consideration may need to be given to providing harmonic filters at the main sources of the harmonic distortion to lower the background harmonic distortion sufficiently.

It should be noted that harmonic filters may “de-tune” in the event of a supply frequency change, for example, when supplied by a local generator that is heavily (or lightly) loaded, with the subsequent issue that the filter is no longer able to filter out the desired harmonic frequencies.

### **20.6.8 Critical Distribution Systems**

UPS power shall be reticulated via the building’s critical power distribution system. The critical distribution system shall consist of suitable area or room critical distribution boards to supply the critical load. Redundancy is not normally a requirement of the critical distribution system unless specified by the FDB or as required to meet the availability criterion.

Critical distribution boards are the preferred method for connecting large or unspecified equipment and for equipment rooms. These distribution switchboards are to be provided in the equipment room for connection of the equipment.

The critical distribution system is not normally load shed; however, where the load is significant and would prevent the LEG or CEPs generators from coming online they shall be suitably load shed controlled. This shall also include the contributed effect of a number of UPS where not supported by LEG. Load shedding requirements where necessary are provided in the standard Electrical FDB clauses (Appendix C Standard Engineering Inclusions on the IM) and the arrangement needs to be agreed by DEEP.

#### **Static Transfer Switches**

Separate static transfer switches can be used where dual supplies are adopted in the distribution system. These static transfer switches allow synchronous transfer between supplies and where used shall be appropriately supervised to prevent any harmful effect when changing between normal and alternate supplies. The changeover period will need to be checked to ensure suitability with the critical load; typically loads must be able to tolerate a 10 millisecond outage. Consideration should also be given to the requirement for the static transfer switch to also switch the supply neutrals and guidance should be sought from the local Network Provider and Industry Regulator before finalising the transfer switch design arrangement.

#### **Maintenance Bypass**

Defence UPSs shall be provided with a maintenance bypass that allows the UPS unit to be taken offline or removed. A maintenance bypass facility for UPS unit is useful for maintenance and testing purposes. A maintenance bypass switch consists of interlocked isolators which can be manually operated to connect either an alternate supply or UPS output to the critical load. An open transfer switch arrangement has been shown on the diagrams for simplicity. In most installations it will be possible to provide closed transition switching when the source of the bypass is always the same as the UPS input. Care is needed with this arrangement which requires the UPS output and the bypass supply to be switched and interlocked at the same switchboard. For closed transition switching, the input and bypass supplies must be from the same source. The switching shall be

interlocked with the UPS internal bypass to ensure that the UPS changes to internal bypass before the external maintenance bypass can be operated.

The maintenance bypass switch may need to be open transition and switch the supply neutrals if the maintenance bypass supply is a separate supply to the synchronous bypass supply of the UPS unit. This is not a preferred arrangement due to the complexity and dangers of neutral switching.

### **Connection of Dummy Load**

Dummy loads are useful for commissioning and maintenance purposes, however, providing a permanent dummy load just for the UPS would not normally be justified. Where a UPS is incorporated with a LEG the designer shall specify, where appropriate, connection to the LEG dummy load via an interlocked manual supply transfer switch.

### **Input Supply Rating**

The input supply rating of the UPS will exceed the output supply rating due to:

- a) Energy losses of the UPS System (typically less than 10% full load)
- b) Charging current for the battery (typically 15% full load)
- c) Derating due to harmonic content (typically 10%)

The amount of charging current will depend on the specified battery support time and the specified time to recharge. Boost charging for battery equalisation will further increase the load.

The load can be reduced for the benefit of limited standby generator capacity by setting a rectifier current limit to a lower level while on generator supply.

Depending on the level of harmonic distortion and switchgear design, the switchgear may suffer a derating.

Calculations will need to be made for a specific UPS system design but a typical system will require an input rating of 1.2 to 1.4 times the output rating of the UPS.

The bypass supply rating will not be subject to the above effects and can thus be rated to match the output rating of the UPS if desired.

The number of phases in the supply to the UPS shall be specified to suit the rating of the UPS. Small rating UPS systems may not be available with three phase inputs or outputs as a standard product.

### **Critical Submains**

Submains from UPS shall generally consist of radial feeders unless dual supply is specified in the FDB. Dual supply requirements are provided below.

### **Dual Supplies**

Usually the critical load distribution boards are not redundant which means that loss of supply to any submain from the UPS to any distribution board will cause a system failure. It also means that the only supply path to the critical distribution boards is via the UPS distribution system which has a high component count, significant mean time to repair and relatively low availability. Where required by the FDB the source of the alternate submain should bypass as much of the distribution system as possible to lower the component count and shall be configured to meet the specific project requirements.

### **Separation Requirements**

Submain cables may need to be separated to the extent necessary to minimise the potential for a single event to disrupt the ability to supply UPS power to equipment, or portions of a facility.

### **System Capacity**

The electrical distribution system shall be designed for the prospective loads, with consideration of the planned future loads. Provide spare capacity of at least 25% in all elements of the distribution system. Refer standard FDB clauses for further spare capacity requirements.

### **Fault Level and Insulation Level**

Due consideration shall be given to the system fault level, in particular the peak contribution limit available from the UPS. The UPS must withstand system fault levels and must achieve suitable required discrimination.

### **Wiring Systems (WS) Classification**

In addition to the requirements for hazardous areas the wiring systems shall provide resistance to damage from mechanical and fire consistent with the environment and the purpose of the installation.

### **Isolation Transformers**

Separate isolation transformers are sometimes placed in the path between the UPS output supply and some of the critical load. These could be there as part of the tempest protection system. Consideration needs to be taken of the transformer magnetising inrush currents and of the non-linear effect that it may have on the harmonic content of the critical load.

### **Transient and Surge Protection**

Transient and surge protection shall be provided for UPS supply systems to prevent damage and disruption caused by lightning strikes or by switching induced surges and spikes. The location and arrangement will depend on the UPS; however all bypass supplies also need to be suitably protected.

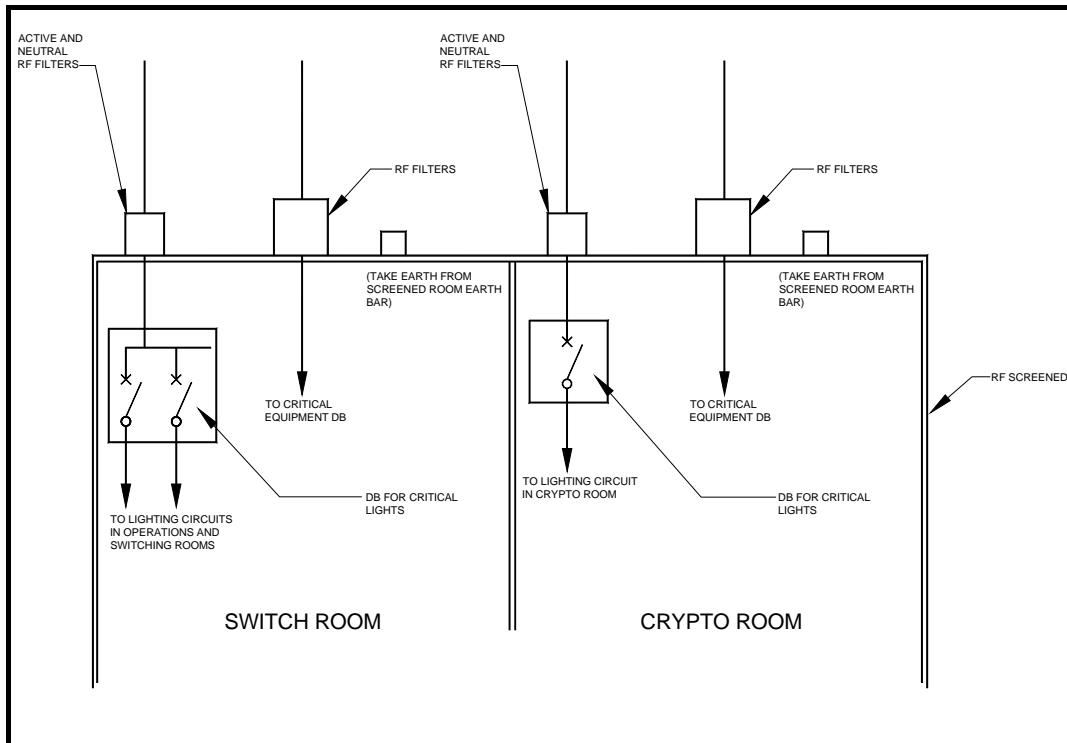
### **Undervoltage Release**

Consideration shall be given to the use of undervoltage releases on the critical load distribution boards. This is important in the case of the UPS being on bypass supply and being transferred to generator load or the mains supply restoring.

Equipment that cannot tolerate being powered up immediately after a supply interruption shall be disconnected on power failure or protected by other suitable means such as under voltage releases. The critical load should be reconnected in a controlled fashion when supply stability has been achieved. This can be manually by operator or other suitable arrangement to suit the users.

### **Filters**

Critical load may be connected to the UPS via suitably rated radio frequency filters. Critical lighting shall not be connected via the same filtered supply as critical equipment loads. During power up, the lighting can generate voltage transients that may be reflected back to the load due to the high impedance that the filters present to the transient voltages. Figure 20.3 illustrates the required arrangement.



■ **Figure 20.3: Arrangement of Critical Lighting Circuits in Screen Areas**

### **20.6.9 UPS Ratings and Size Selection**

There are no standard ratings and performance characteristics for UPS systems. It is necessary to use manufacturer's ratings to determine if the selected UPS will perform in the specified environment. It may be necessary to derate the equipment where the manufacturer's performance specifications are exceeded.

A technical evaluation shall be performed to determine the required size for any new UPS and the optimum connection arrangement. The designer must consult with the sponsor/users and make appropriate determinations for diversity to avoid significant oversizing of the UPS.

#### **Determining the Rating of a UPS**

In order to properly size and select a static UPS system, the load kVA, load power factor, inrush kVA or current, load voltage, number of phases and frequency, and required battery protection time should be determined for the load to be served.

### **Determining load kVA**

In existing installations, the load kVA should be determined by measuring the current with all equipment operating. In three-phase installations, the load current should be measured at each phase.

In cases where the load current cannot be measured or when the installation is in the planning stage, the load kVA should be calculated. Calculating the kVA requires obtaining the individual load kVA from equipment manufacturers' data. The total load kVA is then obtained by vectorial addition of the individual load kVA; when an individual load power factor is not available it needs to be estimated. Also, an approximate but conservative estimate of the load kVA may be obtained by arithmetically adding the individual load kVA.

### **Determining load power factor**

In existing installations, the load power factor should be determined by actual measurements using a power factor meter. In cases where actual measurements cannot be taken or when the installation is in the planning stage, the load power factors must be calculated. To calculate the load power factor, the kVA and power factor of the individual loads should be obtained from the equipment manufacturers' data; when an individual load power factor is not available it needs to be estimated. The total load power factor can then be calculated. Estimating the load power factor is necessary since the kVA rating and performance parameters of most UPS designs are guaranteed only at a power factor range of 0.8 lagging to unity. The UPS system kVA capacity and performance parameters are affected at other power factors, particularly with leading power factors.

### **Determining load inrush kVA**

Determination of the load inrush kVA is particularly important for static UPS configurations without a static transfer switch and bypass capability. In these configurations, if the load inrush kVA requirements exceed the inverter capability, the inverter will reach the “current limit” mode causing the unit to parallel with the mains via the static bypass switch.

In configurations with a static transfer switch and bypass capability, determining the load inrush current requirements is required for proper selection of overcurrent protective devices for the transfer switch and coordination with other overcurrent protective devices.

The load inrush kVA or current in existing installations should be determined by actual measurement using a high speed storage oscilloscope or oscillograph. Since all loads are not normally started simultaneously, the inrush kVA or current requirements should be determined by energising the load with the highest inrush kVA while all other loads are connected.

In cases where measurements cannot be taken or when the installation is in the planning stage, the load inrush requirements should be calculated. Data on individual load inrush kVA and duration should be obtained from equipment manufacturers or otherwise estimated. The maximum inrush current and effective inrush current can then be calculated.

### **Load voltage, number of phases, and frequency**

The load voltage and frequency requirements determine the UPS system output voltage and frequency. Three-phase loads require a system with three-phase output regardless of the kVA rating required. However, when all loads are single-phase, the loads should be distributed among the three phases to minimise the phase unbalance effects on the inverter.

### **Load Growth**

In projecting electrical demand a suitable allowance for load growth, minimum of 25 percent, shall be used unless otherwise approved by DEEP.

### **Single or Multiple Mains Supplies**

As already discussed, it is important to consider the origin of supply to the NBPS and bypass facilities. Having these supplies as independent as possible will improve availability of supply. The disadvantage is the higher cost. In most cases the cost of providing at least independent submains would be justified and is mandated as a primary requirement. Care must be taken with the distribution and interlocking to ensure that under no circumstances should it be possible to parallel unsynchronised supplies.

## **20.6.10 Existing UPS Installations**

### **Existing System Configuration and Capacity**

When considering augmentation to existing systems or additional critical loads, evaluate existing UPS configuration and capacity to determine if it meets the need of the proposed works. In making this evaluation consider:

- a) Additional load contribution;
- b) Existing load and capacity of critical infrastructure;
- c) Quality of supply;
- d) Any particular operating requirements or constraints;
- e) Compliance with this policy;
- f) Planned loads and natural load growth;
- g) Outdated/unserviceable equipment effected by the works requiring replacement.

Should portions of the distribution system have insufficient capacity to meet the required loads investigate the options to establish sufficient capacity including augmentation or reconfiguration of the system.

## **20.6.11 Accommodation**

### **UPS Unit**

The UPS accommodation shall be suitable for the operation and maintenance of the UPS. Particular care shall be taken to ensure that the UPS heat rejection and airflow requirements are met and that the design of the ventilation system does not contaminate the air conditioning or ventilation

systems of the building occupants or adjacent buildings. The UPS accommodation shall also address noise and vibration from the equipment.

Generally, UPS shall be provided in separate UPS plant rooms clear of all other services. The batteries must be installed in a manner that prevents any subsequent damage to other equipment or systems in the event of catastrophic battery failure.

The UPS plant room must have suitable access to the Main Switchboard (MSB) and therefore should normally be provided adjacent to the MSB room. Consideration can be given to installing the UPS within the MSB room (with the batteries in a separate room where vented batteries are used). An acceptable exception to locating the UPS in or adjacent the MSB room would be for large installations or distributed UPS arrangements, where it is demonstrated that the UPS should be near the load. This would need to be agreed through the design report process by DEEP.

Generally the arrangement of the UPS within the room shall provide suitable access to all sides of the equipment allowing maintenance to easily be performed. Care must be taken to ensure any access doors/panels may be opened and not restrict free-access past the door/panel, particularly those for entry and exit/escape.

The equipment layout shall provide adequate access for operation with all controls placed for ready access and with all indicators and instrumentation in easy to read locations.

In the design of the equipment layout, adequate access for the installation, erection and maintenance of the equipment shall be provided. Major equipment items shall not be located in such a manner that would prevent the safe removal and replacement of any other major item of the installation (e.g. require dismantling).

The UPS must be located in an area that is generally clear of other services, except those directly related to the UPS or MSB. The selected site shall be clear of any obstruction that could interfere with the operation, maintenance and removal of any part of the UPS.

### **Batteries**

The Australian Standards AS 2676 and AS 3011 provide detailed information on requirements and recommendations related to battery accommodation. Issues covered include:

- a) Layout and location
- b) Ventilation
- c) Access
- d) Floor loadings
- e) Lighting and power
- f) Safety signs
- g) Arrangement and support of batteries. Separate battery room shall be considered for vented cell batteries

- h) Protection and alarms

### **20.6.12 Environmental Conditions**

#### **Heat Gain**

Due consideration shall be given to the impact of radiated heat on the internal operating temperatures of the UPS.

Provide additional thermal treatment where UPS are located where the internal temperature rise is expected to exceed that which is acceptable or will have a detrimental effect to equipment life. This may include:

- a) Increased ventilation; and/or
- b) Additional insulation.

#### **Heat Rejection**

The conversion of mains frequency to DC and from DC to AC again by static UPS systems involves loss of energy and therefore heat rejection from the UPS. Similarly, rotary UPS systems will generate heat because of the losses in the MG set windings and bearings. If a diesel generator is co-located with the UPS, it too will generate significant heat. This heat must be extracted from the UPS accommodation to ensure the ambient air temperature does not rise beyond the UPS equipment allowable operating limit (usually 40°C).

There are two methods commonly used to extract the heat produced by the UPS; these are discussed at paragraph 20.6.17.

#### **Battery Life**

The conditions under which a battery operates affects the performance and life of a battery. Low temperatures reduce the capacity of a battery below its rated capacity (which is usually for 25°C). Higher temperatures shorten the battery life. Different specific gravities of electrolyte are sometimes used to compensate for continuous lower or higher than normal operating temperatures. In some climates either heating or cooling may be required for separate battery room accommodation. While it would be important to maintain ventilation all the time, it may not be necessary to provide heating or cooling during the input power supply failure period.

The designer must make all suitable provisions to ensure battery life is not unduly shortened. The designer must consider a separate battery room or enclosure to facilitate suitable temperature control.

### **20.6.13 UPS Requirements**

#### **Input Isolation**

Input isolation is not a standard arrangement but may be provided by the use of an input transformer as part of a static UPS system. Input isolation provides the following:

- a) Isolates the battery from earth. This is no longer as important as it was in the past due to the introduction of sealed cell technology and the necessity current safety requirements to isolate sections of battery strings prior to carrying out any maintenance.
- b) Delta primary connection cancels the effect of any triplen harmonic current generated on the output of the transformer.
- c) Guarantees that no DC component can be drawn from or injected into the mains supply.
- d) Can be used to allow 12 pulse rectification by use of auxiliary phase shifted windings.
- e) Can assist in decoupling and attenuating noise and transients to and from the mains supply.

Disadvantages include the additional space requirements, power losses, cost and an added component count. It is usually necessary to provide a method of limiting magnetising inrush currents when the transformer is energised so that overload and short circuit protection equipment is not tripped. This is usually avoided by the use of series inductors or resistors which are bypassed by contactors once the transformer has magnetised.

#### **Availability and Mean Time between Failure**

The purpose of a UPS is to increase the mean time between failure (MTBF) of the power supply to the critical load. The UPS system achieves this by using stored energy to allow the power supply output to “ride through” short interruptions to power on the input side of the UPS. The mains power supply in Australia can have very high “availability” especially in the central business districts of capital cities. Here a UPS system won’t increase the “availability” of the power supply necessarily but will prevent the disruption that would otherwise occur to the critical load caused by short interruptions to supply or voltage fluctuations. Many interruptions of several seconds duration do not have much effect on the availability of power supply averaged over the year, but do have a major implication in terms of disruption and downtime caused to computer load.

As the above description implies, the definition of “availability” in reliability theory and practice is the ratio of “uptime” divided by the sum of “uptime plus downtime” and is usually taken over an interval of one year.

It is important to realise that mean time between failure (MTBF) figures quoted by UPS suppliers are figures that may assume the synchronous bypass facility may operate to maintain supply during a UPS system malfunction and this is not counted as a system failure. Very high figures (typically 100,000 hours) are quoted as they assume high availability figures for main supply (typical 0.5 hours per annum unavailability). Typical MTBF figures for a UPS system excluding the effect of the bypass supply would be 20,000 hours or less. Thus it can be seen that the effect of the UPS system is unlikely to improve availability of supply and in fact due to the high system series component count tends to reduce the availability of supply. Care should therefore be taken not to compound the problem with complicated configuration of the power supply with many other series components and instead to perhaps consider a method to increase the overall availability of the power supply by having a simple bypass system around the UPS and other series components.

The designer must specify appropriate availability data for the proposed UPS.

### **Voltage Limits**

The distribution voltages and voltage limits shall suit the critical equipment load requirements. Where the installation requires conformance to specific standards these are to be identified in the FDB. Guidance on standard voltages are given in the standard FDB clauses.

Provide protection or otherwise ensure correct operation of the installation and equipment where voltage excursions are anticipated outside the permissible range are possible.

Where equipment is susceptible to voltage transients provide suitable protection.

### **Rotary UPS**

The inertia-driven ride-through configuration should be considered at sites where the power distribution system has a high reliability and long duration interruptions are not frequently experienced. The battery supported inertia configuration should be considered at sites with frequent long duration power interruptions. The battery protection time shall not be less than one minute and shall not exceed the maximum time the load can be operated with the loss of the environmental support equipment.

The required ride-through time depends largely on the nature of the power supply source. It should be longer than the longest momentary interruption experienced or expected at the particular installation. The longest momentary interruption time is usually the duration of reclosing operations on the power supply distribution feeders. In addition, the nature and percentage of non-linear loads should be determined. This is necessary to insure that the system's level of voltage distortion when supplying such loads is acceptable.

Rotary UPS bearings must be replaced periodically and the impact of this activity must be addressed and catered for by the designer.

Rotary UPS shall be selected on a through life basis, however, Defence preference is for arrangements which allow removal of the prime mover with minimal impact on the UPS functionality (i.e. the ability to remove the generator and still provide UPS functionality and allowing separate generator support through mobile generator arrangement).

### **Motor and generator ratings**

Motor and generator ratings and performance characteristics are standardised by the National Electrical Manufacturers Association (NEMA) in ANSI/NEMA Publication MG-1, 1978. Motors and generator rating shall be continuous duty in accordance with the NEMA rating structure based on site rating.

### **Flywheel sizing**

The flywheel inertia is selected such that the stored energy is sufficient to supply the electric generator while operating at rated power for a sufficient duration while keeping the speed from falling to maintain the frequency drop to a maximum of 0.5 Hz; this duration being the time for the diesel generator backed essential supply being made available to the UPS.

#### **20.6.14 Control and Monitoring**

The UPS shall have appropriate control and monitoring interfaces to enable semi-skilled operators to operate the UPS and reset minor UPS faults.

All of the controls, instrumentation, alarms and indicators for operation of the UPS module shall be accessible without opening doors or panels.

The UPS must be supplied with a control system monitor. The panel should be on the front surface of the cubicle and shall not be obscured by doors or secondary viewing windows.

Consideration needs to be given as to where the local UPS system alarms need to be repeated for alarms generated during normal and after hour's operation. The type of alarms relayed need also be considered.

The following functions (as a minimum requirement) shall be metered and logged:

- a) Input voltage and current, frequency, power factor, kW & kVA.
- b) Battery voltage and charge/discharge current, where appropriate.
- c) Output voltage and current, power factor, kW, kVA and frequency for each of the three phases.

All meters should be accurate to within  $\pm 1.5\%$ .

The system should include the following controls:

- a) Lamp test/reset pushbutton
- b) Battery circuit breaker trip, where appropriate
- c) Automatic start/stop
- d) Individual rectifier start/stop
- e) Online/offline and/or transfer controls
- f) Extended synchronisation controls as applicable
- g) Battery boost start/stop (if applicable)
- h) Emergency shutdown with protective cover

The UPS should have a mimic panel in the form of a single line diagram with status indicators or other suitable arrangement agreed by DEEP.

The system shall include indicators to clearly indicate the current operating mode and whether there is any outstanding alarm condition.

The following conditions should be monitored and alarmed and indicated on the local display panel. Any alarm condition when activated should be recorded with date and time of occurrence and should have a mnemonic and code associated for efficient interpretation and follow up. All alarm conditions should annunciate on a summary alarm and audible alarm. All alarm conditions shall be stored in non volatile RAM and should be recoverable even after a complete outage.

It is suggested that the system should include monitoring and alarms for most of the following conditions:

- a) Input supply abnormalities
- b) Input/output overloads
- c) Emergency off
- d) Internal diagnostic messages
- e) Bypass supply abnormalities
- f) Incorrect equipment operating conditions
- g) DC overvoltage, discharging, low warning, discharged conditions
- h) Ambient over temperature
- i) Equipment over temperature
- j) Frequency and synchronising conditions
- k) Battery circuit breaker open
- l) Battery discharging
- m) Battery residual time
- n) Input power failures/restorations
- o) Fan failure (per module)
- p) All circuit breaker status indications
- q) Static switch unable
- r) Load on bypass
- s) AC overvoltage/undervoltage
- t) All generator functions as detailed in the IM LEG Requirements, where appropriate
- u) Any manual or automatic switching and or control operations
- v) Diagnostic messages relating to any abnormal or unsuccessful control operations
- w) Summary alarm

#### **Defence Engineering Service Network (DESN) and Building Management Systems (BMS)**

Voltage free contacts shall be provided to interface with DESN and BMS. Monitoring requirements are provided in the Defence Engineering Service Network (DESN) requirements which have been repeated here for convenience.

- a) UPS online

- b) UPS in bypass
- c) Mains Supply Failure
- d) UPS Fail
- e) UPS Warning
- f) Battery Low Warning
- g) Summary Alarm

Other monitoring options include:

- a) Batteries Discharging
- b) Battery Residual time
- c) Load on Bypass
- d) Overload Warning
- e) Over temperature
- f) New Alarm

### **20.6.15 Defence UPS Configuration Philosophy**

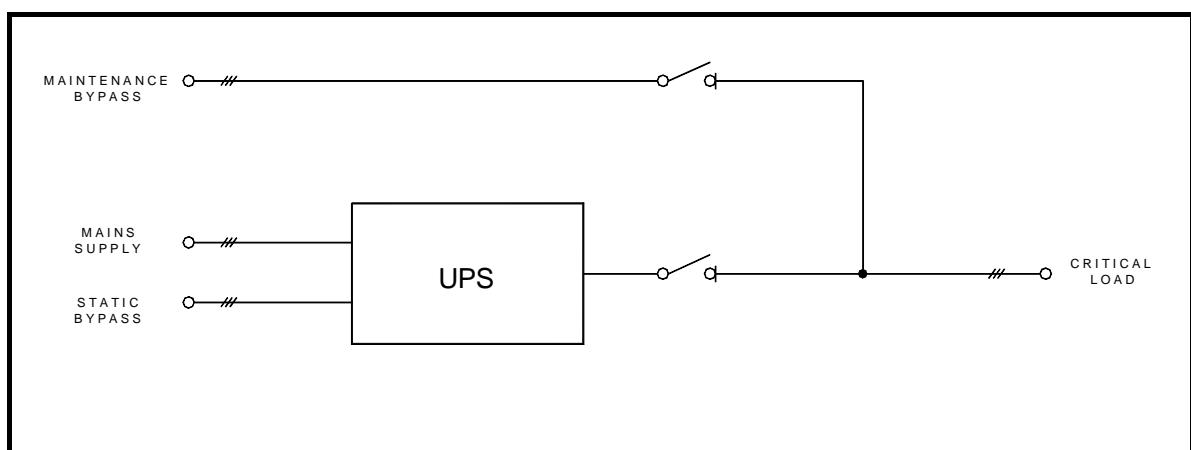
Defence UPS systems shall generally be configured in one of three ways:

- a) Single non-redundant UPS
- b) Parallel redundant UPS.
- c) Redundant independent A/B systems.

It is important in determining the required UPS system, that there is consistency with the configuration of the other services. For this purpose, it is recommended to refer to the US ANSI Standard TIA-942 for guidance on consistent topologies required to achieve a desired overall system availability.

#### **20.6.15.1 Single Non-Redundant UPS**

A typical non-redundant UPS system configuration is shown on Figure 20.4.



- **Figure 20.4: Single Non Redundant UPS Configuration**

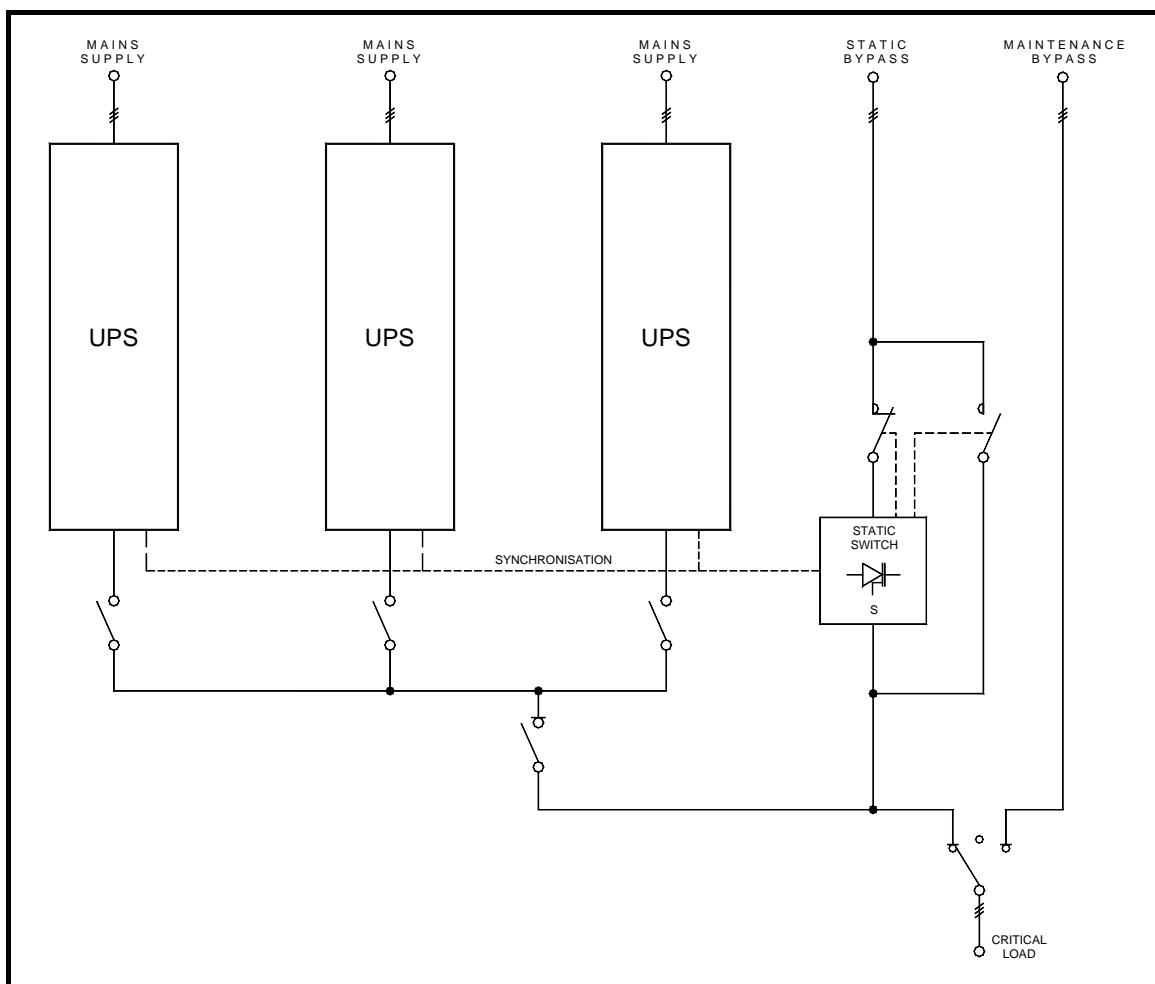
This configuration would satisfy the majority of applications that require UPS. Note that although there are several possible single points that could cause failure, the simplicity of the system provides a high degree of reliability in a cost effective manner. Other items to note with this configuration are as follows:

- a) Separate submains back to the main switchboard for UPS Input and UPS Bypass supplies has the advantage that the critical load can be supplied by the UPS bypass while the UPS rectifier and inverter are being tested and recommissioned after a problem. If both shared a common submain then possible overloading would occur and if the UPS Input caused a momentary overloading due to commissioning problems, the one and only submain circuit breaker could be tripped, thereby interrupting critical power. Although both input and bypass supplies could be connected to a common submains from one point in the power supply network, it is better from a reliability and maintainability aspect if separate submains are provided.
- b) Major maintenance on the UPS or replacement can be carried out with relative ease and only a short shut down due to UPS switchboard and manual maintenance bypass switch being completely independent of the UPS.
- c) The maintenance bypass manual supply transfer switch on the Critical DB's improves the overall system power availability by providing a very simple and reliable path around the more complex series links. It should be noted that while the mains does not have a very good MTBF (mean time between failure) it does have an extremely high availability (percentage of uptime). The UPS while being very successful in extending the power supply MTBF does cause a reduction in the theoretical power availability because of the addition of several components in series with the power supply.
- d) Note that the neutral conductor may not be required for the input supply to the transformer/rectifier section of the UPS. The neutral is reticulated with the bypass supply and is connected to the star point of the secondary of the output transformer. Note that there is no "MEN" point at the UPS. The "MEN" point remains at the main switchboard. Unlike the situation with standby generators, there is not the concern of the fault current having to return to the star point of the UPS transformer via the MEN in the main switchboard not reaching high enough values to trip the circuit protection due to the high impedance path. The reason for this is that most UPS systems are high impedance sources anyway which automatically current limit to protect themselves under overload conditions. Under fault conditions, the inverter output is current limited and the UPS output is transferred to the bypass supply which provides the low impedance fault path necessary to trip circuit protection and clear the fault
- e) Input Isolation Transformer is an optional component with many UPS suppliers. Its incorporation can be very useful as discussed above. Not shown but required are the additional components for transformer magnetising inrush current prevention.

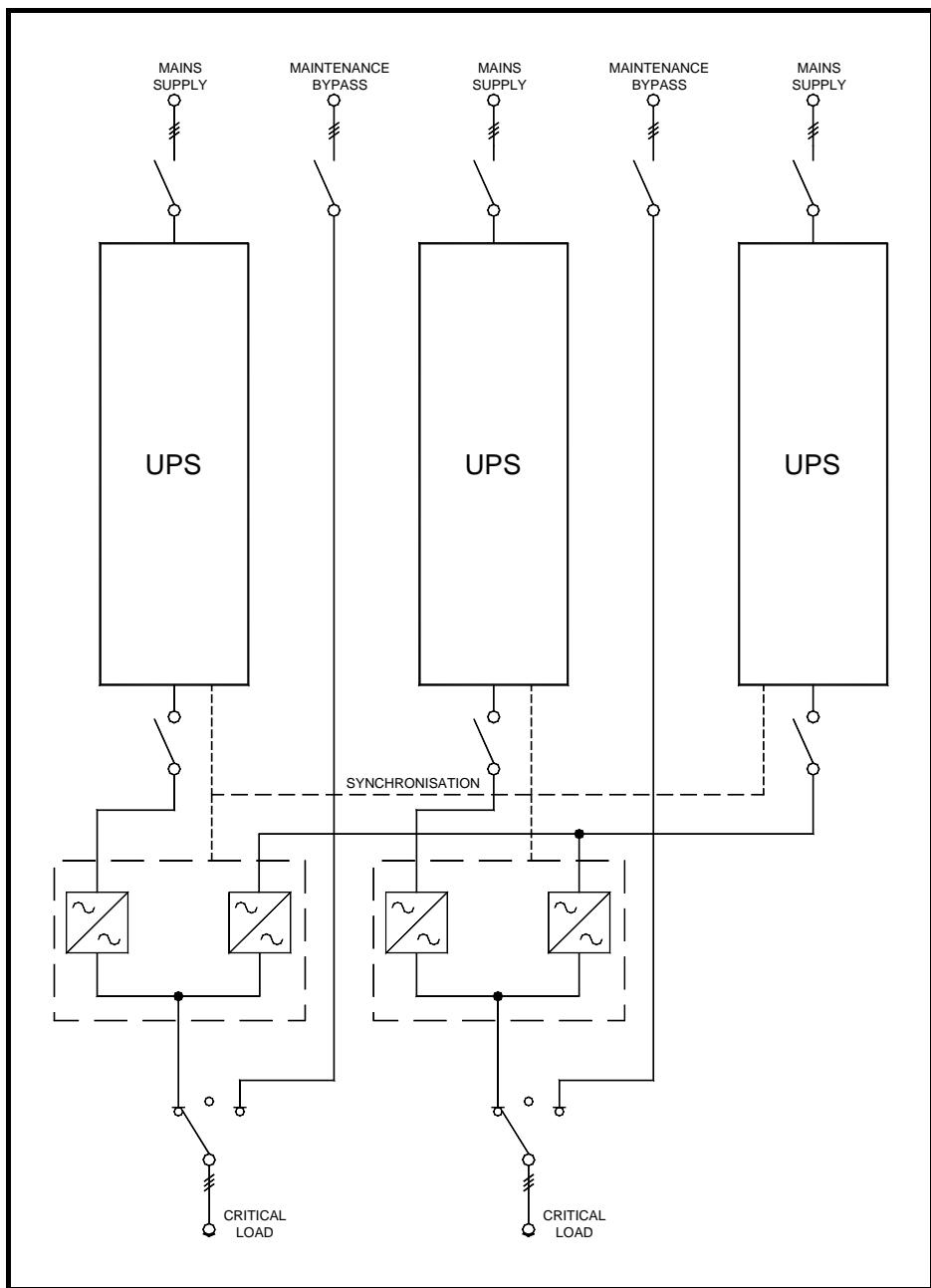
### 20.6.15.2 Parallel Redundant UPS

Arrangements are possible with parallel redundant units including systems where each NBPS has its own synchronous bypass facility so that there are two synchronous bypass facilities in parallel. If this option is adopted, care needs to be taken to ensure that the common static bypass is powered from a common source so that there is no possibility of paralleling supplies which may be out of synchronism or may otherwise not be permitted to be in parallel. Multiple synchronous bypass facilities require a master control facility or interlocking to ensure that all units operate and that all inverter outputs are isolated.

Note also that the system becomes less reliable should the ratings of the individual NBPS not exceed the rating of the load. It is preferred that the redundant A/B system or distributed static bypass be used with synchronous switches at each respective critical distribution board.



▪ **Figure 20.5: Parallel Redundant UPS Configuration**



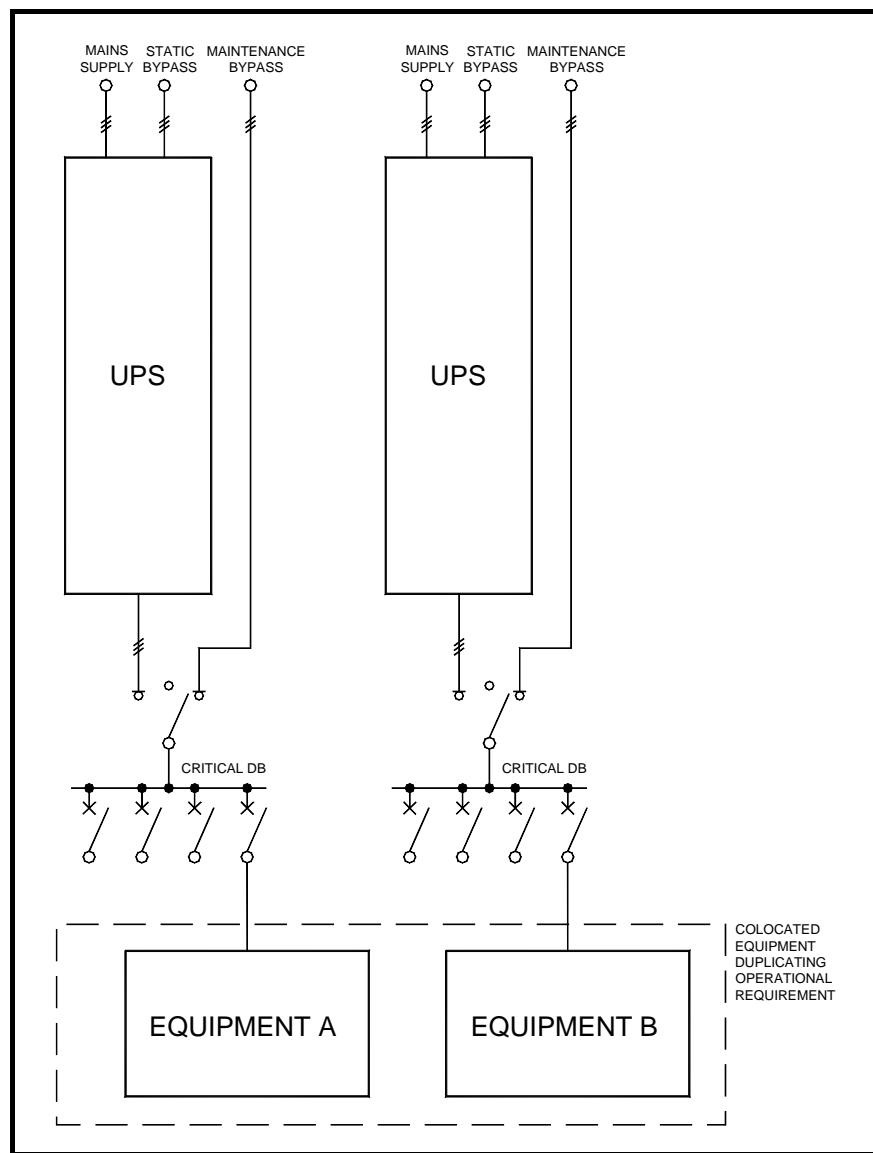
■ **Figure 20.6: Parallel Redundant UPS Configuration with Distributed Static Bypass Switches**

The Parallel Redundant UPS Configuration with Distributed Static Bypass option requires the equipment load to tolerate switching outages typically of 10 milliseconds.

### Redundant Independent A/B Systems

Figure 20.7 shows an example of an independent redundant A/B system.

This system, while highly reliable with a long mean time between failure (MTBF), may not have a significantly higher availability than the previous examples. This option required complete duplication of the distribution and equipment. Note that the provision of a maintenance bypass facility for this configuration is optional and is usually not justified because the redundancy already provides an alternate path.



■ **Figure 20.7: Redundant Independent A/B System**

### **20.6.16 Routine Testing**

Routine testing of UPS is critical to its proper operation. The agency responsible for the maintenance of the UPS shall ensure that all required testing and maintenance is undertaken and that the performance of the UPS is proven. The testing shall include at least an annual performance test of the entire UPS and critical distribution system and any associated essential systems (i.e. LEG).

#### Performance Testing and Start-up

Routine performance testing and start-up procedures shall be included in the Operating and Maintenance Manuals. They shall be in a format suitable for semi skilled operators. The start-up procedures shall include suitable checks of the component's operation once energised.

All test results including the acceptance testing shall be suitable recorded for comparison. The possible failures of the equipment drawn out from the test results should be identified and discussed in the test report with any necessary corrective action implemented. Test equipment used should be in accordance with the manufacturer's recommendation.

#### **Maintenance**

Maintenance of the UPS consists of preventive and corrective maintenance. Preventive maintenance consists of a scheduled list of activities included in the Operations and Maintenance Manuals. Performing these activities keeps the UPS in good working order and helps to prevent failures. Corrective maintenance is performed as a result of a failure. Corrective maintenance fixes the problem and gets the unit working again. Suitable procedures and maintenance schedules shall be provided by the equipment manufacturer and installer and incorporated into the O&M manuals and must include both preventative and corrective maintenance procedures.

Battery monitoring and maintenance is extremely important and becomes more critical as a battery moves towards its end of life. Measures may need to be taken to ensure that a disastrous "thermal runaway" condition is preventable or very unlikely to occur. Optional aides to maintenance offered by UPS suppliers include microprocessor based battery cell voltage monitoring systems.

It is not good practice to regularly discharge the UPS batteries as this will significantly shorten its operating life.

System and battery maintenance logs should be kept and completed with every inspection. A record of battery cell voltages and float currents gives a good picture of battery condition by looking at the changes over time.

### **20.6.17 Guidance On UPS Ventilation And HVAC System Arrangements**

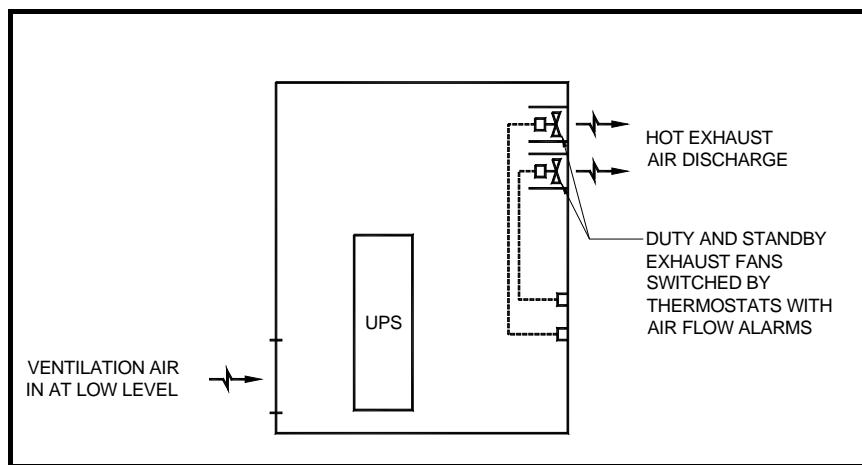
The other environment that requires consideration is the battery room or enclosure. Australian Standards AS 2676 and AS 3011 provide detailed information on requirements and recommendations related to battery accommodation.

### Forced ventilation

This method is only suitable in regions where the ambient outside air temperature seldom rises above 34°C.

The exhaust fans should be sized to limit any temperature rise to less than 6°C. The inlet air should be introduced at low level and preferably from within the building to avoid introducing hot air into the UPS room. The fans should discharge at high level.

It is recommended each fan be switched by a thermostat. The duty fan should operate at a lower set temperature (say 25 °C) and be fitted with an air flow switch so an alarm can be activated if it fails. The standby fan should operate at a higher temperature (say 30°C) and raise an alarm if it is needed. Fans and controls should be powered from the output of the UPS. Refer to Figure 20.8.



■ **Figure 20.8: Exhaust Fan Option**

Some useful formulas needed to calculate the required exhaust fan capacity and the rate of temperature rise when there is no cooling are provide as follows:

### Required Exhaust Fan Capacity

To calculate the exhaust fan capacity that will result in a nominated air temperature rise:

$$\text{Fan Capacity (l/s)} = \frac{\text{Heat load W} \times 0.845 \text{m}^3/\text{kg}}{1.025 \text{ kJ/kg K} \times \Delta T (\text{K})}$$

Where  
 -1.025 kJ/kg K - specific heat of moist air  
 0.845 m<sup>3</sup>/kg specific volume of moist air

For example, assume heat load 20,000 W and air temperature rise of 6° K

$$\text{Required Fan Capacity} = \frac{20000 \times 0.845}{1.025 \times 6} = 2748 \text{ l/s}$$

### Rate of Air Temperature Rise

The rate of air temperature rise depends on the room volume and heat emission into the air.

$$\text{Rate of temperature rise (°K/s)} = \frac{\text{Heat load (W)}}{1.213 \times \text{room volume (m}^3\text{)} \times 1000}$$

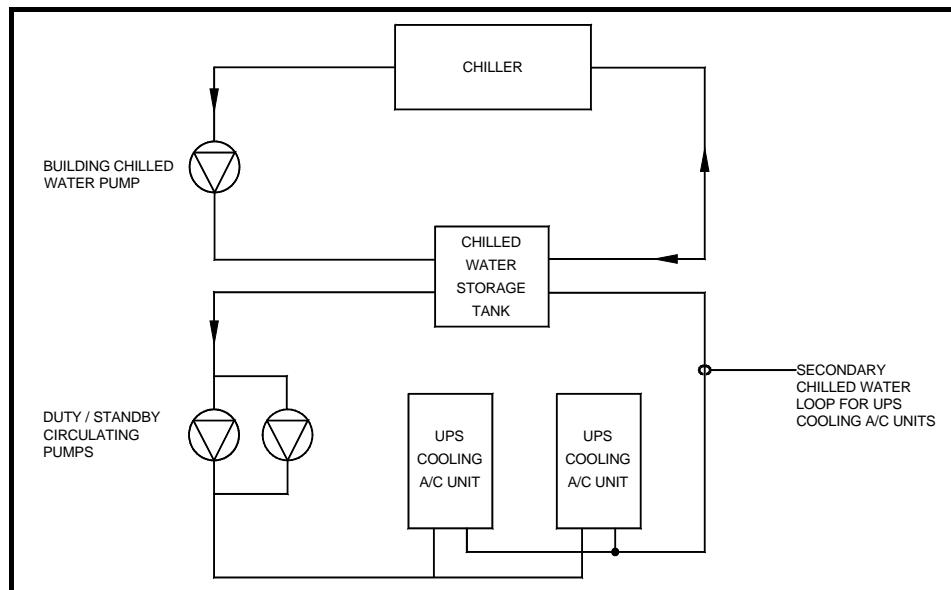
For example, assume heat load of 20,000 W and room volume of 300m<sup>3</sup>

$$\begin{aligned} \text{Temperature Rise} &= \frac{20000}{1.213 \times 300 \times 1000} = 0.055 \text{ °K/s} \\ &= 3.3 \text{ °K/min} \end{aligned}$$

### Conditioned space

This option allows for 2 fan coil units each capable of cooling the UPS and maintaining the room at 25°C. It is recommended that the fan coil units be floor mounted on a stand with a down discharge to direct cooling air at low level – computer room units are ideal.

Both units should operate and an alarm raised if one unit fails. The fan coil units are normally connected to the building chilled water system but on power failure a secondary pump should pull the chilled water from a storage tank sized to allow for operation during the support time. The fan coil units, secondary chilled water circulation pump and controls will need to be connected to the output of the UPS. Refer to Figure 20.9.



■ **Figure 20.9: Chilled Water Option**

# 21 Local Emergency Generator (LEG) Requirements

## 21.1 Background

A Local Emergency Generator (LEG) is a fixed generator installation provided for an essential facility to ensure continued operation of the facility or equipment during a power failure. In the context of this chapter, a LEG is to be taken to incorporate the entire essential or emergency power supply system including the generator and the distribution network provided throughout the facility.

There are three main types of permanently installed emergency power systems provided at Defence establishments and facilities, namely the Central Emergency Power Station (CEPS), the LEG and the Uninterruptible Power Supply (UPS). Each emergency power system has a different application as indicated below:

- a) **CEPS** - Provided at key operational establishments to support important functions and the LEGs at the establishment.
- b) **LEG** - Provided to support essential loads at a facility or essential facilities. Essential loads can generally tolerate a minor power outage, but require emergency power to continue operation during a prolonged power outage.
- c) **UPS** - Provided to support critical loads at a facility. Critical loads cannot tolerate any power outage or uncontrolled power down.

Based on the above, power distribution at Defence facilities is classified as shown in the table below:

■ **Table 21.1: Power Distribution Classification**

Power Distribution Classification	Type of Support
CRITICAL	UPS supported
ESSENTIAL	LEG supported
NORMAL or NON-ESSENTIAL	No UPS or LEG support May be supported by CEPS or mobile generator

LEGs are used to support essential loads to prevent loss of key facilities during periods of failure of the normal supply. The LEG supplies the essential loads through the essential power distribution system, whilst the UPS supplies the critical loads through the critical power distribution system. The CEPS distribution system is through the normal high voltage reticulation and supports the normal, essential and critical power supply systems. The term 'essential' is not to be taken to apply to facilities supported by CEPS or mobile generators alone.

The requirements of this chapter are applicable to fully automated LEG systems only. Although manual LEG systems are not specifically covered, the basic requirements of this chapter could apply to manual LEGs systems as well.

LEG systems are specialised systems that can be configured in many ways and can significantly impact on the immediate environment. Therefore, due consideration shall be given to the issues of compatibility with, and impact on, other services and the building environment respectively.

The capabilities and limitations of LEGs shall be considered to ensure their suitability for supplying equipment and loads whose requirements and operational characteristics shall be adequately defined. This places an important emphasis on defining the equipment requirements and the responses under failure conditions.

Selection of LEG systems shall achieve best value for money on whole of life basis and shall also take cognisance of the level of product support provided in Australia and locally in the region installed.

## **21.2 Reference Documents**

Designers shall be responsible for meeting the requirements of this chapter together with those of applicable legislation and standards such as, but not limited to:

AS/NZS 3000	Wiring rules;
AS 3010	Electrical Installations - Supply by Generating Set
AS/NZS 3009	Electrical Installations - Emergency Power Supplies in Hospitals
AS 1359	Rotating Electrical Machines
AS 4594	Internal Combustion Engines
ISO 8528	Reciprocating Internal Combustion Engines Driven Alternating Current Generating Sets

## **21.3 Justification**

This chapter does not prescribe the type of facility or area that requires the installation of emergency power. Instead, this chapter identifies those areas or functions which are normally LEG supported and establishes the basis on which project staff, sponsors and consultants shall evaluate the need and type of system required.

LEGs shall be provided to support key Defence operational facilities such as communications facilities, operational command buildings, and Air Traffic Control (ATC) facilities and in certain circumstances, Defence hospitals. LEGs may also be considered when, based on the availability of the normal supply, the costs of down time exceed the through life costs of a LEG.

The determination as to whether a LEG is required shall be by assessment, on a case by case basis, supported where appropriate by an analysis of the risks involved. The risk analysis shall be in

accordance with AS 4360 and shall consider the impact of the all possible opportunities and/or detrimental outcomes in the Defence context inclusive, but not limited to, the following:

- a) statutory requirements, standards and Defence policy requirements
- b) consequences of power supply interruption in terms of:
  - loss of function
  - disruption of process
  - time to recover
- c) frequency and duration of power outages
- d) quality of the power supply in terms of voltage and frequency stability and ability to meet the equipment requirements
- e) area or equipment to be supported (entire facility or part)
- f) ability of any site emergency power supply (e.g. CEPS) to meet the emergency power requirements
- g) suitability of other more cost effective means, such as mobile generators, UPS or battery backed systems

LEG systems shall only be considered when:

- a) statutory requirement, standard or Defence policy requirement dictates the provision of a LEG (e.g. ATC Tower, Aircraft Navigation Aids , certain hospitals);
- b) regular critical operations are undertaken at the facility that would be adversely affected by interruption of electricity supply (e.g. Operational Command Centres, Communication and Information System Centres (CISCEN) and critical communications facilities);
- c) an interruption of the electricity supply would result in a severe life safety or environment incident for critical functions such as emergency response facilities and essential engineering services;
- d) the frequency and duration of operations cannot be supported efficiently and cost effectively by mobile or hire generators. Any facility that can tolerate an outage of around 48 hours can, under normal circumstances, be adequately supported by mobile generator;
- e) essential functions and services cannot be transferred to, or catered by, unaffected areas;
- f) site emergency power supplies such as CEPS cannot meet the emergency power requirement; and
- g) the financial losses due to power interruptions, under normal supply availability conditions, would exceed the through life costs of a LEG (certain tactical training centres and simulator facilities).

Guidance on a case by case basis is available from DEEP in order to determine whether or not a LEG should be provided.

## **21.4 Identify the Characteristics of the Load**

The characteristics of the essential and critical load to be supplied by the LEG system shall be clearly identified. Specifically, the following equipment information shall be determined:

- a) Nominal voltage and allowable voltage limits under steady state and transient state conditions. Transient limits may be different to take into account large step changes in the load and the short duration of a resulting output voltage change;
- b) Full load true power rating (kW) and power factor;
- c) The type of load and its characteristics, particular emphasis should be given to identifying the loads with high inrush currents or high harmonic content;
- d) Indication of the inrush characteristic or harmonic content of the load and the combined affect of these. (An indication of the inrush characteristic harmonic content of a load can be obtained from measurements carried out on existing or similar loads or through consultation with relevant equipment manufacturers and suppliers);
- e) Any special characteristic of the load such the power regeneration on de-energisation, restoration time on power up, restoration process and susceptibility to power outages; and
- f) Required equipment connection interface.

The specifications shall clearly identify the characteristics and parameters of the installation to ensure that the LEG system is adequate for the installed conditions. Particular emphasis shall be placed on defining suitable LEG system performance characteristics to ensure the anticipated step loads, inrush conditions, harmonic content of the load and the particular requirements of sensitive equipment are adequately accommodated.

## **21.5 Other General Design Requirements**

The LEG accommodation shall be suitable for the operation of the LEG. Particular care shall be taken to ensure that the LEG heat rejection and airflow requirements are met and that the design of the ventilation system does not contaminate the air conditioning or ventilation systems of the building occupants or adjacent buildings.

The LEG system shall be fully compatible with the building power reticulation system and its connected loads to ensure harmonious and non-detrimental interfacing between the generating equipment and the building connected loads. The designer shall ensure that appropriate analysis is undertaken to determine the LEG configuration required.

LEG power shall be distributed via the building's essential power reticulation system. Essential distribution boards are the preferred method for connecting large or unspecified equipment and for equipment rooms. The provision of under voltage releases to prevent damage to equipment susceptible to voltage transients or to uncontrolled power up should be considered and reviewed by the designer in consultation with the building's users.

The LEG system shall have appropriate control and monitoring interfaces to enable semi-skilled operators to operate the LEG and reset minor LEG system faults.

## **21.6 Determination of the Required Restoration Time**

The required restoration time may be that required by standards or may be a requirement of the equipment or operations supported. The restoration time is specified as the time required for the equipment to return to full operation, or as the time required for the LEG to stabilise and come online.

The designer shall ensure that the generator is up to speed and its output stabilised before transferring to the load. The designer shall ensure that, where required, the LEG restores power supply in sufficient time to enable the equipment to meet the required restoration time.

As an example, the relevant standards for aeronautical ground lighting require the return of the lighting to service within 15 seconds of a power failure. This will require the LEG to be online and fully stabilised within 8 to 10 seconds of power failure to allow enough time for lighting equipment power up to full illumination within the permissible 15 seconds.

Very short restoration times may require substantial oversizing of the engine of the generator assembly and this may impact on the required minimum load to guarantee the thermal stability of the generator engine. The designer shall ensure that, within practical limits, the adverse effects of generator engine oversizing are minimised. Where possible, as in the case of equipment supported by a UPS, the time for bringing the generator on line shall be extended to reduce or eliminate the impact of engine oversizing.

## **21.7 The Effect of UPS on the Generator**

The controlled rectifiers of UPS systems can be a major source of harmonics which can produce distortions of the voltage and current waveforms and may have a detrimental effect on a variety of electrical equipment both upstream and downstream of the UPS system. The designer shall ensure compliance with relevant Australian Standards AS 2279 *Disturbances in Mains Supply Network*, AS/NZS 61000 *Electromagnetic Capability (EMC)* and AS 62040 *Uninterruptible Power Systems (UPS)* to minimise the effects of harmonics on electrical equipment.

The designer shall ensure that the LEG is suitable for operation with the intended UPS load. When the UPS rectifier load is more than about 50% of the total load connected on a generator, the following special measures shall be considered to ensure stable and reliable operation of the generator:

- a) Using a three phase voltage regulator;
- b) Using permanent magnet field excitation;
- c) Using an electronic governor;
- d) Oversizing the alternator compared to the kW rating required; and

- e) Specifying the UPS with filtering or 12 pulse rectifiers to limit the amount of harmonic distortion, where possible.

When the UPS represents a significant load on a generator that is operating at or close to its maximum output, overloading shall be prevented by inhibiting or limiting the battery charging function of the UPS when connected to the generator supply, where possible.

## **21.8 Essential Load Distribution**

The essential distribution system shall be capable of supplying the essential load connected to the system via the appropriate area or room essential distribution boards. Redundancy is not normally a requirement of the essential distribution system. Where redundancy is required it will be indicated in the FDB.

The transfer switch shall include an interlock to prevent simultaneous connection to both the normal and standby power supplies. The interlock shall preferably be of the mechanical type. Consideration should also be given to the requirement for the transfer switch to also switch the supply neutrals and guidance should be sought from the local Network Provider and Industry Regulator before finalising the transfer switch design arrangement.

Only essential loads shall be LEG supported and load shedding of normal or non-essential loads shall take place when the essential loads are connected to the LEG supply. The load shedding arrangement shall be kept as simple as possible so that it can be operated by the building occupants if required. Normally this load shed device would be a single contactor or motor operated circuit breaker. The proposed LEG load shedding arrangement and controls shall be detailed in the design report for agreement by DEEP.

Where the normal or non-essential load is left connected to normal mains supply at establishments provided with CEPS, the normal or non-essential loads shall be connected to the Base load shedding system. Base load shedding system requirements shall be included in the building design brief.

Transient surge protection shall be considered for LEG supply systems to prevent damage and disruption caused by lightning strikes or by switching surges/spikes.

Equipment that cannot tolerate being powered up immediately after a supply interruption shall be disconnected on power failure or protected by other suitable means such as a UPS system. The reconnection arrangement, where required, shall suit the sponsor/users requirements which can involve manual reconnection to allow controlled reconnection to the standby supply.

### **Redundant Supplies for Critical Facilities to Cater for Cable Failure**

In critical facilities such as ATC towers, redundant submains for the essential distribution system may be specified as a specific to project requirement. This shall normally be achieved by providing, to each essential distribution board, a manual supply transfer switch which connects an

alternate supply path and ensures that no single point of failure exists to the nominated distribution boards. The alternate supply path shall bypass as much of the distribution system as possible for increased system reliability and the manual transfer switch shall prevent simultaneous connection to the two supplies to each essential distribution board.

## **21.9 Control**

The generator shall be capable of operating in manual and automatic modes. Transfer between the generator operating modes shall be bumpless and shall not unnecessarily affect the operation of the generator.

The LEG supply shall not be synchronised and connected in parallel with mains supply. Appropriate switching time delays shall be incorporated to avoid any out of phase problems when changing from the normal supply to the standby supply or vice versa. Any requirement for automatic synchronisation of the LEG system shall be justified by the sponsor and agreed by DEEP before the design stage.

The control system shall be either PLC or microprocessor based and shall be site programmable without the need for any software or hardware changes. All programming tools shall be provided as part of the installation unless already available on site. All software necessary to interrogate and modify the programs shall be provided to Defence with appropriate software licences.

There shall be separate "Auto", "Off" and "Manual" selector switches provided for each of the generator, dummy load, or transfer switch controls. Each respective element shall have appropriate separate manual controls.

### **Control Modes**

#### Manual Mode

Manual mode is control by an operator from the generator control panel. This mode shall be independent of any automatic control functions. A sufficient number of indicators and meters shall be available in this mode to clearly display the operational condition of the generator. All generator protection systems (trips) shall remain in operation regardless of the operating mode and manual controls shall be disabled whenever the control mode is switched to Auto.

#### Automatic Mode

When in automatic mode, the generator control system shall monitor mains supply and on loss of which shall start and connect the LEG automatically to the load. The speed and voltage of the generator shall be stable before any automatic transfer of load to the LEG. On restoration of mains supply the generator control system shall automatically transfer the load back to normal mains supply after an appropriate time delay (adjustable from 1 to 30 minutes). The reconnection of the load to mains supply shall be followed by the automatic shutdown of the generator through the appropriate cool down sequence period.

It shall be possible to remotely start and run the LEG when in automatic mode as required at establishments with remote control capability or requirement such as establishments with ATC towers or CEPS. ATC only require control over the aerodrome navigation and visual aids. Remote control and monitoring requirements are detailed in paragraphs 21.10.4 and 21.10.7 below.

At establishments provided with CEPS, the LEG control system shall be provided with a “GENERATOR RUN ON” signal from the CEPS. The purpose of this signal is to ensure that all the LEGs at the establishment continue to run as required when the CEPS is supplying the Base under mains fail conditions. The LEG control system, on receiving this signal, shall ignore that mains is available and shall continue to run the LEG to supply the load. When mains supply to the Base is restored, the CEPS will no longer provide the “GENERATOR RUN ON” signal and the LEG changeover process back to normal mains supply shall be initiated. At establishments with a PCMS system, the “GENERATOR RUN ON” signal can be combined with the remote start/stop functions as detailed in the remote control and monitoring requirements below.

If the LEG fails in any mode, the load shall be transferred to normal mains supply irrespective of the “GENERATOR RUN ON” signal or source of supply, but provided the transfer switch is in automatic mode.

#### Automatic Control Sequence

The LEG shall be connected to the essential loads when any phase of the normal supply has been interrupted, has failed or is at a voltage that is less than 80 percent of the nominal system voltage. The changeover sequence shall only be initiated if the abnormal condition is maintained for a minimum continuous period of two seconds to prevent unnecessary start up of the generator. The time delay may be changed to meet the specific site requirements after consultation and agreement by DEEP.

On reinstatement of the normal mains supply the LEG system shall automatically restore the normal supply after the voltage has maintained nominal levels on all phases for a continuous period suitable to the Region, usually 15 minutes, adjustable between 1 and 30 minutes.

#### **Testing the LEG**

LEG test runs shall be carried out on a monthly basis and shall use either a dummy load or the essential equipment load. The control system shall be configured to allow the testing to be conducted in an easy and safe manner by both semi skilled and skilled operators. LEG testing shall generally be carried out as follows:

- a) Simulated mains failure condition (once every year by skilled operators only). A power failure is initiated by isolating mains supply at the substation. Removing the fuses from the phase failure relay may not necessarily prove the performance of the system and therefore should not be used for this test. This test should not be a simulation and should involve the facility in its normal operating mode to ensure that the emergency power supply system is fully proven and that the facility and equipment operates in the correct manner.

- b) Manually running the generator to supply the equipment or dummy load as selected by the operator. The generator shall continue to supply the selected load until the operator changes the generator operating mode. When running in this mode, it shall be possible to manually test the generator on the selected load with the transfer switch in either automatic or manual modes as required by the operator (See also transfer switch requirements below). The LEG system shall not be configured in any way that would require the transfer switch to be left in manual position to enable the test to take place. The LEG shall operate in the following manner under mains fail or LEG fail conditions:

**Mains Fail**

- i. If normal mains failure occurs whilst the LEG is supplying the equipment load, the LEG shall continue to run and supply the load until such time as the operator intervenes. On restoration of mains supply, the LEG would continue to supply the equipment load.
- ii. If normal mains failure occurs whilst the generator is supplying a dummy load, the LEG shall automatically switch to the building or equipment load provided the transfer switch is set to automatic mode. Where the transfer switch is in manual mode the operation of the LEG cannot be changed and therefore the test shall be allowed to continue. When mains supply returns, the LEG shall be configured to either continue to supply the equipment load or to restore the test mode depending on the operating requirements of the facility as determined during the design development phase.
- iii. Upon mains failure and where the dummy load is in manual mode, the dummy load shall be disconnected automatically before the LEG is transferred to the building or equipment load. In order to prevent the generator from overloading, the dummy load shall remain disconnected until manually reset by an operator.
- iv. Where test mode is restored on reinstatement of mains supply, appropriate alarms shall be raised to notify the operator of the mains failure condition.

**LEG Fail**

- v. Where the LEG fails under test, the testing shall be suspended and the equipment load shall be reconnected to mains supply. Appropriate alarms shall be raised to notify the operator that the LEG has failed.

## **21.10 LEG Design Parameters**

### **21.10.1 Generator Location**

In determining the location of the generator consideration shall be given to the following:

- a) Noise abatement
- b) Vibration isolation
- c) Ventilation
- d) Exhaust dispersion

- e) Weather protection
- f) Cooling
- g) Fuel supply
- h) Excessive voltage drop
- i) Environmental protection requirements
- j) Fire separation
- k) Maintenance
- l) Security; and
- m) Access

In addition to the requirements of AS 3010, generators shall be located in a separate generator room which shall be suitably fire isolated from the remainder of the building or facility.

Alternatively, the generator can be located in a separate building. The generator room shall house the generator and its associated supporting equipment such as fuel tanks, starting batteries and battery charger.

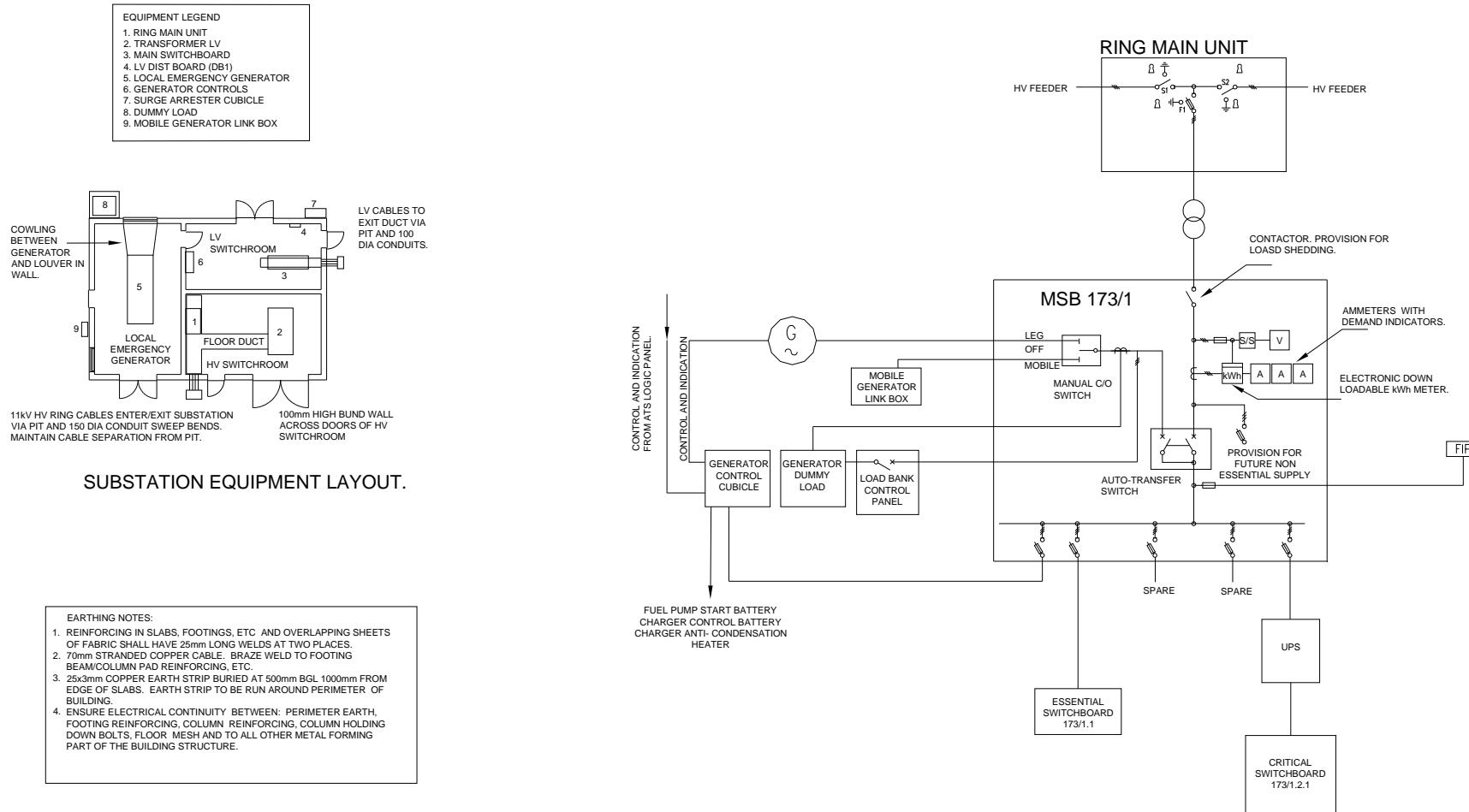
The generator room shall have internal access to the low voltage switch room as well as appropriate external equipment access doors to facilitate the installation and removal of the generator (i.e. double doors to perimeter of building). The generator cooling air inlet or exhaust arrangement shall not restrict access to the generator room through any of the access doors.

The generator shall be sited as close as practicable to the load. Long LEG supply cable runs shall be avoided wherever possible to minimise interference from or damage by outside influences or events.

Where the generator is located in a tropical or subtropical region the designer shall prevent any harmful impact caused by cyclones. Generators are not normally required to run during a cyclone but are to be fully operational after the cyclone has passed. The designer shall consider the need to mount the generator, supporting auxiliaries and switchgear on platforms to prevent water contamination. In addition, the generator windings shall be provided with coalescent filters and other susceptible essential equipment shall be suitably protected to prevent water contamination due to the high moisture content of the atmosphere.

Containerised LEGs shall only be considered where the expense of providing a dedicated generator room cannot be justified and where the alternative will not compromise the operation of the facility or its security. Containerised LEGs shall not be considered for important Defence operational facilities such as ATC towers or for facilities in cyclone regions. Proposals for alternative design solutions based on containerised LEG installations are required to be suitably argued by the designer and agreed by DEEP at project design stage.

An example of a suitable LEG configuration is shown in Figure 21.1.



■ **Figure 21.1: Example LEG Arrangement**

## **21.10.2 Generator Requirements**

### Rating

The generator shall be capable of simultaneously supplying the total rated load of equipment installed on site, ancillary loads such as fuel pumps, battery chargers and Uninterruptible Power Supply (UPS) charging currents whilst maintaining a 25% spare capacity. The designer shall consider the characteristics of the load when determining the generator size and output characteristics, particularly when non linear loads such as UPS systems and high inrush currents from motor starting are to be accommodated. The designer shall ensure that the manufacturer's recommended long term minimum load for the LEG is achieved and maintained without the need for the load bank under normal operating conditions.

The generator duty rating (e.g. standby, prime or continuous) shall be selected to achieve the most cost effective arrangement on a through life basis. Normally, standby rated engines are suitable for most Defence emergency power applications. The following definitions shall apply:

- a) **Prime Power Rating.** Equivalent to continuous power; the power generating set is capable of producing when operating continuously and the generator shall also have the ability of producing 10 percent in excess of the prime rating one hour in every twelve when operating continuously.
- b) **Continuous Power Rating.** As defined by AS 4594.1
- c) **Standby Power Rating.** Equivalent to fuel stop power as defined by AS 4594.1.

The generator shall start and supply the full rated load within the required restoration time after loss of mains supply as described in paragraph 21.9 above.

### Construction

Construction shall be in accordance with the appropriate parts of AS 1359, AS 4594 and ISO 8528. The generator shall be supplied as a complete unit and the supplier shall ensure that the equipment is mechanically and torsionally compatible.

The generator shall be skid mounted and wherever possible, a day service tank shall be incorporated into the base of the skid mounting. The day service tank shall be sized for approximately 16 hours operation at full rated load or where this fuel quantity is not permitted, to the maximum permissible fuel holding capacity of the facility in accordance with relevant codes. Lower tank capacities may be permitted, subject to approval as an alternative design solution, to allow skid mounted day service tanks to be used.

All service connections (i.e. fuel, exhaust, power cabling, etc) shall allow for the easy removal or replacement of the generator as required. All connections to the generator shall ensure that they are suitably flexible to cater for movement of generator and to prevent transmission of vibration.

### Voltage Regulation, Governor Performance and Short Circuit Performance

The characteristics of the generator, particularly the alternator, governor and voltage regulator, shall provide adequate and stable electricity supply to the essential services. The characteristics of the generators and its sub-systems shall be suitable for the load and the likely load steps. Listed below are minimum generator performance requirements which may need to be made more stringent by the designer to meet specific or particular load requirements:

- a) **Steady State Load Conditions.** The generator shall be capable of maintaining the voltage under steady state load conditions to within  $\pm 2.5\%$  of the nominal voltage from no load to full load for power factors between 0.8 lagging and unity inclusive of generator speed droop.
- b) **Transient Load Conditions - Load Acceptance.** The generator shall on the application of a minimum 60 percent load step, or the intended load step whichever the greater, maintain the initial voltage drop within 15 percent of the nominal voltage. The voltage shall recover to within  $\pm 3\%$  of the nominal voltage within one second.
- c) **Transient Load Conditions - Load Rejection.** The generator shall on rejection of 100 percent rated load, maintain the initial voltage rise within 20 percent of nominal voltage. The voltage shall recover to within  $\pm 3\%$  of the nominal voltage within 1.5 seconds.
- d) **Motor Starting.** The generator shall maintain the initial voltage drop within 20 percent of the nominal voltage under the most onerous motor starting conditions.
- e) **Alternator Sub-transient Reactance.** The alternator sub-transient reactance shall be suitable to achieve the voltage performance specified.
- f) **Governor Performance.** The performance of the generator governor shall be in accordance with AS 4594.4 and the following parameters:

i. Performance Class	A1
ii. Maximum speed droop	5%
iii. Maximum transient speed difference	10%
iv. Maximum transient recovery time	8 seconds

The generator waveform shall be sinusoidal of the full range of loads and power factors. Telephone harmonic distortion shall not exceed 5 percent, total harmonic distortion shall not exceed 5 percent and the individual harmonic content shall be less than 3.5 percent.

The generator shall be constructed to withstand a sudden short circuit at the terminals without harmful deformation of the windings or other parts of the machine. Ensure that the generator has sufficient fault current to permit the correct operation of the protection equipment in the essential distribution system. Earth loop fault impedance shall take into consideration the generator voltage performance when achieving the required automatic fault disconnection times.

### Starting System

Battery starting systems shall be used for LEG applications which shall have sufficient capacity for six normal starts or the equivalent of 60 seconds of cranking time, whichever is the greater. The

starting procedure shall incorporate a crank cycle of three 10 second cranks with intermediate delays or other suitable arrangement.

The battery starting system shall be capable of recovering from a completely discharged state to 80 percent of capacity within 4 hours and to full capacity in not more than 12 hours. The batteries shall be suitable for continuous float charging and the starting duty of the generator set.

The starting batteries shall be located as close as possible to the generator to minimise starting circuit resistance. Arrange the batteries to ensure no harmful affect from the generator such as excessive vibration or heat and also to minimise exposure to dirt, oil and water. The start battery system shall allow easy servicing of the batteries.

#### Ventilation

The generator room shall be ventilated so that the safe operating temperature of the generator is not exceeded under full load conditions and that the generator combustion air is adequately supplied. The design of the ventilation system for cyclone prone areas shall minimise entry of water into the building and where necessary, the equipment rooms shall incorporate sumps and drainage to remove any water entering the rooms.

#### Cooling Systems

The generator shall be provided with suitable means to top up the cooling system. The generator shall also be provided with a suitable arrangement such as a tray, to capture any spillage or loss of coolant or oil.

#### Exhaust

The generator exhaust system shall be arranged so that the exhaust gasses, smoke or fumes will not reach dangerous concentrations or enter directly or indirectly any enclosed areas occupied by persons. Exhaust discharge shall also comply with the relevant requirements for air pollution.

The exhaust system shall be provided with a suitable means to prevent rainwater entering the piping and also a means to trap and remove condensate or water from the exhaust system. To reduce condensate, the muffler should be installed as close as practical to the prime mover so that it heats up quickly and horizontal exhaust piping should slope away from the engine to the condensate trap.

The designer shall consider the requirements to insulate the exhaust system or other suitable arrangement to suitably protect personnel, equipment and structures from the effects of heat.

#### Generator Fuel System

Appropriate underground fuel storage sized for 7 days continuous running at full rated load shall be provided, unless otherwise agreed in writing by DEEP. Underground tanks shall be double wall construction with secondary containment and interstitial space. The fuel shall be pumped from the underground bulk fuel tanks to the generator day service tank in the generator room. Prime and

standby fuel transfer pumps are required. The prime pump is normally an electric pump and the standby pump can be a manual pump. Electric pumps shall have automatic and manual operating modes. In the automatic mode the electric pump shall be controlled by a float switch or similar installed in the day service tank. Overflow protection shall remain serviceable at all times.

Suitable fuel gauges shall be provided for the bulk fuel storage normally at the LEG control panel.

All tanks, tank filling facilities and fuel system shall meet the requirements of AS 1940 and also Australian Institute of Petroleum (AIP) Code of Practice 4 (CP4) *The Design, Installation and Operation of Underground Petroleum Storage Systems*. Particular care needs to be taken with the tank filling point spill control which shall be meet the requirements for tank vehicle loading facilities in accordance with AS 1940.

#### Controls and Instrumentation

A separately mounted control panel containing all necessary indicators and controls shall be installed in the LV switch room associated with the facility coincident with the building main switchboard. The LEG panel indicator and control requirements shall be as detailed below.

Control batteries shall be provided, where required, to ensure the control system can function under a normal mains failure condition for a minimum period of 4 hours. The control battery system shall be separate to the start battery system and the batteries shall be suitable for continuous float charging. The control battery charging system shall ensure that the batteries can be fully recharged, from a complete discharged state, within 12 hours.

To cater for control battery system failure, the control battery system, where provided, shall be connected to the start battery system permitting the controls to operate from the starting batteries. The connection shall be made with a diode arrangement to prevent the starting system from drawing power from the control battery system. The diodes shall be sized to ensure they will not fail under short circuit conditions.

#### Generator Protection

The generator shall be provided with all protection devices necessary to ensure the safe operation of the generator and as detailed in below.

### **21.10.3 LEG Distribution System Requirements**

An example of a suitable LEG configuration is shown in Figure 21.1.

Labelling and signage requirements are provided in Chapter 10 – General Technical Requirements.

#### Automatic Transfer Switch

Transfer switches shall isolate one source of supply before connecting the other. Appropriate adjustable time delays shall be incorporated to avoid any out of phase problems when transferring the load from mains supply to generator supply and vice versa. The transfer switch shall have

"Auto", "Off" and "Manual" selections as well an appropriate manual control to allow an operator to select any of the transfer switch positions. Transfer switches shall be provided with suitable indication to show the status of the switch position and shall also be provided with short form operating instructions as detailed in Chapter 10 – General Technical Requirements.

It shall be possible to select the position of the transfer switch in manual mode and retain this selection in automatic mode. The exception to this would be where the generator control system is selected to automatic mode and calls for transfer switch to change. The reason for this is to allow testing of the LEG on the dummy load where the operator would start and run the generator in manual mode but required the transfer switch to retain its position in automatic mode to cater for normal power supply failure. When in automatic mode and the selected source fails, the transfer switch shall change to an available healthy supply or to mains supply where no supply is detected as being available. In manual mode the transfer switch shall retain the operator selected position.

#### **21.10.4 Other Considerations**

##### Auxiliary Services

The LEG and its auxiliary services shall be arranged so that they are fail safe. Failure in an auxiliary service such as the control power supply shall not result in both the LEG supply and normal mains supply becoming unserviceable. The control arrangement shall be configured to provide appropriate fault warning for all battery chargers used as part of the LEG system on the LEG control panel and in the PCMS to warn of the impending failure.

##### Regenerative Loads

Where the LEG supplies loads with inherent energy storage characteristics (e.g. radar head motors where an EMF is produced as the motor winds down on loss of supply) particular care is required to ensure that the necessary delay is allowed in the design (decay time) before the LEG is connected to the load.

##### Remote Control and Monitoring

Provide remote control and monitoring of the LEG in accordance requirements provided at paragraph 21.10.7 below and to suit the requirements of the Region.

Remote control and monitoring of the LEG shall normally be through the PCMS or equivalent system. The LEG system design shall ensure that as a minimum, a LEG summary fault and a LEG summary alarm are monitored by the PCMS system. Appropriate indication shall also be provided locally at the building to meet the building occupant requirements and also at suitable remote monitoring station as appropriate to meet the Regions requirements.

##### Dummy Load

A dummy load is required for all LEG installations. Where the generator minimum long term load can be met by the building loads alone, permanent dummy loads may be omitted. This shall only be considered where there is no risk of permanent harm to the generator, as an alternate design

solution. Where a permanent dummy load is not provided, a portable dummy load connection point, similar to the mobile generator link box, shall be provided to allow connection of a portable dummy load bank. Permanent dummy load bank requirements are detailed below.

#### Mobile Generator Link Box

All LEG installations shall be provided with a Mobile Generator Link Box (MGLB). MGLB requirements are detailed in Chapter 22 – Mobile Generator Link Box (MGLB). The MGLB shall allow the mobile generator to be connected in place of the LEG. The control system shall be configured to initiate the starting and stopping of the mobile generator as required without the need for the LEG to be in place. Dedicated LEG alarms and trips shall be de-activated by the control system when the mobile generator is connected. Suitable control connections shall be provided in the link box (e.g. no volt relays) to facilitate the required control.

#### **21.10.5 LEG Panel Layout and Indicator Requirements**

A sufficient number of indicators and meters shall be provided to clearly and accurately portray the state and condition of the whole plant to semi skilled operators. The following are general requirements:

- a) It should be clear to the operator why the generator is running (e.g. cooling down mode); and
- b) Shutdown or trip of the generator shall not be possible without a visual indicator operating on the generator control panel. Similarly it should be obvious to an operator why a generator will not operate or failed to operate.

The controls shall be arranged in a logical and ergonomic manner with commonality of all control switches, indicators, meters and the like. These shall be easy to operate and appropriately grouped for efficient readability. Devices shall be of the type most suitable to convey their purpose. For example:

- a) meters for comparative purposes should be grouped together, i.e. generator ammeters; and
- b) colour should be used to indicator status/purpose. Indicator colours shall be suitable for the condition portrayed (e.g. red fault, amber alarm, green healthy, white status indication).

Only one operator shall be used for each function (i.e. one push button switch for alarm acknowledge). A single lamp test facility shall be provided on the generator control panel to test all indicating lamps and LEDs simultaneously.

The LEG control panel shall be provided with short form operating instructions securely fixed to the panel. The short form instructions shall be an engraved two colour laminated traffolyte or similar.

All generator alarms and trips shall remain latched until manually reset by an operator.

The following indicators are required as a minimum:

- **REMOTE RUN REQUEST** Indicates a LEG request to run from PCMS (Note The PCMS system combines Start at CEPS, Start at ATC Tower and Generator Run On);
- **GENERATOR RUN ON FROM CEPS** (where not incorporated in Remote Run Request above);
- **START AT ATC TOWER** (where not incorporated in Remote Run Request above);
- **START AT CEPS** (where not incorporated in Remote Run Request above);
- **MAINS AVAILABLE;**
- **MAINS FAIL;**
- **MAINS CONNECTED;**
- **GENERATOR NOT AVAILABLE** (any condition that prevent the generator from coming online incorrect operating mode, transfer switch or circuit breaker mode or position);
- **CALL TO START;**
- **ENGINE RUNNING;**
- **GENERATOR CONNECTED;**
- **SET COOLING DOWN;**
- **EACH GENSET ALARM** (suppress consequential alarms and provide summary indication Generator Alarm for remote monitoring);
- **EACH GENSET TRIP** (provide summary indication Generator Fault for remote monitoring);
- **GENERATOR SUPPLYING DUMMY LOAD;** and
- **MOBILE GENERATOR CONNECTED**

Provide the following operators and meters on the generator control panel as a minimum:

- **MODE SELECTOR;**
  - AUTO
  - OFF
  - MANUAL
- **GENERATOR START** (Only effective in manual mode);
- **GENERATOR STOP** (Only effective in manual mode);
- **EMERGENCY STOP;**
- **AUDIBLE ALARM;**
- **ACKNOWLEDGE PUSHBUTTON;**
- **RESET PUSHBUTTON;**
- **LAMP TEST** (tests all lamps including LED's);
- **TRANSFER SWITCH CONTROLS;**

- **DUMMY LOAD CONTROLS AND INDICATORS;** and
- **METERING;**
  - 3φ Amps (3 off instantaneous)
  - 3φ Volts (selectable between phases)
  - Frequency
  - Power (kW)
  - Power Factor
  - Hours Run
  - KWh (can be behind panel door and normally incorporated with the intelligent meter)
  - Bulk Fuel Level
  - Start Battery Volts (if not on battery charger panel)
  - Control Battery Volts (if not on battery charger panel)

Engine mounted gauges shall be provided to indicate the following engine information:

- Jacket Water Temperature (In and out if radiator is remote);
- Lube Oil Pressure;
- Exhaust Gas Temperature if turbocharger fitted (each bank) for sets greater than 500kW; and
- Engine Speed

### **Generator Alarms**

The following alarms shall be provided:

- **Approaching Low Fuel Level**  
Alarm when fuel level in day tank drops below the minimum fuel level (Note fuel lift pumps should operate whenever the generator is operating and shall return any excess fuel to bulk tank).
- **Approaching Low Oil Pressure**  
Set as per engine manufacturer's recommendations. Provide override until engine up to starter cut out speed.
- **Approaching Engine High Water Temperature**  
Set as per engine manufacturer's recommendations.
- **Start Battery Low and High Volts, Charger Fail**  
(e.g. Low 24.5 volts for 60 seconds, High 30 volts for 60 seconds)

Annunciated as separate alarms on generator control panel if not annunciated separately on battery charger.

- **Control Battery Low and High Volts, Charger Fail**

Annunciated as separate alarms on generator control panel if not annunciated separately on battery charger.

- **Generator Isolated**

Initiated by transfer switch position (or other isolators) if generator is prevented from connecting.

- **Low Water Level**

Initiated by level switch on radiator.

- **Low Oil Level (optional)**

Initiated by level switch in oil level regulator, if provided.

- **Radiator Fan Fail (for remote radiators only)**

Initiated by contactor being open when it should be closed or local isolator being open.

- **Engine Service Due**

Initiated by hours run or time elapsed. Reset by appropriate means such as low oil level signal followed by normal oil level signal while set is isolated (e.g. emergency stop at set initiated).

- Other alarms as necessary to annunciate generator set is not healthy.

Alarms are shall latch until reset by the operator. The generator shall continue to operate under alarm conditions where not harmful to the generator. Provide a common alarm output for input into the PCMS.

Suppress all consequential alarms i.e. Low Oil Pressure after set trips or battery charger failed during mains failure.

Incorporate short time delays wherever possible to prevent spurious alarms due to contact bounce, noise and the like.

### **Generator Set Trips**

Provide the following trips:

- **Fail to Start**

Initiate if set fails to reach nominal speed and nominal voltage after complete crank cycle (e.g. 3 x 10 seconds with intermediate delays).

- **PLC or Microprocessor Failure**

Must be performed by a device external to PLC or microprocessor. Where PLC or microprocessor is critical to the safe operation of the generator, the PLC or microprocessor must be set up so that once CPU fails or PLC power fails a trip signal is sent to the circuit breaker (fail safe i.e. off NC contact on relay) and supply to governor (spring return) and fuel supply is de-energised.

- **Underspeed**

Set to manufacturers recommendations (e.g. 1250 RPM for say five seconds). Circuit to be enabled after starter cut out speed is reached.

- **Overspeed**

Set to manufacturers recommendations (e.g. 1750 RPM instantaneous). Trip shall actuate air flaps and shut off governor and fuel solenoid (Air flaps are required on all two stroke engines with hard wiring from emergency stop and over speed devices).

- **Low Level Fuel**

Initiated by extra low fuel level in day service tank.

- **Low Oil Pressure**

Set to manufacturers recommendations.

- **Low Water Level**

Initiated by level switch on radiator.

- **High Water Temperature**

Set to manufacturers recommendations.

- **Emergency Stop**

Provide on engine control panel and generator set and elsewhere as specified.

- **Over Voltage**

Set point 110% of nominal voltage for 10 second and/or 120% of nominal voltage for five seconds.

- **Under Voltage**

Set point 90% of nominal voltage for 10 seconds.

- **Overcurrent** (Alternator over current and earth fault protection)

Hard wire trip to open ACB or similar, allow cool down cycle on alternator.

- **Alternator Over Temperature Thermistor** (LV sets above 500kW)

Three phase sensing. Immediately open ACB, allow alternator cool down cycle.

- Other trips as required to prevent or limit damage to the generator set or to its associated equipment.

In the case of a trip, the circuit breaker should open and the engine shut down immediately unless noted otherwise and safe for the generator. Ensure that the LEG protection is stable during operation and starting of the LEG and that it is not possible to cause nuisance tripping.

Trips shall latch until reset by operator. Provide common outputs into the PCMS for trips.

All consequential trips shall be suppressed i.e. Low Oil Pressure after set trips or battery charger failed during mains failure.

#### **21.10.6 Data Logging and Trending**

All analogue information displayed on control panels or generator gauges shall be compatible with the PLC or microprocessor based monitoring system. The monitoring and trending of the generator functions and events, where required, shall be carried out by downloading to a central location on the Base. The functional design brief will identify the need and detailed requirements for remote logging and trending.

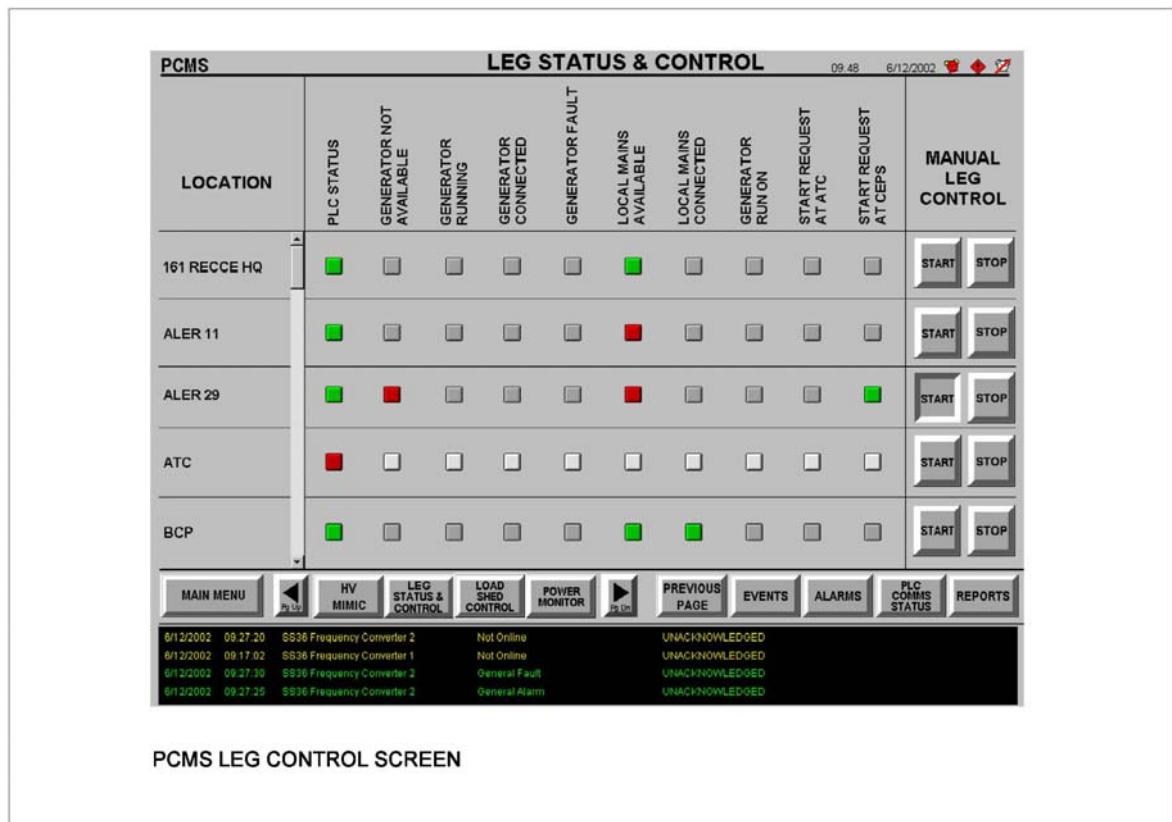
The following is provided as a guide to the future trending requirements:

- It is expected that the PLC or microprocessor system will maintain database of all monitored generator functions and events to include all sequence of events and all analogue data at 15 minute (time averaged) intervals. This data shall be downloaded to the PCMS via an intelligent meter or other suitable means. In addition, minimum voltage, maximum voltage, set maximum demand (thermal current); current, power factor, etc shall be provided for each 15 minute interval as part of the intelligent metering.
- Events log capable of registering intervals down to one second.
- Software to automatically download data from PLC or microprocessor to PCMS or portable computer.
- Output kWh and fuel consumed for calculation of generator efficiency.

#### **21.10.7 LEG Remote Control and Monitoring**

LEGs shall be remotely monitored through the Defence Engineering Services Network (DESN), Base PCMS or other site control and monitoring system. Remote monitoring and control is required at the CEPS, for all LEGs and at the ATC tower where associated with aircraft navigation or visual aids. Monitoring only through the PCMS shall be possible at other locations to suit the local region requirements and at some establishments remote control and monitoring is required as part of the Base energy management system or site building management system.

PCMS screen layout for the LEG status and control requirements is shown in Figure 21.2



■ **Figure 21.2: PCMS LEG Control Screen**

Indicators in the PCMS shall be arranged as follows:

■ **Table 21.2: Colour Indicators in PCMS**

Colour	Condition
White	- Loss of communications/facility
Grey	- Off state
Green	- Selected state, healthy on
Green/Grey Flashing	- Processing selection (if applicable)
Amber	- Alarm Condition
Red	- Fault

The functions required for the PCMS system shall be as shown in Figure 21.2 and detailed below:

**PLC Status.** Status of communications LEG PCMS PLC. LEG control PLC status shall be incorporated into the Generator common fault indication. The indicator colour shall be green if OK, red if fault, white on loss of communications.

**Generator Not Available.** Condition exists that could prevent the LEG from working in its automatic mode (e.g. incorrect operating mode, transfer switch or circuit breaker mode or position,

etc). The indicator colour shall be red if not available, grey default (available), white on loss of communications.

**Generator Running.** Generator running but not necessarily connected. The indicator colour shall be green if running, grey default (not running), white on loss of communications.

**Generator Connected.** Generator on line and supplying the building/equipment load. The indicator colour shall be green if connected, grey default (not connected), white on loss of communications.

**Generator Fault.** Common or summary fault indication showing the generator in a fault/shutdown condition. The common or summary fault shall not include non-critical alarms. The indicator colour shall be red if fault, grey default (no fault), white on loss of communications. As an option, non-critical alarm conditions are permitted to be displayed by the same indicator on the PCMS screen in which case the indication shall have an additional amber indication. Should a common or summary fault and a non-critical alarm be concurrent, then the fault indication shall take precedence or the condition should occult red/amber. In this case the indicator colour shall be red if fault, amber if alarm, grey default (no fault or alarm), white on loss of communications.

**Generator Alarm.** Generator in alarm condition. (where provided and not included as part of the generator fault indication above). The indicator colour shall be amber if alarm condition exists, grey default (no alarm), white on loss of communications.

**Local Mains Available.** From phase failure relay or similar. The indicator colour shall be green if available, red if not available, white on loss of communications.

**Local Mains Connected.** Local mains on line and supplying the building/equipment load. The indicator colour shall be green if connected, grey default (not connected), white on loss of communications.

**Generator Run On.** Provided through PCMS system. The indicator colour shall be green if LEG Run On is initiated by CEPS, grey default (no run on signal), white on loss of communications.

**Start Request at ATC Tower.** Indicates a LEG request to run from the ATC. Note Start at CEPS and Start at ATC Tower can be operated concurrently. The indicator colour shall be green if started from ATC Tower, grey default (no start request), white on loss of communications.

**Start Request at CEPS.** Indicates a LEG request to run from the CEPS. The indicator colour shall be green if started from CEPS, grey default (no start request), white on loss of communications.

**PCMS LEG Start/Stop Control Selection.** Allows selection of manual start/stop control screen. The start and stop request shall be by permissive popup box to allow the operator to confirm request before the PCMS actions the request to prevent accidental starting and stopping of the

LEG. The start and stop pushbuttons shall indicate the status by displaying the button as depressed when selected.

Indicator functions required for the Australian Defence Air Traffic System (ADATS) are as follows. These outputs are required from the PCMS to the ADATS, as voltage free contacts:

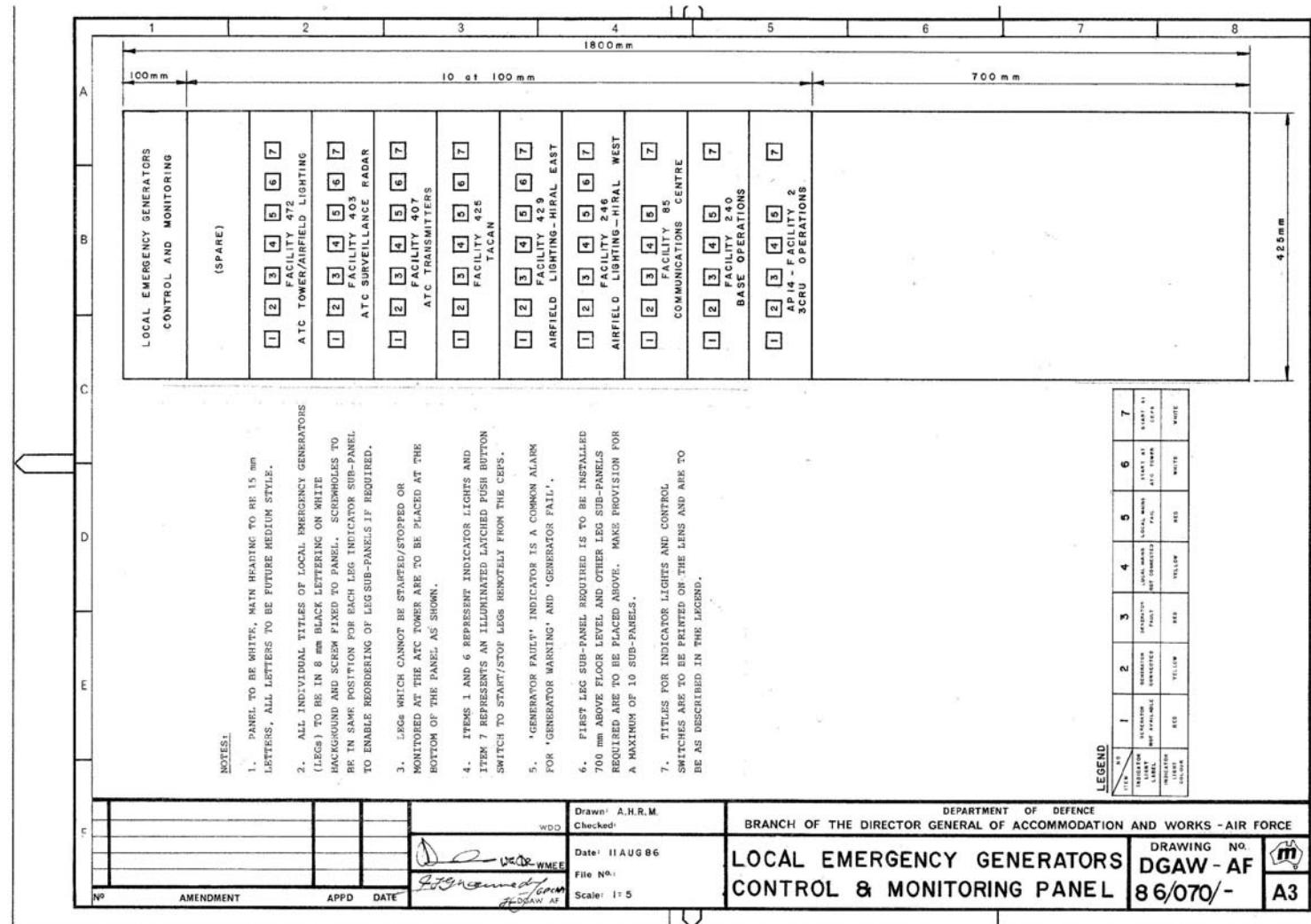
- **Mains Available.** From Local Mains Available
- **Mains in Use.** From Local Mains Connected.
- **Generator in Use.** From Generator Connected.
- **Generator Fail.** From Generator Fault
- **Start Request at ATC Tower.** (may be common through PCMS system as remote run request)

Manual starting and stopping the LEG through the PCMS system shall be through a permissive pop up box to confirm the operation before passing the command through the PCMS.

Selection of the LEG stop removes the requirement for run rather than acts as a true stop function. A true stop function should not be installed, if the LEG is requested to run from any other location (i.e. ATC or power failure) the LEG shall continue to run until all requests to run are removed. This will normally be achieved through the PCMS, with the PCMS system ensuring that all valid run requests have been removed before sending the stop pulse.

Control signals from the PCMS to the LEG shall be separately pulsed on and off via two discrete outputs into the LEG controls to ensure the selected state is maintained under failure conditions. These pulse on, pulse off contacts are normally used for starting and stopping the LEG for all run requests such as the Generator Run On and the start/stop requests from the CEPS and ATC.

At establishments not currently equipped with PCMS LEG monitoring, the existing arrangement shall be maintained, however, the LEG shall be configured to meet both the existing requirements and the requirements of this Chapter. An example of the RAAF requirement is shown in Figure 21.3.



■ Figure 21.3: DGAW-AF 86/070/-

#### **21.10.8 Dummy Load Requirements**

A commercially available resistive dummy load rated at 100 percent of the LEG mechanical rating shall be provided which has appropriate load steps (minimum of five steps) to suit the LEG operations.

The dummy load is provided to ensure minimum load is maintained on the LEG or mobile generator (manually) and to allow testing of the LEG. It should also be used for testing the UPS if practical. The dummy load would only need to be used manually for UPS and mobile generators, however, if practical automatic control should also be implemented for the mobile generator by changing the generator rating parameter in the dummy load control or similar.

Where the building load can provide the generator minimum long term load, a permanent load bank is not essential and a portable load bank can be considered. The LEG installation should be provided with a suitable link box for the connection of the portable dummy load. Justification and agreement of this alternative design solution is required before the generator system design is completed.

The dummy load shall have automatic and manual controls. The automatic control shall monitor the load on the generator and increase or decrease the load steps as required to maintain the load on the generator at a predetermined percentage load. The latter shall be set at or above the manufacturers recommended minimum long term load, nominally between 60 and 70 percent for two stroke engines and above 35 percent for four stroke engines. It shall be possible to adjust the required generator load percentage on site without the need for any software or hardware changes.

The system shall incorporate appropriate controls for management of the load connected to the LEG and shall disconnect the load bank when it is not required. The system shall also prevent cyclic operation of the load bank and shall immediately disconnect the dummy load when the generator load (not including the dummy load) exceeds 75 percent of maximum load. There shall be appropriate measures (e.g. dead bands, load step sizes) to avoid hunting.

It shall be possible to test the generator on the dummy load alone whilst the equipment load is supplied from the mains supply. If during a test mains supply fails, the generator shall be automatically switched to the equipment load provided that the transfer switch is in automatic mode as detailed in paragraph 9.2.9 above. The dummy load shall be automatically disconnected before transfer if the dummy load is selected to manual control mode.

The dummy load controls shall be incorporated into a separate section of the LEG control panel.

The dummy load design parameters include:

- c) Dummy load must be fail safe. It shall not be possible for the dummy load to trip the LEG under any condition. Mechanically latched contactors are not to be used.

- d) Provided with appropriate protection to protect against possible faults such as equipment overheating and vent fan failure.
- e) Provided with vent fan run on to cool the dummy load after use and prolong the life of components.
- f) Cycle the resistive load elements, if possible, to even out usage of all load elements.
- g) The dummy shall be capable of withstanding the environmental conditions of the site, particularly if it is externally mounted.
- h) The generator rating and the percentage load shall easily changeable without the need for software or hardware changes.
- i) Provided with the following controls and indicators:
  - Control mode selector (bumpless transfer between modes)
    - AUTO
    - OFF
    - MANUAL
  - Selector for each load step (only works in manual mode)
  - Indicator showing each load step connected or in use
  - kW meter
  - Ammeter for each phase

#### **21.10.9 Routine Testing and Training**

LEGs shall be routinely tested once a month using a dummy load or the building equipment load. LEG testing shall include a simulated mains failure at least once every 12 months. Testing shall generally be undertaken by the Defence maintenance contractor as part of the regional Comprehensive Maintenance Services contract (CMS) to ensure continuous and reliable operation of the LEG and to optimise on the life and performance of the equipment.

Routine testing of the generator at 100 percent loading shall be carried out to establish that the LEG is capable of supplying the full design load. The test shall also be used to reverse any harmful effect of the LEG operating under low load conditions. Routine tests shall be deemed to have been successfully completed when a stable engine temperature is attained, which is within the permissible range, without failure of the LEG system.

The user unit and/or building occupants shall be trained in the operation of the LEG and should participate in the monthly testing to promote and maintain the required knowledge of the LEG system. The routine tests shall ensure that the LEG is run in all operating modes to ensure that personnel are adequately trained in the operation of the LEG.

It is the responsibility of the Base Network Controller (NC) to test the LEG installation and to train the user unit and/or building occupants. The NC is the authority responsible for the safe operation

of Defence electrical reticulation and generation systems. The NC, appointed and engaged as part of the CMS (reference ***Operation of Low and High Voltage Power Generation and Electrical Reticulation Systems***), shall also be responsible for authorising users or building occupants in the operation of the LEG systems.

# **22 Mobile Generator Link Box (MGLB)**

## **22.1 Background**

Mobile generators are used throughout Defence in various forms to ensure continuity of power supply during times of extended power outages or for deployable sites where there is a need to connect deployable generators and mains power supply may be unavailable. This policy describes the Defence requirements for Mobile Generator Link Boxes (MGLB) used to connect mobile generators to building and equipment loads.

MGLB are switchboards provided to enable the safe and convenient connection of mobile generators, either hire or Defence owned generators, to building and equipment loads. MGLB can be required for deployable equipment hardstands and other important facilities when the expense of a permanent Local Emergency Generator (LEG) cannot be justified. MGLB are also provided for each LEG installation to facilitate continued generator support when the LEG is unserviceable, or undergoing extended maintenance.

## **22.2 Performance Objective**

The objective of this policy is to:

- a) facilitate the safe and convenient connection of mobile generators, and
- b) provide a consistent mobile generator connection interface.

## **22.3 Technical Requirements**

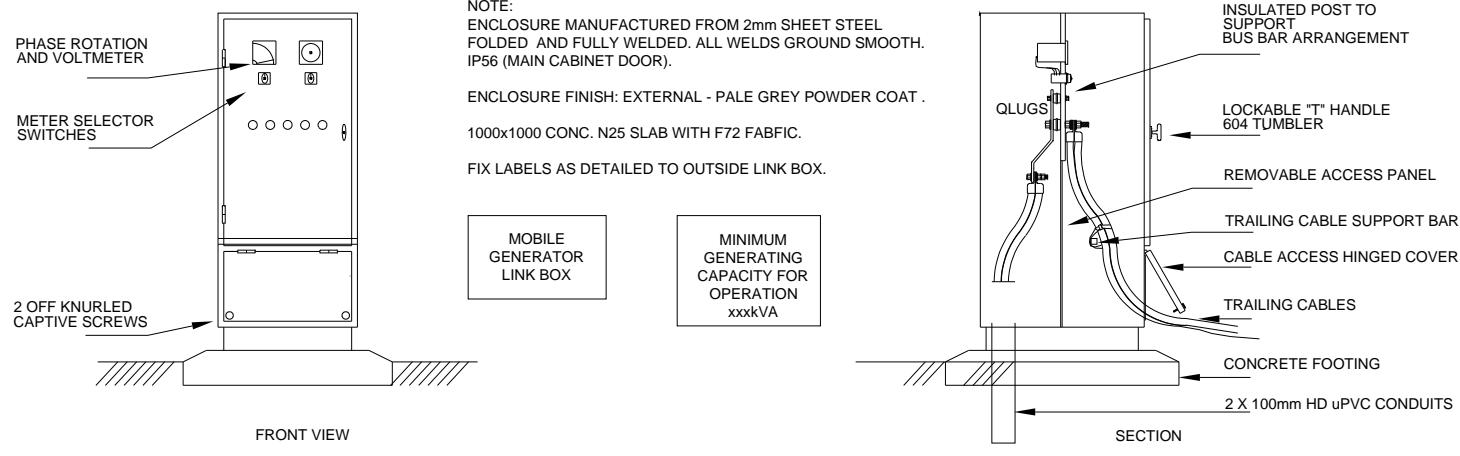
The MGLB can be either wall mounted or free standing. It shall be located adjacent to the mobile generator hardstand, externally to the building where wall mounted, within reasonable access of the generator to minimise cabling. The MGLB and hardstand shall be in a position that ensures the MGLB and the mobile generator will not obstruct access or egress to the facility and in a manner that ensures noise or vibration from the generator will not have an adverse impact on the facility.

The generator hardstand or generator set down area shall include suitable environmental control provisions to accommodate the generator and the required fuel storage. This hardstand or set down area shall be suitably located so that it is directly accessible by truck.

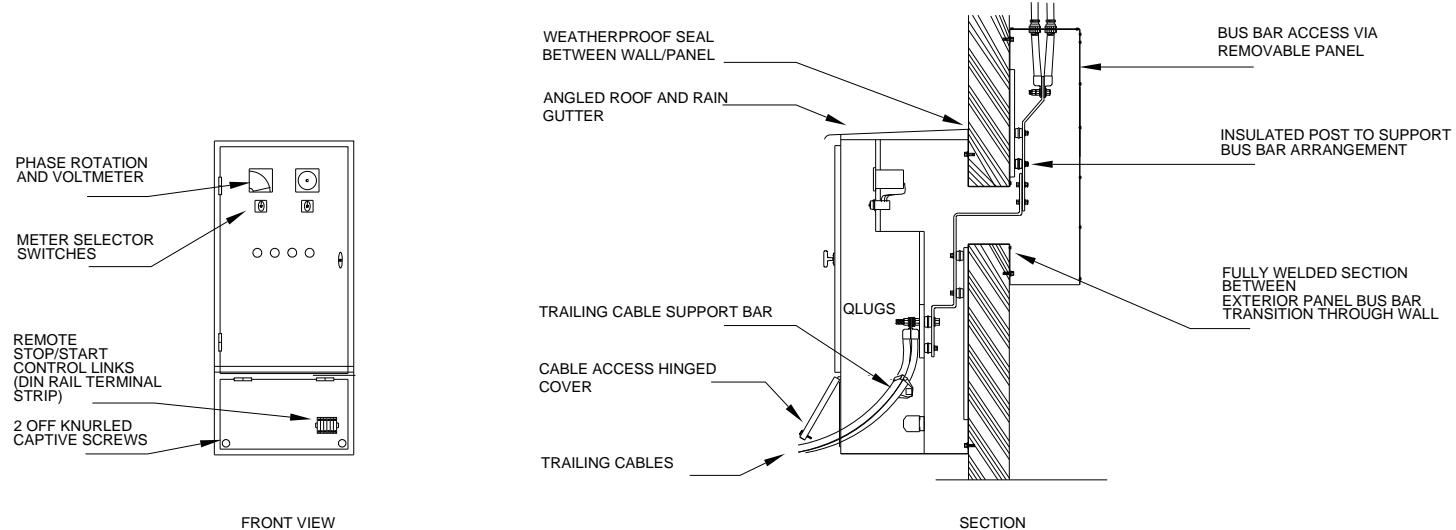
The typical MGLB arrangements are shown in Figure 22.1. The MGLB shall be provided with the following:

- a) 5 suitably sized reusable lugs for the connection of power cabling to the generator such as ALM “KULUG” type Q or QA, or similar;
- b) Fail safe type phase rotation indicator (i.e. indicates both correct and incorrect generator supply phase rotation) and voltmeter with phase selector switch;
- c) Suitable bottom cable entry for the generator connecting cables.

The MGLB connection arrangement shall ensure the weather proofing of the connections, and shall prevent accidental contact of personnel with live parts, in all circumstances; and 230V socket outlet, where mains power is available. The mobile generator link box shall be provided with a suitable 230V socket outlet to allow connection of the generator auxiliaries such as battery charges.



**TYPICAL GROUND MOUNTED ARRANGEMENT**



**TYPICAL WALL MOUNTED ARRANGEMENT**

■ **Figure 22.1: Typical Mobile Generator Link Box Arrangements**

### **22.3.1 Socket Outlets**

Should a plug/socket arrangement be required by the end users to connect the mobile generator, the socket shall be mounted externally on the link box and shall be provided in addition to the typical link box connection arrangements of Figure 22.1 above. The purpose of the plug/socket arrangement is to provide additional flexibility for the connection of the mobile generator and shall in no way interfere with the operation of the link box as described in above. Suitable instructions shall be provided in the link box on the use of the socket outlet in the form of an engraved label. The socket outlet shall be clearly labeled to prevent improper use.

### **22.3.2 Main Switchboards**

The main switchboard shall be provided with an appropriate changeover switch to connect the facility or equipment either to mains supply or to the mobile generator supply as required. The configuration of the changeover switch shall ensure that the mobile generator can be safely connected whilst mains supply remains available to the equipment or facility. The changeover switch shall have three resting positions which shall be labeled “**Mains**”, “**Off**” and “**Mobile Generator**”. Maximum demand indicators shall be provided in the main switchboard to facilitate the assessment of the required generator size for the facility or equipment.

### **22.3.3 MGLB External Labeling**

The link box shall include an external label “**Mobile Generator Link Box**” as well as an internal label “**Minimum Generator Size for Operation XXXKVA**” (the generator size required shall be determined during the design stage and shall be based on the requirements set out in the design brief). MGLBs incorporating the main switchboard shall also be provided with a switchboard label and circuit schedule in accordance with Defence Low Voltage Distribution Pillars and Switchboards Labelling and Numbering requirements.

### **22.3.4 Local Emergency Generator Installations**

In addition to the above requirements, MGLB used for LEG applications also require the control circuit connections necessary to allow automatic starting and stopping of the mobile generator (in lieu of the LEG) through the LEG control system. The control connection shall be provided in a suitable location within the MGLB to allow termination of the control cable from the mobile generator.

The LEG control system shall be suitably arranged to facilitate the remote operation of the mobile generator. To achieve this, the LEG control system may need to monitor the position of the transfer switch to determine when the mobile generator has been selected. The control system shall in no way inhibit the use of manual start generators.

For LEG applications, the main switchboard or generator switchboard shall be provided with an appropriate manual transfer switch that allows connection of the LEG or the mobile generator. The transfer switch shall have an off position to allow both the LEG and the link box to be isolated (to allow the mobile generator to be safely connected or the LEG to be isolated for maintenance). The

manual transfer switch shall be suitably labelled (e.g. “**LEG**”, “**OFF**” and “**Mobile Generator Link Box**”); the switch position shall also be monitored by the LEG control system. Maximum demand indicators are to be provided in the LV switchboard to facilitate the assessment of the required mobile generator size for the facility where the intelligent meter cannot provide the required data.

It shall be possible to use the LEG dummy load, where provided with the mobile generator.

### **22.3.5 Deployable Equipment Sites**

MGLB provided for deployable equipment hardstands shall be incorporated as part of the Main Switchboard (MSB). The MGLB/MSB shall be located adjacent the generator hardstand and the deployable equipment hardstand in a suitable manner to minimise cabling between the switchboard and generator, and the switchboard and equipment cabin, respectively.

Mobile generators used for deployed equipment sites, such as deployable aircraft navigation aids, may have automatic start ability. MGLB provided for these deployed equipment sites should consider the inclusion of an automatic changeover facility to automatically start and connect the mobile generator to the intended load on a power failure. The system shall be suitably configured to allow connection of either automatic or manual start generators. The MGLB for deployed equipment sites needs to incorporate the main switchboard **element**, cable protection and suitable equipment connection arrangements.

## **23 Reserved**

## **24 Reserved**

## **25 Reserved**

# **Electrical Reticulation and Power Generation Systems Requirements**

- 26        High and Low Voltage Distribution System
- 27        Central Emergency Power Stations (CEPS), Central Power Stations (CPS) and Central Energy Plant (CEP)
- 28        Reserved (PCMS)
- 29        Reserved (Operation of High and Low Voltage Reticulation Systems)

# **26 High and Low Voltage Distribution System Requirements**

## **26.1 Background**

This policy defines the technical requirements of:

- a) HV & LV Augmentations;
- b) HV cabling systems;
- c) Indoor Electrical Substations;
- d) Kiosk Electrical Substations;
- e) High Voltage Switching Stations;
- f) High Voltage switch rooms; and
- g) Monitoring and control.

This policy provides guidance and detailed technical material as necessary to define the Defence performance requirements and standards to be applied, in addition to the applicable statutory regulations and standards.

## **26.2 Performance Objective**

The objective of this policy is to:

- a) facilitate reliable electrical systems;
- b) facilitate compliance with the respective installation standards;
- c) facilitate the suitable fault recover performance;
- d) manage the impact of additional loads to ensure no harmful effect or interaction with other installed equipment.

## **26.3 Referenced Documents**

### **Standards/Codes**

All materials and workmanship shall be of the best standard and shall comply with the relevant legislation and Australian Standards, or if such do not exist, with the relevant IEC or International (ISO) Standards.

Irrespective of any requirements shown in these documents the installation as a whole shall comply with:

#### **Australian Standards**

AS 1020

The control of undesirable static electricity.

AS 1025	High Voltage AC Switchgear and Controlgear - Switches and Switch-disconnectors. Part 1 - for rated voltages above 1 kV and less than 52 kV.
AS 1055	Acoustics. (Series).
AS/NZS CISPR 14.2	Electromagnetic compatibility - Requirements for household appliances electric tools and similar apparatus - Immunity - Product family standard
AS 1243	Voltage Transformers for Measurement and Protection.
AS 1306	High Voltage AC Switchgear and Controlgear - Disconnectors (isolators) and Earthing Switches.
AS 1307	Surge Arrestors.
AS 1627	Metal Finishing – Preparation and pre-treatment of surfaces.
AS 1675	Current Transformers - Measurement and Protection.
AS 1767	Insulating Liquids. (Series).
AS/NZS 1768	Lightning Protection.
AS 1939	Degrees of Protection Provided by Enclosures for Electrical Equipment.
AS 2006	High Voltage AC Switchgear and Controlgear - Circuit Breakers
AS 2067	Substations and high voltage installations exceeding 1 kV a.c.
AS 2086	AC metal enclosed switch and control gear for rated voltages above 1 kV up to and including 72.5 kV.
AS 2264	High Voltage Switchgear and Controlgear - Insulation enclosed for rated voltages above 1 kV up to and including 36 kV.
AS 2374	Power Transformers. (Series).
AS 2381	Electrical Equipment for Explosive Atmospheres. (Series)
AS 2467	Maintenance of Electrical Switchgear
AS 2650	High Voltage AC Switchgear and Controlgear - Common Requirements.
AS/NZS 3000	Wiring Rules.

AS 3011.2	Electrical installations secondary batteries installed in buildings - Sealed cells.
AS 3702	Item Designation in Electrotechnology.
AS 3013	Electrical Installations – Wiring Systems for Specific Applications.
AS 4029.2	Stationary batteries - Lead acid - Valve regulated sealed type
AS 4044	Battery chargers for stationary batteries - Type 2.
AS 4070	Recommended Practices for protection of low voltage electrical installations and equipment in MEN systems from transient voltages.
AS 60265	High Voltage AC Switchgear and Controlgear - Switches and Switch-disconnectors. Part 1 - for rated voltages above 1 kV and less than 52 kV.
AS 61000	Electromagnetic Compatibility (series).
AS 60529	Degrees of Protection Provided by Enclosures.
AS 2430	Classification of Hazardous Areas (series)
ESAA Standards	
ESAA C (b)-1:2003	-Guidelines for the Design and Maintenance of Overhead Distribution and Transmission Lines.
ESAA	- Guide to Protective Earthing.
ESAA	- NENS 01 2001-National Electricity Network Safety Code.
ESAA	- NENS 02 2001-National Electricity Network Operator and Service Provider.
ESAA	- NENS 03 2003-National Guidelines for Safe Access to Electrical and Mechanical Apparatus.
ESAA	- Substation Earthing Guide - October 2000.
Any further requirements of ESAA.	

#### **Other Standards**

Any requirements as per the applicable IEEE and IEC Standards.

The rules and regulations of the relevant NSP.

The Building Code of Australia (BCA).

The requirements of any other Authority having jurisdiction over the installation.

## 26.4 Technical Requirements

### 26.4.1 System Configuration

#### Incoming Feeders

For large or important installations there is a requirement for at least two separate feeders from the grid. Guidance on the required arrangement, including the need to undertake any necessary cost benefit analysis, will be provided by DEEP, normally in the FDB.

The primary feeder is required to have adequate capacity for the entire Base load. The secondary feeder is intended for emergency use only and with the approval of DEEP can be of lower capacity.

### 26.4.2 Distribution Cabling

#### HV Distribution

##### HV Rings

Substations shall generally be connected using HV cables configured as ring mains. This arrangement minimises the risk that a single event will have a long-term impact on the ability to supply any individual substation.

Where distribution substations are of low importance or are remote from the Base distribution system, then separate supply from the grid or a single radial feeder can be considered, with the approval of DEEP.

HV ring cables shall be able to support the entire ring load when the ring is fed from one end only.

##### Separation Requirements

HV cables shall be separated to the extent necessary to minimise the potential for a single event to disrupt the ability to supply the Base, or portions of the Base. This includes physically separating the incoming feeders from each other and other major cables, such as Interconnectors.

HV cables on northern airbases are to be separated to the greatest extent practicable in accordance with passive defence assessments. In general the desired separation should be at least 5 metres.

#### LV Submains

Submains from distribution substations to facilities shall consist of radial feeders.

LV ties between separate substations should not generally be used.

### **System Capacity**

The electrical distribution system shall be designed for the prospective loads, with consideration of the planned future loads.

Provide spare capacity of at least 25% in all elements of the distribution system unless a reduced spare capacity is agreed by DEEP.

#### **26.4.3 Assessment of Demand and Connection**

##### **General**

A technical evaluation shall be performed to determine the need for any new substation. As a minimum, the technical evaluation shall consider the issues listed below. Other issues to be addressed may be defined in the FDB or as directed by the project director.

Investigation of the existing power system and infrastructure is required for all new or additional loads when the findings of a previous investigation are not available or as otherwise directed by DSG.

##### **Load Growth**

In projecting electrical demand on high voltage systems an annual load growth of 3% shall be used unless a known or otherwise calculated figure is approved by DEEP.

##### **Existing Facilities**

The electrical demand applicable to an existing facility shall be determined in either of three (3) ways:

- a) Actual recorded measurements for the facility from the DESN or other recognised metering device over a continuous period of twelve (12) months. (Note that data from other than the previous twelve months should be incremented at 3% p.a.).
- b) Detailed evaluation of the facility loads utilising Appendix C of AS/NZS 3000; or
- c) Careful application of recognised W/m<sup>2</sup> rules.

##### **New Facilities**

In the preliminary stages of design the maximum demand of new facilities can be estimated by the careful application of W/m<sup>2</sup> rules. However these preliminary estimates should be updated as more accurate data becomes available during the facility design.

##### **NSP Augmentations**

Where the feeders to the Base or establishment are or will be overloaded or where new feeders are required, the designer is to investigate and liaise with the NSP on the options and costs to provide the appropriate power supply. The designer should note that no undertaking should be given without prior formal Defence agreement.

Where it is necessary for the DNSP to augment their reticulation system, the designer shall submit a report detailing the negotiations with the DNSP for Defence consideration and agreement addressing the following:

- a) Deficiencies in the existing arrangement.
- b) Proposed power supply arrangement to cater for the establishment, addressing the master plan requirements, and for a suitable period of load growth (normally 15 years where possible). The Designer needs to detail the options considered, how the recommended option was chosen and how this option represents the best option to Defence.
- c) NSP reticulation arrangement particularly identifying key redundancies or possible failure points in the reticulation system.
- d) Alternate feeder requirements, if applicable.
- e) Impact to existing electricity retail agreements/contracts and also network connection agreements or similar.
- f) Network charges for each option. Consideration should be given to the most suitable supply option on a through life basis (i.e. capital works costs and ongoing network charges). The most cost effective option based on a five year payback should be considered, even where this requires Defence to take supply at a higher voltage or has higher capital works contribution.
- g) Augmentation costs identifying the Defence contribution to the DNSP and the basis of these costs. The designer should also identify if the works are contestable and whether Defence should go to the market to achieve value for money.
- h) Address any configurational changes required on the Base reticulation system and the costs to implement these.

NPV calculation and through life assessment of the respective costs of each option is to be provided to assist Defence consideration.

#### **26.4.4 Existing Infrastructure**

##### **Existing System Configuration and Capacity**

Evaluate the existing distribution system configuration and capacity to determine if it meets the need of the Works. Consider the following in this evaluation:

- a) Additional load contribution from each facility;
- b) Capacity of each HV ring and feeder;
- c) Existing load on each HV ring and feeder;
- d) Any particular operating requirements or constraints (e.g. feeder cannot be operated in parallel continuously, small ring cable sections, etc);
- e) Planned loads and natural load growth;
- f) Outdated/unserviceable equipment effected by the works requiring replacement.

Should portions of the distribution system have insufficient capacity to meet the required loads investigate the options to establish sufficient capacity including augmentation or reconfiguration of the system.

### **Existing Substations and Switching Stations**

Where it is decided to connect to or upgrade existing substations the Designer shall make subjective technical evaluations of the existing equipment with regard to its impact on the reliability of supply and long-term supportability. This evaluation shall include, but not be limited to:

- a) Capacity;
- b) Condition of equipment;
- c) Availability of spares;
- d) Service history; and
- e) Compliance with present standards and the other requirements listed herein.

Should the evaluation conclude that upgrade or replacement is warranted then that upgrade or replacement shall form part of the works.

#### **26.4.5 Site Selection**

The substation or switching station must be located in an area that is generally clear of other services, except those directly related to the substation or switching station. The selected site shall be clear of any obstruction that could interfere with any part of the earthing system.

Substations and switching stations must not be in an area that is a hazardous area or explosive area as defined by the appropriate regulations.

Indoor substations and switching stations must be located at ground level, not more than 0.5m above finished ground level. The indoor substation/switching station must have at least one frontage on an external wall of the building that faces an uncovered open area. Indoor substations must not have services such as drains, sewers, water services or air-conditioning ducts pass through or encroach on the substation/switching station chamber or the access paths. The access and egress paths must not be located in areas that unduly impede the unrestricted access or escape.

Where practicable, substation/switching station sites shall be located in areas that are level, well drained and clear of underground and overhead obstructions.

The local soil conditions shall be stable and free from steep batters. Retaining walls shall only be utilised where absolutely necessary and must be of robust concrete or block-work construction

Substations/switching stations should not be located in close proximity to any rivers, creeks, natural or man-made watercourses to minimise the effect of oil spillage.

When sighting substations or switching station the following issues shall be considered:

- a) Flood Level - The final sighting of all installations shall ensure that flooding shall not occur under a Q50 (100 year) flood situation
- b) Load Centres - Load Centres are groupings of loads that have a similar function and geographic location. Load Centres hence can form the basic level of priority in the electrical system. For this reason, as far as practical, the loads associated with particular load zones shall be connected on the same feeder and a substation shall supply only loads from a single load group.
- c) Security Zones - Bases have defined security zones that generally divide the site into low, medium and high security zones. These zones are determined by Defence with the knowledge of the work to be carried out in each facility and its level of priority.
- d) As far as practical ensure that substations will be located in the same security zone as the loads being supplied from the substation.
- e) Electrical Requirements – Substations should be located in close proximity to major loads.
- f) Load Requirements - The Designer shall ensure that facilities that may generate disturbances on the supply networks shall not be supplied from the same substation as facilities with sensitive equipment.
- g) Ventilation System Requirements – In corrosive locations (e.g. sites subjected to salty air) consideration shall be given to the isolation of equipment from the corrosive atmosphere. Substations shall not be located adjacent the fresh air intake of any building air-conditioner.

Refer to Figure 26.1, *Kiosk Substation Typical Planting and Structure Clearances* for further details on the required minimum clearances around kiosk substations.

#### **26.4.6 Site Access**

The requirements for access include those for entry and also exist and escape.

The equipment layout shall provide adequate access for operation with all controls placed for ready access and with all indicators and instrumentation in easy to read locations.

In the design of the equipment layout adequate access for the installation and erection of the equipment shall be provided.

Major equipment items shall not be located in such a manner that would prevent the safe removal and replacement of any other major item of the installation.

Particular attention shall be given to allowances for vehicular access to all substations. Vehicles shall be assumed to be of the large flat bed truck types.

#### **26.4.7 System Requirements**

##### **Voltage Limits**

The distribution voltages and voltage limits generally used throughout all Defence sites shall be:

- a) LV System: 230/400V (+10% and -11% at any point in the installation), 3 Phase and neutral (4 wire);
- b) HV System: 11000V (+6% and -6%), 3 Phase (3 wire);

Other voltages can be used subject to DEEP approval.

Provide protection or otherwise ensure correct operation of the installation and equipment where voltage excursions are anticipated outside the permissible range are possible.

Where equipment is susceptible to voltage transients provide suitable protection.

In determining the voltage drop consider:

- a) Use of the electrical installation
- b) Any special equipment requirements
- c) Location and distribution of the load. Location and arrangement of the loads dictate the requirement for additional distribution boards.
- d) Characteristics of the load such as the effect of motors and effect of fluorescent or discharge lighting. Adequate allowance is required to cater for transient performance and the effects of harmonics.

### **Fault Level and Insulation Level**

Due consideration shall be given to the system fault level, in particular the peak contribution of any generators that can connect and operate in parallel with the mains.

Generally the minimum design fault level shall be 250 MVA for one second, unless the NSP specifies a larger fault level. However if large cost implications result from utilising this fault level at facilities where the prospective fault level is much lower, suitable lower fault level equipment may be used if approved by DEEP.

All high voltage equipment shall be rated to a minimum Bulk Insulation Level (BIL) of the following:

11 kV – 95 kV (BIL)
22 kV – 125 kV (BIL)
33 kV – 170 kV (BIL)
66 kV – 325 kV (BIL)

### **Wiring Systems (WS) Classification**

In addition to the requirements for hazardous areas the wiring systems shall provide resistance to damage from mechanical and fire consistent with the environment and the purpose of the installation.

### **26.4.8 High Voltage System Requirements**

In determining the required augmentation work the Designer shall consider the following basic requirements:

- a) The connection point for any extensions shall be given consideration as to the use of:
  - Closest logical connection point considering the current Base Masterplan guidance (if available) and ring loadings;
  - Existing Spare HV breakers;
  - Installing new breakers where spare capacity exists; and
  - Providing a complete new HV breaker and breaker bay.
- b) Each HV feeder is to be able to support the total Base or establishment load with the other feeder out of service, unless agreed that the alternate feeder provides only part alternate supply;
- c) High voltage rings must be able to support the entire ring load in either direction as a full alternate supply through switching (i.e. open point at either end of the ring e.g. CEPS or ISS).
- d) Operational facilities and important facilities shall be connected on a ring main system that provides two (2) sources for high voltage supply through switching to the substation supplying the facility;
- e) Distribution Substations and Switching Stations shall not be connected to an Interconnector;
- f) Sufficient load growth must be allowed in new high voltage rings. Initially rings should be initially designed with spare capacity around 50 percent based on master planned loads but no less than 25 percent;
- g) High voltage cables are to be separated to the greatest extent practicable in accordance with passive defence assessments as determined by operation safebase. As a minimum high voltage cables shall be separated appropriately to avoid single event failure condition and de-rating, or 5m whichever is the greater. This clearance includes the return leg of any cabling to a substation or switching station.
- h) The minimum HV distribution cable sizes shall be determined from the expected electrical load and the maximum prospective fault level for a period of 1 second. As a minimum all HV cables shall be 120mm<sup>2</sup> Copper or the equivalent aluminium.
- i) All establishments have standardised electrical equipment that needs to be accommodated and maintained as part of the design; and
- j) Spares and redundancy requirements need to be addressed and catered for as part of the design.

## **26.5 HV Cabling**

### **26.5.1 Cable Installation**

#### **Installation Method**

HV cables are to be selected and installed in accordance with ESAA *Guide to the Installation of Cables Underground* or the ENA equivalent guidelines.

HV cables shall generally be direct buried at a minimum depth of 900 mm.

Conduits shall be used where the cables are installed under paved areas or roadways.

The backfill material around cables shall be selected on the basis of:

- a) Mechanical properties – the material shall be free of stones, stable and have low plasticity;
- b) Thermal conductivity – Materials that have low thermal conductivity, such as sand shall not be utilised.

All cables shall have marker tape installed above the cable over its entire length as required by AS/NZS 3000.

Conduits bends shall be manufactured to accommodate the minimum bending radius of the cable when it is being pulled.

### **Joints and Terminations**

Joints and terminations shall generally consist of heat shrink type terminations installed strictly in accordance with the Manufacturers recommendations.

The joint or termination shall be rated for the BIL of the installation.

HV cables shall be installed from source to destination with the minimum number of joints.

All cables shall terminate onto equipment. Tee jointing of cables is not permitted.

### **Cable Pits**

Pits shall be used at each bend of underground conduit runs and at intervals not exceeding 100 metres in straight runs.

Cable pits for HV cables shall consist of:

- a) Sand pits;
- b) Precast concrete pits, or
- c) In-situ cast concrete pits.

Pits shall be sized to suit the bending radius of the cable. In particular solid pits used for straight through drawing of cables shall have a minimum length equivalent to four times the minimum-bending radius of the cable. HV cables have large bending radii resulting in large cable pits, The minimum size pits for HV cables shall generally be:

- a) 2000 mm x 2000 mm of bends
- b) 1200 mm x 3000 mm for straight through pits.

### **Service Corridors**

HV cabling shall generally be installed within dedicated service corridors. Where cabling is installed with other services vertical separation is to be provided to allow cabling to be excavated without disturbing the other services.

Many Defence sites have grown in an unplanned way over time and in many sites other services are already installed within these designated corridors. Where this is the case new alignments shall be proposed by the designer using the designated corridors as a basis.

The designer shall ensure that the engineering services are developed in a manner that rationalises the need to cross roads, pathways, car parks, aircraft pavements and other paved surfaces. Any proposal to cross aircraft pavements, apart from within existing ducts, requires DEEP approval.

No high voltage or trunk low voltage services remain or be placed underneath buildings or in a position that could conflict with any proposed building site. Such services, where conflicting with the proposed site shall be relocated clear of the site. Generally, joints in existing cables should be minimised, with preference given to running the cable back to a substation where cost effective.

The designer shall ensure that the requirement for dig permits from the DSG local office is included in the design documentation.

### **Segregation Requirements**

The design shall consider the advisability of segregating major cables so that a single even is less likely to damage multiple cables at one time. This is particularly important in the case of incoming feeder and Interconnector cables.

On northern Bases and important operational establishments major cables shall be separated by a minimum distance of 5 meters.

### **Cable Markers**

Underground cable route concrete markers shall be installed above all underground cable joints, at every change of direction of underground cable and on straight runs at least every 30 metres.

Markers shall consist of a concrete block 400 mm square 100 mm deep with an engraved brass label attached. The marker shall identify the cable and indicate its direction of lay as indicated on the drawings. Labels shall be fixed to the concrete block with screw fixings (not rawl plugs) and epoxy adhesive.

### **Labelling**

Provide a plastic tag at each end of each HV cable that indicates:

- a) The cable source and destination.
- b) The cable size and construction.
- c) The date installed (new cables only).

The labels shall be a proprietary system with the lettering printed in black and letters at least 5 mm high. Hand written labels are not acceptable.

### **26.5.1.1 Technical Requirements**

#### **Cable Construction**

Cables shall have circular compacted stranded conductors and XLPE insulation.

Cables shall be three core, however single core cables can be used where the large size of three core cables makes installation difficult or expensive;

The outer sheath of the cable be either PVC or HDPE, however areas where the water table is high over extended periods HDPE shall be used.

In areas subject to termite attack a termite barrier of Nylon shall be provided under the other sheath.

#### **Cable Ratings**

Cables shall be sized for the worst case system configuration taking into consideration the following factors:

- a) The required current rating;
- b) The fault level;
- c) The maximum voltage drop.

The worst-case configuration for a ring main is when the entire ring is supplied from one end.

While cables are generally direct buried there are often considerable lengths of conduit across road and under paved areas. The rating of the cable shall reflect this and the possibility that additional sections of conduit could be installed at some future time.

## **26.6 Substation Construction**

### **26.6.1 General**

Provision shall be made when allocating space for the transformer for future upgrades of the transformer to a rating of at least 1 MVA. In cases where the overall substation capacity is larger than 1 MVA, due consideration shall be given to provide multiple transformers of equal size capable of operating in parallel.

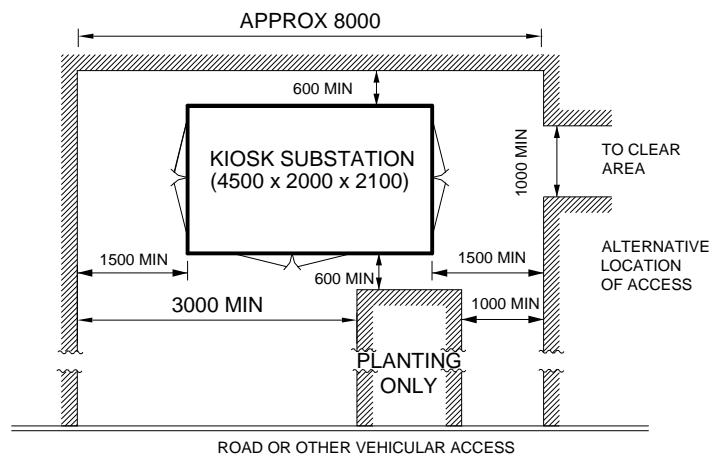
All substations exceeding 1MVA shall be referred to DEEP who will determine the need for an indoor substation arrangement. All substations exceeding 1.5MVA shall be an indoor arrangement.

The requirements provided for Ring Main Units (RMUs), transformers and Low Voltage (LV) distribution boards are applicable irrespective of the substation type.

The use of outdoor distribution substations (open yard type) is not permitted on Defence sites; however older outdoor substations do presently exist on some sites. There are currently no specific Defence standards for the maintenance of these outdoor type substations; however the general requirements as defined in this policy are to be applied, as far as practical. Minor alterations and/or upgrading of existing outdoor substations may be permitted subject to DEEP agreement.

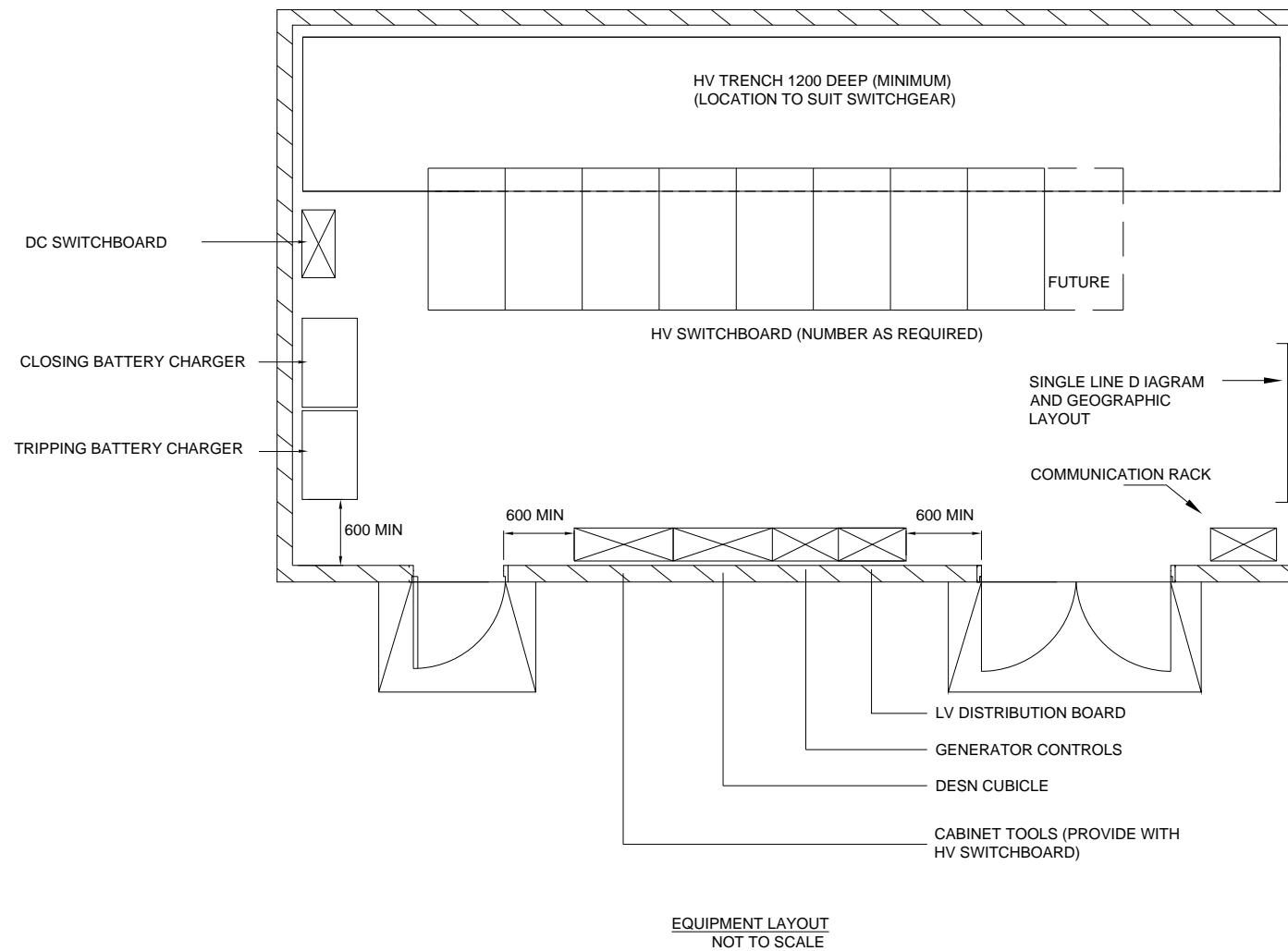
### **General Arrangement Drawings**

General Arrangement drawings are provided for the following:

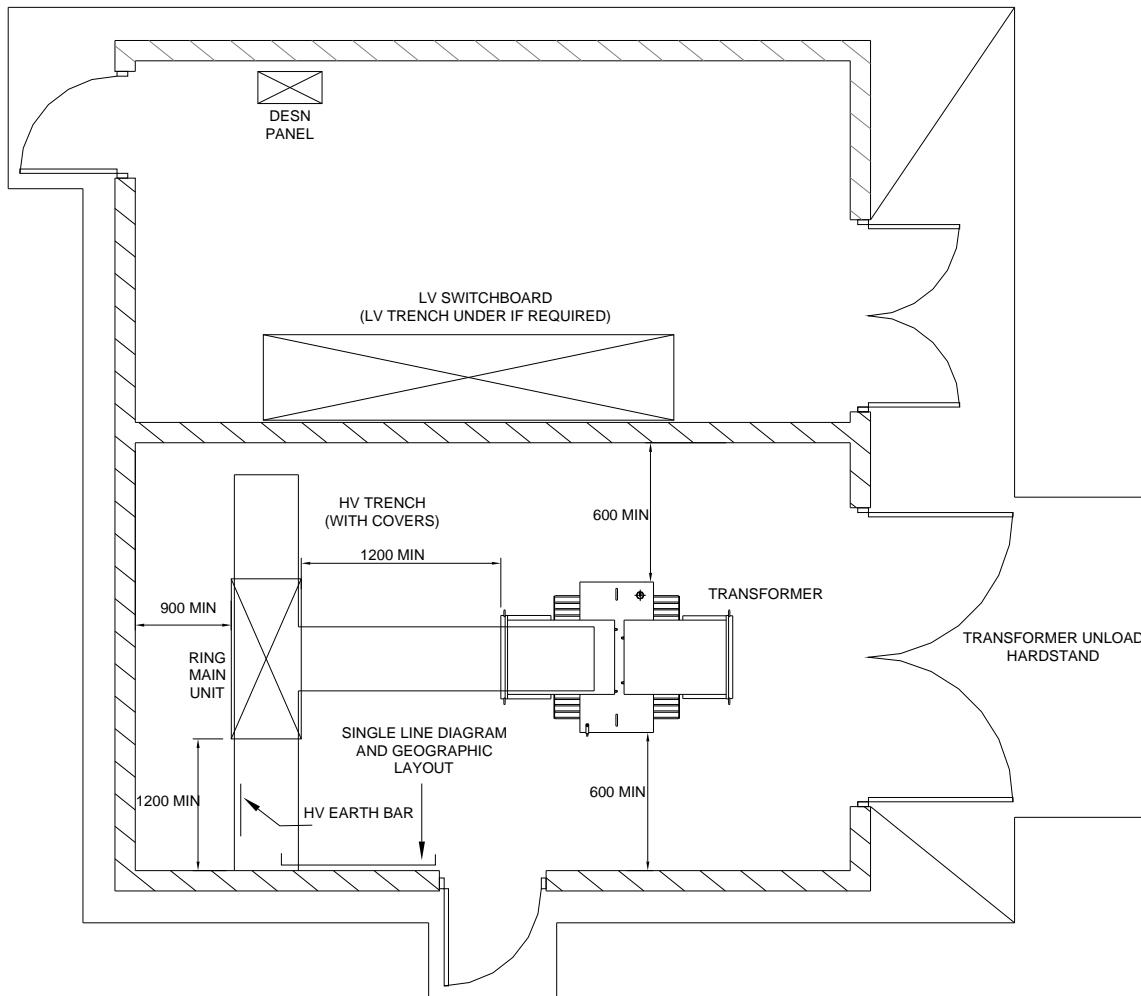


1. 600mm CLEARANCES ARE FOR VENTILATION AND ACCESS FOR REMOVAL OF LITTER OR PAINTING AND FOR GRADING RING.
2. 1500mm CLEARANCES ARE FOR THE SAFE OPERATION AND MAINTENANCE OF SWITCHGEAR
3. 1000mm CLEAR WIDTHS ARE PRIMARILY FOR PERSONNEL ACCESS AND ESCAPE
4. 3000mm CLEAR WIDTHS ARE FOR VEHICULAR ACCESS
5. CLEARANCES SHOWN ARE ABOVE GROUND ONLY LOCATION OF UNDERGROUND CABLES AND EARTH MAT SHOULD ALSO BE CONSIDERED

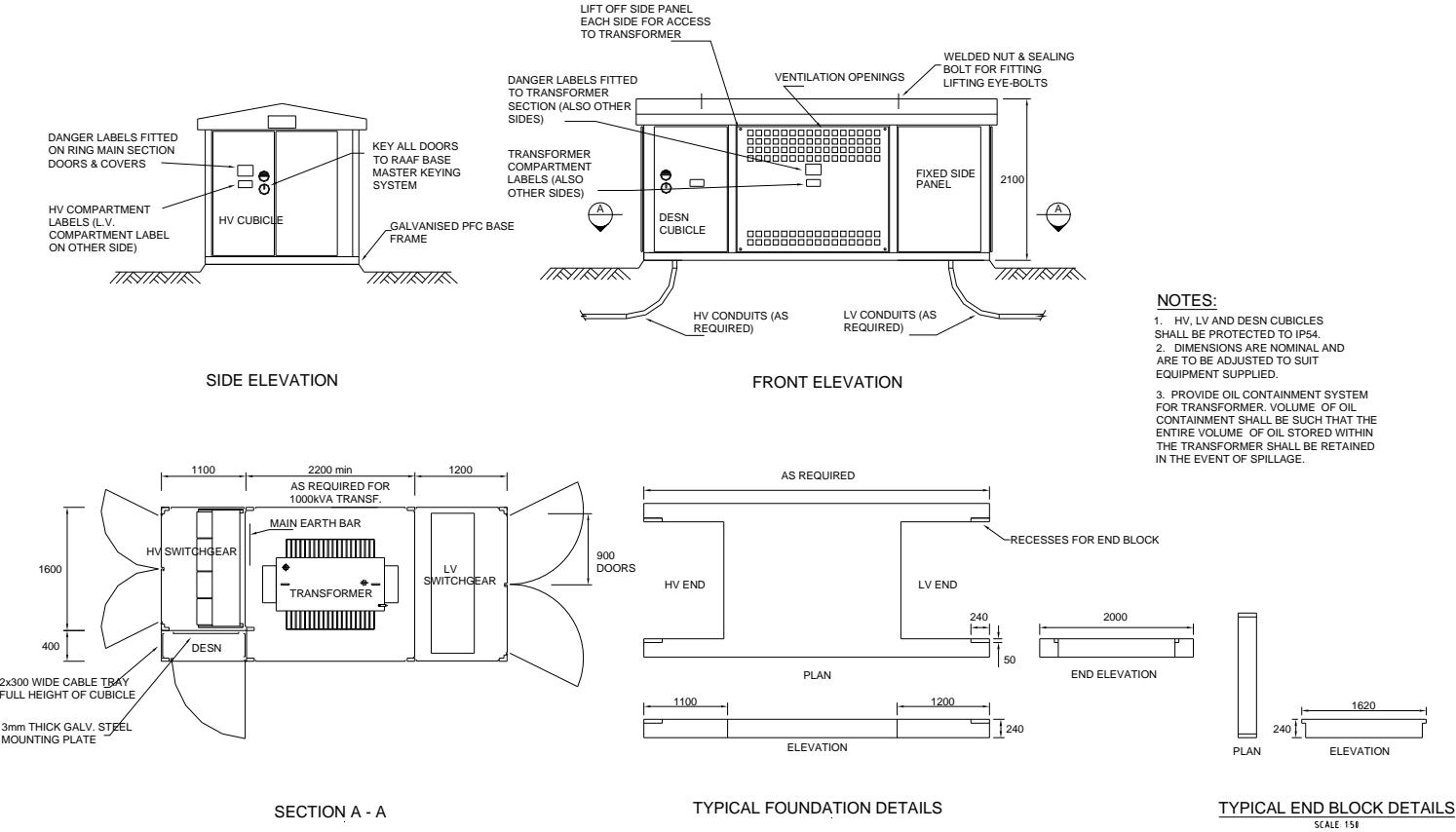
■ **Figure 26.1: Kiosk substation Typical Planting and Structure Clearances**



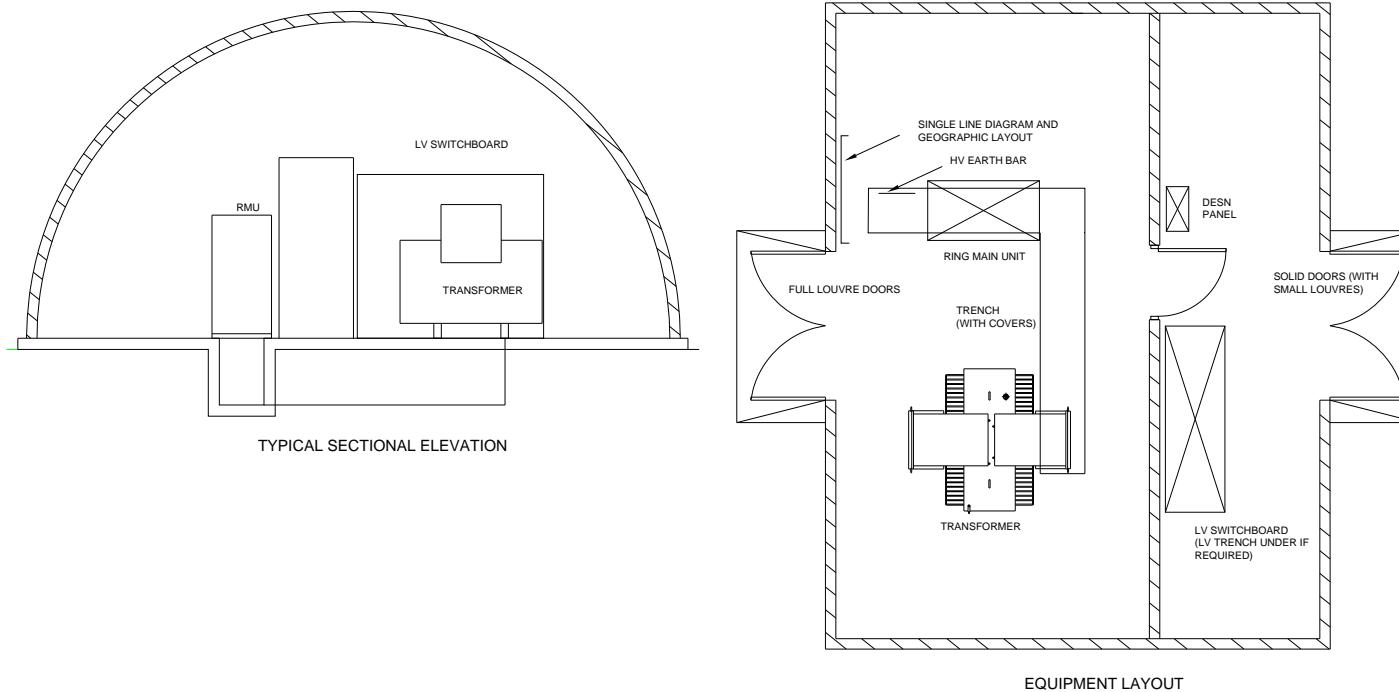
■ **Figure 26.2: Typical High Voltage Switchroom (ISS/PSS) General Arrangement**



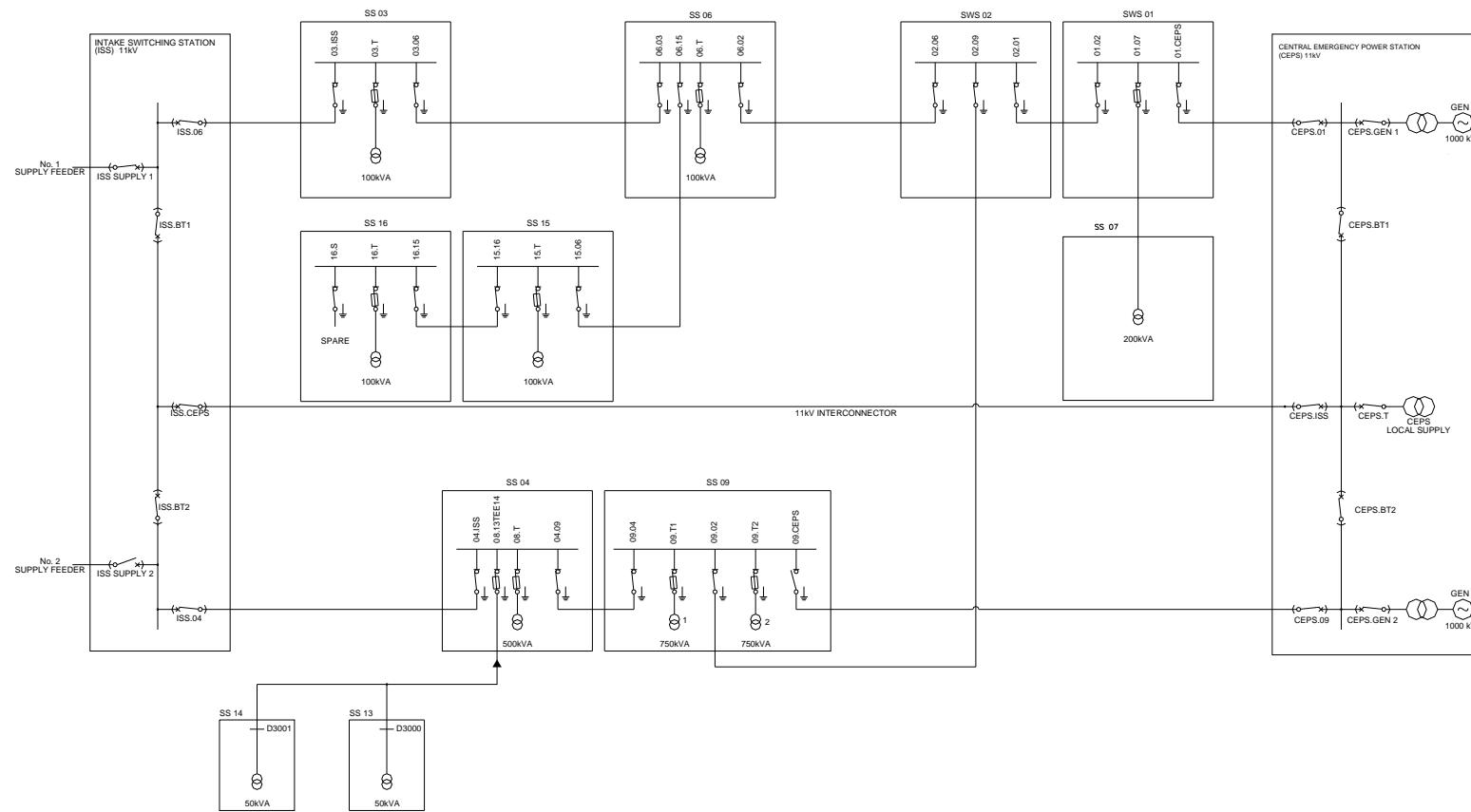
■ **Figure 26.3: Typical Indoor Substation General Arrangement**



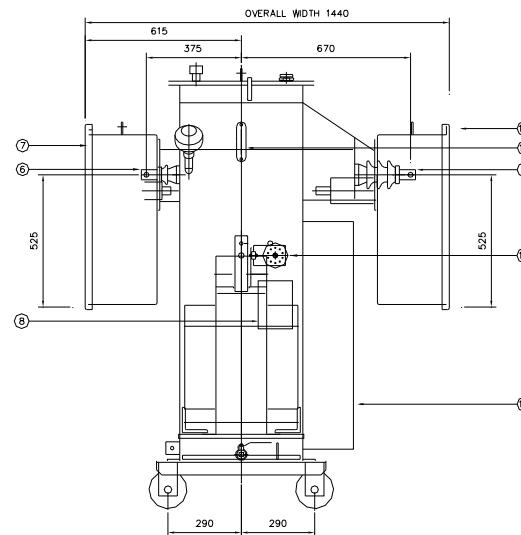
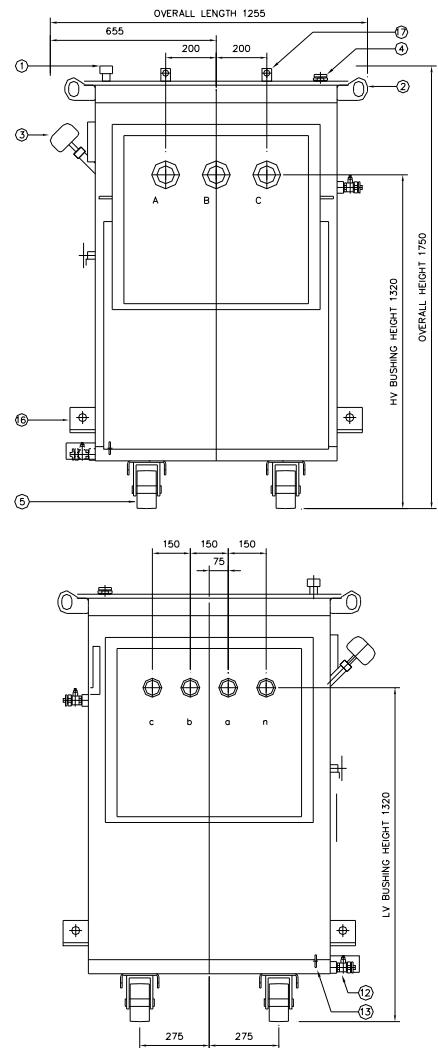
■ **Figure 26.4: Typical Kiosk Substation General Arrangement**



■ **Figure 26.5: Typical Earth Covered Substation General Arrangement**



■ **Figure 26.6: High Voltage Switchgear Labelling Diagram**



#### DESCRIPTION LIST

1. FILLER CAP 032 NOM
2. UNIT LIFTING LUG WITH SLOT 40x60
3. OIL TEMPERATURE INDICATOR WITH 2 SETS OF CONTACTS
4. PRESSURE RELIEF DEVICE
5. BASE CHANNELS FITTED WITH MULTI DIRECTIONAL ROLLERS 0150
6. LV BUSHING ESAA 2/3/0 WITH HOLE IN PALM 014
7. LV AIR INSULATED CABLE BOX COMPLETE WITH REMOVABLE FRONT COVER AND BLANK ALUMINIUM GLAND PLATE
8. RATING AND TAGGING PLATE
9. HV BUSHING ESAA 2/3/0 WITH HOLE IN PALM 014
10. HV AIR INSULATED CABLE BOX COMPLETE WITH REMOVABLE FRONT COVER AND BLANK ALUMINIUM GLAND PLATE
11. FLUSH TYPE OIL GAUGE MARKED '16'
12. DRAIN/SAMPLING VALVE 025 NOM. WITH GUARD
13. EARTH LUG STAINLESS STEEL WITH HOLE 014
14. 5 POSITION OFF CIRCUIT TAPSELECTOR SUITABLE FOR LOCKING IN ANY OPERATING POSITION
15. COOLING FINS
16. JACKING PADS WITH HAULAGE POINTS 032 HOLE
17. LID LIFTING LUGS 024 HOLE

■ Figure 26.7: RAAF Base Curtin Transformer Arrangement

## **26.6.2 Kiosk Substations**

### General

The requirements as stated for kiosk substations shall also be applicable to scenarios where kiosks are utilised as switching stations.

### Access and Clearances

Generally the location of the kiosk substation shall provide personnel access to all sides. Care must be taken to ensure any access doors/panels may be opened and not restrict free-access past the door/panel.

The minimum clearances shall be as per Figure 26.1.

### Foundations

Under normal circumstances, the kiosk substation foundation shall comply with the general details shown in the Standard Drawing. Note that the drawing is indicative only and the actual foundation utilised shall be designed to suit the requirements of the installation.

Under circumstances where the substation site is unstable support pier/s is/are required. The piers shall be bored or formed with a diameter of 600mm and be 1200mm long as a minimum. The actual number of piers required is dependent upon the soil conditions.

### Building Requirements

Each kiosk substation shall be manufactured of 3mm mild steel with galvanised steel PFC base or equivalent strength marine grade aluminium. Preference shall be given to kiosk substation arrangements which offer the lowest through life costs when considering the need for painted structures.

Access doors that open to 180° shall be provided for access to the HV and LV equipment. Access to the transformer compartment may be gain via bolt-on panels.

All penetrations from one compartment to the other shall be via glands.

### Standard Requirements

#### **Permitted Kiosk Types**

Essentially only two (2) types of the kiosk substations are permitted on Defence sites. These are:

- a) Type A – That shown in the Standard Drawings
- b) Type B – Those utilised by the NSP local to the Defence site.

Every effort shall be made to procure kiosk substations that comply with that shown in the Standard Drawings (i.e. Type A). Type A kiosk substations are required when either a DESN or load shedding features are present or required on site.

However under special circumstances, kiosk type substations that comply with those of the local NSP (i.e. Type B) may be utilised with the approval of DEEP.

All kiosk substations shall comply with the following performance requirements:

- a) Permit the installation of a four circuit HV RMU consisting of three ring switches plus one transformer feeder;
- b) Have adequate capacity for the installation of a 1 MVA transformer;
- c) Maximum transformer capacity allowed for kiosk arrangement is 1.5MVA. Greater than 1.5MVA must be an indoor arrangement;
- d) Permit the installation of four LV outgoing feeds each with a capacity of 630A, CT metering and load shedding controls;
- e) Segregated HV, Transformer, LV and DESN compartments;
- f) The facility to remove/install the HV switchgear, Transformer or LV switchgear via the access doors/panels or via a removable roof;
- g) A dust and water ingress protection level of IP 54 for all compartments (other than the transformer compartment) or the respective switchboards within the compartment;
- h) Door switch activated lights for each cubicle;
- i) General purpose GPO in the LV compartment;
- j) DESN GPO in the DESN compartment; and
- k) A grading ring and earth system.

In all cases ease of access and maintenance to all equipment is the first consideration.

#### ***Heat Gain***

Due consideration shall be given to the impact of solar radiation and the heat from the transformer on the internal operating temperatures of the kiosk substation.

Provide additional thermal treatment where kiosk substations are located where the internal temperature rise is expected to exceed that which is acceptable. This may include:

- a) Increased natural ventilation; or
- b) Additional insulation.

#### **Special Circumstances**

Kiosk substations shall not be utilised for Bases subjected to cyclonic conditions unless otherwise instructed by DEEP.

#### **DESN**

A DESN compartment shall be provided at all Type A substations even if DESN equipment is not being provided at this stage or if the Base presently does not have a DESN.

### Switching Stations

On agreement from DEEP, HV switching stations may be utilised to optimise HV cabling where there is no likelihood that a future substation will be required at the site. In these cases a suitable purpose built kiosk arrangement shall be used meeting the general kiosk substation performance requirements, sized to suit the HV RMU only and the associated maintenance clearances. The following additional requirements shall be met:

- a) DESN connection shall be from suitable adjacent site; and
- b) All necessary ancillaries are included such as anti condensation heaters.

### **26.6.3 Indoor Substations**

- General

New HV indoor substations are to allow generally for operations and maintenance indoors in all weather conditions.

The substation shall consist of separate rooms as follows:

- a) The HV room of the substation shall house the HV Ring Main Unit (RMU) and transformer.
- b) The LV room shall house the substation LV switchboard, LEG controls, where required, and provision for the Defence Engineering Services Network (DESN).

The LEG or UPS room to house the generator shall be provided if an LEG or UPS is being installed at the substation. For detailed requirements for LEGs, refer to Chapter 21 – Local Emergency Generator (LEG) Requirements.

Design parameters for the substation include:

- a) Transformer withdrawal and insertion shall be with the transformer wheels or skates without the transformer being required to pass over any in-floor trenches. It shall be possible to drop a transformer on an external hardstand and wheel or skate the transformer into position from that location.
- b) The LV Switchroom should be provided with separate direct access externally of the building and also be readily available to the HV Switchroom or any LEG or Uninterruptible Power Supply (UPS) room. In the case of large facilities the LV Switchroom may also form the building MSB.
- c) It is envisaged that all indoor substations will be communications nodes for the DESN. Appropriate space for the connection to the DESN and communications system is required.
- d) The LEG room is to house the generator and associated services such as fuel, batteries and chargers. The LEG room is to have internal access to the LV Switchroom.
- e) The substation HV Switchroom is to be provided with two clear fronted A0 drawing holders for the Base HV geographic layout and site single line diagram.
- f) Haulage eyes are to be provided in the trenches to facilitate cable pulling. The number and location of haulage eyes are to suit the duct banks installed.

- g) HV transformer tails shall be 3 single core XLPE insulated and screened cables. The HV transformer tails shall be installed a HV trench.
- h) LV transformer tails can be either overhead or in-trench. Overhead cable runs shall maintain suitable minimum clearance of 2700mm AFFL for personnel and equipment access. The LV trench shall be separate to the HV trench.
- i) Floor trenches shall be provided with a sump to allow a portable pump to be used to remove water; and
- j) Trench entries shall be sealed to prevent the entry of water and to contain oil.

– External Clearance Requirements

External clearance requirements for Indoor Substations and Switching Stations shall allow for access of a large flat bed truck on all sides and easy installation and removal of all equipment.

– Internal Clearance Requirements

Provide the minimum internal clearances where applicable as required by Table 26.1 below:

■ **Table 26.1: Indoor Substation Minimum Clearances**

<b>Distance</b>	<b>Description</b>
0.9m	Horizontally between any item of equipment and the substation wall
0.6m	Horizontally between any two (2) items of equipment
1.2m	Horizontally in front of any HV switchgear.

### **Building Requirements**

#### Civil Requirements

Indoor substations can either be free standing structures or constructed as part of another larger facility.

#### Personnel

Each substation chamber shall be provided with two separate means of unimpeded access for personnel. Personnel access must be available at all time and shall be located where they cannot be obstructed by any means which includes vehicles, equipment or other impediments.

Within the substation chamber, access points should be diagonally opposite and positioned such that unimpeded access is maintained to all points that will be normally accessed by personnel.

#### Equipment

A suitable equipment handling area needs to be established to permit the insertion and removal of equipment from the substation. Equipment access can be provided by suitable double sized door or by demountable louver panels. Equipment access shall be arranged such that equipment removal or insertion can be performed without impacting on other major items of equipment.

### Foundations

The substation foundation shall be fully designed to accommodate the expected mass of all equipment to be installed and the inclusion of cable trenches and pits.

### Substation Walls

Walls of substations shall be constructed of solid clay bricks not less than 230mm thick or concrete blocks of not less than 190mm thick.

The use of hollow, core filled bricks, reinforced concrete or pre-cast reinforced concrete is preferred.

All walls shall provide a fire rating of two (2) hours.

### Substation Floor

The floor shall be fully designed to withstand the loadings of the equipment to be installed. The uniformity of the floor shall comply with the requirements as designated by the manufacturer of the switchgear.

All personnel or equipment access ramps shall be cast integrally with the substation floor slab. A suitable hardstand shall be provided outside the substation to allow unloading and subsequent rolling of the transformer into the substation.

Cable trenches and pits shall be cast integrally with the floor slab. They shall be of such depth that the minimum-bending radius of the cable plus 20% is allowed. In all cases the trench shall be 1200mm deep as a minimum.

Rebated edges shall be cast into the top of cable trenches to allow the installation of 6mm aluminium checker plate covers of mass not exceeding 15kg each. Covers are required where the trench will be exposed.

### Substation Ceiling

The ceiling shall be reinforced concrete with a fire rating not less than that of the walls.

The minimum ceiling height shall be 3m at all locations.

### Water Ingress Considerations

A waterproof membrane shall be provided around all walls and/or floors in constant contact with soil.

All walls built below the finished surface level of the ground shall have a drained cavity included along the full length of the wall/s.

All penetrations in the walls shall be sealed to prevent the ingress of water.

If the finished surface level of the substation floor is below the water table or where the water table may rise above the finished surface level, provide gravity drainage to a suitable discharge point or sump.

#### Conduits

All conduits shall be HD uPVC to AS/NZS 2053.2 with all joints being solvent welded. “Corflo” type conduits shall not be utilised.

Where conduits penetrate into the substation through walls etc the conduit shall protrude into the substation and be socket ended.

All conduits exiting the substation shall extend 1500mm past the end of the slab before jointing. Any conduits for future shall have draw wires installed and plugged with a weak sand/cement mix.

The depth of concrete around all conduits shall be 150mm at all times.

Conduits adjacent each other with differing services (e.g. control cables, LV cables or HV cables) shall be separated by 200mm minimum between sides.

#### Painting

The internal surfaces of the substation shall be coated with an acrylic based sealer and at least two (2) coats of cream low sheen acrylic based paint.

All un-galvanised metal surfaces shall be coated with a zinc rich paint e.g. “Killrust grey”.

#### Sound Attenuation

As transformers produce low frequency tones, provide sound mitigation if required.

Special consideration needs to be paid to sound attenuation when an LEG is provided adjacent.

The LV Switchroom room shall be appropriately sound attenuated from other rooms and to the outside with appropriate measures incorporated for all service penetrations between rooms.

#### Ventilation

Where practical all substations shall employ natural ventilation using weatherproof and vermin proof vents or louvers.

### **Special Circumstances**

#### Access Requirements for Substations within a Facility

Where an indoor substation is constructed as part of another facility, it shall not be possible to gain access to the attached facility from the substation.

An attached substation shall have at least one frontage in an external wall of the building. Preference shall be given to locating the substation in an outer corner of a building so as to provide two (2) frontages.

#### Requirements for Northern Bases

Indoor substation structures intended for use at Bases subjected to cyclonic conditions shall be fully cyclone rated.

The location and IP rating of the equipment should consider that large quantities of water could enter the substation during a cyclone and that the substation is required to remain operational at all times.

#### Earth Covered Substations (Passive Defence Measures)

Additional consideration needs to be given to earth covered substation. The actual substation construction and all special considerations such as the required hardening shall be design by a suitably qualified engineer to meet the passive defence requirements. Consideration of the impact vibration due to weapons effects also needs to be addressed.

The spacing limitations within the substation such as those with arch type structures needs to be addressed when determining the equipment layout.

Refer to the Figure 26.5 for an example of an earth-covered substation.

### **26.6.4 Intake Switching Stations, Primary Switching Stations and CEPS**

#### **Standard Requirements**

New HV switch rooms required for ISS, PSS and CEPS are to generally allow for operations and maintenance indoors in all weather conditions.

Design parameters for the substation include:

- a) HV switchboard circuit breaker trucks withdrawal and insertion shall be possible without the trucks being required to pass over any in-floor trenches. It shall be possible to place a switchboard panel on an external hardstand and wheel or skate the panel into position from that location.
- b) LV and control connections to the switchgear shall be overhead on ladder.
- c) HV connections to the switchgear shall be from below with the cables installed in a trench.
- d) It is envisaged that all switching stations will be communications nodes for the control and monitoring system. Appropriate space for the connection to the Defence Engineering Services Network (i.e. DESN) and communications system is required.
- e) The HV Switchroom is to be provided with two clear fronted A0 drawing holders for the Base HV geographic layout and site single line diagram.

- f) Haulage eyes shall be provided in the trenches to facilitate cable pulling. The number and location of haulage eyes are to suit the duct banks installed.
- g) Floor trenches shall be provided with a sump to allow a portable pump to be used to remove water; and
- h) Trench entries shall be sealed to prevent the entry of water and to contain oil.
- i) Switch rooms shall be fully air-conditioned so as to reduce dust and maintain cool temperatures.

### **Special Circumstances**

#### **Requirements for Northern Bases**

Switchroom structures intended for use at Bases subjected to cyclonic conditions shall be fully cyclone rated.

The location and IP rating of the equipment should consider that some water could enter the substation during a cyclone and that the switching station is required to remain operational at all times.

## **26.7 High Voltage Switchgear**

### **26.7.1 General**

Two types of HV Switchgear generally exist in Defence establishments:

- **Switchboards** – These consist of modular, extensible switchgear panels using either fixed or withdraw able switchgear. These are used largely to control the power flow in a HV distribution system.
- **Ring Main Units** – These consist of extensible or non-extensible fixed switchgear that generally couple a distribution transformer to the HV distribution system.

It is Defence policy that high voltage switchgear is standardised for each Defence establishment to ensure a common operator interface. Therefore at each establishment there is a single make/type of switchgear normally used in accordance with Chapter 8 – Construction Requirements and Project Controls. The designer shall acquaint himself with standard arrangements at the Base and must ensure that all new switchgear meets this requirement, unless as allowed otherwise when establishing a standardised arrangement which must be agreed by DEEP.

### **26.7.2 High Voltage Switchboards**

#### **General Requirements**

The switchboard panels shall consist of freestanding, dead front, metal clad, panel types equipped with SF6 or vacuum switchgear with the protection relays generally as a separate panel above.

The requirement for withdraw able or non-withdraw able switchgear is dependent upon DEEP requirements. Generally, the requirement is as follows:

- a) Operational and important Bases – Withdraw able (use the existing switchgear as a guide to determine operational status, the designer must liaise with DEEP when determining operational status); and
- b) Other Bases – Non-withdraw able.

The switchgear shall be capable of delivering continuous full rated load under the site and be fitted with fault-make earth switches.

HV switchboards shall have features and ratings to suit the system characteristics to which it is connected.

The switchboard shall be constructed with separate electrically isolated compartments so that a fault in one compartment does not result in damage in the other compartments, as follows:

- a) Cable Termination Compartment: Space for termination of HV cables, CTs, VTs and separate earthing switch.
- b) Circuit Breaker Compartment: Space for the withdraw able circuit breaker truck.
- c) Busbar Compartment: Space for the interconnecting HV busbar assembly and Bus VTs.
- d) LV Compartment: Space for electrical controls, metering and protection.

Mechanical indicators shall provide visual indication of switch status at all times.

HV surge arrestors shall be fitted to panels that are designated for:

- a) Incoming Feeders; and
- b) Generators.

### **Protection Relays**

#### Generally

The relays shall be mounted on the front panel of the LV compartment in such a way that all indicators are visible and all operations can be carried out without opening any compartment doors.

All microprocessor based protection relays shall be of the monitored type, using a watchdog timer that is independent of the processor.

Protective relays must have suitable setting ranges to meet the system requirements.

Programmable Controllers will not be accepted as an alternative to protection relays or control equipment.

All protection relay contacts that are to be used for tripping, closing, indication or alarms must be of robust and reliable construction and have appropriate current ratings to match the required duty.

The performance of the relays, including measurement, tripping or blocking, indication, and alarm signalling, must not be affected by the levels of harmonics in the current and voltage waveforms of

the system. Nor should the performance of the relays be affected by the quality of the DC supplies from the batteries and chargers.

#### Protection Requirements

Provide as a minimum the following protection elements, in addition to the NEC/NSP protection requirements including those applicable to operation of generators in parallel with the mains:

a) Incomers:

- Feeder Overcurrent;
- Feeder Earth Fault;
- Directional OC/EF, where required;
- Over voltage (set to +12%);

b) Critical HV buses, such as those at Intake Substations:

- High impedance differential or other zonal scheme, on each bus section.

c) Interconnectors:

- Current differential protection;
- Backup IDMT that is enabled on communications failure;

d) Generators >800kW and those that connect at 11kV:

- Complete Alternator Protection; with the following minimum elements:
  - Generator biased differential;
  - Overcurrent;
  - Earth fault;
  - Voltage dependent overcurrent;
  - Over voltage;
  - Under voltage;
  - Loss of excitation;
  - Under excitation;
  - Reverse power;
  - Neutral displacement.

e) Power Factor Correction Capacitors

- Overcurrent
- Earth Fault
- Out of Balance

The operation of any protection element shall be individually indicated to the generator control system and the DESN.

Synchronism check relays shall be provided on all switchboard panels where:

- a) There is a possibility (however remote) that the supplies on each side might not be synchronised, or
- b) To prevent automatic systems mal-operating, such as where:
  - The HV system is energised by on-Base standby generators, and
  - The circuit is subject to automated control or remote manual control.

The protection systems should allow cables to run with a nominal overload for short periods of time under emergency conditions (Emergency Rating), however this situation should not be allowed for extended periods. This will require suitable selection of time multipliers when developing the protection scheme.

### **Metering**

Provide metering in accordance with the local NSP requirements on each incoming feeder.

Private metering shall be provided separate to any protection relay on each HV circuit breaker.

Provide multifunction electronic metering relays complete with an open protocol communications port on each HV feeder. Metering shall include as a minimum

- a) Instantaneous Voltage at cable termination (where VTs are fitted) - (3, min/max);
- b) Instantaneous Current at cable termination - (3, min/max);
- c) Demand Current at cable termination - (3 + N, min/max);
- d) Power factor - (3, av);
- e) kVA, kVAR, kW, kWh, kVA demand, kW demand (total); and
- f) Frequency at cable termination - (av, min/max).

### **Remote Control**

Where switchgear is operated remotely by another system (e.g. GCS) provide the following additional features at each affected panel:

- a) Spring charge motors;
- b) Local/remote rotary selector switch and electrical open/close controls;
- c) Status signals to the other system to indicate:
  - Open (or not racked-in)
  - Closed (In the Service position and racked-in)
  - Tripped (due to the action of any protection relay)
  - Not available in Remote (CB in Local Mode, or the truck not in the Service position and racked-in)

Switches shall have 22 mm diameter oil tight mechanisms.

### **Illuminated Indicators**

Provide illuminated indicators on the front of the LV compartment of each panel as follows:

- a) Open (or not racked in)- Green
- b) Closed (In the Service position and racked-in)- Red
- c) Tripped (due to the action of any protection relay)- Yellow
- d) Not Available in Remote- Yellow  
(CB in Local Mode, or the truck not in the Service position and racked-in).

The Open indicator shall light even if the CB truck is not in the panel.

Indicators shall have 22 mm diameter oil tight mechanisms with multi-chip LED lamps.

### **Defence Engineering Service Network (DESN) Interface**

Provide a separate DESN terminal strip within the LV Compartment for remote monitoring of each panel of switchgear.

Indication signals shall consist of normally open (NO) voltage free contacts provided within the switchboard. Provide the following signals:

- a) Open
- b) Closed (In the Service position and racked-in)
- c) Tripped (due to the action of any protection relay)
- d) Truck Racked out
- e) Not available in Remote (CB in Local Mode, or the truck not in the Service position and racked-in)

Connect the following signals in parallel as a common HV Switchboard Fault that closes on a fault:

- a) The watchdog timer of each protection relay
- b) Trip circuit supervision and other fault outputs of each panel
- c) The Communications Fault of each pilot wire protection relay
- d) Connect this signal to a DESN terminal strip in the incoming CB panel.

### **26.7.3 Ring Main Units**

#### **General Requirements**

The RMUs supplied shall consist of freestanding, dead front, metal clad, panel types equipped with SF6 or vacuum switchgear and fuses or protection relays as a single assembly.

The switchgear shall be capable of delivering continuous full rated load under the site and be fitted with fault-make earth switches.

Unless otherwise stated, RMUs shall have the following characteristics:

- a) Mechanical indicators shall provide visual indication of switch status at all times.
- b) Provision shall be made for locking of the RMU in the ‘OFF’ and ‘Earthed’ positions.
- c) Provide auxiliary switches that indicate the Open/Closed/Tripped status of each item of switchgear. Connect these switches to a separate terminal strip for extension to DESN.
- d) Provide one set of equipment required for the safe and satisfactory operation of the switchgear, such as operating handles, fuse extractors, etc. for each RMU. Mount equipment within a mounting frame suitable for wall mounting in a substation building or fixing within a kiosk substation.

The actual number of RMU ways to be provided shall be as determined by the designer to suit immediate requirements. However, provision shall be made for the installation of four (4) units as a minimum for all substations and switching stations.

#### **26.7.4 HV Power Factor Correction (PFC)**

Power factor correction capacitors shall be fitted with integral resistors to discharge the bank after the supply is removed.

Safety interlocks shall be proved to ensure:

- a) The earth switch cannot be closed until a time period after the CB is opened;
- b) The capacitors or any HV associated with the PFC bank cannot be accessed until the earth switch is closed, and
- c) The CB cannot be reclosed for a time period after the CB is opened.

The time period shall be at least twice that which is necessary to discharge a fully charged PFC bank to a safe level. Ensure that the power factor correction does not interfere with the network provider’s ripple protection on the rest of their network.

#### **26.7.5 Transformers**

##### **General Requirements**

Transformers for use in distribution substations shall generally match those in service with local NSP. However as a minimum all distribution substation transformers shall be of the sealed type.

Unless otherwise stated, transformers shall have the following characteristics defined in Table 26.2 below:

- **Table 26.2: Transformer Characteristics**

<b>Characteristic</b>	<b>Requirement</b>
Voltage Ratios	11kV/400V 22kV/400V 33kV/400V
Voltage Tapings	Primary Substations: Minimum 11 taps to suit detailed design.

<b>Characteristic</b>	<b>Requirement</b>
	Distribution Substations: +10% to -5% (in 2.5% increments)
Vector Group	Primary Substations: To suit detailed design. Distribution Substations: Dyn11 or Dyn1 (to suit local arrangement)
Frequency	50 Hz
Insulating Medium	Mineral Oil to AS 1767
Cooling Methods	Primary Substations: ONAN/ONAF Distribution Substations: ONAN
Maximum Rated Voltage	11 kV - 95 kV (BIL) 22 kV – 125 kV (BIL) 33 kV – 170 kV (BIL) 66 kV – 325 kV (BIL)
Transformers used in other than distribution applications including Unit Step Up transformers associated with generators and major transformers such as 33kV/11kV, 66kV/11kV, 132kV/33kV: DEEP will provide separate requirements	

### **Transformer Ancillaries**

Transformers for distribution substations shall be fully sealed and have the following ancillaries as a minimum:

- a) Off-line Taping Switch c/w lockable locating pin;
- b) Over temperature sensor;
- c) Over pressure sensor, and
- d) Oil Level Sight Glass.

Transformers for use in other than distribution substations (e.g. 33/11kV ISS transformers) shall have features and characteristics suited to the application.

### **Transformer Sizing**

The transformer shall be suitably sized to supply the maximum demand of the loads with an allowance for 25% spare capacity (unless otherwise instructed). Transformers greater than 1.5MVA or multiple transformer arrangements must be installed in an indoor substation.

The transformer shall have the capability (above the spare capacity) to deliver power at 20% overload for a period of two (2) hours in each twenty-four (24) hour period.

### **Transformer Protection**

- Distribution Transformer Protection

Protect against faults within the transformer or in the HV/LV tails with the following protection:

- a) Transformer overload or overload of the HV/LV tails shall be provided by the LV circuit breakers;
- b) Transformer internal faults or faults on the HV/LV tail shall be provided by the HV protection;
- c) Transformer internal faults shall also be sensed using:

- An over pressure switch (on sealed transformers only); and
- An over temperature switch,

All protection shall coordinate fully with all upstream and downstream protection schemes.

Preference shall be given for the use of circuit breakers complete with self-powered protection relays. Protection relays shall have as a minimum:

- a) IEC – Standard Inverse;
- b) IEC – Very Inverse;
- c) IEC – Extremely Inverse; and
- d) Definite Time

curves for both phase and earth fault protection.

- Transformer Protection (other than Distribution Transformers)

For transformers other than those for use as distribution transformers, the following protection shall be provided as a minimum:

- a) Over-temperature;
- b) Overcurrent;
- c) Earth fault;
- d) An overpressure switch (on sealed transformers only)
- e) Buchholz; and
- f) OLTC failure (if OLTC fitted).

Note that where transformers are part of a transformer-ended feeder extra consideration shall be made for the protection offered including the use of inter-tripping.

### **Transformer Impedance and Losses**

All oil-immersed transformers shall meet the requirements of Minimum Energy Performance Standard (MEPS) for Power Transformers as designated in AS 2374.1.2.

Preference shall be given to oil-immersed power transformers that achieve the high power efficiency levels. However this shall only apply if the higher efficiency type transformer is the most cost effective option using an NVP over a period of 20 years.

Transformer impedances shall be as close as practical to those of the transformers in use by the local NSP. Exceptions may occur when fault level or other overriding factors require it.

The details of the losses and the electrical characteristics are to be shown in the O&M Manuals, are to be addressed by the design report and in the tender evaluation technical report.

### **Acoustics**

To avoid the possibility of noise interference to adjacent facilities, the final sighting of the substation shall comply with the requirements of the AS 1055 series and AS 2374.6.

Under normal circumstances, Standard Limit transformers shall be utilised. However, under some circumstances where a substation is positioned adjacent a sensitive facility, Reduced Limit transformers shall be utilised.

### **Transformer Monitoring**

Voltage free contacts shall be connected into the DESN, to provide alarm indication from each of the following:

- a) Over Temperature Switch;
- b) Overpressure Switch (on sealed transformers only); and
- c) Buchholz Relay (on unsealed transformers).

## **26.7.6 LV Switchboards**

### **General Requirements**

Substation low voltage switchboards shall have a minimum of Form 1 segregation and achieve a degree of protection rating of IP52. Consideration should be given to higher forms or segregation for important facilities particularly where incorporated with the building MSB.

Provide suitable load shedding capability for LV distribution feeders. Load shedding is not normally required for the LEG supplies; however, consideration of essential and non-essential sections is required in the substation LV switchboard where LEG supplies are provided.

An intelligent metering system incorporating MDIs, voltmeter, kW and kWh functions, and with integral communications, shall be provided on the LV switchboard for the transformer output. A similar system will be provided for each facility MSB; however, where the substation will only supply one load the intelligent metering in the facility MSB may be omitted subject to DEEP agreement.

Intelligent metering systems shall be compatible with the equipment installed throughout the site.

Flexibility of supply shall remain a high priority at all times.

### **Switchboard and Equipment Sizing**

Where two (2) transformers or more are used to supply large facilities, consideration of the following is required:

- a) Parallel Operation – Transformers are not to be permanently paralleled unless agreed by DEEP. It is preferred that the transformers are operated independently as two supplies, however they shall be capable of operating in parallel in order to provide future flexibility and during switching operations.

- b) The low voltage switchboard(s) are to be configured to allow the transformers to operate in parallel as required via closed transition.
- c) Transformer sizing for important facilities shall be suitable to allow operations of essential activities on failure of one transformer. Low limiting under these arrangements would be manually initiated at the main switchboard.

### **26.7.7 Load Shedding**

#### **General**

Load shedding is required for facilities at a Base provided with a CEPS/CPS or where the LEG will not support the entire facility.

The purpose of the load shedding system is to remove load from the electrical network in the event of a power outage so that the local emergency generators or Base emergency generators in the CEPS can connect. It also regulates the load on the generators while they are powering the Base. As such, the load shedding system needs to operate to open the load shedding devices at times when mains power is not available or lacks the capacity to meet demand.

Where the load shedding is provided to meet the LEG requirements, the load shedding system shall meet the defined performance in this design brief or as agreed in the design report and is suitable for operation either, automatically by the respective LEG/mobile generator system, or manually by the building occupants.

#### **Load Shedding Requirements**

Where Defence establishments are provided with a CEPS/CPS, the load shedding requirements shall be detailed below.

#### **CEPS Load Shedding Requirements**

Where Defence establishments are provided with a CEPS, all building loads and electrical loads shall be controlled by a load shedding systems. The purpose of the load shedding system is to remove load from the electrical network in the event of a power outage so that the Base emergency generators in the CEPS can connect. It also regulates the load on the generators while they are powering the Base. As such, the load shedding system needs to operate to open the load shedding devices at times when mains power is not available.

Load shed devices shall consist of latched contactors or motor operated circuit breakers that are controlled by the local Defence Engineering Services Network (DESN) Power Control and Monitoring System (PCMS) Remote Terminal Unit (RTU) or Programmable Logic Controller (PLC). The outputs of the RTU are 24VDC momentary voltage signals with separate pulse outputs for shed and connect. The RTUs have a battery that enables them to operate in the event of a power outage. 24VDC power for load shedding device controls can be obtained from the RTU. The main contactor or motor operated circuit breakers shall be powered from the 230VAC supply and shall not be connected to the 24VDC battery supply.

The control signals shall be connected to each load shedding device to an adjacent DESN terminal strip.

### **Location and arrangement of the load shedding devices**

In general, each facility is to be controlled by a single load shedding device, however larger installations require a number of load shedding devices to split the facility into a number of manageable building load groups. This is primarily done to optimise the supply of emergency power from the CEPS.

Multiple load shed devices shall be provided to limit the maximum size of any single building load group to less than:

- a) 500kVA, or
- b) 10% of the CEPS capacity, whichever is the greater.

When multiple load shed devices are required, provide load shedding devices that control building load groups according to function. As a guide, separate load shedding devices shall be provided for the following load categories:

- a) General light and power
- b) Air-conditioning
- c) Specialist plant, such as simulators including their support plant

The load shed devices should be installed in the substation wherever possible; however, where two or more load shed devices are required they can be installed at the building main switchboard if more cost effective.

### **Contactor Load shedding Devices**

Contactors used as load shedding devices shall consist of mechanically latched contactors with a 230VAC main and a 24VDC release coil. The coils shall be continuously rated, however, the control circuit shall ensure that once the contactor has operated the coils are de-energised.

The contactor shall open in response to a load shed command.

The contactor shall close in response to a Connect command. Should the contactor be commanded to connect when mains power is not available the operation shall remain pending, at the device, until either:

- a) The mains returns and the contactor closes, or
- b) The connect operation is cancelled by a subsequent shed command.

### **Circuit Breaker Load Shedding Devices**

Circuit breakers used as load shedding devices shall be motorised circuit breakers with 230VAC motor operators to open and close the breaker and 24VDC trip or release coils. The motor and coils

shall be continuously rated, however, the control circuit shall ensure that once the breaker has operated the motor and coils are de-energised.

When mains are available the circuit breaker shall be driven open and closed using the motor operator in response to shed and connect commands.

When the mains are not available the release mechanism shall not be dependant on the 230VAC control voltage and shall consist of either:

- a) A release coil which causes the circuit breaker to go to the open position.
- b) A shunt trip coil that causes the circuit breaker to go to either the open position or trip position.  
If the circuit breaker is in the trip position the shed operation shall remain pending, at the device, until the mains supply returns, the motor shall then automatically drive the circuit breaker to the open position.

At all times, the control circuit shall differentiate between a protection trip and a load shedding operation, with the operation of the circuit breaker protection trip disabling control of the circuit breaker from the RTU. Resetting the circuit breaker following a protection trip shall only be possible by manual operation at the circuit breaker. This manual operation is to involve the normal circuit breaker reset and not require separate reset of the control system wherever possible.

When the circuit breaker is operated rather than tripped off, springs shall be automatically recharged as soon as the 230VAC becomes available.

The circuit breaker shall be pad lockable in the "Off" position when the load shed breaker is isolated to allow maintenance to be undertaken on equipment connected to the circuit.

#### **Local Control and Indication**

Provide local control of each load shed device consisting of:

- a) An open/close centre spring return, rotary, local control switch
- b) An auto/manual rotary switch that enables control of the load shed device either exclusively from the RTU or from the local control switch

Where an auto/manual switch and open/close controls, with the same functionality as above, are provided as part of the motor operator mechanism and these are operable from the front of the switchboard they may be used in lieu of separate controls.

In general, motorised circuit breakers status should be visible from the front of the switchboard without the need to remove panels. However, for contactors or where the status of the circuit breaker is not visible, illuminated indicators shall be provided adjacent to the local controls. Illuminated indicators shall be multi-chip LED assemblies rather than incandescent lamps.

### **Remote Monitoring**

Provide voltage free contacts from each load shedding device wired through the DESN terminal strip as follows:

- a) Manual (closed when the auto/manual switch is in the manual position) and
- b) Closed (closed when the load shed device is closed)

### **Existing CEPS Load Shed Systems**

At some establishments, the existing load shedding system and devices may not be configured in accordance with the above requirements and may not comprise latching contactors or suitable motor operated circuit breakers. At these establishments, the additions to the load shedding system shall comply with the above requirements, and shall also be configured with interposing relays or other suitable arrangement to permit correct operation with the existing system. It is intended that these existing systems will be updated at some time in the future and therefore the interposing arrangement should be easily removable at that time.

Where existing load shed devices comprise motor operated circuit breakers fitted with under voltage release to open the breaker in the event of a mains failure, the under voltage functionality shall be disabled for load shedding purposes when incorporated into the new system.

Circuit breakers that are not suitably reconfigurable as a load shedding device to the above requirements shall not be reused as part of the load shedding system. If it is no practical to change the existing breaker install latching contactors, or suitable motorised circuit breakers, upstream or downstream of the breakers.

### **26.7.8 ELV Systems**

Provide redundant, battery backed DC supplies to power protection, control and indication systems in Primary Substations and Primary Switching Stations, Intake Switching Stations, Intake Substations and Central Emergency Power Stations.

DC systems shall be nominally 24VDC with a minimum back time of 16 hours under the expected load conditions plus an allowance for any future/spare panels.

DC systems shall be of the unearthing floating type complete with earth fault protection.

Provide positive indication of the availability of supply at each DC Switchboard via an indicator lamp and voltage free contact to the DESN.

### **Batteries**

Batteries shall be valve regulated sealed lead acid with a minimum guaranteed life of ten (10) years at the specified location and with the charger provided.

Battery banks shall consist of strings of individual batteries connected in series and shall have 25% spare capacity. Parallel strings of batteries shall not be utilised unless indicated approved by DEEP.

Each parallel string, where approved shall be individually fused.

### **Battery Chargers**

Chargers shall be fully automatic in operation, incorporating microprocessor-based controllers.

Battery chargers shall have sufficient isolation from the mains, or other protective measures, so that they are suitable as the source of supply for SELV or PELV systems.

Charging shall incorporate compensation of the float voltage for battery temperature. The temperature sensor shall be located at the battery.

Provide meters to display the following analogue values:

- a) Battery Voltage
- b) Charger Current
- c) Load Current

Provide all necessary alarms with voltage free contacts for remote monitoring to indicate charger or battery faults. As a minimum this shall include:

- a) Charger Failure;
- b) Low Volts;
- c) High Volts;
- d) Earth Fault, and
- e) Loss of A/C Supply.

### **26.7.9 Substation Earthing**

#### **General**

Distribution Substation earthing shall be a combined earthing system in accordance with AS/NZS 3000.

Bond all exposed metal, including the reinforcing steel in the concrete slab, to the earth bar.

Careful consideration shall be given to the effects of galvanic corrosion on all bonds. Exposed copper bonds shall not be permitted in the concrete slab.

The design shall include an assessment of prospective step and touch potentials, identifying possible conditions for danger according to ENA EG1 - 2006 - Substation Earthing Guide. Potential hazards shall be mitigated by accepted techniques such as the use of grading rings or crushed rock in accordance with ENA Guidelines and AS 2067.

Other earthing systems or earth reference points, where required in buildings, are to be bonded in accordance with AS/NZS 3000, AS 1020, AS/NZS 1768 and AS 2067. In meeting these requirements the design shall not compromise the engineering requirements of the earthing systems and that the potential for earth loops in the facility are eliminated.

## **Special Circumstances**

### Poor Earthing Conditions

Poor earthing conditions exist in a number of regions. This is particularly the case in Northern Australia or more arid regions but can also be a result of local soil conditions such as sand. In these circumstances a reticulated earthing networks shall be used. The reticulated earthing system consists of a bare earth conductor direct buried adjacent to the HV and LV power cables to substations and buildings.

For HV systems the reticulated earth cable shall be brought into the substation earth bar by crimping or “Cadweld” a tail onto the cable as it passes the substation. The earth cable shall not to be looped at the substation earth bar. This allows the reticulated earth to be disconnected without affecting the connections at the other substations. The reticulated earth cables are an earthing system external to the substation and as such do not replace or fulfil the basic substation earthing as required by the Standards.

### Adjacent Structures

Careful consideration shall be given to substations located adjacent any of the following structures to ensure no harmful effect from the substation:

- a) Metallic fences;
- b) External metallic services;
- c) Swimming pools;
- d) Flammable storage facilities;
- e) Electrical railway lines;
- f) Medical facilities; and
- g) Communication centres etc.

The earthing design shall consider the presence of metallic service connection to the building and the presence of adjacent conductive structures, such as fences. If necessary electrical isolation shall be included in these services/structures in order to limit the transfer of voltages, associated with Earth Potential Rise, to acceptable limits.

To minimise the hazard from touch and transfer potentials substations should not be constructed within 2 metres of large metallic objects, particularly metallic fences.

### **26.7.10 Transient Overvoltage Protection**

Appropriate surge protection shall be provided for the HV and LV distribution system.

Surge arresters shall consist of metal oxide varistors (MOV) shunt arresters specifically designed for multi-pulse lightning events on powerlines installed in the accordance with the requirements of AS 4070.

The arresters shall be segregated from other switchboard components by solid metal barriers.

All overhead/underground junctions shall be suitably surge protected.

#### **26.7.11 Defence Engineering Services Network (DESN)**

The requirements for interfacing equipment with the DESN is provided in the section dedicated to that system.

For further information and configuration requirements, refer to the Infrastructure Management - DESN.

#### **26.7.12 Substation Lighting and Power**

Provide general lighting with battery backed operation lighting (2 hour minimum) in the HV room, LV Switchroom and the LEG room, to allow operations to be performed during power outages.

Provide power outlets in each substation room as convenience outlets for maintenance purposes. These power outlets shall be supplied from the substation services section of the LV Switchboard.

# **27 Central Emergency Power Stations (CEPS), Central Power Stations (CPS) and Central Energy Plant (CEP)**

## **27.1 Background**

This policy defines the technical and operating requirements for centralised power generating plant including:

- a) Central Emergency Power Stations (CEPSs);
- b) Central Power Stations (CPSs)
- c) Central Energy Plants (CEPs)

This policy includes requirements for:

- a) Power station building layouts;
- b) Generating sets;
- c) Mechanical auxiliary systems;
- d) Electrical auxiliary systems;
- e) Control system hardware and software;
- f) Communications Networks, and
- g) Operating Philosophy.

This policy provides guidance and detailed technical material as necessary to define the Defence performance requirements and standards to be applied, in addition to the applicable statutory regulations and standards.

The content of reference standards, regulations and other publications, have not been repeated in this publication unless necessary for descriptive purposes. Where necessary and appropriate, reference is made to the source of the information.

When required, Defence establishments are provided with either one of two types of power station:

**Central Emergency Power Station** - is a standby power station provided where there is a requirement to supply power to the Base in the event of loss of the mains power supply. This generally is a requirement at establishments where important functions are performed, an example being aircraft operations as these are highly dependent upon power to ensure the continued operation of the airfield and supporting facilities.

**Central Power Station** - is a prime power station provided where mains supply is unavailable.

**Central Energy Plant** – is a power station that is used primarily to offset power purchases from the grid. It might also have cogeneration facilities to utilise waste heat.

The power station systems, either CEPS or CPS, need to maintain a high level of autonomy and reliability in the provision of electrical supply.

The CEPS/CPS works in close coordination with load shedding controls under the Defence Engineering Services Network (DESN) Power Control and Monitoring System (PCMS) module in order to ensure that the total Base load does not exceed the available generating capacity.

## **27.2 Performance Objective**

The objective of this policy is to:

- a) Facilitate fully automated power generation systems, albeit with routine operator intervention to safeguard the system;
- b) Provide a consistent operator interface for operators;
- c) Provide facilities that are fully compliant with NSP requirements;
- d) Safeguard high voltage systems operating activities;
- e) Ensure the economics of the design on a through life basis;
- f) Minimise the impact of single points of failure; and
- g) Facilitate energy management.

## **27.3 Referenced Documents**

### **Standards/Codes**

All materials and workmanship shall be of the best standard and shall comply with the relevant Australian Standards, or if such do not exist, with the relevant IEC or International (ISO) Standards.

Irrespective of any requirements shown in these documents the installation as a whole shall comply with:

### **Australian Standards**

- |             |   |
|-------------|---|
| AS 60529    | <i>Degrees of Protection Provided by Enclosures.</i>                        |
| AS 2381     | <i>Electrical Equipment for Explosive Atmospheres. (Series)</i>             |
| AS/NZS 3000 | <i>Wiring Rules.</i>  |
| AS 3702     | <i>Item Designation in Electrotechnology.</i>                               |
| AS 3013     | <i>Electrical Installations – Wiring Systems for Specific Applications.</i> |
| AS/NZS 3010 | <i>Electrical Installations – Generating Sets</i>                           |

AS 4070	<i>Recommended Practices for protection of low voltage electrical installations and equipment in MEN systems from transient voltages.</i>
AS 4168	<i>Programmable Controllers Part 2 Equipment Requirements and Tests.</i>
AS 4168	<i>Programmable controller Part 3 Programming Languages Structure.</i>
AS 61000	<i>Electromagnetic Compatibility (series).</i>

### **Other Standards**

The rules and regulations of the relevant NSP.

The Building Code of Australia (BCA).

IEC 61131-3    *Programmable Controllers – Programming Languages*

The requirements of any other Authority having jurisdiction over the installation.

## **27.4 Power Station Building Requirements**

### **27.4.1 Site Selection**

The site for the power station should be in general conformance with the area identified in the site electrical master plan. Detailed site selection within the master planned area needs to be considered. If there is no master planned site selected, the designer shall propose a site in the Concept Design Report. In evaluating sites the Designer shall consider the planning/design site selection and electrical criteria identified in this MIEE.

The final location must be agreed by DEEP as part of the design report process. Final ratification of a site is dependent upon local site approval procedures, such as site selection boards.

### **27.4.2 Site Access**

The requirements for access, including those for entry and also exits and escape, shall be considered in the design.

Particular attention shall be given to allowances for vehicular access. This includes access for:

- a) Construction activities for construction plant and equipment. Vehicles shall be assumed to be of the large flat bed truck types;
- b) Fuel deliveries.

### **27.4.3 Physical Arrangement**

#### Construction

Generating plant, switchboards and controls shall generally be located indoors within purpose built power station buildings. The use of freestanding outdoor generator enclosures can be considered but is subject to approval by DEEP. The materials from which the power station building is constructed, both internally and externally, shall be durable and suitable for long-term use without excessive maintenance.

#### Segregation of Equipment

Major items of plant shall be physically segregated within the building to minimise the potential for a single event to disable the entire station. The preferred arrangement includes the following individual spaces that have substantial physical and 2 hour fire rated barriers between them:

- a) Two generating halls;
- b) Two bulk fuel tank rooms, one associated with each generating hall ( where the bulk fuel storage is located within the building);
- c) Separate day fuel tank rooms for each hall (if required to address hazardous area considerations);
- d) Two HV electrical switch rooms, one associated with each generating hall, with direct access from the control room where possible, and
- e) A single control room.

Where there are no equivalent dedicated facilities accessible in the vicinity of the CEPS installation, the following additional rooms shall also be provided:

- a) A workshop incorporating appropriate space for CEPS spares holdings, and
- b) Lubricating oil store.

#### **Amenities**

The power station building shall include a Control Room, equipped as outlined in below.

Where the power station operates as a CPS or CEP installation, the following additional amenities shall be included:

- a) Toilet facilities;
- b) A sink with boiling water unit;
- c) A shower.

Other facilities as required may be included subject to DEEP approval.

### Visual Monitoring

Where possible the Control Room shall share common walls with the generating halls. Small fire and acoustic rated windows should be included in these walls to allow the operators to visually monitor the generating plant.

### Containerised Arrangement

Enclosures for containerised generating sets shall include the following additional features:

- a) The enclosure shall be trafficable so that an operator can walk around at least three sides of the generating set, within the enclosure.
- b) Safety clearances shall be adequate so that an operator can safely enter the enclosure and access the generating sets while it is running.
- c) The enclosure shall be adequately sound treated for the location in which it is installed.
- d) The enclosure shall be equipped with the following services:
- e) At least two power outlets, one on each side of the set;
- f) Self contained emergency lighting;
- g) A permanent monorail hoist to allow heavy components to be lifted and items of plant to be lifted and placed safely.

### **Equipment Layout**

The layout of the power station shall consider the following issues:

- a) The equipment layout shall provide adequate access for operation with all controls placed for ready access and with all indicators and instrumentation in easy to read locations. Station controls shall be in a single room unless formally agreed by DEEP.
- b) In the design of the equipment layout, adequate access for the installation and erection of the equipment shall be provided.
- c) Major equipment items shall not be located in such a manner that would prevent the safe removal and replacement of any other major item of the installation.

### Noise

The design of the power station shall limit the impact of noise on adjacent habitable spaces to acceptable levels. This should include suitable construction materials and the orientation of openings in the structure through which noise can escape.

Potential sources of noise emission include:

- a) Exhaust stacks;
- b) Radiators;
- c) Ventilation and other mechanical plant;
- d) Transformers, and
- e) Direct emission from the engine.

This includes plant that is located within the building that can escape the building through ventilation openings or the building structure.

The design should also consider the transmission of noise within the building, particularly to spaces that are normally occupied, such as the Control Room.

### Services

#### **Electrical**

Adequate power outlets shall be provided to facilitate the maintenance of equipment. In addition to general power outlets this should include future needs for welding and oil filtration equipment for large transformers.

Electrical lighting within the operational spaces shall be connected to a UPS that provides at least 4 hours of operation with all lights running. In addition single-point emergency and exit lighting shall be provided connected directly to the mains supply.

#### **Mechanical**

The Control Room and Switch rooms shall be air-conditioned. This shall be achieved using at least two AC units to achieve redundancy. 100% redundancy is not required, e.g. when two AC units are installed each should be sized to approximately 70% of the AC load.

#### **Communications**

The Control Room shall be provided with a telephone connected to the site telephone system.

#### **Defence Engineering Services Network (DESN) Provisions**

The Control Room is generally a major node of the DESN. The following facilities shall be provided within the Control Room to allow for the DESN:

- a) A office desk suitable for:
  - A PC and 21 inch screen;
  - Two inkjet printers.
- b) An office chair;
- c) Space for a 19 inch server rack (also to house the system UPS);
- d) Space for a 19 inch communications rack;
- e) Communications ducting from the Communications Rack location to:
  - Outside the building (100 mm dia) for installation of fibre optic cabling from outside the building;
  - To each PC and printer location.
- f) Power ducting (25 mm dia) from the Server Rack location for future installation of UPS cabling to power outlets at:

- At the PC;
  - At each printer;
  - The Communications Rack.
- g) Power ducting (32 mm dia) from each DC switchboard to:
- The Server Rack;
  - The Communications Rack.
- h) Power ducting (25 mm dia) from the AC switchboard to:
- The Server Rack;
  - The Communications Rack.

#### ***Electrical Isolation***

If the power station is connected to the site HV distribution system it will be a major substation on that system. Care should be exercised in the design of any external; services connections to minimise the possibility of transferring dangerous electrical potentials outside the station. This particularly includes adjacent metallic fences, and external pipe and electrical connections.

In general all pipe connections to the building should be non-conductive. Communications connections should be made through isolating transformers or be fibre optic.

#### **Passive Defence**

Passive defence requirements as identified in the Threat Assessment shall be considered in the design. As a minimum this should include:

- a) Location of fuel tanks underground or in other protected locations, with filling points located to minimise tampering;
- b) Location of external equipment out of direct line of sight from boundary fences or the provision of suitable physical protection from ballistic attack;
- c) Location of openings in the structure considering lines of sight from boundary fences; and
- d) Suitability to deal with ground shock and vibration isolation.

At northern bases passive defence normally includes protection against man portable weapons. In general terms this requires an earth covered structure. Such a structure poses a number of technical challenges, not the least of which is getting cooling air through the building while maintaining adequate levels of weapons protection. In addition target identification needs to be considered, particularly the thermal plume created by the power station. Suitable measures to reduce the temperature of the plume are attempering systems such as water sprays.

## **27.5 Generator System Requirements**

### **27.5.1 Reliability Issues**

#### Single Points of Failure

The design of CEPS systems shall eliminate the vulnerability to a single event or failure disabling the whole, or a large portion, of the power station. The only exception to this is the provision of a single Control Room for the whole station as outlined above.

Any other potential single points of failure shall be identified and documented in the design report for Defence agreement.

#### Unitisation

Ancillary plant shall be arranged so that a failure of this plant only affects a single generating unit. In particular the ancillary systems, such as day fuel tanks, fuel pumps, starting compressed air receivers, etc. associated with a particular generator shall not be shared with other generators.

#### Redundancy

Critical common systems, particularly those with higher failure rates, shall be duplicated. In particular:

- a) Duplicated DC supplies for control systems.
- b) Duplicated bulk fuel storage.
- c) Duplicated starting air compressors where air starting is utilised.

#### Segregation of Equipment

Critical systems and services shall be adequately separated so that a failure in one system does not affect adjacent systems. Particular attention shall be paid to separation of services between halls or other central locations.

#### Separation of Equipment from Adverse Environments

Where possible equipment shall be located away from extremes of temperature or vibration.

To the maximum extent that is practical all electronic components shall be located within the CEPS/CPS Control Room.

#### Fault Tolerance

Where common systems cannot be duplicated the system shall be designed to be tolerant of faults. In particular the system shall be capable of operating by alternate means in the event of a failure.

The Generator Control System (GCS) shall offer a manual control mode to mitigate against faults in the generator controllers or other parts of the generator control equipment. The control systems shall also comply with the requirements outlined in paragraph 27.6.2 below.

## **27.5.2 Mechanical System Requirements**

### **Generating Sets**

#### General

The engine shall be fitted with all protection devices necessary to ensure safe operation under the specified operating conditions.

The base frame of the generating set shall be isolated from the floor using seismic vibration isolators.

#### Supportability

Adequate local service support is therefore a key consideration in the selection of the generating sets.

In particular the generating sets installed within a CEPS do not normally operate for long periods and have relatively low running hours each year. They therefore are expected to be in service for a very long time. As such it is foreseen that their service life will eventually be determined by the availability of spare parts.

#### Rating

Generating sets need to be carefully selected according to their rating at a particular duty cycle.

Larger sets are usually rated at different power output levels for three typical duty cycles:

- a) Standby, where the set operates intermittently and for short duration, typically in response to a localised electrical fault;
- b) Prime, where the generator operates for longer periods as the sole power source for a site with a varying load, typically on loss of supply; and
- c) Continuous, where the generating set supports a load continuously, typically at establishments that are not connected to the mains grid but require a constant power source.

Sets for CEPS operations shall be rated for Prime duty under the service conditions expected within the power station.

Sets for CPS and CEP operation shall be rated for continuous duty under the service conditions expected within the power station.

#### Governing

Sets shall be capable of accepting or rejecting their full Standby rated load as a step load.

### **Starting Systems**

Generating sets shall be started using either electric or compressed air starter motors.

Electric starting shall not be used where the use of alternative fuels that are flammable, such as Avtur are to be considered in the design.

Compressed air systems shall include:

- a) At least two compressors (one electric and one diesel), one located in each generating hall;
- b) Isolation valves between the generating halls to allow the system to continue functioning upon the loss of one hall, and
- c) Separate air receiver for each engine.

### **Lubrication Systems**

The lubricating system shall be a positive pressure using an engine driven positive displacement pump.

Oil filters shall be suitable for 500 hours of continuous operation without servicing. They mounted vertically with the engine connection at the top.

It shall be possible to check the engine sump level while the engine is running.

The engine sump shall be provided with a sump drain extended to an accessible position on the base frame and fitted with a ball valve. The ball valve shall be lockable against accidental opening.

The crankcase breather shall be extended to a position that prevents any fouling of the radiator core.

### **Prime Sets**

On sets for prime power applications provide:

- a) An oil manifold that allows oil filters to be changed while the engine is running without affecting oil flow to the engine.
- b) An oil burn system that continuously adds oil to the sump using a dosing pump and burns the excess oil.

### **Fuel Systems**

Fuel storage shall be provided adequate to continuously run the entire station at full load for the following periods:

- a) CEPS, or stations with a CEPS role: 96 hours (4 days), unless agreed in writing be DEEP
- b) CPS stations: 168 hours (7 days), subject to local supply limitations, In particular consideration must be given to events that can isolate the site (flooding, for example) and their potential impact mitigated by correct sizing of the bulk storage.
- c) CEP stations: 24 hours (1 day)

Smaller fuel storages might be considered if:

- a) There are large storages of alternate fuels on the site that can be used to refill the CEPS fuel storage, or

- b) The proposed size of the fuel storage will create fuel management issues. In particular if it is projected that the testing and normal operation of the station will result in the fuel inventory taking in excess of two years to turn-over.

Bulk fuel installations shall generally be underground, with a minimum of two, dual skin tanks with interstitial space monitoring connected and alarmed to DESN.

For fuel dispensing operations, the surrounding area shall be designed to safely accommodate fuel spills. Concrete bunding or channelling and underground fuel traps may be used to contain fuel spills. The bunded area shall be covered or have some automatic means of emptying any rainwater.

It should be noted that, particularly where Avtur is used, a fuel spill could create a hazardous area near the ground (see Avtur Characteristics, below). Electrical equipment in this area may need to be selected for hazardous area use.

Day tanks shall generally be provided. These shall be fitted with an independent fuel shutoff so that they cannot be overfilled should a fault develop with the control system or return fuel lines.

The generating hall floor shall fall towards the floor trenches or a large sump. The trench/sump shall be fitted with sensors so that a fuel spill is detected and fuel supply is isolated.

#### Alternative Primary Fuels

Diesel engines can burn a variety of fuels other than diesel, albeit with various drawbacks. If there are large storages of these alternative fuels on the site at which the power station is being constructed their use as an emergency fuel shall be considered in the design to the extent to which this can be done without adding significantly to the overall cost. These alternative fuels might be present in the fuel tanks as a cocktail with diesel.

The main alternative fuel is Avtur, which is often available if the site supports aviation operations. The main disadvantage of Avtur is that it is a flammable liquid, however there are a number of other issues as discussed below.

It is presently intended that the station exclusively use diesel as a fuel and there is no intention to change this policy at this stage. The design of the power station will consider the requirements for alternative fuels, such as Avtur or diesel/Avtur cocktails in the design. The following discussion on the use of Avtur and diesel / Avtur cocktails, is provided as background information only and should not be taken as definitive.

#### AVTUR Characteristics

- a) Avtur is classified (refer AS 1940) as a flammable liquid and is potentially more hazardous from a fire or explosion perspective than diesel, which is classified as combustible.
- b) Avtur has lower energy content than diesel. Hence the same engines operating under the same fuel delivery conditions will deliver lower output when operating on Avtur.

- c) Viscosity information on Avtur is not readily available, as the relevant standard does not require it to be measured. Information available (such as the Report on “Use of Aviation Turbine Fuel JP-8 as the Single Fuel on the Battlefield”) reports a viscosity of 1.26cSt at 40°C for the JP-8 fuel used for their testing. JP-8 is equivalent to both NATO Code F-34 fuel and to Avtur.
- d) Avtur with FSII absorbs moisture and causes corrosion of fuel components.
- e) Avtur has higher volatility than diesel fuel and when it is drawn from a tank by suction is likely to vaporise.
- f) Avtur is not miscible with diesel and has a tendency to separate out over time.

#### ***Hazardous Area Issues***

Avtur is flammable liquid and so presents a potential explosion hazard if exposed to (electrical) devices where arcing or sparking may occur, and to temperatures above 38°C as will be encountered in the Generator Hall.

Even though the Avtur is only a component of the fuel its presence has a potential to create a flammable gas atmosphere out of proportion to its percentage in the fuel mix. Therefore, there are hazardous areas surrounding the fuel pipe work, including the pumps, flanges and valves.

#### ***Engine Output Issues***

The use of lower energy fuels means that for the same power output the engine uses more fuel. Disregarding other factors, the absolute maximum power output of the engine is therefore limited by how far the fuel rack opens. It should be noted that the engines have a standby rating which is approximately 10% above prime rating. This means that the fuel rack is capable of moving beyond the 100% prime power position to accommodate the lower energy fuel.

#### ***Engine Operating Issues***

Aviation fuel and kerosene are often used in operating diesel engines in cold climates. With the higher ambient temperatures, the viscosity of exclusive Avtur fuel is lowered to such an extent that reduced self-lubrication of the fuel system becomes an issue.

For a typical diesel engine, a minimum viscosity of 1.5cSt at 38°C is required at the engine transfer pump to properly lubricate the fuel system components.

The operation of the generating set diesel engine on exclusive Avtur is feasible but there would be a loss of operational life compared to operation on diesel due to the lower viscosity / lubricity of the fuel. It is noted that Avtur has a lubricity improver added; however the effect on the life of a diesel engine is unknown. Short-term or infrequent operation on Avtur or the use of diesel / Avtur cocktails is not expected to significantly reduce engine life.

### **AVTUR Corrosion Issues**

Problems have been experienced due to the absorption of water vapour by Avtur and consequent corrosion of storage tanks and fuel lines. Industry practise has increasingly moved away from mild steel tanks and lines, and toward the use of coated tanks and stainless steel fuel lines.

### **AVTUR Volatility Issues**

The characteristics of Avtur effectively prevent it being drawn from a tank by suction. Hence the use of Avtur could require the provision of a long-column tank-mounted pump with impellors immersed in the liquid or a pump at a lower level than the tank. Immersed “dispenser” pumps such as the “Red Jacket” pump widely used in the commercial / retail petroleum sector are capable of pumping diesel and Avtur when used in this duty.

### **AVTUR Miscibility Issues**

While Avtur is lighter than diesel, it is not inherently miscible with diesel, and exhibits a tendency to globulate or separate out of mixture. To address separation / stratification issues fuel circulation pumps would be required to mix the fuel in the storage tanks. This would ensure that a fuel cocktail was delivered through the fuel reticulation system to the engines as a homogeneous mixture.

### **Cooling Systems**

In general radiators for standby applications shall be set mounted and prime power applications shall be remote.

Radiators shall be sized to make allowance for not less than 20% reduction in heat transfer capacity as a result of fouling.

The radiator fan shall be sized to provide adequate cooling airflow allowing for any external pressure drop as a result of the inlet and outlet flow path. Where the fan draws air through the generating hall this can include the inlet flow path and/or attenuators, and the outlet flow path and/or attenuators.

### **Exhaust Systems**

Exhaust piping shall consist of spirally welded 302 or 304 stainless steel piping sized in accordance with the engine manufacturer’s recommendations.

Exhaust piping within the building shall be lagged using mineral fibre insulation (not fibreglass), suitable for service up to 650°C, not less than 75 mm thick. The insulation shall be sheathed throughout using 0.5 mm zocalume sheet steel or stainless steel.

The exhaust system and silencer shall be supported on spring suspension hangers to minimise vibration transfer to the structure.

A suitable cowling shall be provided to prevent rain entering the exhaust system. Where passive defence measures require, ensure that the exhausts do not directly exit the building.

The silencer shall be provided with a drain to remove condensation. This drain shall run to a 0.6 litre capacity open top container near ground level to allow the condensation to evaporate.

### **Ventilation**

Generally, where set-mounted radiators are employed, the radiator fans shall be positioned to draw cooling air into the generator hall via a louvered and vermin-proofed penetration in the building wall.

Where use of the radiator fans alone is not considered adequate, additional thermostatically controlled ventilation fans may be installed.

For Bases in cyclone-prone areas where the power station is desired to operate during a cyclone, the ventilation intake and outlet shall be installed on the same side of the CEPS building, with care taken to ensure adequate cooling in all areas of the hall. This practice creates a pressure-equalised building, which allows the ventilation system to continue operating in cyclonic conditions where a significant pressure differential may develop across the building.

The direction and temperature of the exhaust air from the power station should be considered where identification of the power station using its thermal plume has been identified as a risk in the Threat Assessment.

### **27.5.3 Electrical System Requirements**

#### **Wiring Systems (WS) Classification**

In addition to the requirements for hazardous areas the wiring systems shall provide resistance to damage from mechanical factors and fire consistent with the environment and the purpose of the installation. The required WS classification shall be indicated in the design documents.

Wiring systems within 2 metres of the floor of generating halls should be minimum WS2X.

#### **Electrical Connection**

The standard configuration for Defence establishment distribution networks is described in the LV and HV Distribution Systems IM.

In brief:

- a) An establishment has multiple points of electrical supply;
- b) The HV distribution is divided into rings, with each ring starting and terminating at a different electrical supply point;
- c) Dedicated Interconnector cables exist between supply points to facilitate power transfer in the case of partial supply failure; and
- d) The CEPS is located at a supply intake point.

The generating sets shall operate in parallel, sharing equal portions of the load, and connect to a section of the intake bus such that generators may operate in parallel with external mains supply or as the sole source of power.

The various modes of HV network operation are described in Chapter 3 – High Voltage System Master Plans and Project Development Plans and Chapter 26 – High and Low Voltage Distribution System Requirements.

### **Generator Alternators**

Alternators shall generally be self-excited, brushless 400 volt synchronous machines. Where the sets connect to a high voltage network unit step-up transformers shall be used. The generating unit shall be provided with an automatic voltage regulator (AVR) designed to offer regulation to  $\pm 1\%$  for power factors between 0.8 and unity for all load levels.

Should physical constraints preclude the use of step-up transformers the use of high voltage alternators can be considered subject to DEEP agreement.

As with all other generating components, the alternators shall be selected on the basis of reliability, availability and quality of local support services from the manufacturer or their representative.

### **Alternator Protection**

Provide a protection-grade specialist generator protection relay to provide electrical protection of the alternator on generating sets with the following protection elements:

- a) Over current;
- b) Earth fault;
- c) Reverse power, and
- d) Stator winding temperature.
- e) Over voltage;
- f) Under voltage;
- g) Over frequency;

For generating sets rated above 800 kW, or those which power high voltage electrical networks under normal operation the following additional protection elements shall be provided:

- a) Generator biased differential;
- b) Voltage dependent over current;
- c) Loss of excitation;
- d) Over fluxing;

### **DC Systems**

The control system shall be powered from a redundant, battery-backed DC supply.

The system shall consist of:

- a) Two hot-swappable battery chargers (A&B), each capable of supplying the full load of the control system while charging one battery bank in a period of less than 16 hours from 90% discharged;
- b) Two battery banks (A&B), each capable of supplying the full load of the control system with all equipment running for a period of more than 16 hours without mains supply.
- c) A DC switchboard with two bus sections. The switchboard shall incorporate:
  - A separate circuit from each bus section to each control panel;
  - A separate circuit from each bus section to each other control system load that is connected directly to the switchboard;
  - Sufficient switching so that each battery and charger can be disconnected from the bus or that the two buses can be cross connected.

Chargers shall be capable of running in parallel. The battery system shall be fitted with all protection devices necessary to ensure safe operation under the specified operating conditions. It shall be appropriately monitored by DESN.

In the event of failure of one DC bus, the system shall automatically changeover to the other.

Batteries shall consist of single strings unless parallel strings are specifically required by DEEP.

Batteries shall have sealed cells with a design life of at least 10 years under the conditions in which they are installed.

Battery systems shall only be sourced from manufacturers with prominent factory support within Australia and preferably within the region where the sets are installed. They shall be of a model with a large installed user base in the local region.

At each load there shall be either:

- a) An arrangement to select which DC bus is connected, or
- b) Contactors so that the equipment can seamlessly take supply from either DC bus.

#### HV Requirements

Requirements for the HV installations are contained in chapter 26. Particular attention is drawn to the requirement for synchronism check relays on HV circuit breakers.

It is preferred that the alternators be solidly earthed however the use of resistive/reactive earthing or Neutral Earthing Contactors (NEC) might be necessary to limit the impact of circulating currents.

## 27.5.4 Control System Requirements

### Reliability Issues

#### Segregated Control Panels

Each generator shall have its own segregated Generator Control Panel that houses the Generator Controller, the AVR, and governor/load sharing module and all local indication and control pushbuttons specifically for that generator.

A Station Control Panel shall be provided to house the GCS Station Controller, the GCS Network Hubs and any general local indication and control associated with the power station including the mimic panel, but not directly related to any particular generator.

Wiring from one control panel to another shall not generally pass through other control panels.

#### Fault Tolerance

Each generator shall be capable of operating independently following a failure of the GCS Station Controller or other Generator Controller, or their associated systems. In the event of failure of the GCS Station Controller or systems this is expected to require operation of the generator in the manual mode. As a minimum this shall include:

- a) **Dedicated Controllers** - Each generator shall incorporate a dedicated Controller to monitor and control its respective auxiliaries and operating parameters.
- b) **Dedicated Control Equipment** - Each generator shall incorporate dedicated synchronising, speed control and voltage regulation equipment.

#### Communications Segregation

A dedicated communications network, independent of the Defence Engineering Services Network (DESN) or any other network, shall carry all internal traffic between the elements of the GCS.

All serial communications between GCS components, whether this is Ethernet, RS485 or other protocols, shall occur through hubs. Hubs shall be located in the Station Control Panel.

#### Hazardous Areas

Control Systems shall not be located in hazardous areas or explosives areas as defined by the appropriate regulations, codes and standards.

### Control Panel Requirements

#### Location

The Station Control Panels and Generator Control Panels shall be located side-by-side in the Control Room, preferably on the wall adjoining the generating hall/s.

The Station Control panel shall be located in the middle between the Generator Control Panels for each hall. The order of the Generator Control Panels shall match the physical order of the generating sets when seen from the front of the panel.

### Metering

All analogue information displayed on control panels or generator set gauges shall be input into the Controller for monitoring and trending purposes.

### Operator Interface

The operator interface for each panel shall consist of a single integrated panel, not a collection of display panels from various manufacturers.

The operator interface for each Generator Control Panel shall be similar and these should have a common look and feel with that provided on the Station Control Panel.

Similar events and operations between panels shall be displayed and occur in a consistent fashion.

There should be sufficient indicators and meters to easily and accurately portray the state and condition of the whole plant to semi skilled operators. The following are typical examples:

- a) The operator should understand why the generator is running, e.g. when it is in cooling down mode, and
- b) It should not be possible for a set to trip or shutdown a generator or function without an indicator illuminating on the appropriate panel. This also includes any grouped trips. Similarly, it should be obvious to an operator why a set won't or could not operate.

The controls shall be arranged in a logical and ergonomic manner with commonality of all control switches, indicators, meters and the like. Devices shall be of the type most suitable to convey their purpose. For example:

- a) Circuit breaker status should be indicated by semaphore;
- b) Meters for comparative purposes should be together;
- c) Colour should use to indicator status/purpose, and
- d) Illuminated push buttons can be misleading and confusing and should not be used.

Only one operator should be used to serve one purpose in each panel, i.e. one push button for alarm acknowledge. Provide a lamp test facility on each panel to test all lamps, LED's, etc. on that panel.

The control parameters used by the control system, such as timers etc, must be site programmable without the need for any software or hardware changes. The programmable settings should be easily changeable via the associated control panel.

Indication and control on Generator Control Panels and the Station Control Panel may be provided by LEDs, LCD displays or HMI panels, however as a minimum the following shall be provided independent of the operation of any LCD display or HMI panel. Switches and indicators shall be oil-tight 22mm series.

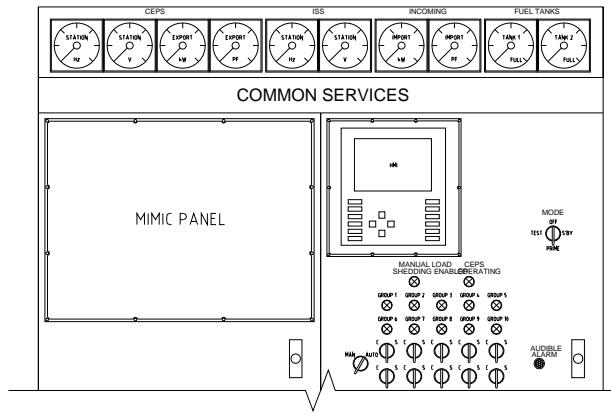
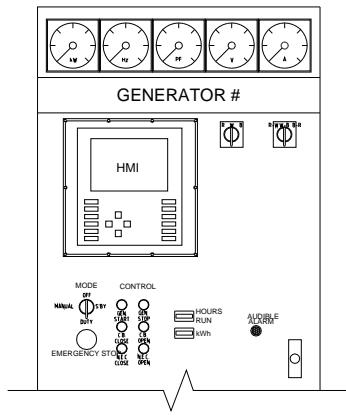
- a) Station Control Panel
  - Station Mode Switch.

- Spinning Reserve on front of panel, other thumb wheel inside (e.g. feeder demand, peak lopping, etc)
  - Load shed controls
  - HV Mimic Panel
  - Electrical metering as detailed below
- b) Generator Control Panels:
- Generator Mode Switch;
  - Emergency Stop pushbutton;
  - Generator Start/Stop pushbuttons;
  - Generator circuit breaker Open/Close pushbuttons;
  - Neutral Earthing Contactor Open/Close pushbuttons;
  - GCB semaphore;
  - NEC semaphore;
  - Generator Running indicator, and
  - Generator Fault indicator
  - Electrical metering as detailed below
  - Generator status indicators as detailed below

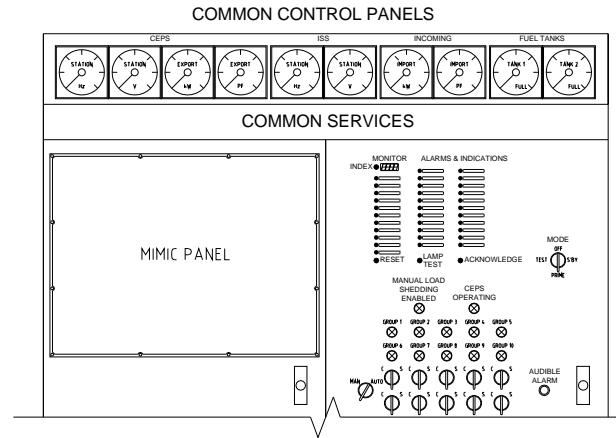
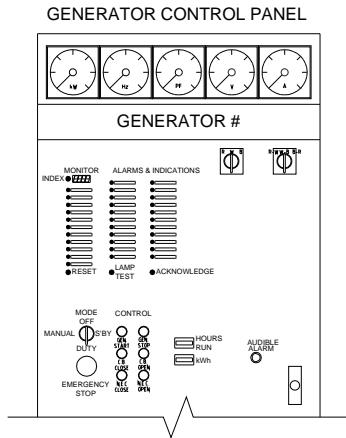
#### Standard LED Based Panel Requirements

Acceptable panel arrangements are provided in Figure 27.1 and Figure 27.2 as detailed below:

#### **Standard Arrangement Drawings**

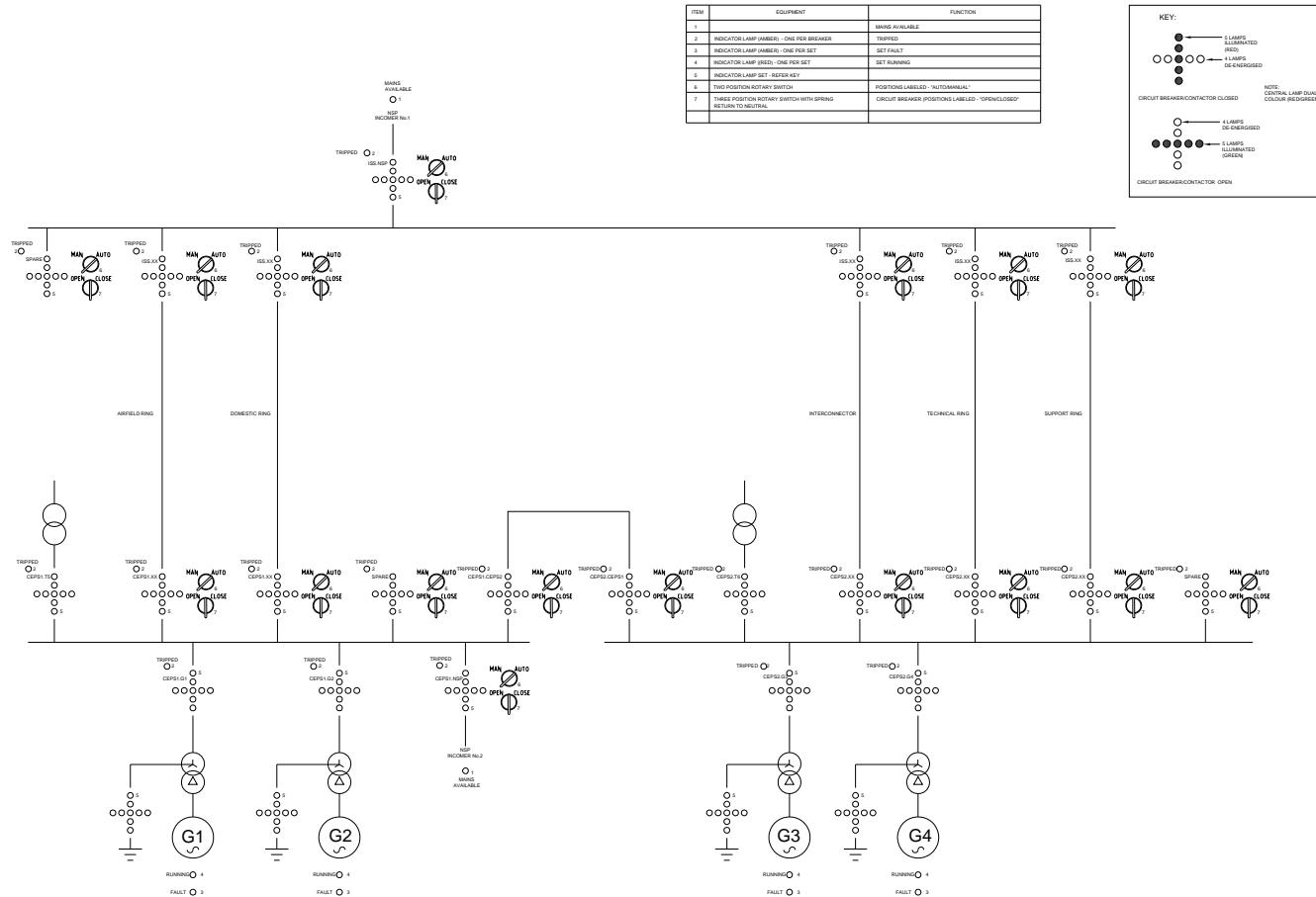


TYPICAL GENERATOR CONTROL PANELS (HMI TYPE)



TYPICAL GENERATOR CONTROL PANELS (MANUAL TYPE)

■ **Figure 27.1: Typical CEPS/CPS Panel Details**



■ **Figure 27.2: Typical CEPS/CPS HV Mimic Panel Details**

### **HMI Panel Requirements**

Defence places great importance on ensuring uniform operator interfaces and therefore HMI panels must ensure common functionality is achieved with the general arrangement of the LED specified above. Where it is proposed that HMI panels be used DEEP requires the system topology and screen layouts including a SCADA map for endorsement prior to finalising the design.

Each HMI panel shall be full colour and of such size and resolution so as to enable easy viewing of the on-screen data.

Touch screen panels shall not be used.

In addition to providing indication and status display, HMI panels may be used to set/adjust the following values:

- a) Trip frequency tolerances
- b) Trip time delays;
- c) Generating set capacity; and
- d) Load shedding values

When this approach is used, provide password protection of the values to prevent inadvertent changes and perform a self-check of the values to ensure values are within acceptable ranges.

Operator screens shall be easy to negotiate and be structured in a logical manner according to:

- a) Generator set;
- b) System Type; and
- c) Importance.

The generator status shall always be displayed on each page so that it is always possible to see what is happening with the set.

Similarly it shall always be possible to see what the overall station is doing and why.

### **Generator Control Panels**

In addition to any controls and indicators described elsewhere, provide the following at each Generator Control Panel:

- a) Metering of electrical parameters;
- b) Metering of engine parameters;
- c) Status of generator set including:
  - Running
  - Synchronising
  - Online
  - Cooling down

- Engine Stopped
  - Not available
  - Call to Start
  - Call to Stop
- d) Individual indicators for each Warning and Alarm condition.

#### Metering

The level of metering provided for each generating set will be dependent upon the installation and in particular the size of the generating set. As a minimum the following level of metering shall be provided on all generating sets:

- a) Frequency;
- b) Volts (each phase);
- c) Current (each phase);
- d) Power factor;
- e) kWh;
- f) Hours run;
- g) Speed;
- h) Oil pressure after filter
- i) Cooling water outlet temperature;
- j) Starting battery volts or air pressure.

For generating sets above about 800 kW the following additional metering shall be provided:

- a) Oil pressure before filter;
- b) Oil temperature;
- c) Cooling water inlet temperature;
- d) Combustion air temperature;
- e) Exhaust temperature (each bank);
- f) Alternator winding temperatures;
- g) Alternator bearing temperature;
- h) Boost pressure;

Where the metering being provided is to a lower level than described above the designer shall detail this in the CDR.

Metering for kWh and Hours Run shall be from the controller.

### **Generator Warnings**

In response to the operation of an engine or alternator warning shutdown the set when another set is online to take over (see paragraph 27.5.5 Control Philosophy). Reset the warning flag upon removal of the condition and the Reset button being pressed.

Provide sufficient Warnings for each generator set such that adequate indication is provided of any pending alarm. Generally provide warnings for the following:

- a) Low Pressure Condition;
- b) High Temperature Condition;
- c) Fuel High/Low;
- d) Overload Condition;
- e) Neutral Earthing Contactor (NEC) fault;
- f) Non-critical generator ancillary faults; and
- g) Other warnings as necessary to annunciate generator set is not healthy i.e. Controller alarm, synchroniser alarm etc.

### **Generator Shutdown Alarms**

In response to a Shutdown being initiated immediately:

- a) Open the generator circuit breaker
- b) Remove excitation and, after a cool-down period
- c) Stop the generating set.
- d) Flag the set as being Not Available and lockout any attempt to start the set. Reset the flag and lockout when the condition is removed and the Reset button is pressed.

Provide sufficient Alarms for each generator set such that equipment does not reach a damaging state or limits that damaging state. Generally provide Alarms for the following:

- a) Alternator over temperature;
- b) Set underspeed / overspeed;
- c) HV Protection Relay fault;
- d) HV Protection Shutdown signal including the individual display for actual protective element that has operated;
- e) Fail to synchronise;
- f) Low Fuel;
- g) NEC Fault;
- h) Any other trip that is required to ensure that the generator set or associated equipment does not reach a damaging state or if it does then the limit of damage is a minimum.

### **Generator Trip Alarms**

In response to a Trip being initiated immediately:

- a) Open the generator circuit breaker;
- b) Remove excitation and stop the generating set;
- c) Flag the set as being Not Available and lockout any attempt to start the set. Reset the flag and lockout when the condition is removed and the Reset button is pressed.

Provide sufficient Trip Alarms for each generator set such that equipment does not reach a damaging state or limits that damage state. Generally provide Trip Alarms for the following:

- a) Generating Hall Fire Alarm;
- b) Controller Failure;
- c) Bearing over temperature;
- d) Generator and HV Protection Trip signal, including an individual display for the actual protective element that has operated;
- e) Any other trip that is required to ensure that the generator set or associated equipment does not reach a damaging state or if it does then the limit of damage is a minimum.

#### Generator Starting System Alarms

In response to an alarm being initiated immediately:

- a) Flag the alarm and lockout any future attempt to start the set. Reset the flag and lockout when the condition is removed and the Reset button is pressed.

Provide the following alarms:

- a) Starting air low pressure or starting battery low voltage for more than 15 minutes continuously  
If the set is already running it shall remain running. Any lockout shall only take effect once the set stops.

#### **Station Control Panel**

In some older systems this panel is often known as Common Services.

In addition to any controls and indicators described elsewhere the Station Control Panel shall house the Station Controller. The Station Mode selector switch, HV mimic and load shedding controls shall be mounted on the front.

Provide indicators and meters to indicate the overall status of the station and the incoming feeders so that it is immediately obvious as to why the station is running, or not.

Provide indicators and meters to indicate status of all common or ancillary systems, such as fuel systems. Sufficient of these should be independent of the Station Controller such that if this controller fails then the Station can still be operated manually.

#### Indicators

In addition to indicators for the station auxiliary systems the following indicators shall be provided:

- a) Restricted Operation – Any condition that restricts the automatic operation of the power station, such as if the CEPS bustie is open;
- b) Mains fail;
- c) Lack of Capacity – Insufficient generating capacity to meet the load and spinning reserve;
- d) Load Shed – Load shedding operations in progress;
- e) Peak Lopping – Peak lopping operations in progress.
- f) Feeder Limit – Feeder demand limit operations in progress;
- g) LEG Run on – LEG Run On signal active

### **Warnings and Alarms**

Provide warnings and alarm signals for all major items of station plant.

The following minimum alarms shall be provided:

- a) Fire alarm for each generating hall – Shuts down the generating plant and fuel supply in the affected hall;
- b) Air compressor alarms;
- c) Neutral earthing alarm;
- d) Ventilation faults;
- e) Battery supply faults;
- f) Fuel tank low level alarms;
- g) Generating hall high temperature

### **Metering**

As a minimum the following level of metering shall be provided:

- a) Bulk fuel tank levels
- b) Generating hall temperatures;
- c) Control room temperature;
- d) Starting air system pressure;
- e) Control battery voltages;
- f) Voltage and Watts at each incoming feeder.
- g) Voltage at each bus (ISS, CEPS1 and CEPS2)
- h) Frequency at each CEPS bus (CEPS1 and CEPS2)
- i) Combined Watts and power factor being supplied from the mains.
- j) Combined Watts and power factor being supplied by CEPS.

Frequency, voltage, VA, current and power factor in the HV system shall be provided as 96 mm, 90-degree scale, analogue meters mounted above the control panel.

## Mimic Panel

### **Construction**

The mimic shall consist of an aluminium plate that is screen printed with the mimic layout of the establishment system.

The mimic shall be located on the front of the Station Control Panel.

Alternate mimic arrangements will be considered, but require the approval of DEEP.

### **Indicators**

The following indicators shall be located on the mimic:

- a) Power Available indicator (Red) for each incoming feeder;
- b) Status indicators for each HV CB and NEC, including:
  - Semaphore for Open/Closed status;
  - Tripped status indicator (Yellow) for each HV CB;
  - Manual status indicator (White) for each HV CB that is under manual control from the mimic;
  - Local (Remote control Inhibited at CB) status indicator (Blue);
- c) Running and fault indicators for each generating set. These signals shall be derived directly from the devices not through the Station Controller.

### **Controls**

The following controls shall be located on the mimic:

- a) Auto/\_/Manual mode selector switches for each HV CB that is under the control of the GCS;
- b) Open/\_/Close switch for each HV CB that is under the control of the GCS

Switches shall consist of 22 mm series, oil-tight rotary switches with centre spring return.

### **HV Access Key Switch**

Provide a HV Access key switch that is a permissive on the operation of the HV Mimic as follows:

- a) When the key is withdrawn:
  - A change to the Auto/Manual mode of the HV circuit breakers is inhibited
  - Manual operation of the HV CB in Manual Mode is inhibited.
  - Automatic operation of HV CBs in Manual mode is inhibited
  - Automatic operation of HV CBs in Auto Mode is permitted
- b) When the key is inserted:
  - A change to the Auto/Manual mode of the HV circuit breakers is permitted
  - Manual operation of the HV CB in Manual mode is permitted.
  - Automatic operation of HV CBs in Manual mode is inhibited

- Automatic operation of HV CBs in Auto Mode is permitted

Insertion or removal of the ‘HV Access’ key shall be bump less. The Auto/Manual mode shall remain unchanged when the key is inserted or removed.

An acceptable HV Mimic arrangement is provided at Figure 27.2.

#### Load Shedding Panel

A load shedding panel shall be provided that allows the individual selection of automatic and manual control of each load shedding group. The operation of this panel shall be entirely independent of the Station PLC/Controller to enable the load shedding to be operated in the event of PLC/Controller failure.

The panel shall contain the following:

- a) An Auto/Manual rotary switch for each load group;
- b) A Shed//Connect spring-return rotary switch for each load group;
- c) A Manual (Yellow) that lights if any load group is in Manual control;
- d) A Shed (Blue) indicator for each load group;
- e) A CEPS Operating (Green) indicator;

Switches and indicators shall be 22 mm oil tight.

Transfer between Automatic and Manual mode shall be bump less.

An acceptable load shedding panel arrangement is provided at Figure 27.1

#### **Alternator Protection**

Where a specialist generator protection relay is required it shall be configured to provide the following voltage free outputs:

- a) Trip Prime Mover: This signal is generated if a fault is detected by the protection relay that will cause further damage if the generator continues to rotate. This signal is latching.
- b) Shutdown Prime Mover: This signal is generated if a fault that will not cause further damage if the generator continues to rotate is detected by the protection relay. This signal is latching.

After each of the above signals is received the Generator Controller shall take the required action and interrogate the protection relay to determine the individual protective element that has operated.

Each generator protection relay shall have a voltage free contact to indicate Healthy status (watchdog). The Generator Controller shall use this contact to determine if the protection relay has a fault.

Where a specialist protection relay is not required the above functions shall occur entirely within the Generator Controller.

### **Feeder Protection**

Where parallel operation of the power station with the mains is possible the HV protection shall protect against the following contingencies while running in parallel with the mains:

- a) A fault on the HV network external to the facility. This shall be done using directional overcurrent protection on the incoming feeders as a minimum.
- b) A failure of the mains supply. This shall be done using a combination of the following means:
  - Intertrip signals from the NSP, where available.
  - Reverse power protection, where the station does not export power to the mains;
  - Vector shift or Rate of Change of Frequency (ROCOF) protection.

Protection for loss of the mains shall:

- a) Open the incoming circuit breaker so that it does not lock out and can be reclosed by the GCS when the mains returns, and
- b) Send a signal to the GCS. The GCS will then operate as for a mains failure.

Alternatively the above function can occur entirely within the Station Controller where this functionality exists.

### **Defence Engineering Services Network (DESN)**

The DESN is an establishment wide control and data acquisition system generally consisting of networked data gathering points or Remote Terminal Units (RTUs) and a central operator interface. The system monitors and/or controls various engineering services, with particularly emphasis on the electrical power systems. On a number of bases the DESN is known by other names e.g. PCMS.

Where a DESN is not provided or has not been fully implemented, many control and monitoring functions are instead hardwired back to a central point, usually the CEPS.

### ***Monitoring, Trending and Logging***

Where a DESN has been provided, the DESN shall monitor, trend and log the status and condition of the CEPS plant, including load-shedding commands.

Provide all necessary DESN software and hardware for the DESN to perform this function. This shall include the provision of dedicated display pages covering the CEPS plant and the integration of CEPS alarms/warnings into the DESN alarm-handling algorithm.

The GCS shall pass all plant analogue and event/alarm/warning data to the DESN in such a manner that the DESN is not able to write to the GCS registers or affect the operation of the GCS. It is preferred that this requirement be implemented by some form of hardware firewall.

### **LV Load Shedding**

Where a DESN has been provided it is generally in direct control of the low voltage load shedding devices (where these exist). Alternatively, at older establishments the low voltage load shedding devices can be hardwired back to some central location (usually within the CEPS).

Provide an interface at the GCS to the DESN and/or the hardwired load shedding device. The signals from the GCS shall consist of voltage free contacts, one for each load-shedding group. Also provide a voltage free contact to indicate that the CEPS is operating, i.e. any of the generating sets is running and connected and an analogue output of the Available Capacity.

### **LEG Run-on**

LEG Run-on signals are provided to the LEGs so that they continue to run on power failure, even after the CEPS is supplying the Base.

Where a DESN has been provided it is generally in direct control of the LEG run-on. Alternatively, the run-on is hardwired back to the CEPS.

Provide an interface at the GCS to provide the run-on signal consisting of voltage free contacts. Connect this to the DESN and/or the hardwired control cabling system to achieve the run-n function.

Provide an Auto/Force Off/Force On key switch within the Station Control Panel to provide manual override of this function.

## **27.5.5 Control Philosophy**

### **Control Philosophy Definitions**

**Available:** Generating sets are available if they are in Duty or Standby mode and do not have an alarm showing.

**Available Capacity:** The On-line capacity less the Spinning Reserve.

**Call to Start:** A signal from the Station Controller to a Generator Controller to start, synchronise and connect the generating set. The set remains unloaded until separately commanded to assume load by the Station Controller. The Call to Start shall remain active while ever the generating set is required to run. The Call to Start is removed when the Station Controller issues a Call to Stop.

**Call to Stop:** A signal from the Station Controller to a Generator Controller to unload the generating set, open the generator circuit breaker and after the required cool down period stop the engine. The Call to Stop is removed when the engine has stopped.

**Capacity Control:** The control algorithm that ensures that the correct number of generating sets are operated to supply the present load. When Capacity Control is disabled the system shall operate all available generating sets independent of the load connected.

**Feeder Demand Limit:** A defined capacity (in MVA) for each incoming feeder.

**Load Shedding Control:** The control algorithm that ensures that the connected load is within the capacity of the CEPS. This is achieved by shedding individual facility loads on the LV system and by coarse load shedding on the HV system. When Load Shedding Control is disabled all HV feeders and LV load groups shall connect.

**Load Shedding Hysteresis:** The capacity, in excess of the Spinning Reserve, that must be present for the load shedding system to attempt to connect new load groups. The hysteresis is a nominal value that limits the occurrence of shed-connect-shed hunting in the load shedding system.

**Minimum Import Level:** The minimum power transfer that is permitted on the incoming feeders while the generators are running in parallel with the mains. This is usually a requirement of the NSP, however where such a limit is not imposed by the NSP the limit shall be set so that the Station does not export power to the grid.

**On-line Capacity:** The prime capacity of the generating sets that are presently on-line and supplying Base load. A generating set shall only be included in the calculation if the following conditions are satisfied:

- a) The set is running; and
- b) Its generator circuit breaker is closed

**Remaining Capacity:** The Available Capacity less the System Load.

**Spinning Reserve:** The minimum reserve capacity that shall be available on the system at any time. The spinning reserve is at least equal to the largest load that can be expected to connect during normal system operation. This is usually the largest pump or other motor, or the largest load connected to a LEG.

**System Load:** The total electrical load presently being supplied. This includes all power station loads and system parasitic loads. The system load shall be a thermal load calculated by applying a first order filter, with a time period of 5 seconds, to the instantaneous values.

#### **Assumed Configuration**

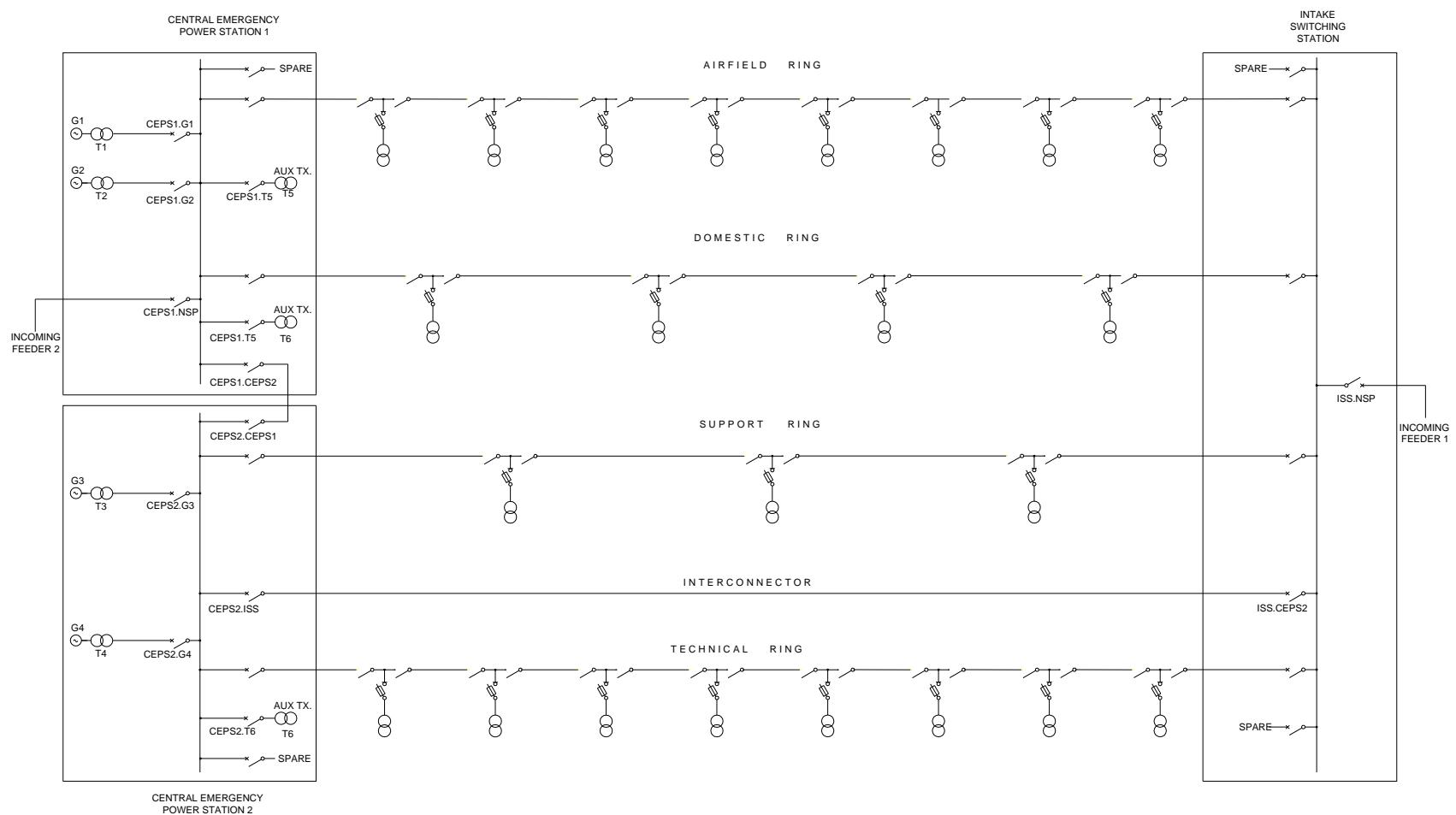
The following control philosophy assumes the following electrical configuration also provided at Figure 3.1, *Typical Base HV System*:

- a) Two HV points of supply, one to CEPS and other to ISS; it is assumed that the NSP only makes one supply available at a time by isolating the other supply at a point external to the Base.
- b) One CEPS facility with generation, connected to a split generator bus;
- c) Interconnector between CEPS and ISS;
- d) Ring mains, generally running between ISS and CEPS.

The control system shall allow the normal operation of the CEPS with any on-base reticulation system configuration except where otherwise allowed in this Chapter. In particular, the CEPS shall continue to operate as a standby power station with any on-base HV configuration.

Modifications to this control configuration that are necessary as a result of other electrical configurations should be indicated in the FDB and be further detailed by the Designer in the CDR for DEEP agreement.

Figure 3.1 is copied again below for convenience.



■ Figure 27.3: Typical Base HV System

### **Generator Control System (GCS) Hardware**

The generator control system shall generally consist of the following individual items:

- a) Station Controller including control, load sharing and mains synchronising functions;
- b) An individual Generator Controller for each generator; including control governor, AVR, load sharing and generator synchronising functions;
- c) Generator Control Communications Network;
- d) DESN interface;
- e) Protection relay interface;
- f) Local indication and controls as required.

Maximum use shall be made of open systems and protocols.

Multifunction Generator Controllers that perform multiple tasks that would normally be performed by separate items of equipment are permitted. However, load sharing and control for the generators shall be separate to the GCB protection relays.

### **HV System Operating Modes**

#### Operation

All HV circuits at CEPS and ISS, with the exception of the generator and auxiliary transformer CBs, shall be under the control of the Station Controller. This enables the GCS to open and close these circuit breakers in coordinated response to a power outage or initiate load shedding, should this be required. The auxiliary transformer CBs shall not be controlled by the GCS and shall be only operated locally at the HV Switchboard.

The generator CBs and any generator Neutral Earthing Contactors (NECs) shall be under the control of the individual Generator Controllers and are controlled with the generating sets (see Generating Set Operating Modes).

#### HV CB Manual Mode

In manual mode the operation of the HV CB shall be from a rotary, centre spring return, “Open/\_/Close”, control switch located on the mimic.

#### HV CB Auto Mode

In auto mode the operation of the HV CB shall be from the GCS.

#### ***Failed Automatic Sequences***

A failure of the following HV CBs to operate either:

- a) An incomer HV CB to open or close, or
- b) A GCB to open

In response to a command under an automatic sequence will affect the execution of the subsequence sequence as follows:

- a) Initially flag a warning and suspend the sequence until the CB operates. Recomence the sequence when the CB operates.
- b) If the sequence is still not complete after 30 minutes flag an alarm and the abort the sequence.

For example the failure of a GCB to open when the generator is being taken off line will result in the set continuing to run indefinitely at no load. A warning will be flagged initially and an alarm after 30 minutes.

Such an event could occur if the CB is in Manual mode at the mimic, in Local mode at the CB or as a result of a fault.

Note: A failure of a GCB to close when synchronising will result in a Fail to Sync alarm being flagged in a quicker timeframe in accordance with the standard Generator Controller requirements.

Failure of an Interconnector or ring main HV CB to operate in response to a command shall be ignored.

### **Generator Operating Modes**

#### Operation

Each generating set, and its associated HV CB and NEC shall be under the control of its own Generator Controller. The Generator Controller shall be able to start and stop the set, and to initiate synchronisation and control the NEC even if the Station Controller or the GCS network is not operational.

The controls for each generating set and its associated HV CB and NEC shall be located within separate control panels segregated from the others and the Station, so that a failure in one panel will not affect the whole station.

An individual Emergency Stop consisting of a red, mushroom head pushbutton that is turn-to-release shall also be mounted on each Generator Control Panel.

#### Mode Selection

Each individual generating set shall have a single, rotary, “Manual/Off/Duty/Standy” selector switch that determines the operating mode of that generating set and its associated HV CB and NEC.

A suitable time lag shall be incorporated in processing the mode selection to allow one mode to be selected directly from any other mode in a bump less transfer.

## Generating Set Operation

### **Manual Mode**

In manual mode starting and stopping of the prime mover shall be from Start and Stop pushbuttons. The GCB shall be controlled from Open and Close pushbuttons. When the Close pushbutton is pressed the generating set shall synchronise with the mains and the circuit breaker close. When the Open pushbutton is pressed the circuit breaker shall immediately open. If the Open pushbutton is held, the control system shall carry out a ‘soft unload’ of the generators. The circuit breaker shall open immediately on release of the button or when the sets are unloaded.

### **Duty and Standby Modes**

In either Duty or Standby mode the generating set shall start, synchronise and connect in response to a Call to Start from the Station Controller. It shall also disconnect, and cool-down and stop in response to a Call to Stop from the Station Controller.

### **Synchronisation**

The first set to reach speed shall connect to the HV Bus by closing its HV CB subject to automatic dead bus control. The other sets shall synchronise with the live HV bus and close their HV CBs, thereby connecting to the HV bus. The automatic start, synchronisation and bus connection shall be coordinated to avoid two machines “racing” each other and both connecting to what appeared to be a dead bus.

## HV Neutral Earthing Operation

### **Run-up, Shutdown and Alarms**

It is preferred that the generator circuit be protected from earth faults during run-up and shutdown using neutral displacement protection. If neutral displacement protection is provided the NEC shall be open whenever the GCB is open. If neutral displacement protection is not provided the neutral earthing contactor shall be closed while the GCB is open during run-up and shutdown in all operating modes.

Following operation of a protective device the NEC shall operate as follows:

- a) Generator Protection Trip: The NEC shall open and remain open
- b) Generator Protection Shutdown: The NEC shall close when the GCB is open and remain closed until the generator stops.

### **Manual Mode**

The NEC shall operate as described above for Generator start-up and shutdown.

During synchronisation the Generator Controller shall monitor the bus voltage on the bus to which it is about to connect. If the bus voltage is healthy it shall assume that the HV system already has an earth reference and open its NEC when the GCB closes. If the bus is dead it shall close its NEC when the GCB closes.

If at any time the NEC Open or Closed pushbuttons are pressed then the NEC shall operate in response.

#### **Duty and Standby Modes**

When the generator circuit breaker is closed the NEC shall close and open in response to a command to the Generator Controller from the Station Controller.

The Station Controller shall ensure that there is one, and only one, earth reference on the HV system, whether this be the mains or a NEC.

Should a NEC fail to operate when commanded then flag a NEC Fault for that set. It shall then attempt to close a NEC on another set.

If the situation is not corrected within 5 minutes then flag a Neutral Earthing alarm.

### **Station Operating Modes**

#### **Mode Selection**

The Station Control Panel shall have a single, rotary, “Test/Standy/Prime” selector switch that determines the operating mode of the entire power station.

A suitable time lag shall be incorporated in processing the mode selection to allow one mode to be selected directly from any other mode in a bump less transfer.

#### **Station Test Mode**

Test Mode is used to periodically load test the generators. This is done by running the sets against the mains and transferring the Base load to the sets.

If it is desired to load test a single set the remaining sets should be set to Off mode at their respective Generator Control Panels.

Capacity Control and Load Shedding Control shall be disabled so that all Available sets run and all load is connected.

Test Mode can only reliably operate when the HV distribution system is in its normal “closed up” configuration. If the HV system is split as a result of a CEPS/CPS Bus-tie being open or an Interconnector cable being out of service the GCS cannot easily identify how its actions will affect the power flows in the HV system or the incoming feeders. In order to prevent undue complications in the control system Test mode shall be disabled if the CEPS/CPS Bus-tie is open or an Interconnector cable is out of service. The Station Control Panel shall have a suitable Test Mode Disabled indication.

#### ***Starting Test Mode***

Upon Test Mode being selected the Station Controller shall sequentially:

- a) Issue a Call to Start all Available sets. (The Station Controller programming shall allow for starting of all sets, including those indicated as future, but shall only effect the starting of those installed initially). In response the individual Generator Controllers shall start the set synchronise with the mains, close their associated generator HV CB and remain unloaded until all available sets are connected.
- b) Progressively load all generators to 100% of prime capacity as derated for the site and service conditions. Should the load of the Base be less than the connected generator capacity, then limit the load on the generators so that the Base always imports the defined Minimum Import Limit. During this period, no power shall be exported from the Base into the Grid.

#### ***Mains Failure***

A failure of the mains supply while running in test mode will be detected by the incoming feeder protection. The HV protection will open the connected incoming feeder circuit breaker to isolate the mains supply and provide a digital signal to the GCS. The GCS mains fail alarm shall remain latched in order to alert the operator to the mains failure.

In response to this event the Station Controller shall sequentially:

- a) Provide “LEG Run-On” signal to the PCMS.
- b) Enable Load Shedding Control. HV ring mains shall remain closed unless commanded to open by the Load Shedding Control
- c) After a programmable delay (from 0 to 20 minutes, initially set at 5 minutes) to reach stable load, enable Capacity Control to operate the appropriate number of generator sets.

#### **Mains Return**

A return of the mains supply will be detected by the phase failure relay/s on the HV switchboard incomers. In response to this condition being continuously present after a programmable time period (0 to 30 minutes, initially set at 5 minutes), the Station Controller shall sequentially:

- a) Synchronise to the mains and close the incoming feeder HV circuit breaker to reconnect mains supply.
- b) Withdraw the “LEG Run-on” signal from the DESN to allow shut down of LEGs.
- c) Remove Capacity Control, which will start and synchronise all available duty/standby sets.
- d) Disable Load Shedding Control, which will reconnect all loads. Reconnection of loads back to mains shall be done in a progressive manner to avoid large load steps to the NSP.
- e) Restore Test Mode operation.

#### ***Selecting Standby Mode When Mains Available***

When Test mode is de-selected and Standby is selected when the mains is available, the Station Controller shall sequentially:

- a) Remove the Call to Start and issue a Call to Stop to all sets.
- b) When each set stops remove its Call to Stop.

- c) If the mains should fail before expiration of the cool down period, the system shall respond with a Black Start as per Standby mode except the generators are already running.

#### ***Selecting Standby Mode When Mains Unavailable***

When Test mode is de-selected and Standby mode is selected after the mains has failed, the Station Controller shall:

- a) Continue to run the generators
- b) Operate in accordance with Standby mode.

#### ***Selecting Prime Mode When Mains Available***

When Test mode is de-selected and Prime mode is selected when the mains is available, the Station Controller shall sequentially:

- a) Disable the minimum import limit on Test Mode, allowing the generators to run to full load.
- b) Enable Load Shedding Control to shed or reconnect facility loads to limit connected load within the station capacity.
- c) Immediately when the power imported from the main falls below the Minimum Import Level open the incoming feeder circuit breaker. Note: This needs to occur within the time constraints of any low forward power or reverse power protection on the incoming feeders.
- d) After a programmable delay (from 0 to 20 minutes, initially set at 5 minutes) to reach stable load, enable Capacity Control in order to operate the appropriate number of generating sets.

#### ***Selecting Prime Mode When Mains Unavailable***

When Test mode is de-selected, and Prime mode is selected after mains has failed (resulting in the system being in a default Standby mode), the Station Controller shall sequentially:

- a) Continue to run the generators
- b) Withdraw the “LEG Run-On” signal from the PCMS to allow shut down of LEGs.
- c) Operate in accordance with Prime mode.

#### **Station Standby Mode**

In this mode the station shall operate as a standby power station that provides power at times when the mains supply is not available.

Capacity control shall be used to operate the appropriate number of generating sets and load shedding control shall be used to regulate the load.

The presence of the mains supply will be detected using phase failure relays on each incoming feeder.

### **Mains Failure (Black Start)**

In response to a mains failure being continuously present for a programmable time period (as directed by the NSP (default 10 seconds)) to allow for automatic reclosing in the mains network the station controller shall sequentially:

- a) Open the connected feeder HV CB.
- b) Issue a Call to Start to all available sets;
- c) Open all HV ring main and Interconnector circuit breakers. Any Bus-ties shall remain closed.
- d) Shed all LV load groups.
- e) Initiate a “LEG Run-On” signal via the PCMS to ensure that the LEGS continue to operate after the CEPS is connected.
- f) Wait till all available sets are connected.
- g) Close the Interconnector HV CBs;
- h) Enable Load Shedding Control, which will:
  - i) Sequentially close all feeder HV CBs,
  - j) Sequentially reconnect load groups
- k) Allow the Load Shedding System to reach a stable state i.e. no load shedding operations for a programmable delay (from 1 to 10 minutes, initially set at 5 minutes) (not necessarily with all loads connected). Enable Capacity Control to operate the appropriate number of generator sets.

### **Mains Return**

In response to mains being continuously available for a programmable period. (as directed by the NSP (0-30 minutes, default 10 minutes)) the Station Controller shall sequentially:

- a) Synchronise to the mains and close incoming feeder circuit breaker.
- b) Remove the “LEG Run-On” signal via the PCMS to allow the LEGS to shutdown
- c) Disable Load Shedding Control, which will reconnect all loads. Reconnection of loads back to mains shall be done in a progressive manner to avoid large load steps to the NSP.
- d) Remove the Call to Start and issue a Call to Stop to all running sets.
- e) When each set stops remove its Call to Stop.

### **CEPS Bus-tie**

Whilst the normal configuration of the CEPS is with the CEPS HV Bus-tie closed, the Station Controller shall monitor the status of the Bus-tie and adjust the station operation to suit.

The GCS shall operate to ensure that there cannot be two unsynchronised supplies connected to the system. In particular:

- a) If the CEPS Bus-tie is open and a ISS/CEPS Interconnector cable is in service:
  - Enable only those generators that are connected on the CEPS bus to which the Interconnector is connected. The station controller shall be inhibited from issuing a Call to

Start to the generators that are connected to the other CEPS bus however they will be able to operate in Manual mode. The disabled generators shall indicate that they are “Not Available in Auto” on their Generator Control Panels when they are in Duty or Standby mode.

- b) If the Bus-tie is open and the ISS/CEPS Interconnector cable is out of service:
  - Enable only those generators that are connected CEPS bus to which has the highest Available Capacity. The Station Controller shall be inhibited from issuing a Call to Start to the generators that are connected to the other CEPS bus however they will be able to operate in Manual mode. The disabled generators shall indicate that they are “Not Available in Auto” on their Generator Control Panels when they are in Duty or Standby mode.

#### ***Selecting Test Mode Under Mains Failure***

When Standby mode is de-selected and Test mode is selected when the CEPS is operating in response to a Mains Failure, the Station Controller sequentially:

- a) Remain in standby mode until mains supply is continuously restored for the mains return time period.
- b) Carry out all sequences as documented under Test mode except that some sets will already be running.

#### ***Selecting Prime Mode Under Mains Failure***

When Standby mode is de-selected and Prime mode is selected when the CEPS is operating in response to a Mains Failure, the Station Controller shall:

- a) Withdraw the “LEG Run-On” signal from the PCMS to allow the LEGs to shutdown.

#### **Station CPS Prime Mode**

Operate as required for prime mode and in particular ignore any restoration of mains supply.

In this mode the station operates as a prime power station islanded from mains supply.

Capacity Control shall be used to operate the appropriate number of generator sets and Load Shedding Control shall be used to regulate the load.

#### ***Starting Prime Mode***

Upon prime mode being selected the Station Controller shall sequentially:

- a) Issue a Call to Start to all Available sets. (The Station Controller programming shall allow for starting of all sets including those marked as future but shall only affect those installed initially). In response the individual Generator Controllers shall start the sets synchronise with the mains, close the associated generator HV CB, and remain unloaded until all available sets are connected.

- b) Progressively load all generators to assume the Base load while maintaining the Minimum Import Level.
- c) Enable Load Shedding Control keep the demand within the capacity of the CEPS.
- d) Open the incoming CB to island the base.
- e) After a programmable delay (from 0 to 10 minutes, initially set at 5 minutes) to reach stable load, enable Capacity Control to operate the appropriate number of generator sets.

#### ***CEPS Bus-tie***

Whilst the normal configuration of the CEPS is with the CEPS HV Bus-tie closed, the Station Controller shall monitor the status of the Bus-tie and adjust the station operation to suit.

The GCS shall operate to ensure that there cannot be two unsynchronised supplies connected to the system. In particular:

- a) If the CEPS Bus-tie is open and a ISS/CEPS Interconnector cable is in service:
  - Enable only those generators that are connected CEPS bus to which the Interconnector is connected. The station controller shall be inhibited from issuing a Call to Start the generators that are connected to the other CEPS bus however they will be able to operate in Manual mode. The disabled generators shall indicate that they are “Not Available in Auto” on their Generator Control Panels when they are in Duty or Standby mode.
- b) If the Bus-tie is open and the ISS/CEPS Interconnector cable is out of service:
  - Enable only those generators that are connected CEPS bus to which has the highest Available Capacity. The Station Controller shall be inhibited from issuing a Call to Start the generators that are connected to the other CEPS bus however they will be able to operate in Manual mode. The disabled generators shall indicate that they are “Not Available in Auto” on their Generator Control Panels when they are in Duty or Standby mode.

#### ***Selecting Standby Mode When Mains Available***

If Prime mode is de-selected and Standby mode is selected when the NSP supply is available, the Station Controller shall sequentially:

- a) Synchronise CEPS with the NSP mains across the appropriate HV incoming circuit breaker depending upon which supply was in use when Prime mode was selected.
- b) Close the incoming circuit breaker.
- c) Disable Load Shedding Control, which will reconnect all loads. Reconnection of loads back to mains shall be done in a progressive manner to avoid large load steps to the NSP.
- d) Disable Capacity Control.
- e) Remove the Call to Start and issue a Call to Stop to all running sets.
- f) When each set stops remove its Call to Stop.

### **Selecting Standby Mode When Mains Unavailable**

When Prime mode is de-selected and Standby mode is selected when the NSP mains has failed, the Station Controller shall sequentially:

- a) Continue to supply the Base load using capacity control to operate the appropriate number of generating sets.
- b) Issue a “LEG Run-On” signal to the PCMS to cause the LEGs to start and continue to run.

### **Selecting Test Mode When Mains Available**

When Prime mode is de-selected and Test mode is selected, when the NSP mains is available, the Station Controller shall sequentially:

- Synchronise with mains across the appropriate incoming circuit breaker.
- a) Close the incoming circuit breaker.
  - b) Disable Load Shedding Control, which will reconnect all loads.
  - c) Disable Capacity Control.
  - d) Operate as required under Test mode.

### **Selecting Test Mode When Mains Unavailable**

When Prime mode is de-selected and Test mode is selected, whilst the NSP mains has failed, the Station Controller shall sequentially:

- a) Issue the “LEG Run-On” signal to the PCMS to cause the LEGS to start and continue to run.
- b) Once the NSP mains returns and remains stable for a predetermined period as directed by the NSP (a programmable time period between 0 to 30 minutes, default 5 minutes), synchronise CEPS with the NSP mains across applicable incoming circuit breaker.
- c) Close the incoming Circuit breaker.
- d) Remove the “LEG Run-On” signal via the PCMS to allow the LEGS to shutdown.
- e) Disable Load Shedding Control, which will reconnect all loads.
- f) Disable Capacity Control
- g) Operate as required under Test mode.

### **Station Peak Lopping Mode**

The GCS shall include a Peak Lopping Mode that enables the generator to be used to supplement the mains supply. The Peak Lopping mode will be enabled whenever the GCS is in Test or Standby Mode.

Peak Lopping Mode can only reliably operate when the HV distribution system is in its normal “closed up” configuration. If the HV system is split as a result of the CEPS Bus-tie being open being out of service the GCS cannot easily identify how its actions will affect the power flows in the HV system or the incoming feeders. In order to prevent undue complications in the control

system Peak Lopping Mode shall be disabled whenever the CEPS Bus-tie is open or an Interconnector cable is out of service.

The peak lopping mode shall be triggered by the following events:

- a) Base Demand Limit: This acts to prevent the Base demand exceeding a defined MW or MVA setpoint. This setpoint is defined from either:
  - A thumbwheel switch or similar, within the Station Control Panel, or
  - A 4-20mA signal from the Energy Management System (EMS).

The selection shall be via a Off/MW Local/MVA Local/MW EMS/MVA EMS rotary switch within the Station Control Panel.

- b) Feeder Demand Limit: This acts to prevent the load on any incoming feeder exceeding the capacity of that feeder and acts independently of the Base Demand Limit.

Upon either Demand Limit being exceeded the generators shall automatically start, synchronise and connect as follows:

- a) The instantaneous load shall be continuously monitored and a first order filter with a time period of 10 minutes applied to calculate a thermal load. When this thermal load exceeds one of the active setpoints the system shall determine how many generators are necessary to keep the demand within the specified limits.
- b) The required number of duty generating sets shall be issued with a Call to Start, causing them to start, synchronise and connect to the mains.
- c) The load on the generator/s will be controlled to maintain the thermal load on the mains at less than the programmed Peak level and also maintain the minimum recommended load on the generator/s. The GCS shall also maintain the Minimum Import Level on all feeders.
- d) Enable Capacity Control to operate the appropriate number of generating sets.
- e) When the thermal load of the Base drops below the relevant setpoint (less the Spinning Reserve as hysteresis to ensure stability) for a predetermined period, the last generating set shall be issued with a Call to Stop.

Example

For:

Feeder Demand Limit = 6.0MVA

Spinning Reserve = 0.5MVA

Genset Capacity = 1.0MVA

Genset Minimum Load = 0.3MVA

- f) When the 10 minute thermal demand rises above 6.0MVA one set will receive a Call to Start.
- g) The set will synchronise and connect. It will then ramp up until it operates at 0.3MVA. This will reduce the feeder load to 5.7MVA.

- h) If the Base load increases to above 6.3MVA the set will take on more load to ensure the feeder load stays below 6.0MVA.
- i) If the Base load increases above 7.0MVA a second set will start and once connect will share load with the existing set.
- j) If the load then falls below 6.5MVA the second set will disconnect and stop
- k) If the load falls below 5.5MVA the last set will disconnect and stop.

### **Station Capacity Control**

The Station Controller shall determine the amount of generation capacity required to meet the System Load and Spinning Reserve. It shall use this information to schedule on the required number of generating sets.

Should the HV ring mains or load groups be shed as a result of a lack of Available Capacity the system shall seek to run additional sets to provide adequate capacity.

When determining which sets to schedule on the Station Controller shall first issue a Call to Start to those Available sets that are in Duty mode and then those in Standby mode. If all Available sets are running, and additional capacity is still required, the Station Controller shall issue a Call to Start to those sets that are not Available due to a Warning, however these sets shall be used as a last resort only.

Should a set become not Available while running the Station Controller shall immediately issue a Call to Start to a replacement set, if available, and transfer the load to this new set. Once the new set has assumed the load the Station Controller shall then issue a Call to Stop to the set that is no longer Available. If no replacement set is Available then the not Available set shall continue to receive a Call to Start.

The running sets shall share both real and reactive power in proportion to the set capacities. Set capacity shall be determined from a value stored in the relevant Generator Controller, not in the Station Controller. This figure shall be stored in a single location in the controller program, and shall be initially set at the prime rating of the set appropriately de-rated for the site.

In order to prevent unnecessary starting and stopping of sets the system shall provide hysteresis between starting and stopping of sets based on the Remaining Capacity of the CEPS and the time at that load. This can be done as a percentage of the On-line Capacity such that trigger points at say 80%, 90% and 100% of capacity as well as having a predictive load ramp function. At 100% load it is expected that an immediate signal would be sent to run available engines. The same procedure would be adopted for reductions in load to shut down generator sets. It is preferred that some of the time delays are incorporated in the Generator Controller thus permitting the “Call to Start” and “Call to Stop” indicators to represent their true function.

When Capacity Control is disabled the GCS shall issue a Call to Start to all Available sets. This will cause these sets to run and connect.

## **Station Load Shedding Control**

### Load Shedding Devices

Load-shed devices are provided on the LV side of the distribution substations or at the facilities that enable those facilities to be disconnected from the electrical system. These load-shed devices are under the control of the Power Control and Monitoring System (PCMS) that runs on the Defence Engineering Services Network (DESN). Each load-shed device is allocated to one of ten load groups within the PCMS and can be individually controlled from the DESN Terminal. The PCMS disconnects and connects load groups on request by the Station Controller. These requests are passed using hardwired lines that connect the two.

Load shedding, at a more course level, can also be accomplished by operating of the HV circuit breakers that control the HV ring mains. These HV circuit breakers are under the direct control of the Station Controller.

### Load Shedding Mode Selection

Each load group shall have a single, rotary, “Manual/Auto” selector switch located on the front of the Station Control Panel that determines the operating mode of that load group.

The control switches, and indicators showing the status of each load group are also located on the front of the Station Control Panel, directly below HV system mimic.

Changing between modes shall be bump less.

### Load Shedding Manual Mode

In manual mode the operation of the load group shall be from a rotary, centre spring return, “Shed/\_/Connect”, control switch.

### Load Shedding Auto Mode

In auto mode the operation of the load group shall be from the Station Controller.

The following parameters determine the operation of the load shedding system:

- a) Spinning Reserve – see Definitions.
- b) Load Shedding Hysteresis – see Definitions.
- c) On-line Capacity – see Definitions.
- d) Available Capacity – see Definitions.
- e) System Load – see Definitions.
- f) System frequency

Three (3) events shall initiate an automatic disconnection of load. These events shall be based on the following parameters (with adjustment of trigger levels and ring main priorities programmed into the Station Controller at a single location to allow easy alteration):

- a) **System Load exceeds Available Capacity:** Under this event either the power station is overloaded or there is inadequate reserve. Load must be disconnected to restore the Spinning Reserve. In most cases this is a relatively minor overload that can be corrected by minor load shedding.
- b) **Set failure:** A set has failed and as a result there is likely to be a shortage of capacity. As each set has a significant capacity the shortage in capacity is likely to be large and need more extensive load shedding.
- c) **System Frequency:** and Time at this Frequency: Should the system frequency fall then there has been a significant failure event and the stability of the entire system is at risk. In order to prevent collapse of the system and the need for manual re-start, gross load shedding is necessary to remove bulk load from the system as quickly as possible.

The load-shed strategy shall be as follows:

■ **Table 27.1 Load Shed Strategy**

Event	Event Trigger	Action
1a	System Load exceeds On-line Capacity for more than 2 seconds	Shed one load group immediately then the remained, in priority order, at 2-second intervals until the situation is corrected.
1b	System Load exceeds Available Capacity for more than 120 seconds	Shed one load group immediately then the remained, in priority order, at 2-second intervals until the situation is corrected.
2	Set failure	<p>Reducing the Available Capacity by the capacity of the set that has failed.</p> <p>Shed the next two load groups immediately then monitor capacity as per Event 1. Number of load groups to be shed shall be site adjustable. Start another set, if available, to replace the one that has failed.</p>
3a	System below 48.5 Hz for 1 second	Shed all connected load groups in priority order at 0.5 second intervals
3b	System below 48.5 Hz for 2 second	<p>Shed all connected load groups.</p> <p>0.5 second later shed the lowest priority HV ring main then the others, in priority order, at 0.5 second intervals until the situation is corrected</p>
3c	System below 47 Hz for 0.5 seconds	Shed all connected load groups Shed all HV ring mains.

The timing of the load shedding actions shall be trimmed during commissioning to ensure system stability. When the CEPS is supplying the Base the GCS shall automatically reinstate loads as capacity becomes available. The GCS shall continue to connect loads provided:

- a) System frequency is above 49 Hz for the last 15 seconds, and
- b) System Load is lower than the Available Capacity less the Load Shedding Hysteresis

The connection of loads shall proceed as follows:

- a) Connect the HV ring mains, one end at a time, in priority order, at 4-second intervals.

- b) Once all ring mains are connected and the system has been stable for 6 seconds it shall start connecting load groups in priority order at 4-second intervals until the connected load exceeds 80% of the Remaining Capacity. Then loads shall be reconnected at 20-second intervals.

The connection of any HV ring main or load group shall be reversed if either of the following conditions occurs:

- a) System Load exceeds the On-Line Capacity for more than 2 seconds, or
- b) System Load exceeds the Available Capacity for more than 120 seconds.

The GCS shall measure System Load before a HV ring main or load group is connected and also the System Load at the time of disconnection. From these values it shall calculate the incremental load associated with that HV ring main or load group. Before the GCS attempts to reconnect this HV ring main or load group it needs to ensure that there is adequate capacity for this increased load. It shall do this by changing the Load Shed Hysteresis to equal the size of the incremental load with an additional 10% margin to avoid any possibility of hunting. Thus when spare capacity exceeding the new load shed hysteresis is available the GCS will again try to reconnect the load.

The Load Shed Hysteresis shall be reset to its default value when:

- a) The load reconnection is successful, or
- b) The relevant load group is switched to Manual mode at the Load Shedding Panel or the HV ring is switched to Manual mode at the HV mimic.

When Load Shedding Control is disabled the GCS shall progressively reconnect all remaining loads, as above, until the system is fully connected. Load Shedding Control shall remain active until the last load group is reconnected. In particular it shall ensure that the feeders do not exceed their Feeder Demand Limits as the loads are restored.

#### **Detection of Mains Failure while in Parallel with Mains**

The control system shall detect a mains failure while the generators are running in parallel with the mains and immediately open (non-latching) the incoming HV CB to isolate the Base. The system shall then operate as for a mains failure.

The following means shall be used to detect a mains failure:

- a) Reverse power (when the installation is not permitted to export power)
- b) Vector shift or Rate of Change of Frequency, particularly when the installation is running at relatively high import or export levels.
- c) Power flow at the incomer dropping to zero: The control system should not operate at zero power transfer across the incomer HV CB for extended period if the CB is closed. If the power flow remains near zero for an extended period then a power failure has occurred.

## **Setting of Control Parameters**

### Spinning Reserve

The spinning reserve is set using a 3½ digit thumb wheel switch or other approved device on the front of the GCS Station Controller cabinet and will initially be set to accommodate the largest single load that can be expected to be started (default 300 kW).

### Load Shedding Hysteresis

Its default value is set using a 3½-digit thumb wheel switch or other approved device within the GCS Station Controller cabinet (default 200 kW).

### Feeder Demand Limit

The values shall be set using a 3½ digit thumb wheel switch for each incoming feeder or other approved device within the GCS Station Controller cabinet and be settable up to the maximum expected long term feeder load (in MVA). It is recommended that initially the Feeder Demand Limit be set to the Authorised Feeder Demand defined in any connection agreement with the NSP.

### Final Values

The final values of the control parameters shall be determined during commissioning to ensure system stability.

## **27.5.6 Controller Requirements**

### **General and Hardware**

The general topology of the generator control system shall include the use of a Generator Controller in each of the Generator Control Panels and a Station Controller in the Station Control Panel within the CEPS Control Room. Remote controllers or I/O modules shall be located at any other PSSs.

Inclusive in the Controllers shall be watchdog timer, real time clock/calendar and all other facilities to ensure successful operation.

### **Input and Outputs**

The Design shall maintain a level of not less than 20% spare I/O within each Controller.

### **Software**

#### Standard

All custom software to be in accordance with AS 4168.3 (IEC 1131.1 - 1993) Programmable controller Part 3 Programming Languages Structure.

### Nomenclature

The Design shall coordinate with other Trades to ensure that I/O descriptions, tags, displays, software annotation and labelling are consistent generally and the same for any individual signal or function throughout the establishment.

### Functional Description

A copy of the functional description shall be provided in the operations and maintenance manuals.

### Licensing

Provide a full version, licensed copy of all software necessary to reprogram or interrogate each Controller, registered in the name of the Principal.

At least 1 (one) copy of all appropriate custom Controller software developed by the Contractor shall remain with the Principal.

Any software patches issued within the defects and liability period that pertain to the brand and version of software utilised within the GCS system shall be supplied free of charge from the Contractor.

### **Diagnostic Functions**

The Controller CPU shall constantly perform self-checks to identify any memory, system-program or user-program faults. The power supply, battery, I/O bus and cycle time shall also be monitored.

### Self Test

The Controller shall be provided with a self-test facility that can be activated by service personnel only. This facility shall test the correct operation of the major elements of the Controller.

### Power Supply

The Controller shall be suitable for operation from a nominal 24 V DC power supply.

## **27.5.7 Attempering Control Systems**

### **General**

Attempering systems use water sprays to reduce exhaust gas temperatures from each generator set. The purpose of the cooling sprays is to reduce the exhaust gas temperatures expelled into the atmosphere so as to reduce the heat signature of the CEPS installation.

Provide an On/Off switch on the Station Control Panel cabinet to enable or disable the Attempering System

### **Control Philosophy**

Modulate the water flow in the Attempering System in response to exhaust air temperature. The control algorithm shall ensure that the maximum exhaust air temperature reduction is achieved and

at the same time the risk of fogging external to the building and wastewater discharge are minimised. To achieve this compensate for ambient air conditions.

#### **27.5.8 Communications**

Communications equipment shall generally be connected to the local batteries that supply the GCS. Where this is not possible, the equipment shall be connected to a guaranteed supply from either a standalone UPS with at least the same standby duration as the GCS battery system or from an inverter off the GCS batteries. The GCS network shall be completely separate to and segregated from any other network.

## **28 Reserved (PCMS)**

## **29 Reserved (Operation of Power Generation and Electrical Reticulation Systems)**

## **Appendix A Electrical Engineering Design Compliance Guide**

# Introduction

## Background

There are numerous policies, regulations, codes of practice and standards that must be complied with throughout the design process. This applies to a number of disciplines including mechanical engineering, civil engineering (pavements), fire protection, electrical services and security services.

Whilst design policies exist, the design compliance framework needs to be made more transparent to designers and acceptance reviewers alike to ensure high rates of compliance and efficiency throughout the process.

## Purpose of this document

To provide a Design Acceptance Compliance Guide that assists DSG Project Managers and Designers to understand and comply with the DSG – DEEP electrical engineering design policy and wider Defence requirements as required by the Manual of Infrastructure Engineering Electrical (MIEE).

# Design Compliance Guide Instructions

## Design Plan

Prior to undertaking the design, the designer shall prepare a detailed design plan. During the design, it shall be regularly updated to reflect any changes. It is recognised that the design plan will need continual development and updates but the basic information as best known at the time should be contained in the plan. The design plan shall conform to the requirements of the designers' quality manual but in addition shall include the following minimum requirements:

- 1) Which version of the Building Code of Australia is likely to apply to the installation.  
If the version is likely to change prior to finalising the design, provide a plan for managing the required change.
- 2) Relevant parts of the Building Code of Australia that will apply to the electrical installation.
- 3) Key Regulations and Standards applicable to the project.
- 4) Identify all potential hazardous areas.
- 5) Minimum qualifications and competencies required to undertake the design tasks relevant for the specific project.
- 6) Roles, responsibilities and qualifications of the various members of the design team.  
Who will undertake the peer review of the various stages and their qualifications.
- 7) External resources needed to provide the required competencies.
- 8) Electrical Compliance Statements required by the MIEE and other authorities and who will provide them.
- 9) Key consultations required with other design disciplines to ensure all power supply requirements are identified and that electrical plant and equipment will be adequately accommodated. Ensure adequate access and egress provisions are made. Ensure smoke sealing or fire separations are provided. Ensure ventilation or cooling is provided as required. Ensure door heights and widths are adequate for equipment installation and removal.
- 10) Demonstrate that all equipment can be economically maintained or replaced.
- 11) Demonstrate that the design has been reviewed for adherence to the principle of inherent safety in design.
- 12) Consultations required with external authorities.

- 13) Key steps in the design process including site investigation, obtaining further briefing or clarification of requirements, design calculations, preparation of reports and drawings, submissions for approval.
- 14) List of proposed software to be used in the design and verification process.
- 15) Proposed list of drawings and when these will be prepared.

The design plan shall be kept up to date during the design phase and shall be available for auditing purposes by Defence or its representatives.

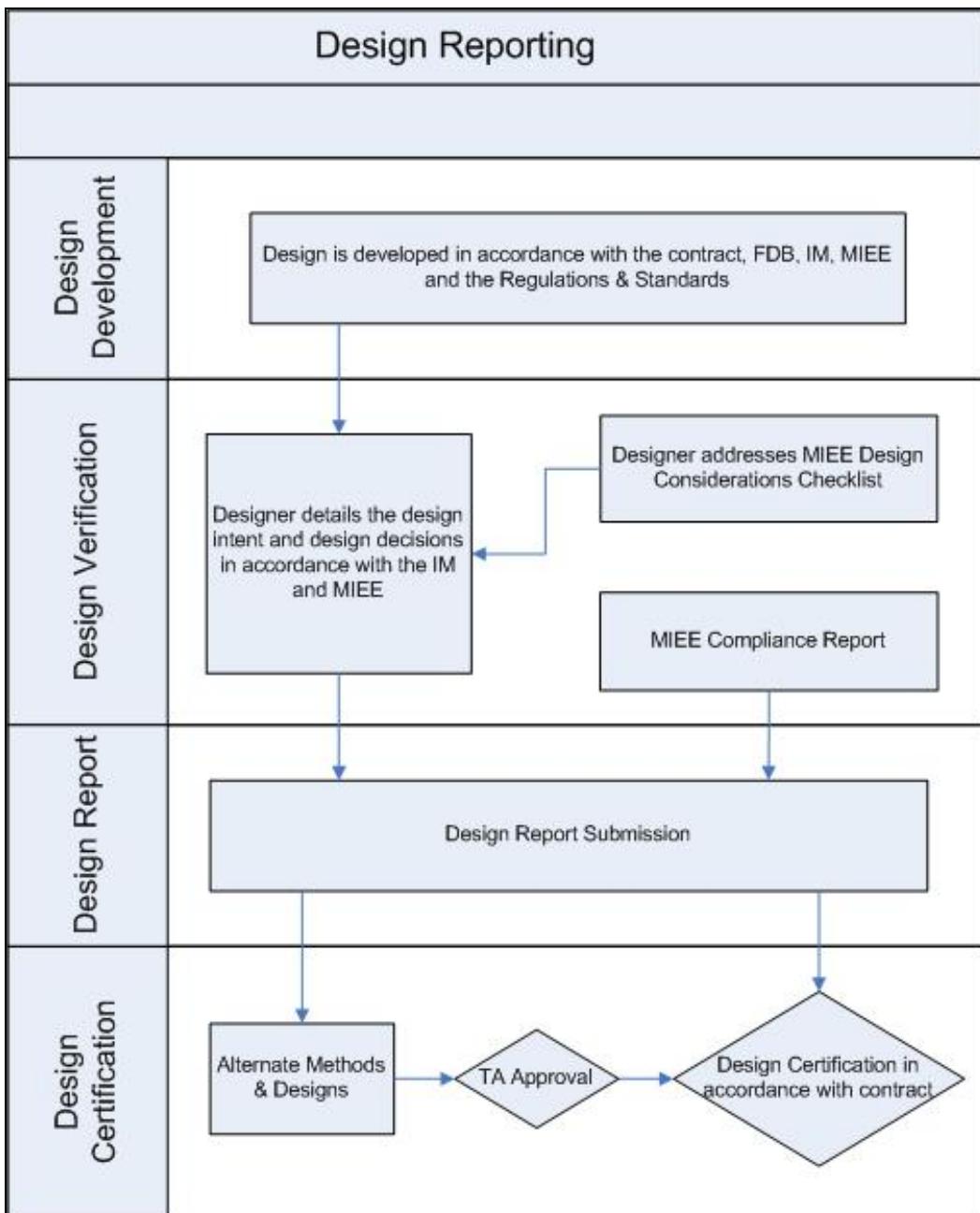
### **Design Reports**

When undertaking the design of a system or installation it is important that the designer adequately demonstrate the design intent and compliance. Transparency of the design process is very important in demonstrating due diligence and Defence under the IM Design Management process uses design reports for this purpose. Typically infrastructure project design reports comprise the following:

- 1) Concept Design Report (nominally 30%)
- 2) Schematic Design Report (nominally 50%)
- 3) Detailed Design Report (nominally 90%)
- 4) Tender Design Report or Final Design Report (100%)

At each design review stage and design report submission, it is the responsibility of the designer to provide a robust audit trail in the form of a design report that demonstrates the design is in accordance with the following requirements:

- All regulatory and statutory obligations;
- The MIEE;
- Functional Design Brief (FDB) and the Contract; and
- The Infrastructure Management System (IM) Design Management process.



■ **Figure A.10: Design Reporting Process**

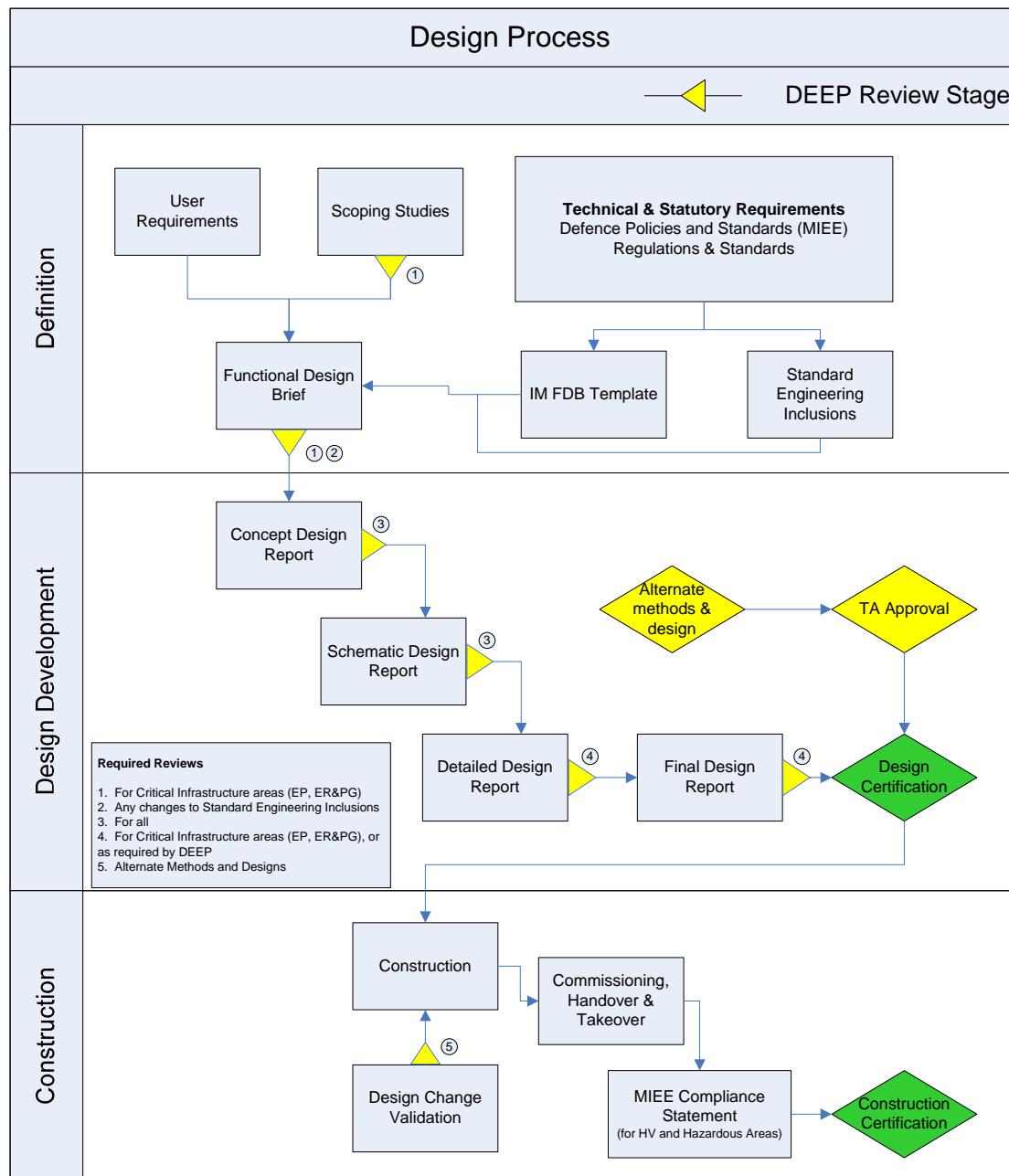
## Certification

As detailed in Chapter 6 of the MIEE, the designer must also certify that the design meets all Statutory Requirements as detailed and required by the respective contract (e.g. Design Services Contract). Upon completion of construction of the system / installation, the designer must further certify the installation has met the design, as required by the contract. The MIEE also requires for critical installations that the designer provide additional compliance statements as detailed in the MIEE and herein confirming:

- The installation has been fully commissioned and tested to prove compliance; and
- Installation documentation is complete and all required training has been provided.

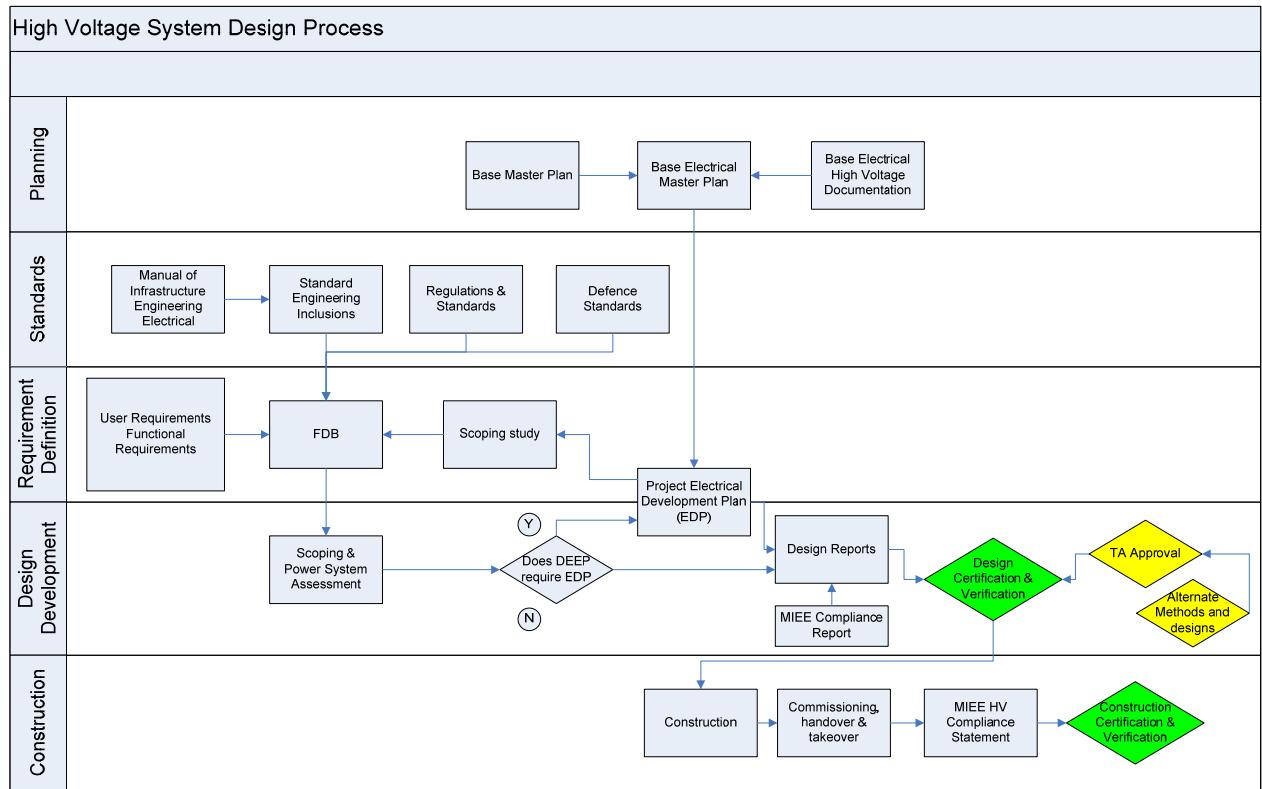
## Design Process

The design process is summarised in the diagram below.



■ **Figure A.2: Design Process**

The high voltage system design process is depicted in the following diagram



■ **Figure A.3: High Voltage System Design Process**

Compliance documentation required at each phase of the design process is described in the following sections.

### **Design Phase - Design Considerations**

To assist designers in complying with the additional Defence requirements and to ensure that they are aware of all requirements, a list of considerations (refer section - Design Considerations) is available for designers to refer to. This list is also available as a checklist to be provided with each design report submission. The designer must ensure that, in addition to demonstrating in the design report that the design has met all applicable requirements, that all elements of the checklists have been adequately addressed and documented in the design report to facilitate Defence review.

It is important for designers to achieve the required level of reporting to provide a basic audit trail, to prevent project delays or abortive design work and also to gain Defence agreement to any required Alternate Method or Design (dispensation).

**Design Phase – MIEE Design Compliance Report**

A MIEE Compliance Report, as detailed in Chapter 6 of the MIEE, is to be provided by the designer with each design report submission. The MIEE Compliance Report confirms that:

- The design is in accordance with the Regulations and Standards and the requirements of the Manual of Infrastructure Engineering Electrical (MIEE); and
- The design report submission has adequately documented the design intent and met all documentation requirements of the MIEE.

Where there are key items in the **design** that are non-compliant, they are to be detailed in the Design Compliance Statement summary checklist (refer - *MIEE Compliance Statement Summary Checklist*).

**Construction Phase - Construction Compliance Statements**

In addition to the Consultants Design Certificate, as required by the respective Defence contract, the Designer is to provide compliance statements as required by Chapter 6 in the MIEE. The compliance statements verify that the designer has suitably witnessed the construction, commissioning and performed all necessary inspections to confirm that the system or installation:

- design and works complies with the required regulations and standards;
- installation complies with the design and design intent;
- installation has been fully commissioned and tested to prove compliance; and
- Installation documentation, including Defence system documentation, is complete and training provided.

The Designer must complete a Compliance Statement (refer to *Construction Phase Compliance Report*) to certify that the design and installation is compliant as per the aforementioned. Certification and verification of the system must only be provided once the system / installation is deemed compliant.

Where there are key items in the **design, commissioning, documentation and training** that are non-compliant, they should be detailed in the Compliance Statement summary checklist and actioned as appropriate in accordance with the contract. Any qualified compliance statements must be referred to DEEP (refer to *Construction Phase Compliance Report*).

The table below summarises the compliance documents which must be submitted at the various phases of the design and construction process.

<b>Phase of the design process</b>	<b>Compliance document / guidance</b>	<b>Description</b>
Design Development	Design considerations (and preliminary checklist)	<p>Provides guidance at each stage of the design process to ensure all relevant electrical engineering policies, regulations, codes of practice and standards are considered.</p> <p>These considerations also form a checklist of items for the designer to consider.</p>
Design Certification	Defence Contract	Consultant Design Certificate or Sub-consultant Design Certificate
Design Verification	<p>Design report and compliance statements comprising:</p> <ul style="list-style-type: none"> <li>■ Design Report Documented as required by chapter 3 and 4 of the MIEE</li> <li>■ MIEE Compliance Report With every design report submission, the designer confirms the system / installation is in accordance with the Statutory Requirements and the MIEE.</li> <li>■ MIEE Compliance Report summary checklist Key items that need to be addressed in detail by the designer and documented in the design report. In addition all elements of the design that are non-compliant must be identified in the Compliance Statement summary checklist. The compliance statement summary checklist is attached to each design report in addition to the compliance statement.</li> </ul>	
Construction Certification	Defence Contract	Consultant Design Certificate or Sub-consultant Design Certificate
Construction Verification	<p>Construction compliance statements comprising:</p> <ul style="list-style-type: none"> <li>■ Construction Compliance Statement Upon <b>completion of construction and commissioning</b> of the system / installation, the designer confirms the installation has been tested and inspected and that the works are in accordance with the design intent and the MIEE, that the appropriate documentation and training has been supplied and that testing and commissioning is complete. Construction Compliance Statements are required for:           <ul style="list-style-type: none"> <li>■ All high voltage installations</li> <li>■ All hazardous and explosives area electrical installations</li> </ul> </li> <li>■ Construction Compliance Statement summary checklist Key items to be addressed in the Construction Compliance Statement. The Construction compliance statement summary checklist is attached to the Construction Compliance statement.</li> </ul>	

# Design Considerations

The Defence electrical design considerations are list of items that must be demonstrated in the design report at each stage (CDR, SDR, DDR and FDR). The list is not to be considered exhaustive but forms a basic checklist of items requiring consideration during the design phase (refer Design Considerations).

The designer shall ensure that, in addition to demonstrating in the design report that the design has met all applicable requirements, that all elements of the checklists below have been adequately addressed and documented in the design report.

## General Considerations

General design considerations include the following:

- a) Energy management and ESD implications;
- b) Signage and labelling requirements;
- c) Impact to other loads or systems;
- d) Load shedding requirements (at establishments provided with a power station);
- e) Verification of the installation including inspection testing and commissioning;
- f) Documentation of the installation;
- g) Standardisation, maintainability and supportability;
- h) Servicing and maintenance requirements incorporating adequate flexibility and versatility for these tasks; and
- i) Installation complies environmental legislation and that environmental control measures have been appropriately incorporated as required.

## Power Factor Correction Design Considerations

Power Factor Correction (PFC) design considerations include the following:

- a) Identify the characteristics of the load and the load profile;
- b) Identify the harmonics present and confirm PFC suitability for both harmonic performance and resonance;
- c) Determine the most appropriate PFC arrangement. Do comparisons for cost effectiveness;
- d) Check the effect of the PFC on the normal and emergency supplies. Take measures to ensure compatibility is maintained;
- e) Fire protection requirements;
- f) Failure modes and effects;
- g) Maintenance and spares requirements;
- h) Monitoring of the system during operation including the interfacing requirements to monitoring and alarm systems;
- i) Energy consumption and energy efficiency;

- j) Transient and surge suppression that may be required;
- k) Installation complies with Australian Standards, Defence Standards and NSP requirements; and
- l) The solution is the most cost effective in achieving all the requirements.

### **Artificial Lighting Design Considerations**

Artificial lighting design considerations include the following:

- a) Identification of the activities, tasks and use;
- b) Selection of the most suitable lighting installation taking into consideration the tasks and activities to be performed;
- c) Suitable energy efficiency measures to ensure compliance with the required energy performance objectives and that the design solution offers the best energy performance both in terms of equipment efficiency and usage;
- d) ESD and environmental implications;
- e) MEPS;
- f) Most suitable control methodology (see further lighting control considerations below);
- g) Extraneous lighting control requirements particularly near airfields;
- h) Electromagnetic compatibility and the requirement to suppress electromagnetic radiation and radio frequency interference;
- i) Interfacing requirements with BMS, SMS or other monitoring systems;
- j) Regional requirements and standardisation with other installations at the site;
- k) Servicing and maintenance requirements incorporating adequate flexibility and versatility for these tasks;
- l) Signage and labelling requirements;
- m) Training requirements;
- n) Ongoing reporting requirements including the requirement for energy management reports; and
- o) Security patrols and cleaning activities and incorporating adequate flexibility for these tasks.

### **Additional Lighting Control Considerations**

Artificial lighting control considerations include the following:

- a) Control philosophy and user requirements;
- b) Type and choice of control system;
- c) Management of the control system and the ability to implement changes;
- d) System design and application including location, arrangement and system performance;
- e) Human Machine Interface: e.g. DALI driven from personal computer;
- f) Interfacing with building and site energy management systems;
- g) Recover strategies (e.g. on power failures), and

- h) Reporting including usage, energy consumption, faults and monitoring.

## **400Hz Design Considerations**

400Hz design considerations include the following:

- a) Determination of the required performance standard;
- b) Determining the aircraft characteristics or any special characteristics that need to be catered for;
- c) Determination of the aircraft interfacing requirements;
- d) Earthing system requirements;
- e) Most suitable frequency converter arrangement for example centralised and decentralised units;
- f) Determination of the system capacity and anticipated load profile;
- g) Voltage regulation performance requirements;
- h) Use of 400Hz compatible equipment;
- i) Determination of the most suitable control arrangement;
- j) Electromagnetic compatibility and the requirement to suppress electromagnetic radiation and radio frequency interference;
- k) Environmental requirements and the implementation of appropriate measures;
- l) Servicing and maintenance requirements incorporating adequate flexibility and versatility for these tasks;
- m) Adequate isolation and shutdown systems to allow emergency operation and removal of equipment; and
- n) DESN/PCMS requirements.

## **Hazardous Area and Explosive Area Design Considerations**

Hazardous Area and Explosive Area design considerations include the following:

- a) Confirmation of the required standards and installation requirements in consultation with this policy, the FDB and the sponsor/user. For explosives areas, the required installation standards have been identified by the licensing agent;
- b) Only essential electrical equipment is installed in hazardous and explosives areas;
- c) Identification of the nature and characteristics of the hazards such as the type of hazard and the probability of occurrence;
- d) Determine the need for Hazard Analysis or Hazard Operations Analysis;
- e) Delineation and classification of the hazardous or explosives area;
- f) Selection of the most suitable protection technique taking into consideration the characteristics of the hazard;
- g) Selection of suitable equipment and its certification;
- h) Use of compatible materials;
- i) Transient/surge suppression is required;

- j) Lightning protection requirements;
- k) Electrostatic protection requirements;
- l) Earthing system requirements and confirming no earth loop is created either through the facility design or the intended operations;
- m) Electromagnetic compatibility and the requirement to suppress electromagnetic radiation and radio frequency interference;
- n) Servicing and maintenance requirements incorporating adequate flexibility and versatility for these tasks;
- o) Adequate isolation and shutdown systems to allow emergency operation and removal of equipment; and
- p) Documentation of the installation and the provision of suitable verification dossier.

### **Uninterruptible Power System Design Considerations**

Uninterruptible Power System design considerations include the following:

- a) Identify the characteristics of the critical load;
- b) Determine if alternate solutions such as filtering or power line conditioning are suitable;
- c) Determine the most suitable configuration. Consider the advantages and disadvantages of static UPS compared to a rotary UPS; including desired support time, inrush/surge capacity, effect of power factor on (de)rating, noise, etc. Do comparisons for cost effectiveness including system reliability and availability comparisons;
- d) Determine the required support time in consultation with the users;
- e) Check the effect of the UPS on the mains supply and generator supply. Take measures to ensure compatibility is maintained;
- f) Determine the UPS accommodation requirements;
- g) Determine the environmental conditions required for UPS operation. Decide what to do if the environmental conditions go beyond operating limits;
- h) Determine the fire protection requirements;
- i) Determine the required input supply capacity to allow for the UPS system losses and battery charging requirements for static systems. Allow to size switchgear and sub-mains to take into account these plus any de-rating due to the harmonic content. Check to see whether it is necessary to inhibit battery boost charging when a generator is connected to the input supply;
- j) Confirm the installation design complies with Australian Standards, Defence Standards and NSP requirements;
- k) Determine the most appropriate battery performance and configuration. Determine suitable type, taking into account performance, maintenance, reliability, and layout and discharge capacity. Consider whether an automatically monitored cell voltage system is justified;

- l) Identify any critical air conditioning loads or other loads that are necessary to keep the critical load running for the battery reserve time. Take measures to ensure the functionality of the facility is maintained during the support time;
- m) Determine the overall required system Mean Time Between Failure (MTBF), Maximum Time to Repair (MAXTTR) and availability requirements. Confirm compliance with specified criterion;
- n) Consider a failure mode and effect analysis. Determine appropriate response strategies.
- o) Determine maintenance and spares requirements. Determine the maintenance strategy and projected maintenance downtimes for Defence agreement;
- p) Determine the system monitoring requirements. Identify UPS interfacing requirements to monitoring and alarm systems such as DESN and BMS;
- q) Determine the transient surge suppression required at the UPS inputs and output;
- r) Determine transient surge suppression and power conditioning requirements for all bypass supplies where the UPS could be offline; and
- s) Determine the through life cost of the proposed solution. Where required, provide cost benefit analysis for UPS options.

### **LEG Design Considerations**

LEG design considerations include the following:

- a) Justification of the system
- b) Identification of the requirements and characteristics of the essential and critical load;
- c) Determination of the required LEG restoration time in consultation with the sponsor/user. Consideration shall also be given to the LEG changeover requirements including the need for appropriate time delays necessary to prevent equipment damage;
- d) Configuration options to enable the selection of the most suitable solution on a cost effectiveness, reliability, and availability basis, particularly where redundancy is required in the essential distribution system. Consideration shall also be given to the various failure scenarios and their consequences;
- e) Analysis of the effect of the LEG on the connected equipment and the implementation of measures to ensure LEG to load compatibility where appropriate;
- f) Consideration of the environmental requirements of the LEG and the implementation of the appropriate measures when environmental conditions are outside of the normal operational range;
- g) Fire protection and fire separation aspects of LEG systems to ensure system's integrity, reliability and redundancy where required;
- h) Determination that the capacity of the LEG is adequate for supplying steady state and transient loads. Consideration shall be given to the impact of any large inrush currents, such as motor loads, to ensure the generator can cater for these and that the resultant generator performance under motor starting conditions is suitable for all connected essential loads;

- i) Checking of loads for high harmonic content and ensuring that the necessary allowances have been made whilst sizing the alternator and all associated switchgear and submains. Consideration shall be given to the need for any derating of generator capacity due to harmonic content;
- j) Need to inhibit certain equipment when the generator is operating at or close to its capacity (e.g. UPS battery boost charging inhibited when on LEG supply);
- k) Check the required generator configuration including the Automatic Voltage Regulator (AVR) and governor performance to ensure that the generator will adequately cater for all connected loads under all operating conditions particularly against the impacts of (g) and (h) above;
- l) Verification that the required LEG spare capacity is provided and that the generator minimum long term load is maintained. Furthermore, where a dummy load is provided, ensure that it operates only under abnormal conditions and that it will not be used excessively;
- m) Verification that the installation complies with all relevant legislation, Australian Standards, Defence Standards and Network Provider requirements;
- n) Identification of any essential air conditioning or other ancillary loads that are necessary to keep the essential or critical load running. Ensuring that the loads identified are adequately supported by the LEG and that the respective control systems operate congruently;
- o) Overall system's Mean Time Between Failure (MTBF) and availability where the system's reliability is specified;
- p) Maintenance requirements of the LEG system and the availability of the appropriate spare parts. Equipment specifications shall be determined based on the required performance and the criteria for maintainability, reliability and the availability of comprehensive manufacturer's product support locally. Specifications shall include the requirement for the supplier to submit a Statement of Supportability;
- q) Need to service the generator whilst the generator remains in operation supplying power. This is a consideration for important operational facilities with the potential for long continuous operating periods;
- r) Determination of the required spares. Specifications shall include the requirement for suppliers to nominate recommended spares and those essential spares shall be provided as part of the installation for retention onsite by Defence;
- s) How the system will be monitored. The LEG is to be adequately monitored by the Power Control and Monitoring System (PCMS) or similar, where existing. Additional monitoring may be required by the Region and the building occupants may involve interfacing to the building monitoring and alarm systems, such as BMS;
- t) Transient surge suppression is required; and
- u) The sponsor/users are responsible for identifying what equipment shall be LEG supported and for providing detailed information on the equipment identified. In circumstances where equipment data is not available or cannot be sourced, the designer

may be made responsible for carrying out all necessary assessments and surveys of existing equipment to establish their characteristics.

## **HV & LV Distribution System Design Considerations**

HV & LV distribution systems design considerations include the following:

- a) Use of compatible equipment;
- b) Point of connection and the high voltage system augmentations;
- c) Confirmation of the need for High Voltage Development Plan
- d) Earthing system requirements;
- e) Electromagnetic compatibility and the requirement to suppress electromagnetic radiation and radio frequency interference;
- f) Servicing and maintenance requirements incorporating adequate flexibility and versatility for these tasks;
- g) Adequate isolation and shutdown systems to allow emergency operation and removal of equipment;
- h) Impact to other loads;
- i) Load shedding requirements; and
- j) DESN/PCMS requirements.

## **CEPS Design Considerations**

CEPS design considerations include the following:

- a) Determination and DEEP agreement to the number and size of generators;
- b) Equipment selection including use of compatible equipment, standardisation, supportability and maintainability;
- c) Location, building layout, including requirements for physical and fire segregation and access/egress;
- d) Passive Defence;
- e) Identification of all single points of failure and treatment strategies;
- f) Load profile of the site and any special site considerations;
- g) Ability to parallel with the mains supply and impact of the NSP rules;
- h) Required electrical bus configurations;
- i) Power station control philosophy, in particular any site specific modifications required;
- j) Control panel arrangements;
- k) HMI SCADA plan and screens;
- l) Required alarms and trips;
- m) Point of connection and any high voltage system augmentation;
- n) Earthing system requirements and arrangement;
- o) NEC requirements and those of the NSP;

- p) Electromagnetic compatibility and the requirement to suppress electromagnetic radiation and radio frequency interference;
- q) Ventilation system;
- r) Fuel system;
- s) Lubrication system;
- t) Cooling system;
- u) Acoustic treatment and performance;
- v) Adequate isolation and shutdown systems to allow emergency operation and removal of equipment;
- w) Load shedding requirements and system interfaces;
- x) DESN/PCMS requirements and interfacing with the GCS; and
- y) Provision of adequate spares.

# Design Phase MIEE Compliance Report

The MIEE compliance report comprises:

- MIEE compliance statement; and
- MIEE compliance statement summary checklist
- Design Considerations checklist.

The contents of each are described below.

## MIEE Compliance Statement

This Compliance Statement shall confirm that:

- The design is in accordance with the Regulations and Standards and the requirements of the Manual of Infrastructure Engineering Electrical (MIEE); and
- The design report submission has met all the requirements of the MIEE.

The MIEE Compliance Statement is to be completed by the Designer at each stage of the design reporting phase and attached to the relevant design report (CDR, SDR, DDR, and FDR). The MIEE Compliance Statement shall be in the form of a minute as detailed below.

## MIEE Compliance Statement

<Insert project details>

<CDR/SDR/DDR/Final> Design Submission

Date:

---

Prepared by:

---

Reviewed by:

---

**Details of installation**

Location: \_\_\_\_\_

Building: \_\_\_\_\_

Area: \_\_\_\_\_

I/we being the person(s) responsible for the design of the installation, particulars of which are described later in this report, hereby certify that:

- the design is in accordance with the Regulations and Standards and the requirements of the Manual of Infrastructure Engineering Electrical (MIEE); and
- that the design report submission has met all the requirements of the MIEE.

Details of those items not in accordance with the above are listed in the compliance statement summary checklist attached.

Name of designer: \_\_\_\_\_

Company: \_\_\_\_\_

Address: \_\_\_\_\_  
\_\_\_\_\_

Signature \_\_\_\_\_

Date \_\_\_\_\_

**MIEE Compliance Statement Summary Checklist**

The following checklists summarise key compliance elements that must be addressed by the Designer. Where an item is non-compliant, clarification must be provided.

Manual of Infrastructure Engineering Electrical – Compliance Report Summary					CDR	SDR	DDR	FDR
Field		Key Reference Standards	Comply (Y/N/NA)	Report Reference Clause	Comment/Clarification/Justification if no			
General	Regulations and Standards							
	MIEE General Requirement							
Internal Electrical Services	Switchboard location and Labelling							
	RCD protection							
	Power Factor Correction							
	Artificial Lighting							
	Hazardous Area Installations							
	Explosives Area Installations							
	400 Hz Systems							
	Aircraft Earth Reference Points							

	Wharf Services				
Emergency Power Systems	Uninterruptible Power Systems				
	Local Emergency Generators				
	Mobile Generator Link Box				
	HV & LV Distribution Systems				
	Power Stations				
	Power Control and Monitoring Systems				
	Operation of HV & LV Distribution Systems				

**Design Considerations Checklist**

All of the following elements below have been adequately addressed and documented in the design report:

<b>General</b>		Report Reference
Energy management and ESD implications;	<input type="checkbox"/>	
Signage and labelling requirements;	<input type="checkbox"/>	
Impact to other loads or systems;	<input type="checkbox"/>	
Load shedding requirements;	<input type="checkbox"/>	
Verification of the installation including inspection testing and commissioning;	<input type="checkbox"/>	
Documentation of the installation;	<input type="checkbox"/>	
Servicing and maintenance requirements incorporating adequate flexibility and versatility for these tasks; and	<input type="checkbox"/>	
Installation complies environmental legislation and that environmental control measures have been appropriately incorporated as required.	<input type="checkbox"/>	
<b>PFC</b>		
Identify the characteristics of the load and the load profile;	<input type="checkbox"/>	
Identify the harmonics present and confirm PFC suitability for both harmonic performance and resonance;	<input type="checkbox"/>	
Determine the most appropriate PFC arrangement. Do comparisons for cost effectiveness;	<input type="checkbox"/>	
Check the effect of the PFC on the normal and emergency supplies. Take measures to ensure compatibility is maintained;	<input type="checkbox"/>	
Fire protection requirements;	<input type="checkbox"/>	
Failure modes and effects;	<input type="checkbox"/>	
Maintenance and spares requirements;	<input type="checkbox"/>	
Monitoring of the system during operation including the interfacing requirements to monitoring and alarm systems;	<input type="checkbox"/>	
Energy consumption and energy efficiency;	<input type="checkbox"/>	
Transient and surge suppression that may be required;	<input type="checkbox"/>	
Installation complies with Australian Standards, Defence Standards and NSP requirements; and	<input type="checkbox"/>	
The solution is the most cost effective in achieving all the requirements.	<input type="checkbox"/>	

<b>Artificial lighting design</b>		Report Reference
Identification of the activities, tasks and use;	<input type="checkbox"/>	
Selection of the most suitable lighting installation taking into consideration the tasks and activities to be performed;	<input type="checkbox"/>	
Suitable energy efficiency measures to ensure compliance with the required energy performance objectives and that the design solution offers the best energy performance both in terms of equipment efficiency and usage;	<input type="checkbox"/>	
ESD and environmental implications;	<input type="checkbox"/>	
MEPS;	<input type="checkbox"/>	
Most suitable control methodology (see further lighting control considerations below);	<input type="checkbox"/>	
Extraneous lighting control requirements particularly near airfields;	<input type="checkbox"/>	
Electromagnetic compatibility and the requirement to suppress electromagnetic radiation and radio frequency interference;	<input type="checkbox"/>	
Interfacing requirements with BMS, SMS or other monitoring systems;	<input type="checkbox"/>	
Regional requirements and standardisation with other installations at the site;	<input type="checkbox"/>	
Servicing and maintenance requirements incorporating adequate flexibility and versatility for these tasks;	<input type="checkbox"/>	
Signage and labelling requirements;	<input type="checkbox"/>	
Training requirements;	<input type="checkbox"/>	
Ongoing reporting requirements including the requirement for energy management reports; and	<input type="checkbox"/>	
Security patrols and cleaning activities and incorporating adequate flexibility for these tasks.	<input type="checkbox"/>	
<b>Additional lighting control</b>		
Control philosophy and user requirements;	<input type="checkbox"/>	
Type and choice of control system;	<input type="checkbox"/>	
Management of the control system and the ability to implement changes;	<input type="checkbox"/>	
System design and application including location, arrangement and system performance;	<input type="checkbox"/>	
Human Machine Interface: e.g. DALI driven from personal computer;	<input type="checkbox"/>	
Interfacing with building and site energy management systems;	<input type="checkbox"/>	
Recover strategies (e.g. on power failures), and	<input type="checkbox"/>	
Reporting including usage, energy consumption, faults and monitoring.	<input type="checkbox"/>	

<b>400Hz</b>		Report Reference
Required performance standard;	<input type="checkbox"/>	
Determining the aircraft characteristics or any special characteristics that need to be catered for;	<input type="checkbox"/>	
Determination of the aircraft interfacing requirements;	<input type="checkbox"/>	
Earthing system requirements;	<input type="checkbox"/>	
Most suitable frequency converter arrangement for example centralised and decentralised units;	<input type="checkbox"/>	
Determination of the system capacity and anticipated load profile;	<input type="checkbox"/>	
Voltage regulation performance requirements;	<input type="checkbox"/>	
Use of 400Hz compatible equipment;	<input type="checkbox"/>	
Determination of the most suitable control arrangement;	<input type="checkbox"/>	
Electromagnetic compatibility and the requirement to suppress electromagnetic radiation and radio frequency interference;	<input type="checkbox"/>	
Environmental requirements and the implementation of appropriate measures;	<input type="checkbox"/>	
Servicing and maintenance requirements incorporating adequate flexibility and versatility for these tasks;	<input type="checkbox"/>	
Adequate isolation and shutdown systems to allow emergency operation and removal of equipment; and	<input type="checkbox"/>	
DESN/PCMS requirements.	<input type="checkbox"/>	

<b>Hazardous Area and Explosive Area</b>		Report Reference
Confirmation that the designer holds the relevant competencies as detailed in AS/NZS 4761.1 Competencies for working with electrical equipment for hazardous areas (EEHA) Part 1 Competency Standards	<input type="checkbox"/>	
Confirmation of the required standards and installation requirements in consultation with this policy, the FDB and the sponsor/user. For explosives areas, the required installation standards have been identified by the licensing agent;	<input type="checkbox"/>	

Hazardous Area and Explosive Area		Report Reference
Only essential electrical equipment is installed in hazardous and explosives areas;	<input type="checkbox"/>	
Identification of the nature and characteristics of the hazards such as the type of hazard and the probability of occurrence;	<input type="checkbox"/>	
Determine the need for Hazard Analysis or Hazard Operations Analysis;	<input type="checkbox"/>	
Delineation and classification of the hazardous or explosives area;	<input type="checkbox"/>	
Selection of the most suitable protection technique taking into consideration the characteristics of the hazard;	<input type="checkbox"/>	
Selection of suitable equipment and its certification;	<input type="checkbox"/>	
Use of compatible materials;	<input type="checkbox"/>	
Transient/surge suppression is required;	<input type="checkbox"/>	
Lightning protection requirements;	<input type="checkbox"/>	
Electrostatic protection requirements;	<input type="checkbox"/>	
Earthing system requirements and confirming no earth loop is created either through the facility design or the intended operations;	<input type="checkbox"/>	
Electromagnetic compatibility and the requirement to suppress electromagnetic radiation and radio frequency interference;	<input type="checkbox"/>	
Servicing and maintenance requirements incorporating adequate flexibility and versatility for these tasks;	<input type="checkbox"/>	
Adequate isolation and shutdown systems to allow emergency operation and removal of equipment; and	<input type="checkbox"/>	
Documentation of the installation and the provision of suitable verification dossier.	<input type="checkbox"/>	

UPS		Report Reference
Identify the characteristics of the critical load;	<input type="checkbox"/>	
Determine if alternate solutions such as filtering or power line conditioning are suitable;	<input type="checkbox"/>	
Determine the most suitable configuration. Consider the advantages and disadvantages of static UPS compared to a rotary UPS; including desired support time, inrush/surge capacity, effect of power factor on (de)rating, noise, etc. Do comparisons for cost effectiveness including system reliability and availability comparisons;	<input type="checkbox"/>	
Determine the required support time in consultation with the users;	<input type="checkbox"/>	

UPS		Report Reference
Check the effect of the UPS on the mains supply and generator supply. Take measures to ensure compatibility is maintained;	<input type="checkbox"/>	
Determine the UPS accommodation requirements;	<input type="checkbox"/>	
Determine the environmental conditions required for UPS operation. Decide what to do if the environmental conditions go beyond operating limits;	<input type="checkbox"/>	
Determine the fire protection requirements;	<input type="checkbox"/>	
Determine the required input supply capacity to allow for the UPS system losses and battery charging requirements for static systems. Allow to size switchgear and submains to take into account these plus any derating due to the harmonic content. Check to see whether it is necessary to inhibit battery boost charging when a generator is connected to the input supply;	<input type="checkbox"/>	
Confirm the installation design complies with Australian Standards, Defence Standards and NSP requirements;	<input type="checkbox"/>	
Determine the most appropriate battery performance and configuration. Determine suitable type, taking into account performance, maintenance, reliability, and layout and discharge capacity. Consider whether an automatically monitored cell voltage system is justified;	<input type="checkbox"/>	
Identify any critical air conditioning loads or other loads that are necessary to keep the critical load running for the battery reserve time. Take measures to ensure the functionality of the facility is maintained during the support time;	<input type="checkbox"/>	
Determine the overall required system Mean Time Between Failure (MTBF), Maximum Time to Repair (MAXTTR) and availability requirements. Confirm compliance with specified criterion;	<input type="checkbox"/>	
Consider a failure mode and effect analysis. Determine appropriate response strategies.	<input type="checkbox"/>	
Determine maintenance and spares requirements. Determine the maintenance strategy and projected maintenance downtimes for Defence agreement;	<input type="checkbox"/>	
Determine the system monitoring requirements. Identify UPS interfacing requirements to monitoring and alarm systems such as DESN and BMS;	<input type="checkbox"/>	
Determine the transient surge suppression required at the UPS inputs and output;	<input type="checkbox"/>	
Determine transient surge suppression and power conditioning requirements for all by-pass supplies where the UPS could be offline; and	<input type="checkbox"/>	
Determine the through life cost of the proposed solution. Where required, provide cost benefit analysis for UPS options.	<input type="checkbox"/>	

LEG		Report Reference
Justification of the system	<input type="checkbox"/>	
Identification of the requirements and characteristics of the essential and critical load;	<input type="checkbox"/>	
Determination of the required LEG restoration time in consultation with the sponsor/user. Consideration shall also be given to the LEG changeover requirements including the need for appropriate time delays necessary to prevent equipment damage;	<input type="checkbox"/>	
Configuration options to enable the selection of the most suitable solution on a cost effectiveness, reliability, and availability basis, particularly where redundancy is required in the essential distribution system. Consideration shall also be given to the various failure scenarios and their consequences;	<input type="checkbox"/>	
Analysis of the effect of the LEG on the connected equipment and the implementation of measures to ensure LEG to load compatibility where appropriate;	<input type="checkbox"/>	
Consideration of the environmental requirements of the LEG and the implementation of the appropriate measures when environmental conditions are outside of the normal operational range;	<input type="checkbox"/>	
Fire protection and fire separation aspects of LEG systems to ensure system's integrity, reliability and redundancy where required;	<input type="checkbox"/>	
Determination that the capacity of the LEG is adequate for supplying steady state and transient loads. Consideration shall be given to the impact of any large inrush currents, such as motor loads, to ensure the generator can cater for these and that the resultant generator performance under motor starting conditions is suitable for all connected essential loads;	<input type="checkbox"/>	
Check the required generator configuration including the Automatic Voltage Regulator (AVR) and governor performance to ensure that the generator will adequately cater for all connected loads under all operating conditions particularly against the impacts of the two previous items above;	<input type="checkbox"/>	
Checking of loads for high harmonic content and ensuring that the necessary allowances have been made whilst sizing the alternator and all associated switchgear and submains. Consideration shall be given to the need for any derating of generator capacity due to harmonic content;	<input type="checkbox"/>	
Need to inhibit certain equipment when the generator is operating at or close to its capacity (e.g. UPS battery boost charging inhibited when on LEG supply);	<input type="checkbox"/>	
Verification that the required LEG spare capacity is provided and that the generator minimum long term load is maintained. Furthermore, where a dummy load is provided, ensure that it operates only under abnormal conditions and that it will not be used excessively;	<input type="checkbox"/>	
Verification that the installation complies with all relevant legislation, Australian Standards, Defence Standards and Network Provider	<input type="checkbox"/>	

LEG		Report Reference
requirements;		
Identification of any essential air conditioning or other ancillary loads that are necessary to keep the essential or critical load running. Ensuring that the loads identified are adequately supported by the LEG and that the respective control systems operate congruently;	<input type="checkbox"/>	
Overall system's Mean Time Between Failure (MTBF) and availability where the system's reliability is specified;	<input type="checkbox"/>	
Maintenance requirements of the LEG system and the availability of the appropriate spare parts. Equipment specifications shall be determined based on the required performance and the criteria for maintainability, reliability and the availability of comprehensive manufacturer's product support locally. Specifications shall include the requirement for the supplier to submit a Statement of Supportability;	<input type="checkbox"/>	
Need to service the generator whilst the generator remains in operation supplying power. This is a consideration for important operational facilities with the potential for long continuous operating periods;	<input type="checkbox"/>	
Determination of the required spares. Specifications shall include the requirement for suppliers to nominate recommended spares and those essential spares shall be provided as part of the installation for retention onsite by Defence;	<input type="checkbox"/>	
How the system will be monitored. The LEG is to be adequately monitored by the Power Control and Monitoring System (PCMS) or similar, where existing. Additional monitoring may be required by the Region and the building occupants may involve interfacing to the building monitoring and alarm systems, such as BMS;	<input type="checkbox"/>	
Transient surge suppression is required; and	<input type="checkbox"/>	
The sponsor/users are responsible for identifying what equipment shall be LEG supported and for providing detailed information on the equipment identified. In circumstances where equipment data is not available or cannot be sourced, the designer may be made responsible for carrying out all necessary assessments and surveys of existing equipment to establish their characteristics.	<input type="checkbox"/>	

<b>HV &amp; LV distribution system</b>		Report Reference
Use of compatible equipment;	<input type="checkbox"/>	
Point of connection and the high voltage system augmentations;	<input type="checkbox"/>	
Confirmation of the need for High Voltage Development Plan	<input type="checkbox"/>	
Earthing system requirements;	<input type="checkbox"/>	
Electromagnetic compatibility and the requirement to suppress electromagnetic radiation and radio frequency interference;	<input type="checkbox"/>	
Servicing and maintenance requirements incorporating adequate flexibility and versatility for these tasks;	<input type="checkbox"/>	
Adequate isolation and shutdown systems to allow emergency operation and removal of equipment;	<input type="checkbox"/>	
Impact to other loads;	<input type="checkbox"/>	
Load shedding requirements; and	<input type="checkbox"/>	
DESN/PCMS requirements.	<input type="checkbox"/>	

<b>CEPS</b>		Report Reference
Determination and DEEP agreement to the number and size of generators;	<input type="checkbox"/>	
Equipment selection including use of compatible equipment, standardisation, supportability and maintainability;	<input type="checkbox"/>	
Location, building layout, including requirements for physical and fire segregation and access/egress;	<input type="checkbox"/>	
Passive Defence;	<input type="checkbox"/>	

<b>CEPS</b>		Report Reference
Identification of all single points of failure and treatment strategies;	<input type="checkbox"/>	
Load profile of the site and any special site considerations;	<input type="checkbox"/>	
Ability to parallel with the mains supply and impact of the NSP rules;	<input type="checkbox"/>	
Required electrical bus configurations;	<input type="checkbox"/>	
Power station control philosophy, in particular any site specific modifications required;	<input type="checkbox"/>	
Control panel arrangements;	<input type="checkbox"/>	
HMI SCADA plan and screens;	<input type="checkbox"/>	
Required alarms and trips;	<input type="checkbox"/>	
Point of connection and any high voltage system augmentation;	<input type="checkbox"/>	
Earthing system requirements and arrangement;	<input type="checkbox"/>	
NEC requirements and those of the NSP;	<input type="checkbox"/>	
Electromagnetic compatibility and the requirement to suppress electromagnetic radiation and radio frequency interference;	<input type="checkbox"/>	
Ventilation system;	<input type="checkbox"/>	
Fuel system;	<input type="checkbox"/>	
Lubrication system;	<input type="checkbox"/>	
Cooling system;	<input type="checkbox"/>	
Acoustic treatment and performance;	<input type="checkbox"/>	
Adequate isolation and shutdown systems to allow emergency operation and removal of equipment;	<input type="checkbox"/>	
Load shedding requirements and system interfaces;	<input type="checkbox"/>	
DESN/PCMS requirements and interfacing with the GCS; and	<input type="checkbox"/>	
Provision of adequate spares.	<input type="checkbox"/>	

# Construction Phase Compliance Report

The Construction phase compliance report comprises:

- Construction phase compliance statement; and
- Construction phase compliance statement summary checklist.

The contents of each are described below.

## Defence High Voltage Installations

In addition to any statutory requirements, provide a Defence High Voltage Compliance Statement, prepared by a responsible person, covering all high voltage works.

This Compliance Statement shall confirm that the design and works complies with the required regulations and standards, the installation complies with the design and that the installation has been commissioned and tested to prove compliance.

An integral part of the certification and verification is the completion of all relevant documentation and training to ensure the system when handed over is functioning correctly and safely and that the users have the required documentation and training to operate the installation safely.

The Compliance Statement is to be completed by the Designer. The High Voltage Compliance Statement shall be in the form of a minute as detailed in - *High Voltage Compliance Statement*.

It must be noted that Defence installation requirements are in addition to the regulations and standards applicable to electrical installations. The installation must comply with all relevant regulations and standards unless formal exemption is granted by the appropriate regulator.

## Hazardous Areas and Explosives Area Installations

The designer is to certify all electrical installations in hazardous areas and explosives areas in accordance as meeting the requirements of the applicable regulations and standards in accordance with Chapter 15 of the MIEE. This includes certification of explosives area installations to the Defence licensing agencies requirements and any relevant regulations and standards.

Certification involves all statutory obligations as required by the regulations such as the Notification of Electrical Works/Certificate of Electrical Safety or equivalent and accredited certifier's certificates where required. In addition, a Defence Hazardous/Explosives Area Certificate is required as outlined below.

Certification and verification must be completed before connection to electricity supply and energising the installation. All certification and verification documents must be provided in the verification dossier.

The Defence Hazardous/Explosives Area Compliance Statement is in addition to statutory requirements and is required to confirm the design, construction, commissioning and the satisfactory completion of the works.

The purpose of this report is to ensure that the designer certifies that the design complies with the required regulations and standards, the installation complies with the design and that the installation has been commissioning and tested to prove compliance.

An integral part of the Defence Compliance Statement is the completion of all relevant documentation and training. This is to ensure the system when handed over is functioning correctly and safely and that the users have the required documentation and training to operate the installation safely.

The report is to be completed by the designer, however, for minor works where no designer is involved the licensed electrical installation contractor can complete the certificate. An example of the Hazardous/Explosives Area Compliance Statement and checklist is provided in the sections below. The report is to be included with the Verification Dossier.

These certificates must be completed for all new works or any alteration or addition to an existing installation.

It must be noted that Defence explosives area installation requirements are in addition to the regulations and standards applicable to hazardous area installations and the Defence Contracts. These installations must also comply with all relevant hazardous area regulations and standards with the only exception being under formal exemption granted by the Defence licensing agent and other appropriate regulatory authority as appropriate.

## **Construction Phase Compliance Statements**

### **High Voltage Compliance Statement**

#### **Details of installation**

Location: \_\_\_\_\_

Building: \_\_\_\_\_

Area: \_\_\_\_\_

I/we being the person(s) responsible for the design of the installation, particulars of which are described later in this report, hereby certify that in our opinion, the installation has been thoroughly tested and inspected and that the works are in accordance with the requirements of the design intent and the Manual of Infrastructure Engineering Electrical with the exception of those items listed in the compliance statement summary checklist attached.

Name of designer: \_\_\_\_\_

Company: \_\_\_\_\_

Address: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Signature \_\_\_\_\_

Date \_\_\_\_\_

The compliance report must confirm the installation meets:

- a) All statutory obligations as required by the regulations (such as the Notification of Electrical Works/Certificate of Electrical Safety) or equivalent;
- b) Accredited auditor's certificates where required; and
- c) The Manual of Infrastructure Engineering Electrical compliance.

## **Construction Phase Compliance Statement Summary Checklist - High Voltage System**

The following checklists summarise key compliance elements that must be addressed by the Designer following construction. Where an item is non-compliant, clarification must be provided Note: Customise to suit project. Include preliminary checklist in design reports.

<b>Construction Phase Compliance Report Summary Checklist High Voltage Systems</b>			
<b>Item</b>		<b>Completed (Y/N/NA)</b>	<b>Comment/clarification/justification if no</b>
Installation	Meets the design and is functioning as intended		
	Tested in accordance with relevant standards AS/NZS 3000, AS/NZ 2067, etc (add as necessary)		
	Earthing system (soil resistivity tests and final earth impedance)		
	Insulation resistance and continuity tests		
	High Voltage power frequency withstand tests		
	Protection systems operate correctly (secondary injection tests)		
	Instrumentation configuration and calibration		
	Notification of Electrical Works/Certificate of Electrical Safety completed by the installation contractor and lodged		
	Keying, signage, labelling and safety notices installed		

Documentation Refer to chapter 3 of the MIEE	Earthing Report, Protection Report and load flow report completed and included in the Maintenance manuals		
	Updated High Voltage Systems Drawings updated and provided to the High Voltage system operator		
	Updated High Voltage System Configuration Manual		
	Operation and Maintenance Manuals Complete and handed over		
	As-constructed information is complete		
Training	Operators training in the operation of the system		
	Maintainers training in the maintenance of the system		

## **Hazardous / Explosives Area Electrical Compliance Statement**

### **Details of installation**

Location: \_\_\_\_\_

Building: \_\_\_\_\_

Area: \_\_\_\_\_

I/we being the person(s) responsible for the design of the installation, particulars of which are described later in this report, hereby certify that in our opinion, the installation has been thoroughly tested and inspected and that the works are in accordance with the requirements of the design intent and the Manual of Infrastructure Engineering Electrical with the exception of those items listed in the compliance statement summary checklist attached.

Name of designer: \_\_\_\_\_

Company: \_\_\_\_\_

Address: \_\_\_\_\_  
\_\_\_\_\_

Signature \_\_\_\_\_

Date \_\_\_\_\_

### **Particulars of the Installation**

This section of the report must include a full record of the installation details including:

- a) Description of the installation
- b) Hazardous/Explosives area Zone Plan
- c) Details of the electrical equipment and installation
- d) Details of the earthing and equipotential bonding system
- e) Details of the lightning protection system and electrostatic protection system
- f) Details of particular operational requirements

## **Construction Phase Compliance Statement Summary Checklist Hazardous Areas and Explosives Areas**

The following checklists summarise key compliance elements that must be addressed by the Designer following construction. Where an item is non-compliant, clarification must be provided. Note: Customise to suit project. Include preliminary checklist in design reports.

<b>Construction Phase Compliance Report Summary Checklist</b> <b>Hazardous areas and explosives areas</b>			
<b>Item</b>		<b>Completed (Y/N/NA)</b>	<b>Comment/clarification/justification if no</b>
Installation	Meets the design and is functioning as intended		
	Tested in accordance with the relevant standards including the mandatory and optional tests required by AS/NZS 3000, AS/NZS 2381.1, AS/NZS 1768 and (add other test standards or test to prove other standards e.g. AS 1020, EO standards)		
	Earthing system		
	Insulation resistance		
	Protection systems operate correctly		
	Equipment proof tests		
	Notification of Electrical Works/Certificate of Electrical Safety completed by the installation contractor and lodged		

	Signage, labelling and safety notices installed		
Documentation	Verification Dossier - assembled and complete		
	Operation and Maintenance Manuals Complete and handed over		
	As-constructed information is complete		
Training	Users training in the operation of the system		
	Maintainers training the operation and maintenance of the system		

## **Appendix B Sample Dispensation Request**

# Sample Dispensation Request



Australian Government

Department of Defence  
Defence Support Group

## Minute

PO details  
**BP3-XXXX**  
Department of Defence  
CANBERRA ACT 2600  
Tel:  
Fax:

*File Number*

**ASEPE (BP-2-B001)**  
**DEEP (BP-2-B049)**

## REQUEST FOR DISPENSATIONS FROM INFRASTRUCTURE MANAGEMENT MANUAL OF INFRASTRUCTURE ENGINEERING - ELECTRICAL REQUIREMENTS

### References:

- A. Letter from design consultant requesting dispensation for clause  
XXXX.....(Attachment A)  
B.

### Clause XXX .....

1. Reference A details the ..... The following compensating factors are proposed:

- a. ;  
b. ;  
c. .

2. Project Designer's Concurrence:

I agree with the dispensations proposed in paragraphs X, X, and X. Defence approval of this dispensations will allow me, as the electrical designer, to complete the design certification and IM high voltage certification report.

Name:

NPER No:

Company:

Signature .....Project Consultant

Date

3. Director of Estate Engineering Policy Comments:

1.

Recommended/Not Recommended

Name: Mark Turner Signature.....DEEP  
Director Estate Engineering Policy Date

4. Dispensation:

A dispensation from the provisions of the XXXX and the associated provisions of the Electrical Standard Engineering Inclusions as detailed in paragraphs X, X and X above is approved subject to the comments of DEEP.

Approved/Not Approved

Terry Weston Signature.....ASEPE  
Assistant Secretary Estate Policy and Date  
Environment

5. If you require further information on this matter, please contact the Project Officer on (02) 6266.

**Project Director**

(Location)  
(Telephone number)

Date

**Enclosures:**

1. Reference A

## **Appendix C Electrical Standard Engineering Inclusions**

# Electrical Standard Engineering Inclusions

## Electrical Engineering

Electrical installations in Defence establishments and in Defence leased premises shall conform to the requirements of:

- a. all applicable legislation, regulations, codes of practice and guidance publications (*Regulations*) relevant to the State or Territory where the installation or facility is located;
- b. all relevant standards (*Standards*); and
- c. the Defence Manual of Infrastructure Engineering Electrical (MIEE).

The MIEE can be found on the IM at [www.defence.gov.au/im](http://www.defence.gov.au/im) under engineering and maintenance. The MIEE has requirements for:

### General Electrical Installation Requirements

#### Internal Electrical Services

- Switchboard locations, labelling and numbering
- RCD protection
- Power Factor Correction
- Artificial Lighting
- 400 Hertz Systems
- Hazardous Area and Explosive Area Installations
- Aircraft Earth Reference Points
- Wharf Services

#### Emergency Power Systems

- Uninterruptible Power Systems (UPS)
- Local Emergency Generators (LEG)
- Mobile Generator Link Boxes (MGLB)

#### Electrical Reticulation and Power Generation Systems

- High and Low Voltage Distribution Systems
- Central Emergency Power Stations (CEPS), Central Power Stations (CPS) and Central Energy Plant (CEP)
- Power Control and Monitoring Systems (PCMS)

## **Design Reporting**

Provide Design Reports as required by, and in accordance with:

- a. this FDB and the Contract;
- b. the Infrastructure Management System (IM) *Design Management* process; and
- c. the MIEE (The MIEE details the content required for electrical systems design reports).

With every design report submission provide a **MIEE Compliance Report**, in accordance with the MIEE.

## **Certification and Verification**

All Defence new construction and refurbishment projects are to be certified by the designer as meeting the requirements of the *Regulations and Standards* and the MIEE as detailed in the contact and the MIEE.

In addition to the certification above, the designer is also required to provide verification reports as required by the MIEE.

## **Classification of Defence Power Systems**

The classification of Defence power systems is founded on the type of emergency power support provided as shown in the table below:

<b>Power System Classification</b>	<b>Type of Support</b>
<b>Critical</b>	UPS supported
<b>Essential</b>	LEG supported
<b>Normal or Non-essential</b>	No UPS or LEG support May be supported by CEPS or mobile generator

**Classification of Defence Power Supplies**

## **External Electrical Services**

### *Option A*

*(check the IM for availability)*

*The Base HV Infrastructure Report, available from the IM, provides a description of the existing electrical reticulation system)*

### *Option B*

*The Base Electrical reticulation system is described below (suggested content)*

#### *Existing 11kV System*

- *General information including owner, DNSP and electricity retailer contact details applicable to the site, etc*
- *NSP feeders to the Base (including system fault level and BIL), rating and current load*
- *Configuration of on base High Voltage Rings and equipment including the ratings and loads for each ring (e.g. Ring Main 1, Ring Main 2, Ring Main 3), ISS, CEPS, Substations, HV Cables, etc*
- *Any specific operating arrangements and system limitations*
- *Any specific standards currently adopted at the site*

#### *Power Supply*

The designer shall provide each new, refurbished or leased facility with a suitable power supply in accordance with the requirements of the MIEE.

The designer must review the existing reticulation system and the feeders to the establishment to confirm there is adequate capacity and this must include assessing the impact to the current energy contracts and network agreements. The Director Energy Services and the Regional Manager can provide advice on existing retail contracts or network agreements respectively.

Where the required augmentation is only simple in nature such as the addition of a single substation and the existing reticulation system has adequate capacity, the design report is to reflect the outcome of these investigations and detail the proposed works for agreement. Alternatively where considerable high voltage system augmentations are required such as a number of substations, more than one hundred metres of high voltage cable or the ring does not have capacity, a project *High Voltage Development Plan* in accordance with the MIEE must be prepared to assist Defence consideration.

It is important to identify the required reticulation system augmentations as early as possible so that the Director of Estate Engineering Policy (DEEP) can agree to the proposed augmentation and also advise the need for a High Voltage Development Plan. Refer to the MIEE for the Development Plan requirements or liaise with DEEP for any clarification.

All electrical reticulation system modifications must be formally agreed by DEEP through the design report process.

### Distribution Network Service Provider (DNSP)

The designer when considering if reticulation system augmentation works are required, needs to consider who owns the reticulation, Defence, DNSP or other agency. The designer must not make any undertaking with the NSP or third party without prior formal Defence agreement. It is important that all such works be agreed by Defence prior to any formal agreement with these agencies.

### High Voltage System Documentation

The designer shall prepare revised High Voltage System Documentation whenever an alteration is performed to the reticulation system in accordance with the MIEE. This documentation must be handed over to the electrical operating authority prior to completing any construction work to ensure safety.

## **Emergency Power**

### Justification

**Emergency power installations shall only proceed if their respective sponsors have successfully argued for their justification. Guidance on the justification process and the associated risk assessment and analysis is included in the MIEE.**

### *Option A*

*There is no emergency power requirement for these facilities. Where the Base has a Central Emergency Power Station (CEPS) load shedding must be provided in accordance with the MIEE and connected to the Base Power Control and Monitoring System (PCMS).*

### *Option B*

*A Mobile Generator Link Box (MGLB), complying with the requirements of the MIEE, is needed for this facility. The MGLB is required to supply the following equipment/ areas:*

- a. (insert applicable areas or equipment)
- b. (insert applicable areas or equipment)
- c. (insert applicable areas or equipment)

The MGLB arrangement shall be suitable for semi skilled operators. Ensure suitable operating instructions are provided on or adjacent the main switchboard or the MGLB. The procedures must detail connection and operation of the mobile generator link box particularly where the mobile generator only supports part of the facility.

### *Option C*

*A Local Emergency Generator (LEG), complying with the requirements of the MIEE, is required for this facility. The LEG is to be configured as further detailed at Annex B1.*

## *Option D*

*An Uninterruptible Power System (UPS), complying with the requirements of the MIEE, is required for this facility. The UPS is to be configured as further detailed at Annex B2.*

### **Load Shedding**

Load shedding connected to the Base Power Control and Monitoring System (PCMS) shall be provided for all facilities located at an establishment provided with a CEPS or where the LEG or mobile generator will not support the entire facility. Load shedding system requirements are provided in the MIEE Part 4 Chapter 26 *Low Voltage and High Voltage Distribution Systems Design Standards*.

### **Switchboards, Circuit Arrangements and Spare Capacity**

Switchboards are to be located and labelled as required by the MIEE. Circuiting and spare capacity shall be in accordance with the MIEE.

### **Residual Current Devices**

RCDs shall be provided as required by the MIEE. All socket outlets not provided with RCD protection are to be detailed in the design report for agreement in accordance with the MIEE.

### **Lighting**

Lighting installations shall comply with the MIEE Artificial Lighting Requirements.

*Include in the FDB:*

- a. *Additional or specific lighting functionality requirements;*
- b. *Suitable room data schedules identifying the tasks/activities for each area and any specific design considerations;*
- c. *Where appropriate (e.g. not covered by AS), required levels of illumination for each area or suitable performance requirements;*

### **Power Factor Correction**

The designer shall provide power factor correction as required by, and in accordance with the MIEE.

### **Hazardous Area & Explosive Area Electrical Installations**

Electrical installations in hazardous areas or explosives areas shall comply with the relevant standards and the additional requirements of the MIEE.

The sponsor/users are responsible for classification of the area and for identifying what processes and hazards will exist and for providing detailed information on these. In circumstances where appropriate data is not available or cannot be sourced, the designer must assist in the proper classification and for carrying out all necessary surveys of existing installations to establish their characteristics.

*Include in the FDB*

- a. *Responsible person(s) for site classification, process identification and key stakeholders for hazard analysis and certification;*
- b. *For Explosives areas, the nominated Defence Standard applicable (refer the MIEE for guidance);*
- c. *Functionality requirements and equipment configuration;*

- d. Any specific requirements of the installation including the regional requirements; and
- e. Any additional processes which must be followed as part of the design.

## **400 Hertz Systems**

Aircraft servicing and other 400 Hertz installations shall comply with the relevant standards and the additional requirements of the MIEE.

*Include in the FDB*

- a. The applicable 400Hz supply standard to be adopted in the design (the sponsor or System Project Office (SPO) will identify the applicable 400Hz standards);
- b. The aircraft or systems to be supported (the sponsor or SPO must identify the applicable equipment);
- c. The supply requirements applicable to any high reliability facility;
- d. The interaction with other systems.

## **Aircraft Earth Reference Points**

Aircraft earth reference points shall comply with the requirements of Australian Air Publications (AAP) 7045.002-01 Chapter 14. Where associated with a facility or future facility they shall be equipotentially bonded in accordance with AS/NZS 3000, AS1020 and AS1768. Note the FDB needs to specify the required location of the aircraft earth reference points.

*Include in the FDB*

- a. The required location for the earth reference points.

## **Wharf Services**

Shore electrical power for Royal Australian Navy (RAN) ships and submarines shall meet the requirements of Navy Standard DEF AUST 5000 Vol 05 Pt 11.

*Include in the FDB*

- a. The required location for the cope points;
- b. Functional requirements and systems/ships to be connected.

## **Liquid Dry Breathing Oxygen (LDBO)/Cryogenic Facilities**

Liquid Dry Breathing Oxygen and Cryogenic facility electrical installations shall comply with DI AF AAP 7002.023 and the relevant standards.

## **Battery Rooms and Installations**

Battery installations shall comply with the MIEE and the relevant standards.

## **Central Emergency Power Stations (CEPS), Central Power Station (CPS), Central Energy Plant (CEP)**

CEPS/CPS/CEP installations or upgrades will require a separate FDB brief developed on a case by case basis to suit the specific installation requirements. Normally a suitable scoping study will be required to form the basis of the requirement. When required, seek DEEP guidance for developing the FDB for CEPS/CPS/CEP. Aspects that will need to be addressed include:

- a. Determination of required capacity, configuration, location, connection arrangement or the need to investigate and determine these;
- a. Post disaster and passive defence functionality requirements;
- b. Fuel types, use emergency fuels, such as Avtur. As a general requirement the designer must undertake suitable analysis/cost benefit study of all fuel types available and make recommendations to Defence on the most appropriate fuel for the power station.

**Local Emergency Generator (LEG)**

The sponsor/user shall detail the loads or portions of the building to be supported by LEG, as well as the equipment requirements and/or other particular functional requirements. These should be incorporated into the FDB or will need to be provided to the designer as part of the design process.

*Include in the FDB*

- a. *equipment or areas supported by the LEG;*
- b. *equipment load performance requirements including:*
  - *Nominal voltage and allowable voltage limits under steady state and transient state conditions.*
  - *Full load true power rating (kW) and power factor.*
  - *The type of load and its characteristics, particular emphasis should be given to identifying the loads with high inrush currents or high harmonic content.*
  - *Indication of the inrush characteristic or harmonic content of the load and the combined affect of these. (An indication of the inrush characteristic harmonic content of a load can be obtained from measurements carried out on existing or similar loads or through consultation with relevant equipment manufacturers and suppliers); and*
  - *Any special characteristic of the load such the power regeneration on de-energisation, restoration time on power up, restoration process and susceptibility to power outages.*
- c. *required generator restoration time;*
- d. *required redundancy or availability;*
- e. *required equipment connection interface;*
- f. *required output characteristics of the LEG;*
- g. *load shedding system if required; and*
- h. *any specific to project or other special requirements to be met by the LEG.*

**LEG Proforma**

The Designer shall ensure that the LEG is suitably configured to meet the performance requirements in accordance the MIEE.

## LEG Requirements

Required Location:	
Passive Defence Requirements:	
Site and Service Conditions:	
Nominal Rating:	To be determined by designer
Configuration & System Requirements:	Required output characteristics Required load shedding arrangement for systems providing only partial support
Generator Restoration Time/ Support period required:	
Redundancy requirements:	
Essential Power Distribution:	Dedicated outlet/connection Distribution (description of requirement also need to be provided e.g. redundancy required in the distribution if any) Under voltage releases required
LEG Control and Monitoring Additional equipment interfaces:	Defence Engineering Service Network (DESN) Interface to Building Management System (BMS) Local Control and Monitoring
Local Environment/Considerations/ interfacing requirements:	Central Emergency Power Station (CEPS) support Tempest/Filters Power factor correction
Investigations required:	
Regional Requirements:	
Other Requirements	

## Equipment to be Supported

Equipment Description	Location	Characteristics
		VA: Voltage: kW & Power Factor: Inrush Current: Harmonic Content: Power Quality Standard:
		VA: Voltage: kW & Power Factor: Inrush Current: Harmonic Content: Power Quality Standard:
		VA: Voltage: kW & Power Factor: Inrush Current: Harmonic Content: Power Quality Standard:
		VA: Voltage: kW & Power Factor: Inrush Current: Harmonic Content: Power Quality Standard:

**Uninterruptible Power Systems (UPS)**

The sponsor/user shall detail the loads or portions of the building to be supported by UPS, as well as the equipment requirements and/or other particular functional requirements. These should be incorporated into the FDB or will need to be provided to the designer as part of the design process.

*Include in the FDB*

- a. *equipment or areas supported by the UPS;*
- b. *equipment characteristics of the load or equipment;*
- c. *required UPS configuration and redundancy provisions;*
- d. *required UPS support time*
- e. *required supply characteristics applicable including voltage and frequency performance;*
- f. *required availability and reliability criterion including Mean Time Between Failures (MTBF), Mean Time to Repair (MTTR) and Maximum Time to Repair (MAXTTR);*
- g. *additional control and monitoring requirements;*
- h. *requirements to incorporate other elements such as LEGs; and*
- i. *complete the proforma attached.*

## **UPS FDB Proforma**

### **UNINTERRUPTIBLE POWER SYSTEMS (UPS)**

#### **Communications Network UPS**

Individual small UPS are required in this facility to support the nominated servers and communications equipment as detailed below:

- a. (insert applicable equipment)
- b. (insert applicable equipment)
- c. (insert applicable equipment)
- d. (insert applicable equipment)

These UPS shall meet the Chief Information Office Group (CIOG) standard UPS equipment specifications/contracts for communications systems including DRN and DSN requirements and also standardised UPS monitoring through the communications network.

#### **Other UPS systems**

In addition to any communications systems UPS requirement, provide a UPS for the following equipment specified below.

Provide a UPS complying with the MIEE, AS 62040.2 *Uninterruptible Power Systems (UPS) - Electromagnetic Compatibility* and AS 62040.3 *Uninterruptible Power Systems (UPS) - Method of specifying performance and testing requirements*. The equipment characteristics and requirements are specified at Annex XXXXX to this FDB.

The designer in meeting the UPS system requirement shall consider centralised and decentralised UPS systems and also rotary and static systems. Selection of the most suitable system shall be based on achieving the equipment requirements on the lowest through life basis. Provide in the design report a suitable cost benefit analysis confirming the recommended system.

## UPS Requirements

Required Location:	
Additional Space Requirements:	
Site and Service Conditions:	
Passive Defence Requirements:	
Nominal Rating:	
Configuration:	single, parallel, parallel redundant
Scalability and concurrent operation	
Support period required:	
Redundant battery strings required:	
Manual Maintenance Bypass Location:	
Critical Power Distribution:	Dedicated outlet/connection Distribution (description of requirement also need to be provided e.g. redundancy required in the distribution if any) Under voltage releases required
System Requirements	Redundancy: Availability: MTBF: MTTR: MaxTTR
UPS Control and Monitoring	Defence Engineering Service Network (DESN) Interface to Building Management System (BMS) Local Control and Monitoring
Local Environment/Considerations/ UPS interfacing requirements:	Local Emergency Generator (LEG) connection Central Emergency Power Station (CEPS) support Tempest/Filters Power factor correction
Investigations required:	
Regional Requirements:	
Other Requirements	

## Equipment to be Supported

Equipment Description	Location	Characteristics
		VA: Voltage: Power Factor: Harmonic Content: Power Quality Standard:
		VA: Voltage: Power Factor: Harmonic Content: Power Quality Standard:
		VA: Voltage: Power Factor: Harmonic Content: Power Quality Standard:

# Glossary of Definitions

ABR 862	Australian Book of Reference 862
AC	Alternating Current
ADO	Australian Defence Organisation
Availability:	The ability of an item to perform its intended function at any instant of time. It is usually given as the ratio uptime/(uptime + downtime).
Battery:	A device that converts chemical energy into electrical energy by means of an electrochemical reaction. Usually defined as consisting of two or more cells, but commonly used to refer to one cell.
BCA	Building Code of Australia.
BMS:	Building Management System. Building automation system used to control and monitor building services.
Brownout:	Conditions under which power is available but not sufficient to fully meet the needs (voltage, current) of the load; partial power failure.
Capacity (battery):	The number of ampere-hours (Ah) a fully charged cell or battery can deliver under specified conditions of discharge.
CB	Circuit Breaker.
CEPS	Central Emergency Power Station. A centralised standby power station that supplies power to the Base in the event of power failure.
CEP	Central Energy Plant. A centralised power station used to offset power purchases from the grid.
CMS	Comprehensive Maintenance Services
Controller	The device used to automatically process data and control equipment based upon programmable algorithms as either firmware or software (e.g. PLC).
CPS	Central Power Station. A centralised prime power station that supplies power to the Base.
Crest Factor (Fc):	Ratio between the peak value to the root mean square (RMS) current value.
DALI:	Digital Addressable Lighting Interface: a protocol for digital communications between lighting devices. This allows for individual control of each light within a building where each light has its own address.
DC	Direct Current

DEEP	Directorate of Estate Engineering Policy
Defence	Department of Defence
DEMS-FM	Defence Estate Management System - Facilities Management
DEOP-103	Defence Explosive Ordnance Safety Manual
DEOS	Directorate of Explosive Ordnance Services
Design	The intent of the works as performed by the Designer and Installer
Designer	The party engaged to perform a design function for Defence.
DESN:	Defence Engineering Services Network. A site wide system that usually monitors the electrical power system parameters and other engineering services elements.
DEMP	Directorate of Engineering Maintenance Policy
Distortion (individual):	Ratio between the RMS value of an nth order harmonic and the RMS value of the fundamental.
Distribution Substation	A substation used to directly supply loads (typically at 400/230V) consisting of facilities or processes. The distribution substation typically consists of the following major components: <ul style="list-style-type: none"> <li>– RMU</li> <li>– Transformer; and</li> <li>– LV Switchboard</li> </ul> however either or both of the RMU or LV Switchboard can be located remote to the substation.
DNSP	Distribution Network Service Provider: The authority providing access to the electricity grid that own, control and/or operate the transmission or distribution systems.
DOS	Directorate of Ordnance Safety
DSG	Defence Support Group
DSI:	Digital Serial Interface: A protocol enabling dimming of an electronic ballast
ELV	Extra Low Voltage.
EO	Explosive Ordnance
EPE	Estate Policy and Environment Branch

ESAA	Electrical Supply Association of Australia.
Failure Rate:	The number of failures of an item per unit measure of life, where life is expressed cycles, time, events, etc., as applicable for the item.
FDB/FRB	Functional Design Brief/Functional Requirements Brief
FQCC	Fuel Quality Control Centre
GCB	Generator Circuit Breaker
GCS	Generator Control System. The collective name for the overall system that controls the operation of the CEPS. It generally consists of a network of CONTROLLERs and other control devices.
GCS Station	The master CONTROLLER in the GCS Controller network. It performs overall power station coordination functions.
Harmonic Analysis.	Harmonic Analysis is the determination of the harmonic content of the load or supply.
Harmonic Distortion (total) THD:	Ratio between the RMS value of all harmonics of a non-sinusoidal alternating periodic value and that of the fundamental.
Harmonics:	Distortions of the sine wave that characterises normal AC current. Harmonics are transmitted into an AC line by non-linear loads (i.e., loads that do not draw power in regular sine waves), such as computers, copiers, FAX machines, and variable-speed motors. Harmonics can cause communication errors and equipment damage. In three-phase systems, they can cause transformers and neutral conductors to overheat creating a possible fire hazard.
HAZAN	Hazard Analysis
HAZOP	Hazard Operability
HMI	Human-Machine Interface.
HV	High Voltage: Above 1000V AC or 1500V DC.
HV Feeders	HV cabling from the DNSP to the establishment ISS.
HV Rings	HV cabling on the establishment on which substations and switching stations are connected, but not the Feeders or Interconnectors.
HV Switchroom	Normally an indoor arrangement provided for HV circuit breakers and HV switchgear panels
IAD	Infrastructure Asset Development Branch

ID	Infrastructure Division
Indoor Substations	Substations where the various major components are housed within a building, either as a freestanding structure or part of a larger structure.
Interconnector	A direct intertie HV power cable connection between two (2) PSSs or PSS/ISS/CEPS, that facilitates power flow used to transfer power between them.
ISS	Intake Switching Station or Intake Substation as appropriate.
Kiosk Substations	Stand alone, freestanding substations, where the various major components are housed within a metal or composite enclosure. This form of construction is limited to distribution substations.
LEG:	Local Emergency Generator: An independent standby generator at a facility that supplies power to that facility in the event of power failure.
LV	Low Voltage: Less than High Voltage but higher than 50V AC or 120V DC.
Maintainability:	The ability to retain and restore an item to its functional state when maintenance is performed under stated conditions and using prescribed procedures and resources. Measures include probability to repair within a given time, repair rate, and mean time to repair.
MEPS:	Minimum Energy Performance Standard
MFPE	Manual of Fire Protection Engineering.
Motor-Generator (M-G):	Power systems that use a rotating AC generator to generate the needed output power. A motor-generator that is powered by a battery or a diesel or gas-powered engine when utility power is lost, constitutes a rotary or hybrid UPS.
MTBF:	Mean Time Between Failure. A measure of reliability. As applied to repairable items, the mean value of the length of time between each item's consecutive failures, calculated as the ratio of OK cumulative time to the total number of failures during the stated period.
MTBM:	Mean Time Between Maintenance: The interval between scheduled major maintenance activities (i.e. major overhaul), not routine maintenance (i.e. routine servicing).
MTTF:	Mean Time To Failure. As applied to non-repairable items (i.e. for which a MTBF is not possible), the ratio of the OK cumulative time to the total number of items failed during the stated period.
MTTR:	Mean Time To Repair. A measure of maintainability. Mathematical calculation (or statistical average if available) of the time required to repair a device.

MaxTTR:	Maximum Time to Repair. Required maximum time to repair specified as a supportability requirement. MaxTTR is the maximum corrective maintenance downtime within which corrective maintenance actions can be accomplished.
NBPS:	No Break Power Supply.
NEC	National Electricity Code.
NEC	Neutral earthing contactor
NECA	National Electricity Code Administrator.
NEM	National Electricity Market.
NEMMCO	National Electricity Market Management Corporation.
NOD	National Operations Division
NSP	Network Service Provider The authority providing access to the electricity grid and the owner/controller of the local sub-transmission and distribution systems.
OLA	Ordinance Loading Apron or Area
On-Line UPS:	An UPS that continuously powers the load from the inverter under normal operation.
OPSMAN 3	Safety Principles for the Handling of Explosive Ordnance
OSC(E)81/1	Operational Safety Committee (Explosives)
Outdoor SS	Substations where the various major components are outdoors without further enclosure.
Output (rated):	Apparent power Pn that the UPS can deliver under given load conditions (power factor = 0.8).
Oversizing:	Increasing the capacity of an UPS beyond that required to exactly meet the needed power requirements. Oversizing allows an UPS to efficiently and effectively handle surges and provides for growth in the power requirements.
PCMS	Power Control and Monitoring System: A software module on the DESN, which monitors and controls the power distribution system.
PELV	Protected Extra Low Voltage in accordance with AS/NZS 3000
PHA	Preliminary Hazard Analysis
PLC	Programmable Logic Controller.

Point of Supply	(see AS/NZS 60038) The point where the distribution system of the DNSP and the electrical system of the customer are connected.
Power Factor:	The power factor is the mathematical relationship between apparent or effective power, measured in kVA, and real or average power, measured in kW. When the current and voltage are in phase, purely resistive load, the power factor is 1. In a purely reactive load in which voltage and current are 90° out of phase, the power factor is 0.
Power Failure:	See AS 62040
Primary Power:	See AS 62040
PSS	Primary Switching Station / Primary Substation as appropriate— Are switching stations/substation that form part of the primary electrical distribution system, to which Incomers and Interconnectors are connected.
RCD	Residual Current Device (RCD) - see AS/NZS 3000 - A device intended to isolate supply to protected circuits, socket outlets or equipment in the event of a current flow to earth which exceeds a predetermined value.
Redundancy (active):	Parallel UPS configuration in which several UPS units with equal outputs are parallel connected and share the load. In the event one UPS unit fails, the other units pick up its share without any interruption in the supply of power to the load.
Redundancy (standby):	UPS configuration in which one or several UPS units operate on standby, with no load or only a partial load, and can immediately back up a faulty UPS unit by no-break transfer of the load, carried out by a static switch.
Reliability:	The probability that an item will perform as intended for a specified period of time under a stated set of conditions. Usually measured as a probability, a failure rate, or a mean time between failures.
Resonance.	Resonance results in voltage surges and transients of several times the supply voltage. PFC connected to a supply can cause resonance between the supply and the PFC capacitors or between other equipment and the PFC capacitors.
RMU	Ring Main Unit, compartmentalised HV switching/protection panels normally switch/fuse switch disconnector unit. Switchgear normally used at substations
RTU	Remote Terminal Unit
Sag:	A low-voltage condition in which the voltage on one or more phases of AC power falls below 80 to 85 percent of the nominal value for more than one cycle (1/60th of a second for 60-cycle AC). Can be caused by ground faults, starting large loads, inadequate power supply, utility switching, utility equipment failure, and lightning. Can cause computer crashes and damage equipment.

SELV	Separated Extra Low Voltage in accordance with AS/NZS 3000.
SF6	Sulphur Hexaflouride An electrically insulating gas utilised in HV switchgear equipment.
SMS:	Site wide Management System. Typically a distributed site wide BMS application
Standby Power:	See AS 62040
Static Bypass:	See AS 62040
Static Switch:	Synchronous Bypass Facility. The combination static (semiconductor) and electromagnetic switch that bypasses the UPS to connect the critical load to the bypass power source.
Substation (SS)	A facility in the electrical distribution system at which voltage transformation occurs, i.e. the voltage is changed from one voltage to another. The typical substation generally comprises as a minimum a power transformer. Substations may also include the associated switchboards, however either or both of these can be located remotely.
Support Time:	Time during which the UPS can supply the rated load with nominal-quality power while the primary power is down.
Surge:	A high voltage condition in which the voltage on one or more phases of AC power exceeds 100 percent of the nominal value for more than one cycle (1/60th of a second for 60-cycle AC). Can be caused by a rapid load reduction or switching, and can damage equipment.
Switching Station (SWS)	A facility in the electrical distribution system that is specifically designed for electrical switching. Normally housing HV RMUs.
System Control:	The control circuits that provides total UPS system control, alarm annunciation and instrumentation metering.
Systems Project Office (SPO)	Defence agency responsible for the engineering integrity of aircraft systems, subsystems and interfaces
Thermal Runaway:	A condition that is caused by a battery charging current that produces more internal heat than the battery can dissipate. This condition ultimately causes cell venting and premature failure.
Transients:	Disturbances to electrical power lasting less than one cycle (1/60th of a second for 60-cycle AC). Also referred to as voltage spikes. Can be caused by lightning strikes, sudden load-shedding on the primary power system, and shutdown of equipment that was drawing an extremely large amount of power, or a general rise in voltage on the primary power system after use by a large number of

consumers. Voltage spikes can blow fuses or trigger circuit breakers, destroy electronic circuitry, and corrupt stored data.

**UPS:** Uninterruptible Power System. Refer to AS62640, an electrical device or system providing an interface between the mains power supply and sensitive loads (computer systems, instrumentation, etc.). The UPS supplies sinusoidal AC power free of disturbances and within strict amplitude and frequency tolerances. If input power is removed from the UPS, it will continue to supply the load without interruption. Refer AS62040.

**UPS, Rotary:** An UPS in which a Motor-Generator (M-G) set is used.

**UPS, Static:** A solid-state UPS relying normally on battery power.

**Useful Life (battery):** The time over which a battery can deliver a useful amount of power (normally defined as 80 percent or more of the battery's capacity).