



THE UNIVERSITY OF
SYDNEY

Electrical Services Standard

**Design, Engineering, Planning &
Sustainability**

University Infrastructure

Document Edition Control

Document Name:	Electrical Services Standard
Current Version	3.0
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Version	Date	Created By	Reason for Change	Document Status
001	August 2013	Nav Brah	First Release	Final
002	August 2015	David Clarke	2 Year Revision	Draft
3.0	August 2020	David Clarke	5 Year revision	Final

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1 Purpose

The Electrical Services Standard sets out the University of Sydney's minimum requirements for the design, construction and maintenance of Electrical Services. It ensures new and refurbished systems are energy efficient, fit-for-purpose, made from durable good-quality materials, contain no or minimal environmentally harmful substances, and are cost efficient to operate and maintain.

Applicable requirements documented in Workplace Health and Safety legislation, Disability Discrimination legislation, State Environmental Planning legislation, Commonwealth and State legislation, National Construction Codes (NCC), the Building Code of Australia (BCA) and Australian and New Zealand Standards (AS/NZS) are the minimum and mandatory compliance requirements.

Where any ambiguity exists between this standard and the aforementioned mandatory requirements then:

- a. The highest performance requirements must apply.
- b. Applicable requirements must follow this order of precedence:
- c. Workplace Health and Safety legislation.
- d. Safety in Design.
- e. Disability Discrimination legislation.
- f. State Environmental Planning and Assessment legislation.
- g. All other Commonwealth and State legislation.
- h. NCC, BCA and PCA.
- i. AS/NZS.
- j. This standard and other University of Sydney standards.

2 Scope

This standard describes minimum requirements for design, purchase, construction, and operation and maintenance of electrical services plant, equipment and infrastructure for buildings and spaces owned, operated, maintained and/or managed by the University of Sydney. It applies to:

- a. New building construction.
- b. Refurbishment projects for University-owned spaces.
- c. Refurbishments of spaces that form part of a broader medium-term (less than five years) program/plan of progressive upgrades to a University-owned building.
- d. Refurbishment projects for long-term University-leased spaces.
- e. Facilities maintenance services.

The standard applies to planners, project managers, consultants, contractors, sub-contractors, tenants, managing agents, University staff and others involved in the design, construction, installation, operation and maintenance of existing, new and proposed University buildings and facilities.

The **Standard provides:**

- a. A reference document to enable consistency with the design and engineering objectives.
- b. Details of the minimum performance requirements for planning, architectural design and maintenance.
- c. Support of the University vision for the built environment and best practice.

The **Standard addresses key objectives:**

- a. Quality design which responds, enhances and complements the environment.
- b. Appreciation of the heritage context and cultural history of the campuses.
- c. Value for money in all aspects of the project.
- d. The design of low maintenance buildings and environments.

- e. Longevity of construction approach to design.
- f. Standardization of key flashing and ancillary details.
- g. Flexible design, to future proof building usage for expansion or adaptation to new uses.
- h. Safety in design.

This standard does not cover in detail the special electrical installations for specialised medical, laboratory and research spaces which will be specifically defined in the project. Nonetheless the principles and minimum requirements of this standard must apply to these spaces.

The standard covers provision of electrical services for most University projects. It covers:

- a. Design calculations including grading studies and cable sizing.
- b. Main and distribution switchboards.
- c. External switchboards.
- d. Generators and diesel fuel systems.
- e. Metering and energy monitoring.
- f. Consumer mains, sub-mains and sub-circuit wiring.
- g. Socket outlets, isolators and small power installations.
- h. RCD circuit protection and Laboratory/Workshop Emergency power shutdown.
- i. Cable trays and conduits.
- j. Power factor correction and active harmonic filtering.
- k. Earthing and bonding.
- l. Lightning protection.
- m. Labelling.
- n. Testing and commissioning.
- o. Electromagnetic Compatibility, Hazards and performance.

All Electrical systems products and services provided or specified by designers, consultants, staff and contractors must conform to this standard.

Where specific applications are not explicitly covered, or ambiguity exists, the intent of the design standard must be satisfied. In such cases a return design brief must be provided for review and approval by the issuer of this standard or their appointed delegate who must have relevant technical competence in the subject matter. Additional more stringent requirements may apply on a project-specific basis dependent upon risk management and insurance requirements.

3 Glossary of Terms

Unless the context otherwise requires, the following definitions apply:

ACA	Australian Communications Authority
ACB	Air circuit breaker
AGL	Australian Gas Light Company
AHF	Active Harmonic Filter
ASTA	Association of Short-Circuit Testing Authorities
AS/NZS	Australian / New Zealand Standard
AUMS	University Private Advanced Utilities Monitoring System
BCA	Building Code of Australia
BMCS	Building Management Control System
CB	Circuit breaker
CCEW	Contractor's Completion of Electrical Works
COS	Campus Operations Services
CT	Current Transformer
DB	Distribution Board
Designer	Qualified Electrical Engineer covered by contract limit PI & PL insurances

EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPO	Emergency Power Off
GPO	General Power Outlets
L1 ASP	Supply Authority accredited distribution / substation network installer
L2 ASP	Supply Authority accredited tariff metering installer
L3 ASP	Supply Authority accredited distribution / substation network designer
MCB	Miniature Circuit Breaker
MCCB	Molded Case Circuit Breaker
MDB	Main Distribution Board
MEN	Multiple Earth Neutral (earthing system)
MIMS	Mineral Insulated Metal Sheathed cable (fire rated)
MOV	Metal Oxide Varistors
MSB	Main Switchboard
NCC	National Construction Code of Australia
NATA	National Association of Testing Authorities
O&M	Operation and Maintenance Manual
PCA	Principal Certifying Authority
PI	Professional Indemnity Insurance
PL	Public Liability Insurance
PF / PFC	Power Factor / Power Factor Correction
RCBO	Residual Current Circuit Breaker with Integral Overcurrent Protection
RCD	Residual Current Device
RMSB	Regional Main Switchboard
SPD	Service Protective Device
Supply Authority	Local Statutory Authority controlling electricity distribution in the area
TPS	Thermoplastic sheathed cable
UI	University Infrastructure

4 Roles and Responsibilities

This standard is issued by UI. It is approved and signed off by the Chief University Infrastructure Officer. UI is responsible for maintaining the standard and keeping it up to date.

5 Construction Requirements

Due to the complex nature of the University's Infrastructure, the requirements for construction of new buildings, and the refurbishment of existing buildings differ and must be assessed on a case by case basis. Careful consideration must be taken in relation to connection and disconnection of existing services, and the reuse of existing equipment. This section outlines the construction requirements for both new and existing buildings.

5.1 New Buildings

The Electrical Services provided within the University buildings must be designed and installed in accordance with the minimum legislative requirements incorporating all Statutory Regulations, Australian Standards, Local Council, Work Health & Safety (WHS) and WorkCover requirements.

Each building must be equipped with the appropriate electrical services, all designed and installed in accordance with the requirements of the project PPR, NCC and Australian Standards. Additional measures may also be required to meet specific building hazards and/or the requirements of University Insurers.

The consultant/contractor must take a long-term balanced view of capital costs, energy costs, maintenance costs and longevity when proposing any Alternative Solution', comparing the capital and operational costs of each proposed solution with the applicable Deemed to Satisfy provisions.

The consultant/contractor will consult with UI, and Project User Groups, to discuss any additional electrical services that must be included in the design, in order to suit the proposed occupancy, user expectations, associated hazards and user equipment.

5.2 Refurbishments

All existing electrical services in a building must be extended/replaced as necessary into the given project envelope. The design for projects within existing buildings must be assessed on a case by case basis and developed in conjunction with this standard. The project scope will drive the design requirements and the extent of upgrade of the existing services.

Any items not included in the scope must not be priced into the overall project to achieve the following aim; to reduce the need to value engineer any services.

It is the responsibility of the consultant/ contractor to obtain the gate paper from the Project Manager to understand the UI Engineering brief/scope of works in relation to the space and fit out requirements. New projects within existing buildings must assess what the expectation of the refurbishment will be. This will enable the right outcome for the given project to meet the approved budget.

All project associated redundant pipework, equipment, fixings and wiring, including inaccessible ceiling spaces, must be removed as part of the project works. Make good exposed surfaces before commencing the installation of new services. This includes the removal of redundant underground services and cabling unless otherwise approved by the project superintendent.

5.3 Reuse of existing equipment

Where existing equipment is utilised as part of a project it is the responsibility of the contractor to confirm its performance\condition and provide a written report to the University stating its condition.

Reuse existing services where identified in the Gateway Paper scope of works and the approved Return Brief.

Equipment must be suitable for the intended new purpose and life expectancy of the works, comply with current codes and achieve energy targets.

Equipment must be cleaned, have consumables replaced, tested, relabeled and re-commissioned.

Existing lighting control systems in a building must be extended as necessary into the given project. New lighting control systems must not be installed unless absolutely necessary.

5.3.1 Redundant Equipment Removal

Remove redundant equipment and wiring, including in accessible ceiling spaces, and make good exposed surfaces before commencing the installation of new electrical works.

Remove redundant underground cables unless otherwise approved by the project superintendent. If submain cables are retained, strip and bond together all redundant cable ends left in place. Insulate and label both ends with permanent tags and mark up notes on As Built drawings.

5.3.2 Retrofitting of RCD Protection

Provide RCD protection in refurbishment works in accordance with codes and standards.

It is acknowledged that it can be difficult to clearly quantify the extent of work required to diagnose defective sub-circuit wiring in existing installations.

If necessary, carry out a survey of the existing installation and identify the extent of any existing incorrect / unknown circuit identification and identify the level of risk in carrying out the upgrade works.

Agree a nominal scope of work and base cost which covers the reasonably expected degree of difficulty. A proportionate PC sum should be allocated to cover contingencies.

If additional or unexpected latent conditions arise during the works, notify the Project Manager of the possible extent of additional investigation or rectification required before proceeding.

6 Technical Requirements

6.1 Introduction

The Electrical systems within a University building will include surrounding structures and annex buildings. In some cases, components of the Electrical system will be installed or are to be installed in other buildings. In these cases, the word building in this document must be interpreted as inclusive of these structures, annexes and components.

6.2 Design Scope - Full Design, D&C and DD&C Projects

These specific requirements must be carried out by the Design Consultant, or included in the scope of works specification for Design and Construct (D&C) or Design Develop and Construct (DD&C) contracts of electrical services:

- a. Obtain the project definition Gate Paper from the Project Manager and understand the scope of works in relation to the space and fit-out requirements. Understand the expectation from the end user.
- b. Attend a site inspection / briefing meeting with the Project Manager, UI services representative and Users representative.
- c. Provide a detailed project Return Brief including the project drivers, the final project use, existing site conditions, budget and program.
- d. Provide a section listing any major deviations from this standard and summarising the reason.
- e. Electrical services must be detailed and designed by an experienced and suitably qualified electrical engineer covered by professional indemnity and public liability insurances. Insured values must be in accordance with the contract.
- f. Provision of formal Engineering Certification for the design in accordance with the PCA requirements, and an Engineering certificate of inspection and completion of the works in accordance with the University standards and statutory requirements.
- g. Include "Safety in Design" requirements for installation, operation, maintenance and eventual decommissioning of the works.
- h. Maintain reliability and availability of electrical systems of buildings during and after construction. Provide temporary power systems as required to meet the affected user's requirements and liaise with the users and project manager to determine these requirements.
- i. Warranty requirements for all new equipment and services.
- j. Maintenance requirements during the Defects Liability period.
- k. Compliance with NCC including Section J, Local Authorities' regulations and all relevant Australian and New Zealand Standards (AS/NZS).
- l. Allow for any University work embargo and restriction periods during the construction period.
- m. Provision of electrical maximum demand calculations in editable spreadsheet format, and to satisfy the Supply Authority and to AS/NZS 3000 as a minimum including 20% spare capacity.
- n. Application for connection for new and increased loads to the Supply Authority.
- o. Supply of statutory design certifications and certification of compliance to the University standards.
- p. NCC Section J6 compliance calculations and certifications for energy consumption minimisation.

- q. Annual electrical energy consumption estimate based on building space types, occupancy and operation of planned plant and equipment.
- r. Power system calculations for the whole system in PowerCALC / PowerCAD or approved equal software, covering fault levels, voltage drop, cable sizing and circuit breaker discrimination. NOTE - The Designer must carry out and document the detailed power system calculations for both Detailed design and Design and Construct projects. The Designer will be accountable for the power calculations and a contractor will accept, validate them and take responsibility to check and implement them for the Construction phase.
- s. Supply of all calculations in electronic native software editable file and PDF output format.
- t. Design drawings in AutoCAD (and Revit 3D model where defined in the project brief) format including plans, schematics and single line diagrams.
- u. Testing and commissioning schedules and program.
- v. Contractors must visit project sites to determine constraints and risks when installing electrical services at the University's buildings and include sufficient allowances in the tender price to cover these issues.
- w. Ensure that spatial and building general construction details are satisfactory and equipment can physically be installed within the building.
- x. Additional work items identified during tender inspections, but which may not be documented in the original scope of works.
- y. Early notification of adverse latent conditions and liaison with the University's Superintendent to resolve the issues and agree additional costs before proceeding with the works.
- z. Decommissioning and demolition of all redundant electrical services and infrastructure in the works area. Remove any hazardous materials in accordance with the Resource Recovery and Waste Management Standard.

6.3 Installation Scope of Works

A project-specific scope of works must be prepared by the Designer. It must cover all major electrical systems specifically, and all minor systems generally. It must detail the design requirements for Design and Construct projects, including references to the project definition documents. It must consider and specify any staging and temporary power provisions. The **Design & Construct Checklist Form (UI-ENG-F009)** must be completed by the Designer / Contractor and submitted as part of the Design Process.

The Designer or Contractor is responsible for identifying the faculty technical equipment and designing the electrical infrastructure to meet the technical data requirements plus Australian Standard requirements. This includes but is not limited to Electrical Infrastructure, Earthing, EMI requirements, Body Protection requirements & Backup Power. It is expected to get these provisions signed off as 'Approved' by the end user.

6.3.1 Drawings and Documentation

The contractor shall provide design, construction and as-built drawings, including design drawings produced by the contractor and shop drawings produced by equipment manufacturers.

The contractor is responsible for producing all design and as-built documentation, including, but not limited to:

- a. Concept Design documentation (as required).
- b. Detailed Design documentation, including:
 - i. Layout drawings.
 - ii. Details.
 - iii. Calculations.
 - iv. Schematics.
 - v. Design certification as required by building certifiers.
 - vi. Equipment details.
 - vii. Testing/commissioning procedures.

- viii. Performance Solutions.
- ix. Design & Construct Checklist (**UI-ENG-F009**)
- c. Workshop drawings, including:
 - i. Drawings for the purpose of system manufacture.
- d. As Built drawings, including:
 - i. Detailed drawings demonstrating the as installed system.
 - ii. Enabling works associated with the project.
 - iii. Operations and Maintenance manuals.

6.4 Detail Design Drawings and Calculations

Provide detailed design documents as a minimum:

- a. Power system calculations for the whole system in PowerCALC, PowerCAD, or approved equal software, covering fault levels, voltage drop, cable sizing and circuit breaker discrimination.
- b. Power layouts (1:100 scale) and electrical schematic diagrams.
- c. Switchboard and single line schematic diagrams.
- d. Technical catalogue and documents for electrical installation, power and equipment.
- e. Compliance certifications from accredited qualified Electrical Consulting Engineer.

6.5 Electrical Protection Grading Study Calculations

The Electrical Consulting Engineers and Contractors must supply and install an electrical infrastructure and power supply system with automatic circuit breakers and protective devices that fully grades during overcurrent, short circuit situations and discriminates during fault conditions.

Overcurrent on final sub-circuits must be cleared by the local final sub-circuit protective device only and must not affect any upstream protective device likely to cause disruption to non-related final sub-circuits.

The short-circuit protective devices must be provided to protect the entire electrical installation, personal and live stocks from damage under all fault conditions. The Electrical Consulting Engineers and Contractors must demonstrate and provide evident that the electrical installation achieved the grading fault protection (cascade protection) and discrimination for each protective device.

Co-ordinate the discrimination design with all other trade sub-contractors. Cross reference requirements of the cable section and the circuit breaker fault rating. The Electrical Consulting Engineers must provide short-circuit and overcurrent calculations using electrical design software, e.g. PowerCALC, PowerCAD, or equal proprietary software. Submit to UI Electrical Services Engineer the calculation printouts in PDF documents showing:

- a. System grading for each level of the electrical installation from Substation, Point of Attachment, Main Switchboard, Main Distribution Boards, to final Distribution Boards or major loads.
- b. MCCB/ MCB time/ current co-ordination curves.
- c. Fault level calculations for each level.
- d. Protective device selection includes type, trip unit and setting.
- e. Cable selection includes sizing, current carrying capacity and the method of cable installation.
- f. Cable voltage drop at rated maximum demand load.
- g. Earth fault loop impedance or Earth Fault Return.

6.6 Single Line Diagram, Labels and Marking

Mark operable control devices, indicators, isolating switches and outlets to provide a ready means of identification. Equipment labelling must be used to mark equipment, controls, switchboards, panels, services routes, conduit / duct / pipe runs etc. for easy identification:

Description	Lettering Size/Height and Colour	Type for Indoor Location	Type for Outdoor/ Exposed Location
Equipment name plate	40mm	Engraved two-colour laminated plastic fixed with adhesive Black lettering on white plate.	Engraved stainless steel or brass fixed with adhesive and four metal screws or pins.
Cable marker plate	8mm		
Warning notices	8mm – 12mm		
Automatic control & electrical equipment	5mm – 10mm		
Isolating switch / valve	5mm – 10mm		
Inside panels	3.5mm – 5mm	Engraved two-colour laminated plastic fixed with double sided adhesive. Black lettering on white plate.	
Cable pits	40mm	NA	Engraved stainless steel or brass fixed with adhesive and four metal screws or pins.
Switchrooms, electrical cupboards	Signage in accordance with the existing building system or new project signage schemes. In accordance with NSW Service Installations Rules, AS/NZS 3000 & 3010. Room Number, Switchboard Identifier. Danger and Warning labels must be provided to each Switchroom entry door.		

Labelling must match terminology of 'As-Built' drawings. Locate labels so that they are easily seen and are either attached to, below or beside the items being identified. Thermo printed, Embossed or 'Dymo' type labels are not acceptable.

6.6.1 Alternative Supply Labelling

A notice must be fixed to the main switchboard and other affected switchboards to show:

- a. That the alternative supply facilities exist.
- b. Which section(s) of the installation they can supply.
- c. Their point of control.
- d. The conditions under which they may be operated.

6.7 Fire Rated Sealing of Penetrations and Cuttings

Sealing of all penetrations must comply with NCC requirements for fire resistance. Also refer to **UI Essential Fire Safety Measures Standard**.

Biomedical Hazard – PC 1, 2, 3 Laboratory - sealing of penetrations in PC labs must be completed including cables through walls.

Provide visible permanent labelling immediately adjacent of all Fire and PC sealed penetrations identifying the installer, certifier, and installation date.

Where the new works use or disturb existing non-compliant penetrations, notify the Project Manager and seek confirmation of compliance requirements for the completed works, which may require rework of the latent conditions.

6.8 Accessories Provision & Requirements

Requirements for general outlet switches and sockets are provided below.

6.8.1 Accessories Type

Accessory outlet plates must be Clipsal 2000 series or approved equal. They must have adequate flat, non-removable faceplate area to accommodate identification labels.

Flat stainless-steel type plates may be used for special areas, subject to project brief, budget and architectural approval.

6.8.2 Lighting Switches

Lighting switches must meet the following requirements:

- a. **ELV Lighting Switches:** Use ELV switches compatible with the project approved lighting control system (C-bus, KNX, Dali etc).
- b. **Direct Switched Minimum Rating:** 240VAC, 15 A for mains current switches.
- c. **Colour:** Standard manufacturers range. White, cream, black, stainless steel.
- d. **Labelling:** Provide a permanent label on the plate clearly identifying the purpose, control zone of the switch and the on/off/dimming functions. If the information does not fit directly on the plate, provide a neat engraved matching label adjacent.

6.8.3 Isolating Switches

Provide clearly visible, easily accessible local isolating switches for all electrically operated equipment within the immediate vicinity. Isolators must be lockable and located within 3m of the equipment. The use of any form of ladder to reach isolators is prohibited.

All power sources must be able to be isolated via the Isolator switch.

Use IP56 isolating switches in plant rooms, car parks, damp / wet areas and external locations.

6.8.4 General Power Outlets

Provide power outlets in accordance with the project room data sheets, UI approved User consultation and in any case not less than

- a. Office desk position – 2 double GPOs person, allow density of 1 person per 8m².
- b. Lecture theatre seats – 1 double GPO every third seat divider.
- c. Toilet – 1 GPO.
- d. Corridors – 1 GPO per 10 metres length.
- e. Lobbies / Foyers – 1 GPO per 100m², and as required for equipment such as water coolers, LCD displays etc.
- f. Electrical cupboards – 1 GPO per cupboard.
- g. Comms rooms – double GPO on wall and 15 A circuits for equipment (Refer to the ICT Communications Cabling Standard for quantities and type of pendants acceptable).
- h. Computer laboratories – 1 double GPO per seat.
- i. Seminar rooms – 1 double GPO per 3m of wall.
- j. Kitchen or team room power required to match the installed equipment.
- k. Laboratories – requirement must be provided in user brief which must consider greater demand from anticipated plant and equipment use.
- l. Plantrooms – Generally 10A IP56 GPO per 25m² plus 15A IP56 GPO per main plantroom. Locate outlets to facilitate maintenance and test tools connections.
- m. AUMS – Provide 1 DGPO adjacent the AUMS box inside the MSR.
- n. Cooling Towers – 15A GPO, IP65.

GPOs must have the following features:

- a. **Colour** as per AS/NZS 3003:

- i. General Power – standard manufacturers colours white, cream, black, stainless steel to architect’s selection.
 - ii. Generator Power – Red.
 - iii. UPS Power – Blue.
- b. **Circuit Labelling:** Use engraved traffolyte labels fixed with double sided adhesive tape located on the flat non-removable portion of the faceplate. Use black lettering on white background. Use black lettering on silver background for stainless steel plates.
Use the University standard circuit labelling designations provided in the switchboard section of this specification and label all soft wiring socket outlets.
- c. **Cleaners or special purpose outlets** must incorporate specific labelling to identify their specific use either cast during manufacture or as part of the circuit identification label.

6.8.5 Soft Wiring Systems

Use only 20A rated soft wiring systems. Soft wiring systems must be compatible with the project workstation system, and comply with WHS safety regulations, and Australian codes and standards. The system must be a durable product that is fit for purpose. Quality of the system is defined as follows:

- a. If a soft wiring system fails within the first year, the entire batch of this installation must be replaced.
- b. A failure is defined as a socket outlet arcing or suffering an electrical safety or physical integrity failure.
- c. More than 1 in 100 failures is defined as a batch failure requiring replacement of the entire batch.

The design and specification must specifically co-ordinate the supply of the soft wiring (by Workstation contractor or the Electrician), the installation of the soft wiring, provision of cable containment in the desks and the starter socket/local isolator type and location.

6.8.6 Medical Area Equipment Outlets

This relates to all Body/Cardiac protected areas where medical procedures or body invasive research may be carried out. Comply with any standards specific to the area use, and as a minimum AS/NZS 3000 and AS/NZS 3003.

Complete tests in accordance with the standards and submit records in the completion documents. Where medical gasses are provided in the same area, integrate the power, communication and Nurse Call systems into a proprietary purpose made medical outlet plate or ducting system.

6.8.7 Communication and Computer Equipment Rack Outlets

Pendant sockets for integrated rack power rails must meet the following requirements:

- a. **Minimum Rating:** 15A, with LED Indicator.
- b. **Pin Arrangement:** To suit the equipment standard plug. Liaise with the rack power rail or equipment supplier to ensure co-ordination.
- c. **Plug:** Provide a matching plug top with a captive screw ring for each outlet.
- d. Illuminated power indicator.
- e. **Construction:** IP56 chain pendant mounting type of impact-resistant plastic, with spring loaded flap lid on the socket and captive socket thread. Suspend the outlets in an accessible location overhead in accordance with ICT Communications Cabling Standard.

6.8.8 Emergency Power Off (EPO)

Provide EPO facilities where required by legislation, code, certifier, the University. It is typically required in electrical and chemical laboratories, and mechanical machine workshops.

The method of implementing EPO, and the accessibility of staff to reset the system must be defined with UI and User input in the Project Return Brief. Typically, it is satisfactory for the supply to be reinstated by disengaging the local EPO button.

The location of the Emergency Power Off button must be 400mm clear of any other switches, controls or obstructions with a clear label stating its purpose and how to get it reset. More than one EPO button must be provided in larger or complex spaces where emergency access is impeded.

Locate Power and Gas shutoff switches logically together

The Emergency Power Off button location and type must be coordinated with any Emergency Gas shutoff button. The button locations, colours and labelling must be coordinated with the Architect.

EPO buttons must have shrouds to prevent casual accidental operation.

For loads less than 20A, AC3 rated contactors may be used. For larger or more circuit loads use Motorized CB control of a Distribution board chassis.

6.8.9 Accessory Mounting Heights

Except where mounting heights are self-evident e.g. skirting ducts, workstation situations, etc. the following mounting heights above finished floor level must be assumed:

Lighting switches	The center line of the box to align with the door furniture.
Socket-outlets in plant rooms and car parks	1 300mm to the center line of the box.
Socket-outlets over benches	1 50mm to the center line of the box.
Socket-outlets in other areas	200mm to the center line of the box.
Socket-outlets in laboratories or Hazardous areas	Comply with codes and standards, and in any case >300mm above floor finish level.
Socket outlets above lab benches	Comply with codes and standards, and in any case >300mm above bench top finish level.
Distribution Boards	2200mm to the topmost part of the board.
Telephone, MATV, Voice/Data outlets etc.	200mm to the center line of the box.
Socket-outlets and light switches in disabled toilet	In accordance with the Disabled Persons Code.

The above are required regardless of RCD protection.

6.9 Wiring Systems

6.9.1 Selection

Conceal wiring runs within the building fabric or accessible spaces, except within plant rooms, where the wiring may be run in surface conduits in accordance with the conduit section of this standard.

Install concealed wiring so it can be rewired easily and without damage to finishes or materials.

Generally, comply with the installation requirements of AS/NZS 3000 in relation to safety, protection and fixing.

6.9.2 Cable Calculations

For all submains and long final subcircuits (>50m) provide cable calculations using proprietary software as specified in the Design section of this standard. Note that Earth fault return calculations do not apply for RCD protected final subcircuits.

6.9.3 Voltage Drop

Use the following as design limits for voltage drop, calculated at the rated maximum demand including any future spare capacity:

- a. Total maximum - 7% from the supply substation to the furthest final subcircuit point.
- b. Consumer Mains - 0.5% at the Regional Main Switchboard.
- c. At building Main Switchboards – 1.5% total from the substation.
- d. Total to Final Distribution Boards or Mechanical Services MCCs – 4 %
- e. Final Sub-circuits - 2.5%

Note that lighting and general power sub-circuits are typically limited by RCD limitations on the number of points and aggregate leakage current for electronic loads to avoid nuisance tripping.

6.9.4 Cable Material and Minimum sizes

Use multi-stranded copper conductors with XLPE or elastomeric insulation with the following minimum sizes:

- a. 1.5mm²/16A for lighting sub-circuits.
- b. 2.5mm²/20A for power sub-circuits.
- c. 16mm²/63A for sub-mains.

NOTE - Minimization of PVC insulation is a requirement of Environmental standards.

6.9.5 Proprietary Lighting Subcircuit Cable Looms

Premade “plug & play” wiring systems which incorporate ELV data cabling may be offered as an alternative to hard wiring. Seek approval and submit samples before proceeding.

The systems must;

- a. Have local Sydney Australian agent support, and a large historical customer base.
- b. be compatible with Dali, C-Bus and KNX lighting control systems.
- c. use simple and easily available industry standard data connectors.
- d. Comply with Australian standards.
- e. Be rated minimum 16A.

6.9.6 General Cable Installation

Cables must be installed as follows:

- a. **Marking:** Identify the origin of all wiring using legible indelible marking on permanently fixed tags. Identify multi-core cables and trefoil groups at each end and at crowded intermediate points.
- b. **Installation:** Install and adequately support fixed wiring throughout the installation. For cabling routes not specified in detail, submit a proposed route layout on a workshop drawing.
- c. **Neatness:** All installations must be neat and tidy in appearance and installed parallel and/or perpendicular to building elements.

6.9.7 Subcircuit Cable Installation

Use the following systems:

- a. **Cast Concrete Slabs:** Unsheathed cable in heavy duty rigid UPVC conduit installed with draw boxes on long runs or bends to be re-wireable.
- b. **Accessible Spaces:** Ceilings, Underfloor. Neatly installed, supported and fixed thermoplastic insulated and sheathed cables supported clear of ceilings, located and /or mechanically protected in accordance with AS/NZS 3000.
- c. **Inaccessible Concealed Spaces:** Sheathed cable suspended more than 75mm above the ceiling face.
- d. **General Services Plantrooms:** Unsheathed cable in heavy duty UPVC conduit fixed with double saddles.
- e. Loading Dock, Garbage Room, Carpark, Gas Storage and The Like: Galvanized steel conduit fixed with double saddles.
- f. **Stud Walls:** (Hollow. Acoustic or thermal insulated) Thermoplastic insulated and sheathed cables.

Cables must be installed as follows:

- a. **Cable Colour:** Use Australian Standard colours for active conductors, white for switch wires, and Purple for Technical Earth.
- b. **Installation:** Install and adequately support fixed wiring throughout the installation. For cabling routes not specified in detail, submit a proposed route layout on a workshop drawing.
- c. Where TPS cables are installed in accessible locations concealed from view, or within suspended ceiling spaces, secure them to the roof framing, slab or softwood battens with approved clips, straps, clamps, or saddles located as close to the slab soffit as practicable. Cables must not be secured to the ceiling suspension system or laid on ceiling tiles or on gyprock ceilings.
- d. Use special purpose designed fixings for cables attached under thermal insulation under concrete slabs. Do not attach to the insulation fixings.
- e. Run all conductors associated with two-way lighting switching wires together (i.e. run switch wire from the light fitting to the first switch and then run three conductors from this switch to the second switch). Throughout the installation, keep the live, switch and neutral conductors together to avoid EMI.
- f. Support all cables at a maximum of 1200mm spacing with minimum sag.
- g. All installations must be neat and tidy in appearance and installed parallel and/or perpendicular to building elements.

6.9.8 Submain Cable Installation

Use cable support systems in accordance with the “Cable Supports” section of this document:

6.9.9 Cable Joints

- a. **Continuous Lengths:** Generally, only run cables for their entire route length without joints.
- b. **Permission:** Joints to extend existing cables may only be carried out with prior written approval of UI, and must be essential to minimise disruption or to facilitate reuse of an inherently valuable existing asset / resource.
- c. **Interior Submain Joints:** Must be:
 - i. Preferably be made using a purpose made metallic link panel with internal links or bars.
 - ii. Uncontained joints must be firmly supported on cable tray and tied with multiple wide band stainless steel ties for 300 - 500mm each side of the joint to prevent stress on the joint during fault.
 - iii. Have phase joints staggered to reduce bulk and permit proper fixing.
 - iv. Use straight through compression joiners with double layers of dual wall self-adhesive lined heat shrink.
 - v. Not located in concealed, inaccessible spaces or conduits.
 - vi. Be permanently labelled with the installer’s details and date.
 - vii. Be thermographed under load, with results sent to University PM / UI Engineer.
 - viii. Be located on as built drawing plans and shown single line diagrams.
- d. **Underground Cable Joints:** Use proprietary IP rated, two-part sealant filled, straight through cable joint kits and locate in accessible positions in cable pits which are drained and permanently dry. Show cable joints on the As Built plans, Single Line Diagrams and provide engraved metal labels on

the relevant pit cover. Jointing must be carried out by experienced electricians strictly in accordance with the manufacturer's instructions and witnessed by the Consultant or Project Managers representative.

- e. **Interior Subcircuit Joints:** Only use sub circuit joints where existing switchboards are being relocated. Provide a metal terminal box with neatly arranged and labelled jointing terminals. Do not use taped up BP connectors.

6.9.10 Fire Rated Cable Systems Installation

Provide fire, mechanical and water spray protection to WS52W classification in accordance with AS/NZS 3013.

A Cable Support manufacturers proprietary CSIRO or NATA tested complete cable support system must be used and installed in accordance with their published instructions to achieve the required fire rating. Untested or "extrapolated design" support systems must not be used.

As a minimum requirement for structural and longevity reasons, 12mm threaded hanger rods and metallic expansion fixings into concrete must be used.

Provide stainless steel wide band cable ties at not less than 0.9m intervals horizontal and 0.6m vertical, or as per the manufacturer's recommendations and tested system. Plastic cable ties used to facilitate the installation phase must not remain under load on completion. The cables must be solely supported by the metallic ties.

6.9.11 Cable Terminations

Use compression lugs of the correct size for the conductor, compressed using proprietary cable lug crimping tool.

Do not cut strands of an oversize cable to fit into a smaller lug or drill out an undersized lug hole to fit a larger stud.

6.9.12 Flexible Cable Terminations

Use proprietary purpose made crimp lugs and compression dies designed to ensure adequate clamping of fine multi-stranded cables.

Use compression "bootlace" type terminals for all flexible multi-stranded cable terminations less than 16mm².

For submains terminated within switchboards provide heavy duty double looped and crossed cable ties onto cable tray or cleat supports within 0.4m of the terminal lugs to minimize cable pull out failure under short circuit loads.

6.10 Conduit Systems

6.10.1 Conduits Generally

Generally, conduits must be fixed and supported as follows:

- a. **Types** – refer to the Cabling Section of this document.
- b. **Fixings:** Provide two fixings per conduit saddle.
- c. **Support:** Unless otherwise specified, fix conduit saddles at a maximum of 650mm intervals in horizontal runs and 1000mm intervals in vertical runs.
- d. **Protection in Accessible or Trafficable Space:** Protect PVC conduits installed in all accessible spaces from damage or use galvanized steel conduit.
- e. **Draw Cords:** Provide draw cords in conduits not in use. Leave 1m of cord coiled at each end of the run.

- f. **Draw-in Boxes:** Provide draw-in boxes at suitable intervals and not exceeding 25m.

6.10.2 Concealed Conduits

Concealed conduits must be routed, supported and fixed as follows:

- a. **Route of Run:** Run conduits concealed in wall chases, embedded in floor slabs and installed in inaccessible locations, direct between points of termination with a minimum number of sets. Do not use flexible conduit in concealed runs.
- b. **Steel Conduit:** Steel conduit must be galvanized.
- c. **Fixing:** Fix conduits directly to the reinforcing where the conduits pass above a single layer of reinforcing or fix midway between double layers of reinforcing. Route the conduits in slabs to avoid crossovers and to keep the number of conduits in any one location to a minimum. Space conduits 75mm minimum apart in slabs or as directed by the structural engineer.

6.10.3 Non-Metallic Conduits and Fittings

The following requirements must be met for non-metallic conduits and fittings:

- a. **Conduit in Slab:** Use rigid HD PVC conduit with swept bends generally. Specific purpose designed high compression smooth bore corrugated conduit may be used where the route is unsuited to swept rigid conduit must be restrained at regular intervals to achieve a nominally smooth run. Do not use glued elbows or tees.
- b. **Type:** Unless otherwise specified, use heavy duty conduits. Associated fittings must be of the same material.
- c. **Joints:** Use solvent glued cemented joints. Adopt the manufacturer's recommended procedure for making joints.
- d. **Draw-in Boxes:** Provide draw-in boxes at suitable intervals not exceeding 20m.
- e. **Fittings:** Use inspection-type fittings in accessible and exposed locations.
- f. **Conduit Setting:** Where practicable have conduits pre-formed by the manufacturer. At site, use correctly sized springs to form sets in UPVC conduit. Bends must be of large radii and, after setting, must maintain effective diameter and shape. Reject conduit sets distorted by kinks, wrinkles, flats or heating.
- g. **Expansion Joints:** Install flexible couplings where structural expansion joints occur in buildings.
- h. **Mechanical Damage:** Use galvanized steel conduit in areas subject to mechanical damage where HD PVC conduit is permitted, provide mechanical protection to UPVC conduit for a height of not less than 3m above ground or platform level.

6.10.4 Flexible Conduits

Flexible conduits must meet these requirements:

- a. **Length:** The maximum length of a flexible conduit connection must be 600mm.
- b. **Use:** Use for expansion joints for final connection to equipment and plant subjected to vibration, or where necessary for adjustment or ease of maintenance. Do not use flexible conduits in place of set or glued bends in exposed conduit installation.
- c. **Type:** Use zinc plated steel flexible conduit with associated fittings for areas requiring steel conduit.

6.10.5 Metallic Conduits

Galvanised steel pipe conduits must be used as follows:

- a. **Use:** Purpose made galvanized steel conduit may be used buried in the ground or run in concrete trenches or similar situations.
- b. **Joints:** Seal joints against the entry of water or moisture using proprietary liquid sealant.
- c. **Fittings:** Use matching proprietary metallic corrosion resistant fittings
- d. **Continuity:** metallic conduits must be electrically continuous.

6.11 Cable Tray and Duct Systems

6.11.1 Skirting / Bench Wiring Duct and Baskets

Wiring ducts must satisfy these requirements:

- a. **Type:** Use only extruded purpose designed multichannel aluminium duct with drop-in cover plates.
- b. **Size:** Minimum 50mm deep x 150mm high with two channels.
- c. **Accessories:** Provide purpose-made accessories and covers to match the duct system. Use screw-fixed covers, or clip-on covers removable only with the use of tools. Provide machine punched holes for outlets.
- d. **Under bench wiring baskets must;**
 - i. Be designed to fit the desk system without causing obstruction or hazard to the occupant space.
 - ii. Be powder coated
 - iii. Used only for soft wiring systems
 - iv. Have proprietary clips to neatly and firmly fix all power and data outlets to the face of the basket

6.11.2 Submain Cable Support System

Cable support systems for submains must meet these requirements:

- a. **Cable Tray:** Provide Australian manufactured ladder tray type LT3 (50mm side) up to 300mm nominal width and type LT5 (85mm side) for wider.
- b. **Cable Ladder:** Provide minimum NEMA 2 rated ladder.
- c. **Support System:** Bends, connectors, trays, ladders, brackets, and other supports necessary to make a complete cable or conduit support system must be of the same manufacture, sized to adequately support the installed cabling.
- d. **Finish:** Zinc plated for internal dry spaces, and hot dip galvanized for damp or external locations.
- e. **Small Cable:** Provide additional continuous support for single cables less than 13mm outside diameter on cable ladder.
- f. **Maximum Deflection:** The maximum vertical deflection of any tray span between hangers must be less than 20mm.
- g. **Bend Radius & Protection:** Bends must have a minimum inside radius of not less than twelve times the outside diameter of the largest diameter cable carried. Provide proprietary inside radius cable protection joints at bends and Tees.
- h. **Spare Capacity:** Provide spare space for not less than 20% more cables or conduits than initially required to be installed, and all future design capacity.
- i. **Access:** Position the system to give adequate access for inspecting, replacing, or adding cable. Provide a minimum of 150mm free space above the top edge and 600mm free space on one side of trays and ladders.
- j. **Cable Strapping:** Fix cable to the support system by proprietary nylon ties, straps or saddles, at 800mm centres for vertical runs and 1200mm centres for horizontal runs. Use wide band stainless steel straps on fire rated cables.

6.11.3 Sub Circuit Cable Support System

Cable support systems must meet these requirements:

- a. **Type:** Use in order of preference:
 - i. Cable trays must be used for major trunk routes out of DBs or carrying more than 30 sub circuits.
 - ii. Cable basket systems complying with NEMA 2 standard may be used for final distribution of <30 sub circuits.
 - iii. Proprietary cable tray / basket suspension system, using adjustable wire suspension may be proposed to replace cable ladder tray for small submains and final subcircuits (not

replacing ladder in major submain runs). Submit for UI approval detail design information of the system components proposed to be used, and structural calculations for angled supports. The system must not be inferior to a rod suspended cable tray system.

- b. **Catenary Systems:** Catenary cable support systems may be used to replace cable trays for retrofit or fit out installations where the installation of new cable trays is deemed impractical. Use high tensile multi-stranded galvanised steel cable with proprietary fixings and proprietary compression crimped rigging fittings. Provide cable tension adjustment.
Use only where structurally sound fixing into solid concrete masonry is achieved with chemical or expansion anchors. Provide load calculations and do not load beyond 70% of rating.
Install a maximum of 1 sub-main or 15 TPS sub-circuit cables on any one catenary wire.

6.11.4 Support Systems and Fixings

Cable support systems must be metallic and meet these requirements:

- a. **Fabrication:** Provide brackets, racks, hangers and other supports sized to adequately support the installed system and equipment, fabricated from steel sections or from other materials in sections of equivalent strength approved by a structural engineer in writing.
- b. **Fixing to Building Structure:** Fix the supports by to the building fabric using the following methods, as appropriate:
- Internal Masonry or concrete walls: passivated zinc steel expanding or chemical anchor bolts.
 - Concrete slab ceilings: steel expanding.
 - Structural steel: Grade 8.8 machine bolts, hot dip galvanised.
 - External fixings: Grade 8.8 hot dip galvanised steel or equivalent strength marked stainless-steel bolts with expansion or chemical anchor bolt fixings.
 - Threaded Rods: Minimum 10mm diameter for single trays up to 450mm. Minimum 12mm for 600mm trays and multi-tier installations.
- c. **Spacing:** Space the supports at intervals of not more than 1.2 m, and in accordance with the manufacturers published load table including required spare capacity. Provide supports immediately either side of bends or changes of height.
- d. **Flexible Wire Tray Suspensions:** Proprietary flexible high tensile multistrand wire suspension systems may be used with prior approval of UI engineers. Submit manufacturers details of the system, the proposed detailed use and load calculations.

6.11.5 Cable Baskets

Wiring baskets must;

- Be minimum NEMA VE1 tested.
- Zinc plated (not pre-gal)
- Used only for subcircuit reticulation, and minor submains up to 63A.
- Use proprietary clips to neatly and firmly fix the basket to the hanger rods.
- Be supported at not more than 2m intervals, or as required to limit deflection to 15mm
- Use proprietary bends and Tee pieces with radiused corners.
- NOT have any sharp exposed wire ends.

6.11.6 Cable Support System Coatings and Finishes

The following applies to all conduits, cable tray, ladders, ducts, baskets and their supports or fixings:

- Exposed or Damp Areas:** Use Hot dip galvanized steel or stainless-steel materials where exposed to the weather, physical damage or installed in damp locations.
- internal dry areas:** Use pre electro-galvanised steel materials in interior dry locations.
- Paint Requirement and Colours:
 - In switchrooms and plant rooms, ceiling spaces, cable ways and underground, electrical cable supports may be left unpainted.
 - In public / teaching / office / corridor locations exposed to view coat in an approved colour.

- d. **Labelling:** Install self-adhesive labels on the side of cable trays or fix rigid labels to wire baskets indicating their purpose at <5m intervals.
- e. **Paint System:** Where painting is required, finish systems as follows:
 - i. Indoor locations: Powder coating colour over zinc rich undercoat, or a system using etch primer, full gloss water-borne paint.
 - ii. Outdoor locations: Powder coating over hot dip galvanising, or a system using etch primer, full gloss solvent-borne exterior UV rated epoxy paint.
- f. **Paint Colours:**
 - i. General Electrical - Light orange.
 - ii. Communications - White.
 - iii. Generator power - Olive Green.
 - iv. UPS power – Light Blue.

6.12 Underground Services

6.12.1 Conduits

Use HD PVC conduits for all underground cable runs.

Comply with AS/NZS3000 recommended number of cables in conduits, and provide minimum 25% spare capacity, or one whole spare conduit minimum for sub-mains runs.

6.12.2 Trenching & Backfilling

The University Campus has extensive in ground services in nearly every location. Trenching and backfilling operations must:

- a. **Site Services Plan:** Obtain the University site services plan for the area concerned.
- b. **University Excavation Standard:** Comply with the Excavation Standard which also covers surfaces reinstatement.
- c. **Dial Before You Dig, Services Survey & Finder Trenching:** Obtain DBYD utility plans. Carry out an in-ground services location survey. Carry out investigative slit trench hand excavation across areas concerned. Record services located on the Location Plan. Reinstatement surfaces temporarily if the works will be later disturbed, or permanently if outside of the works area.
- d. **Detailed Hand Excavation:** Allow for detailed hand excavation where the University site services plan or surveys indicate significant or dangerous existing in ground conditions.
- e. **Records Submission:** submit CAD drawings of all in ground services scans and surveys to the UI Fire & Hydraulic Engineer.
- f. Notification to, and attendance of the Project Manager, Engineer and UI representative during major excavation works.
- g. Photographic records of all in ground excavations must to be provided for future University reference.

6.12.3 Cable Pits

(NOTE – Communications pits must be constructed of reinforced cast in situ concrete to ICT Communications Cabling Standard by an ICT approved Telstra certified pit builder.)

Construction of electrical cable pits must satisfy these requirements:

- a. **Construction in Roadways:** Walls and bottom must be steel reinforced cast concrete, 75mm thick, or moulded fibre cement cast in place with minimum 75mm concrete surround. Incorporate an additive to render or concrete to prevent the ingress of water.
- b. **Rating:** Load rate pits to the maximum vehicle wheel load of the roadway.
- c. **Turning Pits:** Provide draw-in and turning pits at maximum 50m intervals or as required to avoid damage to cables during installation.

- d. **Marking:** Mould the word 'ELECTRIC' into a lid for use on any pit containing electrical power cables. Comply with the University labelling and marking standards.
- e. **Pit Covers:**
 - i. General: Provide pit covers to suit expected loads. Fit flush with the top of the pit.
 - ii. Cover type: In trafficable areas provide GATIC brand (or approved equal) heavy-duty cast-iron lid with concrete infill fitted to heavy duty trafficable pits.
 - iii. Pedestrian areas: use an approved non-slip metal lid on a cast metal, cast or precast concrete pit.
 - iv. Maximum Weight: In accordance with WH&S regulations for any section of the cover.
 - v. Lifting Handles: Provide any proprietary lifting handles for pit covers as spare parts.
- f. **Pit Drainage:** Provide each pit with a drain hole in the base, positioned to drain into a drainage pit. Provide a connection to stormwater system or a dedicated drainage pit filled with rubble, graded away from each cable pit for 2000mm.

6.12.4 Underground Cable Route Marking

Cables route marking must meet these requirements:

- a. **Survey:** Accurately survey the routes of underground cables prior to backfilling and provide a survey plan, endorsed by a registered Surveyor, which identifies the cable locations in relation to permanent site features and other underground services.
- b. **Location:** Accurately locate underground cables using route markers placed at intervals of not more than 30m for straight distances, and at pits, route junctions, changes of direction, terminations and entry points to buildings.
- c. **Direction Indicators:** Mark the direction of the cable run by marker plate direction indicators. Provide four distinct versions of the marker plate engraved with a single arrow (->), through (<->), 'L', and 'T' arrows. A group of two or more plates may be required at some route junctions.
- d. **Marker Plates:** Engraved Stainless steel or brass, minimum size 75 x 75 x 1 mm thick.
- e. **Plate Fixing:** Waterproof adhesive and 4 brass or stainless-steel countersunk screws. Set the marker plate flush in a 200mm minimum diameter concrete base, not less than 200mm deep.
- f. **Marker Tape:** Provide a 150mm wide yellow or orange marker tape bearing the words 'WARNING - electric cable buried below', laid in the trench 150mm below ground level.
- g. **CAD drawings** of all in ground services installations must be submitted to UI Engineer.

6.13 Large Switchboards

Regional Main Switch Board and Building Main Switch Boards must be compliant with AS/NZS 61439. The University no longer accepts boards designed & built to AS/NZS 3439.

This section applies to all Regional Main Switchboards (RMSB), building Main Switchboards (MSB), Main Distribution Boards (MDB) and all Distribution Boards (DB). It also applies to Mechanical Services Switchboards/Motor Control Centre's (MCC) rated equal or more than 400A sub-main input, as referenced in the Mechanical Services Standard.

Regional Main Switchboard is defined as a large Main Switchboard supplying two or more buildings, rating equal or above 800A and fed from a substation. Note: All RMSB designs are to be signed off by the UI Electrical Engineer prior to construction.

Building Main Switchboard is defined as a large indoor MSB which distributes electricity supply to multiple DBs within the building.

Main Distribution Board is defined as a large indoor switchboard connecting between MSB and DBs, using Molded Case circuit breakers between 63A and 250A frame rating.

Distribution Board is defined as a switchboard rated less than 250A that distributes electricity to final sub-circuits or loads using DinT miniature circuit breakers rated between 10A and 63A.

6.13.1 Switchboard Rooms and Locations

All new RMSB and MSB must be enclosed in an NCC and AS/NZS 3000 compliant 2-hour fire-rated electrical switch room fitted with a University Bi-lock and code compliant warning signs. All switchrooms must strictly comply with codes and standards egress and clearance requirements.

Provide switchroom ventilation in accordance AS / NZS 1668. Provide fan assisted supply air ventilation and exhaust to outside of the building, fitted with fire dampers at the switchroom fire compartment walls. Provide calculations of the heat load and airflow to maintain an ambient room temperature less than 35°C. Mechanical AC cooling systems may only be used with approval of the University Mechanical Engineer and must be fitted with locked thermostat control.

The electrical switch room or cupboards must not be located in a restricted location including in wet areas, hazardous areas, in/ under fire isolated stairs, in public corridors, above-ground platforms or in communications rooms. Comply with AS/NZS 3000 and the NCC.

Distribution Switchboards must be located within a locked smoke sealed cupboard fitted with University Bi-lock and WHS compliant warning signs. Dedicated clear space not obstructing any cable or service access must be allocated for lighting control panels within the cupboard workshop drawing, or alternatively integrated into a dedicated switchboard compartment.

Distribution boards may be located in open plantrooms without a cupboard but must be fitted with University Bi-lock, be IP52 rated, and lighting control or other controls must be integrated into the Distribution Board chassis in a separated compartment.

Distribution Boards must not serve more than one floor. Only in certain circumstances may this be permitted, and this must be approved by the issuer of this standard.

6.13.2 Main and Generator Supply Remote Control

Where the Main Switchboard is located remotely from the building main entrance or Fire Control point, provide remote Emergency Power Off control of the normal supply Main Switch at the FIP. This applies when the MSB is not located on the same level, and or accessible directly from the Main entrance.

Provide a floor plan showing the location of the Main Switchroom, and any generators. This must also isolate any generator power used for non-safety services.

A shunt trip or motorized Circuit Breaker (with or without protection trip unit) must be used. Provide mechanical protection via either a break glass switch or a cabinet with a University bi-lock key which is available to the Fire Brigade (Master or E key).

The MSB must have LED indicator light to show what loads remain 'ON' during the shunt trip operation.

6.13.3 Manufacturers

Switchboard manufacturers are provided in the **UI Deemed-to-comply Switchboard Manufacturers Form (UI-ENG-F004)**.

Alternative manufacturers may only be submitted at tender time and with prior approval of the UI Electrical Services Engineer.

Alternative manufacturers not shown on the **UI Deemed-to-comply Switchboard Manufacturers Form (UI-ENG-F004)** must submit a typical switchboard workshop drawing, verification certificates, switchgear test certificates / technical information, quality assurance documents, warranty certificates, company profiles and additional requested technical documents to UI Electrical Services Engineer for approval prior to tendering for the works.

Non-compliant switchboard installations will be rejected by UI and the Contractor must replace the non-compliant switchboard with a new Deemed-to-Comply switchboard.

All Board Manufacturers must submit Design Assembly documents for the entire Board, including Device Manufacturer information and Original Board Manufacturer.

The Design Engineer specifying the new switchboard, must design the board to AS/NZS 61439 and provide the Table C.1 completed as part of their design handover.

6.13.4 Types of Acceptable Switchboards

Both modular and fabricated switchboards designed and manufactured in accordance with this University standard and complying with AS/NZS 61439 are acceptable forms of manufacture.

6.13.5 Switchboard Standards

The following standards must be used for University Projects commencing design from the date of issue of this Standard;

Custom Fabricated Fully Welded Construction: Must comply with the new standard AS/NZS 61439.1-2016.

Modular Assembled Construction: Comply with AS/NZS 61439.1-2016 for the assembly and testing process. The Modular system component kits must also be tested to the new standard and relevant Appendices.

Appendix ZC: *Guidelines for Assemblies Intended to Provide Increased Security against the Occurrence or the Effects of Internal Arcing Faults;* All switchboards with an input supply rated at 400A or above, or with a short circuit fault level of more than 28kA must comply with Appendix ZC.

Temperature Rise: for switchboard compartments, equipment and busbars must be verified by Type Test, or Comparison to a clearly related Type Tested reference design. Temperature rise verification by calculation is not permitted.

Short Circuit Withstand Strength: must be verified to AS61439.

Where equipment of alternative brand or type is substituted in a verified assembly, provide technical supporting information validating the equivalence of temperature rise output and component current rating in accordance with the standard and AS/NZS 61439.

6.13.6 Main Switchboard Design

The Switchboard designer must follow AS/NZS 61439 Annex C, within Part 0. This standard provides direction on specifying assemblies. Part C.2 is also to be reviewed, discussed with the university and completed as part of the Tender design.

Design of switchboards must satisfy these requirements:

- a. **Construction:** Provide switchboards using AS/NZS 61439 Standard and assembly. The University will require from the Contractor, Table C.1 from AS/NZS 61439 – Part. This Annexure must be filled out to meet University end user requirements. The Contractor must fill out the form themselves or via a Specifying engineer. This must be included in the tender documents along with the SLD.
- b. **Layout:** Position the switchboard and equipment to provide safe and easy access for operation and maintenance as per AS/NZ 3000. Consider functional relationships between items of equipment in the laying out of equipment on the assembly.
- c. **Service Conditions:** Normal service conditions.
- d. **Rated Currents:**
 - i. **Rated Currents:** Minimum continuous uninterrupted rated currents within the assembly environment, under in-service operating conditions.

- ii. Assembly Short-Circuit Capacity Characteristic: Rate main circuit supply and functional units as follows.
 - iii. Main Switchboards or Main DBs: Rated short-circuit current for 1s.
 - iv. Distribution Switchboards: Rated short-circuit current for the maximum opening time of the associated protective device.
- e. **Form of Separation:**
- i. Regional Switchboards - Form 4B.
 - ii. Main and Distribution Switchboards over 630A - Form 3B.
 - iii. Main and Distribution Boards under 630A – Form 3Bih.
- f. **Type ih Segregation Limitation:** Type ih (insulation & or housing) segregation must **not** be used in Regional or Main Switchboards except that a small distribution chassis section may be permitted as part of a large Form 3 or 4 switchboard on the following conditions:
- i. To save space and cost by aggregating a number of smaller submains circuits each less than 160A.
 - ii. Contained in a fully segregated metallicallly constructed compartment.
 - iii. Protected by a Form 3 segregated protection device rated less than 630A.
 - iv. With approval by UI Electrical Engineer during detail design stage before workshop drawings.
- g. **Degree of Protection:** Minimum IP52 for indoor (see separate Outdoor Switchboard section).
- h. **Spare Circuit Spaces:**
- i. Provide minimum 25% spare sub-main circuit capacity (or minimum two spaces) unless specifically nominated otherwise on the drawings.
 - ii. Allow to fill all required switchboard tiers with spare spaces and where this spare capacity cannot be met due to physical restrictions, seek approval in writing from the University at workshop drawing submission stage.
 - iii. All spare spaces must be fully bus barred for the nominated rating.
- i. **Space Confirmation:**
- i. Design and Construct the main switchboard so it can be incorporated within the room space shown on the drawings. Examine the area for switchboard on site and consider building column locations, beam clearance height etc. prior to commencement of construction of the switchboard.
 - ii. Tenderers must confirm in their tender that the specified dimensions are achievable and will enable the main switchboard arrangement, ratings, connections and equipment etc. to comply with all requirements and conditions as specified in this specification.
 - iii. Ensure that the switchboard final dimensions, arc chutes etc. will not prevent the transportation of the switchboard cubicles through standard height doorways and under the cable ladder tray installation in the applicable areas of the building.
 - iv. Ensure that the design and construction of the Electrical main switchboard makes periodic maintenance easy and as much of the main switchboard equipment, busbars, connections, terminations etc. can be scanned by infra-red imaging equipment.

6.13.7 Switchboard Shop Drawings

Prior to ordering equipment or commencing manufacture for ALL switchboards, switchboard workshop shop drawings must be submitted and approved showing:

- a. Types, model numbers, dimensions and ratings of assemblies.
- b. Component details, utility metering compartment, Service Protective Device (SPD), busbar assembly, metering, electrical switchgears, functional units and transient protection.
- c. Detailed dimensions.
- d. Shipping sections, general arrangement, plan view, front elevations and cross-section of each compartment.
- e. Projections from the assembly that may affect clearances or inadvertent operation, such as handles, knobs, arcing-fault venting flaps and with-drawable components.
- f. Fault level and rated short circuit capacity characteristics, with confirmation that they match the detailed design.
- g. IP rating.
- h. Fixing details for floor or wall mounting.

- i. Front and back equipment connections and top and bottom cable entries.
- j. Hinged doors, hinged escutcheons, and door swings.
- k. External and internal paint colours and paint systems.
- l. Quantity, brand name, type and rating of control and protection equipment.
- m. Construction and plinth details, ventilation openings, internal arcing-fault venting, cable glands, gaskets and gland plate details.
- n. Terminal block layouts and control circuit identification.
- o. Single line power and circuit diagrams.
- p. Details of mains and sub-main routes within assemblies.
- q. Busbar arrangements, links and supports, spacing between busbar phases, and spacing between assemblies, the enclosure and other equipment and clearances to earthed metals.
- r. Dimensions of busbars and interconnecting cables in sufficient detail for calculations to be performed in accordance with Australian Standards.
- s. Internal separation, form of separation and details of shrouding of terminals.
- t. Labels and engraving schedules.

6.13.8 Switchboard Inspections

Switchboard inspections must be carried out by the Designer at the following stages:

- a. **Factory Acceptance Inspection and Tests** - Minimum 4 week before the switchboard is due to be delivered to site, allowing time for corrective action. All Insulation tests, meter function and programming, alarms & controls operation.
- b. **On-site commissioning Tests** - switchboard installation completed, sub-mains connected and ready to be energised.
- c. **ATS and MTS Operation** - on Mains and Generator power, including key or mechanical interlock systems demonstration
- d. **AUMS Metering** local function and connection to the University data network.
- e. **Alarms** - where specified; main supply failure, out of tolerance supply voltage, current overload.

Provide a brief written report summarizing the inspection purpose, attendees, % completion, inspection notes and photographs, tests witnessed and results.

6.13.9 Switchboard Tests

The following tests must be performed:

- a. Factory Witness Tests.
- b. Dielectric/Insulation testing; In accordance with the current Australian switchboard standard.
- c. Functional testing: Operate mechanical devices, relays, programmable logic controllers and logic controls, protection, interlocking and alarm equipment.
- d. Protection relays: current injection tests to verify time/current characteristics and settings.
- e. Secondary current injection tests on adjustable trip circuit breakers to verify time/current characteristics and settings after installation and before site energisation.
- f. Record verification of the CB trip settings on the Single line diagram.
- g. Residual current devices: Test using apparatus which displays the trip current and trip time of each device.

6.13.10 Switchboard Submissions

Submit Design Verification test results for the frame, board, components, functional units and assemblies including internal arcing-fault tests and factory test data. Submissions must include:

- a. **Calculations:** Table D.1 in AS/NZS 61439.1 Annex D lists the design verifications to be performed by:
 - i. Testing, or
 - ii. Comparison with a reference design, or
 - iii. Assessment.

b. **Design Verification**

i. A design verification report must be submitted with the above requirements met.

c. **General:** Verify that type tests and internal arcing-fault tests, if any, were carried out at not less than the designated fault currents at rated operational voltage.

d. **Product Data for Proprietary Assemblies:**

i. Types and model numbers of items of equipment.

ii. Overall dimensions.

iii. Fault level.

iv. IP rating.

v. Rated current of components.

vi. Number of poles and spare capacity.

vii. Mounting details.

viii. Door swings.

ix. Paint colours and finishes.

x. Access details.

xi. Schedule of labels.

6.13.11 Switchboard Metalwork

Switchboard designs must include the following requirements:

a. **General Requirement:** Construct the switchboard using metalwork frames and panels. Segregation of compartments and functional units must be achieved using metal barriers. The completed switchboard must be rigid and free of flex when lifted or when force is applied by an average human.

b. **Supporting Structure:** Fabricate supporting frames from rolled, cold formed or extruded metal sections, with joints fully welded and ground smooth, or bolted in accordance with the Modular design. Provide concealed fixing or brackets located to allow the assembly to be mounted and fixed in the specified location without removal of equipment.

c. **Panels:** Machine fold sheet metal angles, corners and edges with a minimum return of 25mm around the edges of front and rear panels, and 13mm minimum return edge around doors. Provide stiffening to panels and doors where necessary to prevent distortion or drumming.

d. **Corner Reinforcement:** For Modular Construction, provide corner bracing brackets for compartment openings greater than 600mm in width or height.

e. **Lifting Provisions:** Provide fixings in the supporting structure, and removable attachments, for lifting switchboard assemblies whose shipping dimensions exceed 1.8m high x 0.6m wide.

f. **Floor-Mounting:** Provide a metal plinth channel, not less than 75mm high. Bolt fix the switchboard assembly to the plinth and the plinth to the floor.

6.13.12 Cable Entries and Supports

Cable entries must satisfy the following requirements:

a. **General:** Provide sufficient clear space within each enclosure next to cable entries to allow incoming and outgoing cables and wiring to be neatly run and terminated without undue bunching and sharp bends.

b. **Cable Supports:** Provide cable tray or crossbars located and spaced to permit the cables in the cable zone to be adequately secured without strain and against short circuit forces. Cables must be able to be secured without static force or distortion of the cable glands.

c. **Gland Plates:** Provide removable aluminium gland plates fitted with cable glands and gaskets to maintain the degree of protection.

d. **Fire Rated Cable Glands:** Provide metallic cable glands for fire rated submains.

e. **Building Management Control Systems (BMCS) and Lighting Control Terminal Zone (KNX, Dynalite, CBUS):** Provide a fully segregated compartment for low voltage terminal for connection by others. Provide a segregated cable pathway to the exterior of the switchboard to permit cables to be installed and connected with the switchboard operating.

f. **Sealant of Glands:** Where multiple circuits enter through a single large gland, infill the gaps with non-setting mastic.

6.13.13 Switchboard Doors and Covers

Switchboard doors and covers must meet these requirements:

- a. Maximum Width: 800mm.
- b. Minimum Door Swing: Through 90°.
- c. **Door Stays:** Provide stays to outdoor assembly doors.
- d. **Adjacent Doors:** Space adjacent doors to allow both to open to 90° at the same time.
- e. **Hanging:** Provide corrosion-resistant pintle hinges or integrally constructed hinges to support doors. For removable doors, provide staggered pin lengths to achieve progressive engagement as doors are fitted. Provide 3 hinges for doors higher than 1m. Provide restraining devices and opposed hinges for non-lift-off doors.
- f. **Door Interlocking Override:** Provide a tool override for any interlocked switch actuator to permit the door to be opened on load for thermographic testing.
- g. **Door Hardware:** Provide the following:
 - i. Corrosion-resistant lever-type handles, operating a latching system with latching bar and guides strong enough to withstand explosive force resulting from fault conditions within the assembly.
 - ii. Provide 'T' handles for compartments requiring access for servicing or inspecting controls and metering equipment. Provide key locking cylinder only if the switchboard is located in an accessible area. Confirm requirement for keyed door locks before manufacture.
 - iii. For other compartment doors use metallic recessed latches openable with a flat bladed screwdriver.
 - iv. Captive knurled thump screws or door latches with removable plastic key tools must not be used.
- h. **Locking:**
 - i. Incorporate a cylinder lock in the door latching system only if the switchboard is not located in a secured electrical switchroom or cupboard. All the locks of one installation must be keyed alike. Fit University Bi-locks cylinders to all internal switchboards if installed outside the electrical switchroom or cupboard.
 - ii. External switchboards must be fitted with a hasp and staple lock to accept the University standard padlock.
 - iii. Number of Keys Required: TWO per switchboard / room.
- i. **Smoke and Dust Seals:** Provide a resilient strip seal, of foamed neoprene or the equal, around each door, housed in a channel and fixed with an approved industrial adhesive.
- j. **Door Mounted Equipment:** Protect or shroud door mounted equipment and terminals to prevent inadvertent contact with live terminals, wiring, or both.
- k. **Earthing:** Maintain earth continuity to door mounted equipment using multi-stranded, flexible earth wire bonded to the door.
- l. **Covers:**
 - i. Maximum Dimensions: 800mm wide and 1.2m² surface area.
 - ii. Fixing: Fix to frames using at least 4 fixings using corrosion-resistant acorn nuts on threaded studs. Provide support for the cover to hold it in place with the nuts removed. Do not use interlocked covers.
 - iii. Interchange Prevention: Provide offset pins or studs such that covers of the same dimension cannot be interchanged.
- m. **Handles:** Provide corrosion-resistant 'D' type handles.
- n. **Removable Door / Cover Labels:** Provide permanent labels on the inside of covers or removable doors, and matching labels on the switchboard interior to facilitate replacement when multiple covers are removed.

6.13.14 Escutcheon Plates

All compartments containing mains voltage protection devices must be fitted with escutcheon plates that prevent contact with live parts when the cover or door is open. Escutcheon plates must satisfy these requirements:

- a. **Requirement:** Provide removable escutcheon plates with neat cut-outs for circuit breaker handles and corrosion-resistant lifting handles.
- b. **Frame:** Provide a continuous support frame for the fixing of each escutcheon plate, including additional support where necessary to prevent panel distortion.
- c. **Hanging:** Provide corrosion-resistant hinges to support escutcheon plates. Provide 3 hinges for escutcheon plates higher than 1 m.
- d. **Fixing:** Fix each plate to the frame with minimum two metal fixings held captive in the plate and spaced uniformly.
- e. **Maximum Height:** 1200mm.
- f. **Hanging:** Hang escutcheon plates on hinges which allow opening through a minimum of 90° and permit the removal of the escutcheon when in the open position.

6.13.15 Finishes

Finishes must satisfy these requirements:

- a. **Extent:** Apply protective paint or powder coat finishes to internal and external metal surfaces of assembly cabinets including covers, except to stainless steel, galvanized, electroplated, or anodised surfaces and to ventilation mesh covers.
- b. **Paint:** Two pack solvent paint or Powder coat.
- c. **Colours:**
 - i. Indoor assemblies: generally, powder coat Orange X15, Light Grey N42 or other approved colour to University's requirements.
 - ii. Removable equipment panels: White.
 - iii. Assembly interior: White.

6.13.16 Busbars

Use hard drawn copper busbars for all conductors over 250A, or proprietary manufactured insulation encapsulated flexible busbars for less than 250A for all power connections within a switchboard. Flexible wiring is not permitted to used instead of busbars for line side distribution of power within the switchboard. Busbars must meet these requirements:

- a. **Material:** Bare bright hard-drawn, high-conductivity and electrolytic tough pitched copper alloy bars specifically manufactured for electrical conductor use.
- b. **Origin:** Procure busbars from companies with ISO9000 quality assurance certification. These currently include Austral Wright Metals, Oriental Copper and Primary Metals and Alloys.
- c. **Plating:** bright finished electro-tinned busbars, or bare copper is permitted.
- d. **Temperature Rise Limits - Active and Neutral Conductors:**
 - i. Maximum Rated Current Temperature Rise Limits: Refer to AS/NSZ 61439.1 Table 6.
 - ii. Maximum Short-Circuit Withstand Current Temperature Rise Limits: Refer to AS/NSZ 61439.
- e. **Cross Section:** Rectangular section with radiused edges.
- f. **Busbar Joints:**
 - i. Bolts: Use 304 stainless steel, minimum grade 8 bolts with industry standard head markings. Do not use tapped holes and studs or similar situations for jointing current carrying sections.
 - ii. Washers: must be fitted with split spring or Belleville washers.
 - iii. Bolt Holes: Punch busbar bolt holes using purpose made double sided die sets.
 - iv. Cleaning: ensure busbar joint surfaces are flat, bright and chemically clean.
 - v. Bolt Torque Witness: Mark all bolts and nuts with indelible pen across the fastener and adjacent metal when tightened to confirm proper torque has been applied and they have not been tampered with.
- g. **Busbar Insulation:**
 - i. General: Provide colour coded heat shrink covering applied to Active and Neutral Busbars Select from the following:
 - ii. Polyethylene: At least 0.4mm thick with dielectric strength of 2.5 kV rms for 1 min, applied by a fluidised bed process in which the material is phase coloured and directly cured onto the bars.

- iii. Close fitting busbar insulation mouldings at least 1mm thick.
- iv. Heat shrink material: Use only on rounded edge busbars.
- v. DO NOT apply tape or heat shrink to busbar joints to permit inspection.
- h. **Busbar Systems:** Use multi-pole proprietary busbar assemblies or busbar systems, which have been verified for short circuit capacity and temperature rise-limits by AS/NZS 61439. Where used in type "ih" segregation, they must be tested to comply with the increased insulation required limits.
- i. **Current Carrying Capacity:**
 - i. Active Conductors: Maximum 90°C final temperature.
 - ii. Neutral Conductors: Use full size neutral conductors unless approved in writing.
 - iii. Protective Earth Conductors: Size for at least 50% of the rated short circuit withstands current for 100% of the time duration.
- j. **Tee-Off Busbars Current Rating:**
 - i. For Individual Outgoing Functional Units: Equal to maximum frame size rating of the functional unit.
 - ii. For Multiple Functional Units: Equal to the diversity factors in accordance with Australian Standards, based on frame size rating.
- k. **Cable Connection Flags:**
 - i. General: Provide and support busbar flags for equipment with main terminals too small for cable lugs. Use flags sized to suit cable lug termination, with current rating of at least the maximum equipment frame size.
 - ii. Phase Isolation: Provide phase isolation between flags where the minimum clearance distances phase-to-phase and phase-to-earth are below the component terminal spacing.
- l. **Future Extensions:** Pre-drill the main circuit supply busbar for future extensions and extend busbar droppers into future functional unit locations.

6.13.17 Wiring

Wiring must satisfy these requirements:

- a. **Cable Type:** Provide PVC insulated 0.6 kV V-75 multi stranded copper conductor cables for general internal wiring, and V-90 insulated cables for connection to equipment capable of raising the insulation temperatures above 75°C.
- b. **Control and Indication Circuits:** Provide stranded copper conductors of not less than 1.0mm².
- c. **Cable Colours:** Colour code the wiring in accordance with Australian Standard AS/NZS3000 and other relevant Australian Standards.
- d. **Wiring Support:** Use mechanically fixed ducting or clips. Do not use self-adhesive cable clips of any type.
- e. **Terminations:**
 - i. Terminals: For connections up to 15 kW load provide rail-mounted tunnel type terminal blocks.
 - ii. Lugs: Terminate wiring into terminal blocks using compression type lugs compatible with the terminals and crimped using the correct tool. Lugs for connection to tunnel type blocks must be of pre-insulated lipped blade type.
 - iii. Grouping: Segregate terminal groups and install together terminals for each outgoing circuit, in the same order throughout.
 - iv. Spare Terminal Space: Provide sufficient space on mounting rails for 25% future outgoing circuits possible in any cabling compartment.
 - v. Wiring Identification: Identify power and control cables at both ends using neat fitting ring type ferrules agreeing with record circuit diagrams.

6.14 Distribution Switchboards

6.14.1 University Standard Distribution Board Design Intent

Standard switchboards must be used for University Capital Works projects and for all DB replacements for consistency of quality and ease of maintenance. The switchboards must be manufactured by **Deemed-to-Comply** suppliers, fully compliant with University Electrical Standards and available through using of the shelf standard materials in order to reduce manufacture time.

Switchboard features must include:

- a. High quality, future-proof uniform modular design.
- b. Uniform compartment sizes, configuration and equipment locations.
- c. Spacious uncramped cable zones and equipment space.
- d. Reliable design with capacity for future electrical demand.
- e. Includes all the UI electrical safety, AUMS, lighting control, sustainability initiatives and requirements.

6.14.2 Minimum Configuration and Construction

For the reasons of safety, easy maintenance, and quality controls for projects with short project delivery time during University term breaks, The University of Sydney has adopted a range of standardised Distribution Boards. The following University Standard DB minimum configuration requirements must be met:

a. **Minimum Size and Configuration:**

- i. Minimum configuration.
- ii. Type 1 – 100A supply, 24 poles for lighting and 48 poles for power sections.
- iii. Type 2 – 80A supply, 48 pole shared power and lighting sections.
- iv. Type 3 – Main Floor/Lab DB – 400-630A supply, 30 poles, 630A chassis, 160-250A MCCB Frame.

b. **Distribution Board Construction Details:**

- i. Comply with switchboard section of this standard including switchboard metalwork, doors, escutcheon plates, cable entries, finishes, conductors, busbars and wiring.
- ii. Wall mounted front connected, totally enclosed type.
- iii. Be constructed of folded sheet steel with a powder coat finish.
- iv. Utilise standard manufacturer's encapsulated insulated copper busbar chassis mounted vertically on a separate backing plate. Do not provide soft wired power distribution systems.
- v. Allow for interchangeability of single and multiple pole breakers without alteration to busbar connection or breaker mounting fixtures.
- vi. Have all equipment including the chassis backing plate accessible and removable from the front without dismantling the switchboard from its position.
- vii. Use din rail beside main switch for ancillaries, potential fuse and transducers in the metering section.
- viii. Fit University Bi-locks either in an electrical cupboard door, or in the switchboard doors if the DB is not located in a dedicated electrical cupboard.
- ix. Provide 18mm wide single-pole din-rail mounted 6kA miniature circuit breakers in proprietary insulated 250A 3 phase busbar chassis.
- x. Din-type single pole space RCBO circuit breakers - Minimum 16A for lighting and 20A for power circuits.
- xi. 160-250A Main switch.
- xii. Provide Multi-function energy metering in accordance with the metering section of this standard and the **UI AUMS Standard** for sub-main and lighting sections complete with transducers having a Modbus interface. Mount on the din-rail in the metering section.

c. **Spare Capacity;** The chassis pole capacity must be increased from the minimum to accommodate all initial sub circuits plus:

- i. 20% spare pole spaces for power.
- ii. 15% spare pole spaces for lighting.
- iii. Schedule card holder fixed inside the door with screws and a clear cover with a University Standard MS Excel spreadsheet schedule. Provide a separate schedule for lighting and power sections. Provide soft copy of the schedule in the manuals.
- iv. Provide a hinged removable escutcheon panel that conceals all live parts.

6.14.3 Standard Distribution Board Design

Type 1

Application: new builds, general lighting and power requirements:

- a. 100A supply on a 250A chassis.
- b. Form 1.
- c. 24 poles for lighting and 48 poles for power sections, optional 18 pole emergency generator power.
- d. Top Centre, Single main switch required to isolate both chassis.
- e. Separate AUMS compliant meters located on din-rails at the top of the DB. If the upstream MSB already has a meter, only a single meter is necessary for the lighting section (BCA Compliance calculation necessary with the upstream meter).
- f. Separate din rail for lighting control and emergency lighting test switch.
- g. Gland plates with gaskets.
- h. Hinged doors with University Bi-locks if not located in an electrical cupboard or switchroom.
- i. Hinged escutcheons can be opened when main switch is in 'ON' position.

Type 2

Application: existing building refurbishments or fit-out, shared lighting and power Requirements:

- a. 80A supply on a 250A chassis.
- b. Form 1.
- c. 48 pole shared power and lighting sections.
- d. Top Centre Main switch.
- e. Separate AUMS compliant meter located on din-rails at the top of the DB. If the upstream MSB already has a meter, only a single meter is necessary for the lighting section (BCA compliance based on PCA certifier advice).
- f. Separate din rail for lighting control and emergency lighting test switch.
- g. Gland plates with gaskets.
- h. Hinged doors with University Bi-locks if not located in an electrical cupboard or switchroom.
- i. Hinged escutcheons can be opened when main switch is in 'ON' position.

Type 3

Application: typical floor/lab Main DB, submain supply to DBs Features:

- a. 400-630A supply on a 630A MCCB chassis, for 160-250A frame MCCBs.
- b. Electronic trip units and terminal shrouds.
- c. Form 3Bih, Annex ZC.
- d. 30 Pole.
- e. Top Centre Main switch.
- f. Separate AUMS compliant meter located on din-rails at the top of the DB. If the upstream MSB already has a meter, then no meter is required on the Type 3 DB.
- g. Gland plates with gaskets.
- h. Hinged doors with University Bi-locks if not located in an electrical cupboard or switchroom.
- i. Hinged escutcheons can be opened when main switch is in 'ON' position.
- j. Surge diverter.

6.14.4 Sub-Circuit Loading

The following requirements for maximum sub-circuit loading must be complied with:

- a. 16A Lighting sub-circuits must have a maximum initial lighting connected load of 15 luminaires of any type up to maximum 12A load, allowing a spare capacity of 5 additional luminaires within the RCD trip tolerance with spurious device leakage current.
- b. 20A Power sub-circuits must have a maximum 6-off double socket outlets or 12-off single socket outlets initial connected load or maximum connected load of 16A. Typically a maximum cluster of 6-off workstation positions or 6-off single offices with wall outlets may be connected to one circuit.

6.14.5 Non-RCD Protected Outlets

The following non-RCD sub-circuit requirements must be complied with:

- a. **Non RCD OUTLETS:** Provide correctly labelled dedicated non-RCD outlets to the following load groups:
 - i. UPS powered equipment using socket outlets labelled 'UPS Power – No RCD Protection'.

- ii. Any other Non RCD protected outlets must be justified to the UI Electrical Engineer against AS/NZS 3000:2018 on a case by case basis.

6.14.6 Distribution Board Name and Designation Labels

Provide labels of material, colours and set out in accordance with the University Standard requirements. All new switchboard identification numbers must be obtained from the University through a formal Request for Information.

Generally, name and designation labels must be as follows:

- a. Identification Number must be based on the room number where the board is located e.g. DB304 – will be in room number 304, being room 4 on L3.
- b. Additional location identifiers such as a letter from the alphabet (sequentially) must be used if there is more than one switchboard in a room e.g. DB304A and DB304B.
- c. Mechanical boards must be labelled as above, followed by the words 'Mechanical Services Board'.
- d. All switchboards must have a separate label identifying the building number and name where it is located e.g. G12 Services Building.
- e. All switchboards must be labelled with the origin of supply e.g. Supplied from G12 MSB X.
- f. All outgoing sub-circuits must be labelled 'DB-xx-yy' where xx is the DB number, and yy is the circuit breaker number.

6.15 External Switchboards

RMSB, MSB, MDB, DBs and switchboards are NOT permitted to be installed externally. They must be installed within a weatherproof fire rated / smoke sealed electrical switch room or cupboard in a building with roof. The safety risks of operating or working on an outdoor external switchboard under wet weather and dark environment is not acceptable.

Only Generator Mobile Connection Panels may be installed in exterior unprotected locations. Provide the following:

- a. **IP Rating:** IP6x
- b. **Material:** Fabricate the switchboard from grade 304 stainless steel and powder coat in a colour to match the external area where it is located.
- c. **Roof:** Free of openings and fastenings, graded away from entries to the enclosure, and with a 50mm minimum overhang on any openings.
- d. **Ventilation:** A ventilated air space between the roof and the top of the cubicle, and louvered openings at the top and bottom of the internal cubicle panels to give convective heat dissipation.
- e. **Screening:** Stainless steel or bronze insect screen mesh to ventilation and cable entry openings to prevent entry of vermin.
- f. **Flanges to Openings:** Provide a drained drip tray at the door opening.
- g. **Bottom Cable Entry Escutcheon:** Removeable sealed cover panel or hinged flap in the bottom of the panel to permit entry of temporary mobile generator cables. Provide flexible rubber sheet seals in the cable opening.

6.16 Switchgear and Control Gear

6.16.1 Switchgear Uniformity

Switchgear and Circuit Breaker protection equipment must be of one brand throughout any single installation and must be fully coordinated and compatible.

New equipment being installed into an existing installation must match the brand / type installed as far as practical and available.

6.16.2 Molded Case and Miniature Circuit Breakers

The following types of automatic circuit breakers current must be used:

- a. 10A-63A: Din-mounted 18mm module Miniature Circuit Breaker (MCB/RCBO) protection within a single pole space (RCBO).
- b. 100A –1600A Moulded Case Circuit Breakers (MCCB).
- c. >1600A Withdrawable Air Circuit Breakers (ACB).

The Deemed-to-Comply circuit breakers for new installations are:

- a. Schneider - Multi 9, Compact NS and Masterpact NT systems.
- b. NHP – Din-T, Terasaki TemBreak systems.
- c. Transient and Surge Protection

Provide transient and surge protection devices in all switchboards in accordance with the relevant Australian Standards. These protection levels must be provided:

Main Switchboards:

- a. Protection Level: consistent with the prospective surge current at the incoming supply point to the switchboard, graded appropriately between upstream and downstream switchboards or systems.
- b. For Main Switchboard - Minimum 200kA aggregate rating at 8/20uS waveform rise times;
- c. Primary Protection: Provide shunt connected metal oxide varistors at assembly incoming supply terminals, on the line side of incoming functional units.
- d. Secondary Protection: Provide metal oxide varistors or zener diode surge protection to in-built equipment and semi-conductor components which are not able to withstand transient over-voltages exceeding primary protection let-through residual levels.
- e. Failure Indication: Provide integrated indicating lamps to show arrester status.
- f. Remote Monitoring: For Regional Main Switchboards, building Main Switchboards and main distribution boards provide transient protection units complete with volt-free contacts, in order to allow provision for remote monitoring of the status of the unit components.
- g. Short-circuit protective devices and isolators: Back-up each arrester active supply with a live side totally enclosed fault current limiting fuse in accordance with the manufacturer's nominated rating. Provide a multi-pole automatic miniature circuit breaker on load side of fuses as an arrester isolator.
- h. Locate Regional Main Switchboard, Main Switchboards and Main Distribution Boards surge diverters in segregated metal compartments within the switchboard with a clear polycarbonate inspection window.
- i. Surge Arrester Enclosures: Totally ventilated sheet metal wall boxes with hinged covers, mounted within the switchboards.

Distribution Boards:

- a. Provide Metal Oxide Varistor (MOV) transient protection devices in all switchboards in accordance with the relevant AS/NZS.
- b. Protection Level must be consistent with the prospective surge current at the incoming supply, graded between upstream and downstream switchboards or systems.
- c. Provide visual illuminated indication of correct operation, and fail alarm monitoring; and
- d. Provide terminals for connection to the AUMS system.

6.16.3 Control Relays

Control relays must satisfy the following requirements:

- a. **Application/Release:** must be applied and released without the use of tools;
- b. **Minimum Contact Rating:** 6A at 240V for ac applications.
- c. **Time Delay Relays:** Time delay relays must be adjustable over the full timing range and have a timing repeatability within 12.5% of the nominal setting.
- d. **Phase Failure Relays:** Solid-state type phase failure relays which drop out at 80% of the normal voltage after an adjustable time delay. The sensing circuit must reject disturbances having frequencies other than 50 Hz, and induced voltage spikes.

6.16.4 Dry Contacts

a. Dry contacts must be setup for UPS, Surge Diversion and Power Factor Correction units.

6.16.5 Extra-Low Voltage Transformers and DC Supplies

Provide low loss electronic switchmode for DC power supplies, or low loss iron cored transformers for 50Hz AC power supplies.

The transformer output loading must be $\leq 80\%$ of transformer continuous rating, taking account of degree of ventilation and ambient temperature within assembly and supplied load.

6.17 Switchboard Accessories and Instruments

6.17.1 Metering Transformers

Metering transformers must meet these requirements:

- a. **Test Links:** Provide test links for the connection of calibration instruments.
- b. **Type:** Split core CTs may be used following written approval, in locations where solid CTs cannot be fitted. In this case, split core CTs may be specified at Class 1 accuracy.
- c. **Accuracy:** Accuracy classification and class:
 - i. Energy measurements: 0.5M.
 - ii. Indicating and recording instruments: 1M.

6.17.2 Indicator Lights

Indicator lights must be provided:

- a. **Status:** Lamps must indicate:
 - i. Power Supplies available (e.g. Mains, generator, UPS, Photovoltaic supplies)
 - ii. Power Supplies connected where there is more than one supply
 - iii. the 'run' state of motors.
 - iv. The state of ATS input and MTS output supplies.
 - v. The state of busbar, by-pass or interconnect switches.
- b. **Lamps:** Lamps must be multi-element LED type and must be changeable from the front of the panel without removing the holder.
- c. **Lamp Test:** Provide a lamp test button.

6.17.3 Labels

Labels must be provided to meet these requirements:

- a. **Marking:** Marking must include labels for each switchboard control, circuit designations and ratings, fuses fitted to fuse holders, current-limiting fuses, warning notices for operational and maintenance personnel, and the like.
- b. **Set Out:** Align horizontally and vertically with adjacent labels.
- c. **Fixing:** Attach labels using plastic blind plugs through drilled holes.
- d. **Exterior Labels:**
 - i. Manufacturer's Name.
 - ii. source of electrical supply.
 - iii. Circuit designation for main switches, main controls and sub-mains controls.
 - iv. Details of consumers' mains and sub-mains.
 - v. Incoming busbar or cable rating to first tee-off.
 - vi. controls and fault current limiters.
 - vii. Fuse link size.
 - viii. Circuit breaker frame size & trip current settings.
 - ix. Meter function identification immediately adjacent to the meter.

- x. Interior Labels: Provide labels for equipment within assemblies. Locate so it is clear which equipment is referred to, and lettering is not obscured by equipment or wiring.
- xi. Samples: Provide samples of proposed label material, label sizes, lettering sizes and lettering text for approval.
- e. **Material:** Engraved two-colour laminated plastic, engraved filled metal or photo-anodised rigid aluminium.
- f. Colours:
 - i. Warning Notices: White letters on red background.
 - ii. Other Labels: Black letters on white background.
- g. **Lettering Height:** Generally, not less than the following:
 - i. Main Switchboard Designation: 25mm.
 - ii. Main Switches: 20mm.
 - iii. Feeder Control Switches: 10mm.
 - iv. Identifying Labels: On outside of cubicle rear covers etc.: 4mm.
 - v. Equipment labels within cubicles: 3mm.
 - vi. Warning notices: 10mm for heading and 5mm for remainder.
- h. **Schedule Cards:** For distribution boards provide schedule cards of minimum size 200mm x 150mm with text to show:
 - i. Sub-main designation and rating.
 - ii. Light and power circuit number, type and area supplied.
 - iii. Submit the proposed schedule for approval.
 - iv. Mount the schedule card in a holder fixed to the inside of the enclosure door, adjacent to the distribution circuit switches, and protect the schedule with a hard-plastic cover.

6.18 Switchboard Thermographic Survey

Carry out a thermographic survey on the operational switchboard two months prior to the end of the defect liability period. Use an advanced thermal imaging camera driven by a software program and provide a report on the thermographic heat pattern of the relevant switchboards. Any anomalous heat emissions which indicate presence of faults or hot joints must be rectified before the end of the defect liability period.

Provide the Thermographic report as part of the Defects Liability Completion documentation.

6.19 Metering Systems

6.19.1 Authority Tariff Metering

All tariff metering must comply with:

- a. The NSW Service and Installation Rules.
- b. The Energy Retailer metering requirements – note these are significantly changed in 2018 giving the Retailer statutory control over their metering equipment type and locations.
Request information on the retailer for the site from the Project Manager through the University application process and comply with the retailer's requirements.
- c. The local Supply Authority regulations.

All regional main switch boards (RMSB) and main switchboards (MSB) directly connected to a substation must contain Electricity Supply Authority Metering current transformers within the switchboard enclosure.

Any power supply that is a tenancy, must also be provided with a Tariff meter unless agreed otherwise with the Property team and the tenant.

All MSB supplied from a RMSB must include cubicle space and removable links for the future installation of Electricity Supply Authority Metering current transformers, allowing future re-configuration of electrical supplies.

Current signals from the CTs must be clearly colour coded to the phase and labelled at each end of the cable to indicate the phase and secondary orientation of current signal (e.g. Red S1 and S2).

A non-metered supply is required in new builds with tenancies.

6.19.2 Power Quality Metering

For each primary power supply into a Regional or Main Switchboard provide a multifunction meter with mid-range Power Quality event recording.

The meter must be programmed to monitor for supply voltage or current events above or below programmable thresholds. The meter must record waveforms and absolute maximum and minimum values of these events in non-volatile memory. The meter must provide:

- a. Colour LCD display.
- b. Power quality monitoring IEC 62586.
- c. Programmability (logic and math functions).
- d. Voltage sag and swell detection.
- e. Waveform capture.
- f. Harmonic distortion measurement.
- g. Power quality measurement IEC 61000-4-30: class S.
- h. Compliance report EN 50160.
- i. Event time stamps.
- j. Minimum 512MB memory.

The Power Quality event data must be downloadable to a windows-based PC with basic software and Ethernet port, and the meter must also be connected into the AUMS system.

One meter which meets these requirements is the Schneider PowerLogic PM8000 - PM8240 series.

6.19.3 Private Metering (Multi-Function Meter)

All MSB supplies and sub-tenant sub-main supplies must be fitted with private energy smart meters and CTs of Tariff Accuracy classification and class 0.5M. These meters may be used to allocate energy usage charges as distinct from just monitoring energy use.

Meters must record and report kVA, kWh, Pf, V, A, maximum demand and power harmonics quality. Meters must be connected to and configured in conformance to the **UI AUMS Standard**.

6.19.4 Energy Consumption Metering (Secondary Class Meter)

Sub-metering must be installed to monitor the following loads, or as required to meet any energy rating scheme for the project including NCC compliance, during any switchboard upgrade/new installation:

- a. Mechanical services.
- b. Vacuum Pumps and Air Compressors
- c. Essential services.
- d. Lifts.
- e. Individual building floors supplies.
- f. House services general supply.
- g. Any tenanted or potentially tenanted space.
- h. Separate lighting and general power for each DB via split chassis metering.
Note: the standard type DB only includes one single meter installed on the lighting section of the DB; the power meter is typically installed on the upstream MSB. If the upstream MSB does not have provision for metering the DB, a second meter is required on the DB on the power section.
- i. DIN rail mounted integrated dual meters with separate CTs for lighting and power may be used. Do not use whole current meters.
- j. Any laboratory/specialist equipment or high energy use area with total load > 50 amps/ph.

Sub-meters and all communication hardware software must be connected to, and configured in, the University's AUMS in conformance to AUMS Standard.

6.19.5 Summary of Meter Requirements

Items to be Individually Metered	Meter Quality
Supplies to RMSB or MSB	Authority Tariff Meter
Supplies from RMSBs to MSBs/MSSB's etc.	Multi-Function Meter
Supplies from MSB to all DBs/MSSBs etc.	Multi-Function Meter
Tenants Supply from an Unmetered Supply from the MSB or RMSB	Authority Tariff Meter
Lighting at DB Level	Secondary Class Meter
Power at DB Level	Secondary Class Meter
Kitchens	Secondary Class Meter
Photo Voltaic Metering (Contractor to Confirm Supply Authority Requirements)	Bi-directional Multi-Function Power Meter with 'Time of Use' Capabilities
Lifts	Secondary Class Meter
External Lighting	Secondary Class Meter
Individual Chillers	Secondary Class Meter
General Sub-Mechanical Boards (e.g. where an MSSB is a sub-feed from an MSB/ DB /MSSB)	Secondary Class Meter
HVAC Water Pumping Power	Secondary Class Meter
Electrical Heating Water Plant	Secondary Class Meter
Electrical Hot Water Plant	Secondary Class Meter
Laboratory or Research Equipment Larger than > 50 amps/phase	Multi-Function Meter
Cooling Tower Fans	Secondary Class Meter
HVAC AHUs including associated supply, return, relief and outside air fans	Secondary Class Meter

Note: All meters must use native Modbus protocol.

6.19.6 Meter Labelling

All new meters installed must be physically labelled with new Traffolyte labels as per the AUMS system. Meters are to be identified as per their asset (i.e. Power Meter no. 1 located on DB-05 shall be labelled DB-05 – Power Meter).

6.19.7 Meter Documentation

The contractor must supply the UI, Sustainability & Engineering Team with:

- a. Switchboard single line diagrams.
- b. Network communications schematics, including for devices within the switchboard.
- c. Network address identification schedules in editable spreadsheet format.
- d. Plans showing meter locations, meter identification and coverage.

6.19.8 Utilities Metering and Account Connections, Disconnections and Transfers

The University uses the services of an external utilities advisor to manage changes to utilities metering and account connections, disconnections and transfers. All utilities connections, disconnections and transfers for the University must be requested by Project Managers, Facilities Managers or their delegates via the external utility's advisor for a fee. The procedure for connections, disconnection and transfers of utility metering and accounts is documented in **Utilities Connections, Disconnections and Transfers Form (COS-ENG-F010)**. Project Managers, Facilities Managers or their delegates must make the external utilities advisor aware of any changes to utility metering or accounts including requests for new meters, transfer of accounts or disconnection of existing meters within the timeframes stipulated in the procedure and by completing **Utilities Connections, Disconnections and Transfers Form (COS-ENG-F010)**.

6.20 Technical Earthing Systems

Provide complete technical communications / technical earthing systems for all computer rooms and laboratory or sensitive areas. Where a technical earthing system is required for research / measurement facilities, it must be segregated from the communications and power earthing systems, except for the single bond at the building main earth bar.

The system must include:

- a. A dedicated buried earth grid external to the building with a maximum impedance of 0.5 Ohms, or as required by specialist laboratory equipment suppliers.
- b. A main technical earth bar with provision of slack cable and space to place a clamp current meter onto every outgoing radial cable.
- c. Radial dedicated technical earth cable distribution to every equipment room or laboratory;
- d. A single link to the building main earth bar in the main switchroom.
- e. Earth leakage / circulation current alarm monitoring on the link to the main earth bar.

Provide independent earthing for raised floors, and all metallic building elements connected radially to the power protective earth bar.

Carry out preliminary site testing to determine the base site earth soil resistivity and the viability of the Earthing System Design to achieve the required performance. Discuss the results with the Project Management team and agree a final achievable target value.

6.21 Lightning Protection System

Provide a compliant lightning protection system in accordance with AS/NZS 1768. Dynasphere systems are not acceptable.

6.21.1 Existing Systems

Where the project involves alterations and additions to an existing system, or a major upgrade of the building;

- a. Assess the existing system for compliance to current code and condition.
- b. Identify any repairs or upgrades required to bring the existing system up to current code.
- c. Identify any alterations or additions to the system where the building is altered.
- d. Provide a budget to undertake the works.

6.21.2 Materials

Provide a coating of polyurethane compound to copper strip materials embedded in concrete. Do not use aluminum.

6.21.3 Fixings

Fixing must meet these requirements:

- a. **Fixing to Masonry:** Screws or bolts set in approved expansion-type masonry anchors contained in properly formed holes. Do not use explosive-driven fixings.
- b. **Fixing to Steel:** Bolts of appropriate size (not less than 6mm diameter), with nuts and lock washers.
- c. Fixing to Timber: Wood screws.

6.21.4 Joints and Bonds

The following types of joints and bonds must be used:

a. **Types of Joints:**

- i. Accessible Connections: TIG welded or bolted with high tensile SS bolts.
- ii. Inaccessible Connections: CAD or TIG welded.
- iii. Stranded Copper Connections: Bond corners, tee joints, and between the ends of non-overlapping bars by means of stranded copper connections, double-bolted at each end with appropriately sized stainless-steel bolts, nuts, and lock washers. For this purpose, provide a 25mm gap between the members to be joined.

b. **Bonding:**

- i. Roof Projections: Bond to the air termination network the metallic projections shown on the Drawings on or above the main roof area, including TV aerials, flagpoles, handrails, metal roofing of secondary roofs, water tanks, ventilators, guttering, access ladders, and the like.
- ii. Services:
- iii. Bond metallic service pipes to the lightning protective system at the point of entry or exit outside the structure on the supply side of the service.
- iv. Bond metallic sheathing or armouring of electric cables at the point of entry to the building.
- v. Down Conductors:
- vi. Where a metal part of a building runs for more than 10 m in close proximity to a down conductor, bond the metal at top and bottom to the conductor.
- vii. Where a down conductor occurs on the external face of a column, bond it at top and bottom to terminals on the column reinforcement.
- viii. Where the column reinforcement is the down conductor, provide terminals and bond it at top and bottom to the conductor network.

c. **Terminals:**

- i. For the above cases, provide 50mm x 6mm terminals of stainless steel, grade 304 to AS 1449, clamped and bolted to not less than four reinforcing rods.

6.21.5 Installation

Before commencing the installation, submit for approval drawings showing the proposed layout of the protective system, including details of the locations and types of joints, terminals and earthing terminals, and the arrangement of components in earthing pits.

Submit your Compliant Design to AS1768 for review prior. Include plan drawings, sections and elevations, pts, connecting to building, earth bars, etc.

6.21.6 Earth Terminations

These requirements must be met for earth terminations:

- a. **Terminating Lugs:** Provide terminating lugs on each electrode or earth termination network for the connection of down conductors or base conductors.
- b. **Base Conductors:** Provide base conductors between each driven electrode and buried electrodes to interconnect the buried earthing system. The connections between the base conductor and the individual electrodes must be capable of acting as removable test links.
- c. **Electrode Pits:**
 - i. Locate each driven electrode within a concrete pit of internal dimensions 300mm x 300mm x 500mm deep, so that the top of the electrode is not less than 150mm above the bottom of the pit and not less than 150mm below the underside of the pit cover.

- ii. Pit Walls: 150mm concrete or 200mm solid blockwork.
- iii. Pit Cover: Reinforced concrete 75mm thick, or equivalent. Set the top of the cover flush with the adjacent finished surface level. Label the pit cover in letters 10mm high: 'LIGHTNING PROTECTION EARTH ELECTRODE'.
- iv. Method of Labelling: engraved stainless steel or brass plate.

6.22 Power Factor Correction

Power Factor Correction may not be required initially in many projects due to the proliferation of HPF lights and motor VSDs. This must be assessed by the electrical consultant and contractor before tender:

- a. If the power factor is assessed and PFC expected to not be required, the regional or main switch room must still allow space for future connection and installation of at least one cubicle of PFC.
- b. If power factor is required, then the items below are applicable.

Provide Power Factor Correction (PFC) equipment to maintain the PF at between 0.95 and unity. It must be reliable with a minimum life expectancy of 10 years for all components.

The following PF equipment along with all necessary ancillary requirements must be provided for satisfactory operation:

- a. PFC Equipment with:
 - i. High voltage MPP capacitors.
 - ii. Special duty rated step contactors.
 - iii. High quality iron cored harmonic rejection inductors.
 - iv. Microprocessor step controller.
- b. Items within the Main Switchboards or Regional MSB for:
 - i. Sub-main protection for the PFC feeder cables.
 - ii. Incorporation of the PFC Current Sensing Transformer.
- c. Sub-mains and cable tray support between the MSB/ RMSB and PFC equipment.
- d. Terminals for connection of a remote group alarm.
- e. PFC calculation.
- f. Shop drawings.
- g. As installed drawings and maintenance manuals.
- h. 24-month warranty with six monthly service.
- i. Determine how a PFC unit will interface, if a generator is installed.
- j. The PFC equipment must be located as close as possible to the main switchboards or RMSB.

6.22.1 Authority Approvals

Obtain Supply Authority approval for the installation, including submission of equipment details prior to construction or installation.

6.22.2 Shop Drawings

Shop drawings must include the following:

- a. General arrangement of each cubicle.
- b. All equipment listing.
- c. Equipment site plan including cable routes.
- d. General arrangements including method of construction, materials used, finishes, clearance distances and method of support for busbars and cables.
- e. Maker's or manufacturer's name and catalogue number of all proprietary equipment.
- f. Schedules of all labels for all equipment.
- g. Control schematics. Provide a description of operation with all controlled schematics.

6.22.3 Cubicle

The cubicle must:

- a. Be manufactured in accordance with the specification section for switchboards. (Obtain a copy of this section prior to completing the tender).
- b. Be painted a colour to match the Main Switchboard.

6.22.4 Capacitor Type

The capacitors must:

- a. Comply with AS/NZS1013 and IEC 831-1.
- b. Be vacuum oil impregnated metallised polypropylene.
- c. Incorporate discharge resistance.
- d. Have a minimum dielectric rating of 500VAC as required to accommodate the series reactor voltage addition.
- e. Be rated for 60oC maximum surface temperature.
- f. Incorporate automatic overpressure disconnection.
- g. Be of cylindrical construction with single capacitor units per can.
- h. Have a tolerance of -5%, +10% of value.
- i. Have their kVAR rating at 415V.

6.22.5 Step Size

The capacitor installation must have minimum 2 off 25kVAR steps for fine tuning at low loads, and the remainder in 50kVAR steps.

6.22.6 Capacitor Installation

The capacitor installation must have:

- a. Inductors mounted in a separate cubicle, segregated from capacitors, fuses and switchgear.
- b. Capacitors cans separated by a minimum air space of 25mm for ventilation.
- c. Layout arranged for easy removal and replacement of capacitors.
- d. All live parts insulated to protect personnel from accidental contact.
- e. Be ventilated to ensure internal cabinet temperature rise is less than 15oC above ambient.
- f. A maximum step size of 50 KVAR with fuses for each step.

6.22.7 Cooling Fans

The cubicle cooling fans must:

- a. Be muffin type axial fans for 240VAC.
- b. Be twin units per cubicle.
- c. Be sized to limit the internal cabinet temperature rise to less than 5°C above ambient room temperature.

6.22.8 Wiring

The following details must be incorporated:

- a. Generous space must be provided for use of a clamp on ammeter to measure individual capacitor phase currents.
- b. Where welding type multi-stranded flexible cables are used, they must be terminated in a manner which ensures adequate clamping of the fine conductors. Compression ferules must be used for tunnel type terminations.
- c. Where there is a no-fault protection device incorporated in the Main switchboard, the cable to the PFC cubicle must be Radox or XLPE, installed to withstand the prospective fault current.

6.22.9 Contactors

The capacitor switching contactors must:

- a. Be rated for capacitor switching duty at 1.5 times the capacitor step full load current. For example, 100AMPS AC3 for a 50KVAR capacitor at 415V.
- b. Comply with IEC 947 contactors for capacitor switching AC-6b.

6.22.10 Step Controller

The capacitor switching step controller must:

- a. Be of fully electronic microprocessor type.
- b. Be easily site programmable.
- c. Have spare capacity increase in the number of steps.
- d. Incorporate non-volatile program and data memory.
- e. Have a digital display for the following parameters:
 - i. Power Factor.
 - ii. Incoming supply load.
 - iii. Number of capacitor steps in use in the incoming supply.
 - iv. % Harmonic current.
- f. Incorporate harmonic monitoring and automatic disconnection in the case of overload of the capacitors.
- g. Provide for automatic alarm and isolation of the capacitors in case of over temperature or overcurrent.
- h. Provide for automatic disabling of all capacitor steps when the installation is being powered from any existing diesel generator. A signal for this control must be derived from the phase failure relay in the MSB.
- i. Automatically cycle the capacitor steps to ensure equal ageing of components;
- j. Have a local and remote group alarm facility for any abnormal condition.
- k. An integral MODBUS data interface for connection of a monitoring system, complete with associated software.

6.22.11 Inrush Current Surge Limiting

Limitation of the capacitor inrush current must be achieved by means of inductance in series with the capacitors.

6.22.12 Harmonic and Supply Authority Ripple Signal Rejection

This must be achieved using series-connected iron cored reactors tuned to a frequency suitable to limit the harmonic current within the capacitors to less than 5% of their nominal rating, and to limit the increase in the incoming supply voltage total harmonic distortion to less than 2.5% and in no instance to be more than 4% total THD. (Typically, this frequency will be slightly above or below the 4th harmonic).

The reactors must be purpose designed and manufactured to Australian standards and carry a compliance and rating plate.

Provide calculations for the sizing of the reactors, and workshop drawings showing form of construction and all materials.

The reactors must:

- a. Be provided for each capacitor step.
- b. Be of very low loss design.
- c. Be wound from high purity copper conductors using Class F temperature rated insulation.
- d. Have insulated, laminated, high permeability silicon iron (or equivalent) cores.
- e. Have non-ferrous mounting hardware.

- f. Be designed to carry 1.5 times the rated capacitor current at 50Hz without saturating.
- g. (i.e. 100A for 50KVAR capacitor at 415V at 40°C Ambient).
- h. Have a Q factor >10.
- i. Be firmly constructed to avoid the possibility of noise due to vibration.
- j. Have a tolerance on inductance value of $\pm 5\%$ at rated current.
- k. Be permanently labelled with manufacturers' details and rating information.
- l. Have a nominal current rating of at least 1.25 times the nominal capacitor current.

6.23 Voltage Reduction Transformers

6.23.1 General

Stepdown transformers must be provided where User supplied equipment is rated at voltages differing to the Australian standard 230/400V.

Obtain written manufacturers details of the loads from the User.

Provide transformers with;

- a. IP24 minimum rated metal enclosure with equipment details on a permanent label.
- b. Rated with 20% spare capacity over the full load.
- c. 400V rated primary (NOT 415V).
- d. Full isolation (NOT auto transformers)
- e. Electrostatic shield between primary and secondary windings.
- f. Delta primary / star secondary with MEN Point inside the cabinet.
- g. Local isolators for input and output.
- h. Primary and secondary CB protection, with allowance for inrush currents and losses.
- i. Carry out an EMI assessment and locate transformers away from sensitive areas.

6.24 Uninterruptible Power Supply

6.24.1 UPS Provision Policy

If UPS systems are to be provided within the project infrastructure (as opposed to User procured systems), refer to the **UI UPS Services Standard**. Where the cost and complexity are warranted by the criticality of the building, a large central building UPS would be required with a power distribution system.

The type, configuration and complexity of UPS system must be tailored to the load rating and criticality as defined in the UPS Standard including battery autonomy time.

End User UPS Systems

UPS installations are typically a small UPS dedicated to a specific local purpose identified by a user. UPS systems are procured, owned and operated by the end user.

The End User is responsible for the ongoing maintenance expenses associated with the UPS and annual maintenance certificates must be provided to COS.

Dry contacts for alarms must be included with the requirements for UPS systems.

6.25 Electromagnetic Interference and Compatibility (EMI and EMC)

6.25.1 Project Definition Phase

There are various levels of sensitivity to EMI across the wide range of University space uses, ranging from low sensitivity transient human occupancy to extreme sensitivity world class ultra-sensitive research laboratory spaces. There are also many instances where the equipment within laboratories poses an external interference or EMI hazard to external occupants or processes, which must be managed or mitigated.

Generally, projects need only consider basic EMI considerations of separating power supply infrastructure from user spaces by distances in the range of 5-10 meters. The unit of measurement for magnetic fields is the milligauss (mG), and for electric fields it is Volts/meter. Electric fields are easily stopped by thin metal sheet or mesh, whereas magnetic fields are more penetrative (e.g. connecting the individual cables in the trefoil formation minimizes the magnetic field around the conductor and reduces the heating).

Each project definition phase shall include a basic EMI sensitivity analysis identifying the classes of space, defined occupancy, the maximum permissible EMI levels within those spaces, and any potential user equipment posing an external risk. It is up to the Design Consultant to understand the equipment requirements and to design the electrical infrastructure according to those requirements.

Where special needs are identified outside of the normal permissible range (5-50mG), a detailed investigation and specification of the performance levels shall be undertaken.

Special use spaces (typically electronic or physics laboratories) being created within existing buildings requiring EMI levels below 2mG will require a site EMI survey to be carried out as part of the project definition phase to determine if the space is fundamentally suitable for the use, and / or expensive shielding or other mitigation is required, or even feasible.

Residential and office spaces must carefully consider the location of substations, switchboards and sub-main routes to avoid long term exposure to residents or staff.

The location of lift cores and loading docks to highly sensitive spaces must be considered in the spatial design. Lifts and large vehicle traffic on adjacent roadways pose an EMI risk to sensitive laboratory spaces as they generate fluctuations in the surrounding earth magnetic field that can affect measurements or equipment calibration.

6.25.2 EMI types

There are broad classes of EMI or field as follows:

- a. **Static Magnetic** (0 Hz) - Earth magnetic field, powerful DC or permanent magnets in lab equipment.
- b. **Fluctuating Magnetic** (0.01 - 1 Hz) - generated by Lift counterweight, large vehicle etc. moving.
- c. **Oscillating Magnetic** (50 - 1000Hz) - typically mains power electrical equipment including substations, switchboards, sub-mains, and single-phase sub-circuit cables loaded to more than 10 amps.
- d. **Radio Frequency Interference** (10kHz - 10GHz) - Electronic light fitting ballasts, Mobile phones, Microwaves, some lab equipment, RF heating dryers, high power Laser drivers, mobile telephone base stations etc.

Generally, the higher the frequency, the less penetration that radiated interference will have.

6.25.3 EMI Mitigation

Electric fields (radio frequency) are easily stopped by thin metal or mesh. Magnetic fields are much more penetrative and troublesome. The methods for mitigating or reducing EMI impact are:

- a. **Spacing** - This is the best and cheapest option. EMI fields fall off at the square of the distance between source and receptor ($2 \times \text{distance} = \frac{1}{4} \text{ field strength}$). Move the source and receptor apart as far as possible. Typically, 10m for a substation and 5m for major sub-main routes is satisfactory.
- b. **Shielding of The Receptor** - Room Shielding is very expensive and a last resort. It requires complex design, verification, large amounts of expensive specialist metals and labour-intensive installation. Usually the whole room must be fully enclosed, including special doors and frames.
- c. **Shielding of The Source** - Shielding at the source is less expensive as it usually requires a smaller area to be covered, such as a single cable tray or Distribution switchboard. It may only be used where the situation is already nearly satisfactory and does not require a major improvement, and the source is small, such as a cable tray or Distribution switchboard.

It is extremely difficult if not impossible to shield a substation, and the Supply Authorities are uncooperative in permitting it.

- a. **Active Cancellation** - This is applicable for slowly changing EMI or static fields, working by generating a counter field with a large coil of wire surrounding the space. It requires complex design verification, and large expensive equipment.

6.25.4 Design Guidelines

Provide equipment designed and manufactured to minimize the impact of EMI where particular risks exist to or from other systems. Generally:

- a. Substations are to be located to ensure that the Electromagnetic Interference (EMI) on surrounding facilities is below the specified levels. Substations or Main Switchboards shall not be located directly underneath or adjacent at ground level to a residential dormitory, office, laboratory or teaching space. The minimum separation from occupied areas shall be 10m in any direction.
- b. Main sub-main routes or risers shall not be located backing directly onto, or passing on the ceiling under, any office space or residential dormitory. The minimum separation from occupied areas shall be 5m for major sub-main routes.
- c. Shielding of the sources or receptor areas is to be used only as a last resort, and dispensation must be sought from the UI Electrical Engineer. Dispensation will not be automatic, and the designer will need to prove that there is no alternative. The Design Submission is to include detailed calculation of the EMI in occupied areas by a specialist using CAD modelling software.
- d. Special (laboratory) spaces requiring EMI fields less than 2mG must have an EMI specialist involved in the concept design phase.

The Designer must provide a specialist report indicating all types of EMI interference (from a particular source or from the equipment itself. This include EMI issues within existing buildings). The report will identify a solution to mitigate the EMI issue, so user equipment is not impacted, so existing surrounding equipment is not impacted).

6.25.5 Power Line Filtration

Where there is significant high frequency EMI (10kHz – 10GHz) generated from laboratory equipment, or sensitivity within the laboratory, provide whole current pass-through passive power line filters on the sub-mains to the dedicated Distribution Switchboard. These shall be equal to Schaffner FN351, rated for the line current.

6.25.6 Signage Requirements

It is further advised that warning signage shall be provided:

- a. Where areas have oscillating magnetic fields above 20 mG and below 1,000 mG and staff or students may occupy such areas regularly. Regularly means more than once per week for periods over an hour.

- b. Areas that have oscillating magnetic fields of 1,000 mG or above should have an appropriate warning sign posted. Entry to such areas must be controlled by a Permit system.
- c. Appropriate Safe Work Method Statements should be applied to all incidences of elevated electromagnetic or electric fields.

6.25.7 Construction and Commissioning Verification Requirements

Provide equipment designed and manufactured to minimise the impact of EMI where particular risks exist to or from other systems. Generally:

- a. Shielding of the EMI source or of the receptor areas is to be used only as a last resort, and dispensation must be sought from the UI Electrical Engineer. Dispensation will not be automatic, and the designer will need to prove that there is no alternative. The Design Submission is to include detailed calculation of the EMI in occupied areas and calculations from EMI sources.
- b. The electrical contractor shall engage the services of a specialised EMI consultant to identify sources of EMI interference and propose remedial actions to limit the field levels to comply. Provide all shielding and screening of EMI sources as directed by the EMI after review and approval by the UI Electrical Engineer.
- c. At the discretion of the UI representative based upon likelihood of any EMI issues in the finished project, carry out 1-minute average broadband EMI measurements in areas of concern in the room at 1m above floor level. They shall be measured using a tri-axial Gauss meter on 15Hz -10kHz range, plus the DC / ELF range for laboratories. Record the measurements on a floor plan drawing and submit for approval.

The site shall be complete and electrically operational with at least all the lighting and air conditioning systems running.

6.25.8 EMI Acceptance Levels

The following maximum EMI levels shall apply, unless written permission to deviate is received from UI. These levels are the maximum 1-minute average broadband EMI level at any occupiable location in the room at 1m above floor level. They shall be measured using a tri-axial Gauss meter on 15Hz -10kHz range, and DC range for laboratories.

Space Type	Typical Occupancy	Maximum Average Emi
Residential	24 hours	5mG
Office	10 hours	10mG
Teaching Space	4 hours	15mG
Transient space	1 hour	50mG
General Laboratories	Note -Pre-occupancy / fit-out	15mG
Special Laboratories	E.g. – Medical, electrical, physics	0.1 – 2mG

Within existing buildings, an on-site measurement is required to determine the existing EMF readings in order to assess if any mitigation measures are required.

6.25.9 EMC Standards

The following standards apply for design and equipment:

The whole series of AS/NZS 61000, and specifically:

AS/NZS 61000.1.1:2000

Electromagnetic compatibility (EMC) - General - Application and interpretation of fundamental definitions and terms.

AS/NZS 61000.2.7:2009

Electromagnetic compatibility (EMC) - Environment - Low frequency magnetic fields in various environments.

AS/NZS 61000.3.2:2013

Electromagnetic compatibility (EMC) - Limits - Limits for harmonic current emissions (equipment input current =16A per phase).

AS/NZS 61000.3.4:2007

Electromagnetic compatibility (EMC) - Limits - Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 75A.

AS/NZS 61000.3.11:2002 (R2013)

Electromagnetic compatibility (EMC) - Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems - Equipment with rated current less than or equal to 75 A and subject to conditional connection.

AS/NZS 61000.3.12:2013

Electromagnetic compatibility (EMC) - Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and =75 A per phase.

AS/NZS 61000.6.3:2012

Electromagnetic compatibility (EMC) - Generic standards - Emission standard for residential, commercial and light-industrial environments.

AS/NZS CISPR 14.1:2013

Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus – Emission.

AS/NZS CISPR 32:2013

Electromagnetic compatibility of multimedia equipment - Emission requirements.

6.25.10 EMC Coordination with Other Services

Provide details to the Mechanical and Hydraulic contractor of the power supply system fault level and cable impedance at the local switchboard termination for co-ordination of Variable Speed Drive load EMC compliance and power system Harmonic Distortion limitation.

Assist these contractors to read the AUMS meters provided by the electrical contractor to determine the voltage and current THD at the metering point.

6.26 Diesel Emergency Generators

6.26.1 Generator Policy

It is not normal University practice to install diesel emergency generators or ATS systems, unless it is specifically required by the statutory regulations for life safety or specified for the project.

Generators provided for buildings are generally for Safety Services systems only and not for general building load. Normal University practice is to provide manual transfer switches within regional and main switchboards, and temporary mobile generator connection terminal boxes external to the building.

Only critical equipment identified by the stakeholders and approved by UI will be included within the generator load and size. The project return brief must identify the statutory requirements or UI approved User requirements for emergency power supply.

Should a Generator be necessary, the type of ATS required needs to be discussed (i.e. Open and Closed Transitions) prior to procurement. The University has many critical loads which cannot sustain any type of power outage, not even milliseconds which must be considered during the design phase.

The type of generator procured must be reviewed by the UI Engineering Team, including all auxiliary systems. The generator manufacture must be reputable, with a history of working within Australia.

UI will review generator proposals and will require time to go through all the set requirements from Australian Standards, University Standards and Project requirements.

6.26.2 Safety Services and Critical Load Backup

Generally, only small generators less than 1000kVA for safety services and some critical user loads are to be provided.

The minimum run time required for NCC safety services compliance is 2 hours, noting that the non-safety services loads must be disconnected in this mode.

For University defined Critical loads, the University only requires 8 hours minimum run time, with refuelling arranged by the FM team.

Critical Loads that may require emergency generator power include:

- a. Lab animal services, mechanical systems.
- b. Storage freezers.
- c. Medical tissue cold storage.
- d. Mortuary.
- e. Chemical / mechanical plant and equipment which would pose a safety, fire, explosion, toxic hazard if power is interrupted, noting that UPS backup may also be required.

Where diesel life safety generators are required, they must comply with relevant AS/NZS and a specialist specification must be prepared covering:

- a. Location (external canopy or generator plantroom).
- b. Fuel storage.
- c. Noise control.
- d. Exhaust flue placement.
- e. Ventilation grilles and acoustic attenuation.
- f. Vibration control.
- g. Controls and BMCS monitoring.
- h. Alarms connected to BMCS or Security Access System.
- i. Cabling.
- j. Emergency Shutdown controls at the Fire Indicator Panel / Building entrance location.

6.26.3 Authority Approval for Generator or Large PV Connections

The proposed arrangements for a standby generator or large PV system must be approved by the electricity distributor. Approval must be given for facilities to connect the alternative source of supply to the electrical installation normally supplied from the distribution system.

Where the electricity distributor agrees to the installation of facilities to enable an installation to be disconnected from the distribution system and connected to the alternate source, the systems must comply with the electricity distributor's requirements. They must prevent the electricity distributor's service and metering equipment and distribution system from being energised by the alternative source.

6.26.4 Generator Connection Provisions

Switchboard generator connections must satisfy these requirements:

- a. **Compliance:** Attention is drawn to the amended and strict requirements of AS/NZS 3010-2017 Electrical installations - Generating sets, which sets out the connection, control and protection requirements for generators.

- b. **Requirement:** Provide a generator connection terminal box and manual changeover switch for every Main Switchboard and as required in Regional Main Switchboards.
- c. Incorporate a **manual changeover switch** into all new Main Switchboards. Provide a remote generator connection terminal box and fire rated sub-main between the MSB and generator connection box which must be located adjacent to a nominated temporary generator location.
- d. **Construction:** Comply with the requirements for switchboards and external switchboards.
- e. **Cable Entry:** Provide cable flags and removable gland plate in the bottom of the connection cubicle for temporary generator cables as shown on the University Standard Generator Connection Box.
- f. **Rating:** To match the main switch capacity of the associated Main Switchboard, or 1600A maximum (based on a 1000kVA mobile generator size)
- g. **Labelling:** Provide;
 - i. a schematic within the cubicle to describe the procedure for connecting a temporary generator.
 - ii. Maximum Generator Connection: xxx Amps
 - iii. Phase sequence: e.g. RWB Clockwise
 - iv. Manual Transfer Switch: 3P Mains / 4P Generator (3P/3P)
 - v. MSB MEN located: before / after MTS
 - vi. Earthing Arrangement: Generator must / not have star point bond & earth cable connection
- h. **Battery Charger Supply:** Provide a 15A IP56 power outlet for connection to a mobile generator battery charger / auxiliary panel.

6.26.5 Emergency Shut Off

Provide an Emergency Shutdown control for the diesel generator or large PV systems at the Fire Indicator Panel or Main Building entrance, and in accordance with codes.

Provide location plans for the Main Switchboard and Generator systems at the shutoff point. Coordinate the Emergency Shut Off button with the MSB, Generator and any other Shut Off buttons such as the Shunt Trip Button (required for upper level MSBs).

6.26.6 UPS or Generator Backed-Up Distribution Boards

All distribution boards that are either UPS or generator backed must be labelled to identify mains and UPS / Generator supplies for isolation purposes.

6.27 Diesel Fuel Storage and Pipework

6.27.1 Diesel Fuel Handling Safety

The University has a strict WH&S and Environmental compliance requirement, and the fuel system must be designed, installed and labelled to meet all University and statutory standards.

Specific issues that must be addresses include;

- a. fuel spill prevention and containment.
- b. spill kits.
- c. ease of filling from ground level at a safe location.
- d. fill vehicle and personnel access and safety.
- e. public access and safety.
- f. Adequate signage for safe operation and Emergency Response.

6.27.2 Diesel Fuel Storage Sizing

<1000L Day tank only storage is strongly preferred, with a ground floor fill point.

Generally, only small generators less than 1000kVA for safety services and some critical user loads are to be provided. The minimum run time required for NCC safety services compliance is 2 hours, noting that the non-safety services loads must be disconnected in this mode.

For University defined critical loads, the University only requires minimum 8 hours run time, noting that only some of the safety services will also be running only in normal mode. Fire pumps and smoke exhaust systems will not be operating.

Carry out load estimates for both scenarios and provide day tank storage adequate for the worst case, with 30 minutes spare capacity.

6.27.3 Diesel Fuel Storage

Comply with AS/NZS 1940 – 2017 “The Storage & Handling of Flammable and Combustible Liquids”

- a. Day Tanks up to 1000L may be co-located WITH the generator almost anywhere in the building, either as a standalone or base mounted tank. This is the preferred solution.
- b. Any storage greater than 1000L within the building MUST be located on or below the lowest level of the building, or in an above ground external tank. NOTE – it is strongly preferred to NOT have bulk fuel storage on site.
- c. All storage tanks and any underground pipework MUST be dual skinned with integral leak detection and alarms and confirm to the EPA legislation.

As a basic rule, fuel consumption is estimated as:

$$\text{FUEL used (Litres/hour)} = \text{kW true electrical load}/4$$

NOTE – a 1000L day tank only has 800L of usable fuel pickup, with 200L remaining in the bottom

6.27.4 Diesel Fuel Fill Point

Provide an architecturally integrated stainless-steel fuel fill point cabinet with integral bund complying with codes and standards. Fit a University standard Bi-lock to the door.

Provide a fuel spill kit in a secure location immediately nearby the fill point, with signage.

Provide a fuel tank level gauge indicating the dynamic true level of the tank to be filled in litres.

Provide a positive displacement gear type pressure lift pump if the day tank is above the fill point, complete with a full control and emergency shutdown system.

Coordinate the design with the architectural, civil, fire and hydraulic services to ensure that environmental, safety and access requirements are achieved.

6.27.5 Above Ground/Non-Concealed Diesel Fuel Pipework

All above ground pipework passing between / through separated fire zones unrelated to the generator system must be stainless steel material with screwed or TIG welded joints.

Crimp type pipework joints relying on non-metallic seals are only permitted where the system is contained within a single fire compartment. Use only with specific UL exemption requiring certification of the systems for fire rated fuel transfer applications. Do not use any copper pipe.

Example; The pipework within a fire separated fill point / pump room at ground floor may be crimped joint type. The pipework to the generator container or room that passes through other building areas must be welded or screw joint. The pipework within the generator room may be crimp joint.

6.27.6 Pipe Support and Fixings

- a. **General:** Support and protect the pipework against operational stress or external interference to its integrity.

- b. **Supports:** Provide supports to adequately support the system and equipment fabricated from approved corrosion resistant materials suitable for the environment and operational life expectancy.
- c. **Electrolytic Compatibility:** Do not use metals in contact which will cause electrolytic corrosion.
- d. **Footings:** Provide concrete cast in situ footings to support pipework in soil areas.
- e. **Fixing:** Fix the pipework supports using the following methods, as appropriate.
- f. **External Fixings:** Grade 8 (stamped marked) stainless steel bolts and chemical anchor bolt fixings.
- g. **Masonry or Concrete Walls:** steel expanding or chemical anchor bolts.
- h. **Threaded Rods:** minimum 12mm metric.
- i. **Structural Steel:** Grade 8.8 machine bolts, hot dip galvanised.
- j. Concrete Slab Ceilings: steel expanding.
- k. **Spacing:** Space the supports at intervals of not more than 1.2m.
- l. **Expansion:** Do not restrict the pipework from expansion. Do not locate fixings or restrictions adjacent joints. Provide expansion U turns in straight sections more than 4m length.

6.27.7 Pipe Testing

Carry out pressure testing of the completed (but isolated) pipework systems, witnessed by the client's representative.

The systems must hold 8 bar pressure for 24 hours.

Record all manufacturers standard test sheets for proprietary pipework systems, plus your own installers ITP test sheets for the pipework system.

6.27.8 Pipe Cleaning

Carry out flushing of pipework systems with a suitable general-purpose hydrocarbon solvent followed by compressed dry air or nitrogen drying prior to commissioning and testing.

6.27.9 Below Ground / in Building Fuel Pipe Systems

Below ground pipework is not endorsed by the University due to ongoing maintenance costs, environmental impacts and hazard to human life operating/working or maintaining the tanks.

Pipework must be high density virgin polyethylene bonded composite structure pipe in pipe type with interstitial leak detection.

Run pipework straight and without joints as far as practical.

Joints must be proprietary double skinned electro-thermal plastic welded with integrated quality control indication. Record all joint locations and tests in the manuals.

Any joints must be located in accessible pits with removable heavy-duty trafficable covers.

Compression or crimp type pipework joints relying on elastic seals are not permitted.

Bury the pipework in a stabilised excavated trench in accordance with the manufacturer's recommendations. The details of the pipework trench are very specific to each manufacturer's pipework test and must be complied with. Refer to the full manufacturer's documentation and this specification. An example for the Durapipe system is provided below:

Saw cut the existing pavement evenly along the full length. Backfill the pipes with a full 150mm surrounding bed of clean sharp gravel of 5mm minimum to 10mm maximum size compacted to withstand heavy vehicle traffic without sagging or compression. Overlay a polyethylene (or approved equal) protection and warning strip along the full length of pipework. Protect the buried pipework with a steel reinforced concrete topping slab of 500mm minimum width and 100mm thickness rated at >20kPA load bearing strength, leaving minimum 50mm for final topping with asphalt.

Place engraved stainless-steel pipe route identity markers on the finished pavement at 5m intervals and every change of direction.

6.27.10 Workshop Drawings

Prepare and submit pipework system schematics and plan drawings for approval.

Identify:

- a. Pipework materials, sizes and installation method.
- b. Valves, filters and joint flanges type and location.
- c. Control schematic for pumps and level indication.
- d. Pump and valve set physical plan and construction details.
- e. Submit Pipework on the final BIM model that is handed over.

7 Commissioning

Comprehensive pre-commissioning, commissioning and quality monitoring must be specified by the consultant/designer and builder.

A project specific commissioning plan is to be developed and provided to the University for review and approval.

Detailed testing and commissioning records must be provided for each system and each component as appropriate. All such records must be witnessed and verified by the project consultant/head contractor prior to witness commissioning by UI engineers

Project handover plan must be developed by the consultant/designer to allow the system to be handed over to The University. A 12-month building tuning process will commence at Project handover with systems monitored monthly, reported and assessed quarterly, and include assessment of feedback from the occupants.

A project specific commissioning plan is to be developed and provided to the University for review and approval. UI have developed an **Electrical Services Commissioning Checklist (UI-ENG-F021)** which should be used as a minimum guide when preparing the project specific commissioning plan.

Do not conceal or permanently energize works that require inspection and test prior to entering service. Provide contract notice to the University to witness all testing and commissioning activities. Provide Inspection & Test plans for University approval at least two weeks prior to any tests.

8 Safety in Design

The contractor must consider risk during the design. A design safety report must be submitted to the relevant UI Project Manager for every design project. Contractors must confirm, so far as it is reasonably practicable (SFAIRP), that the structure is without risks to health and safety.

Design risks must be considered for the asset lifecycle covering construction, operational and maintenance, refurbishments, and decommissioning.

The design safety report must include the following:

- a. Description of design element.
- b. Description of potential risks and hazards associated with the design element.
- c. A low/medium/high risk assessment considering likelihood and consequence.
- d. Proposed measures to eliminate risks where practicable.
- e. Control measures to mitigate and manage design risks.
- f. Nominating responsibilities for managing the design risks.

This may be provided as a design risk register where appropriate and must include results of any calculations, testing and analysis etc.

9 Documentation and Records

9.1 Design Documentation

Prior to commencing construction of new or refurbishment projects, the consultant/contractor must fully investigate and document the requirements for each Electrical system required to be installed, altered or modified as part of the project works.

This must include:

- a. Return Brief defining the systems proposed and any deviations from this specification;
- b. Electrical maximum demand calculation spreadsheet.
- c. Computer design calculation files for circuit breaker grading study, fault levels, voltage drops and cable calculations.
- d. Budget calculations.
- e. Applications to Supply Authorities, and their responses.
- f. Designers statutory compliance certificates.
- g. Requests for all variations to this Standard submitted using the **UI Request for Dispensation Form (UI-ENG-F001)**.
- h. Complete the Design & Construct checklist using the **UI Design & Construct Electrical Services Checklist Form (UI-ENG-F009)**.

These documentations must be provided by the consultant/contractor in electronic copy format and approved by the University.

9.2 Completion Documents

At the completion of all projects, the following documentation must be provided for electrical service installed or altered as part of the project works:

- a. O&M manual(s).
- b. As-built drawings (including schematics and block plans).
- c. System schematics.
- d. Complete As-built drawings, including all workshop drawings updated to As Built status.
- e. Electrical and wiring diagrams.
- f. Asset schedules and labelling (as per the Asset Identification and Labelling Standard).
- g. Commissioning test results.
- h. Product manufacturer specific information.
- i. Licensed versions any computerised software required to program and monitoring systems.
- j. Details of all usernames and passwords required to access all equipment and software.
- k. Warranty schedules for all major items of equipment, including but not limited to switchboards, switchgear.
- l. Maintenance requirements for all items of equipment.
- m. Building User Guide.
- n. System functionality and operation description.
- o. System set point values.
- p. Installers Statutory certificates.
- q. Supply authority completion forms and inspection records, including the CCEW (completion certificate).
- r. Contractors completed self-regulated Inspection & Test plans for the energization of new works (replacing Supply Authority Inspectors attendances for inspections in 2018)
- s. Certification of (Design/Install) compliance to The University Standards, Australian Standards and NCC.

- t. As-Built single line diagrams to be permanently fixed to the wall in Regional or Main Switchrooms. Minimum size A1 or as required to be legible, anti-reflective laminated.
- u. Laminated A4 Operating Procedures for special equipment such as castell key interlock arrangements, manual transfer operations, fuelling instructions of diesel tanks and UPS service bypass operation.

This documentation must be provided by the contractor in both electronic and hard copy formats and approved by the University prior to Practical Completion being granted.

10 Assets and Warranties

Assets are to be tagged in accordance with the COS Universities Asset & Labelling Standard for the purpose of maintenance and operation of University Assets. For refurbishment projects the project manager is to provide the existing asset list to the contractor to ensure modified and redundant equipment are captured in the contractors submitted asset list.

Each asset required to be collected can be found in the Asset Form **COS-ASSET-F001**, each asset required to be coded will be identified by a unique equipment code.

The equipment code will be one the three following types:

- a. Virtual asset (This is a concatenation **Building Code - Floor - Room Number**)
- b. Item count asset (This is a concatenation **Building Code - Floor - Room number**)
- c. Unique bar code asset (Unique bar code in the million series number affixed to the asset)

Asset lists are to be submitted prior to practical completion of the project for review and approval by COS.

Equipment Warranties are to be provided for a minimum of 12 months from the date of practical completion. Warranties are to be provided as certificates as part of the O&M from the supplier of the equipment. It is the responsibility of the installation contractor to ensure all maintenance\servicing required to the equipment is provided to ensure warranties are valid at the end of the project DLP period.

11 Defects and Liability Period

Consultants/designers must include in the project specification detailed requirements for the defects and liability period following completion of the fire services installation.

The contractor must include and allow for recommissioning of all major plant and equipment in the last month of the 12-month defects and liability period and confirm they achieve the original design requirements.

In addition, all commissioning must be witnessed by UI Engineering staff with commissioning reports/results formally submitted to UI Engineering. Commissioning reports/results must be formally submitted to Sydney University UI engineering.

11.1 Maintenance and Testing

For Electrical systems installed as part of a refurbishment project of an existing building, regular statutory maintenance and testing must be carried out by the University essential services maintenance contractor during the Defects Liability Period (DLP).

The installation contractor must provide a comprehensive handover and the required completion documentation at Practical Completion.

All defects arising from regular statutory maintenance and testing performed during the DLP will be documented and passed onto the installation contractor for rectification. The installation contractor must be responsible for all defect rectification works identified during the DLP.

Prior to the completion of the DLP, the installation contractor will perform all annual maintenance procedures in the presence of the University essential services maintenance contractor and provide documentation confirming the provision of all statutory maintenance has been performed during the DLP.

12 Operations and Maintenance Manuals

Consultants/designers must include in the project specification detailed requirements for operation and maintenance manuals, including system description, operation procedures, testing and commissioning records, maintenance instructions, product support information and recovery protocols for any computer related systems. Contractors must provide these to the satisfaction of the consultant/designer. Providing a collection of manufacturers' brochures and catalogues is not acceptable to the University.

Contractors must submit the University designed software Sydney University Asset Register (**COS-ASSET-F001**), designed for recording operational and maintenance activities including materials used, test results, comments for future maintenance actions and notes covering asset condition. Completed logbook pages recording the operational and maintenance activities undertaken for Practical Completion and during the Defects Liability Period must also be provided.

Facilities Maintenance must establish, document and implement procedures for operation and maintenance of electrical services, plant and equipment to ensure electrical services are fit-for-purpose, provide secure, efficient, safe and reliable electrical power, and comply with requirements of this standard.

13 Authorization of Variations

Project managers, consultants, contractors, commissioning agents and facilities maintenance personnel must ensure compliance with these requirements is achieved.

Variations to this standard must only be considered where:

- a. The University Standard's requirement cannot physically or technically be achieved.
- b. The alternative solution delivers demonstrated and proven superior performance for the same capital and life cycle cost or better.

Consultants and contractors must identify and justify requirements of the standard that do not apply to the project or which need to be varied and these which must be approved by the issuer of this standard. Formal requests for all variations to this Standard must be submitted using the **UI Request for Dispensation Form (UI-ENG-F001)**. The issuer of this standard or their delegated authority must review and consider requirements of stakeholders from clients, projects and facilities management before deciding whether to approve variations. Their formal sign-off is required for acceptance of any non-compliances and departures from this standard's requirements.

14 Quality Control

14.1 Design Standard Compliance

Compliance with requirements of this standard must be checked throughout the design, construction and commissioning phases of projects by UI' services consultant. Any issues or deviations from this standard must be reviewed and approved in writing by the author of this standard.

Competent UI consultants and representatives must check compliance with this standard during design reviews and formal site inspections. Any non-conformances with requirements of this standard must be documented and provided to the UI Project Manager for issue to contractors and their consultants.

Project Managers must maintain a formal register of non-conformances and manage close out of outstanding non-conformances. Contractors and their consultants issued with non-conformances must take appropriate corrective actions. The UI Project Manager must ensure:

- a. Proposed corrective actions are implemented.
- b. Close out of non-conformances in relation to this standard is formally approved and signed off by the author of the standard or their delegate.

14.2 Design Standard Certification

Contractors and Consultants must certify compliance to the design standard by submitting a company Design Certification Form to the UI Project Manager at each of the following project phases:

- a. Design and Documentation.
- b. Tender.
- c. Construction.

Notwithstanding UI' internal quality control processes, contractors and their consultants must implement their own robust quality assurance and control procedures to ensure compliance with requirements of this standard.

14.3 Construction Compliance

Consultants and contractors are expected to include check sheets for each system component detailing each item that needs to be checked, tested and verified during the installation process. Such check sheets must be completed and verified by the project consultant/contractors, including the identification of any defects and the closing out of such defects.

Designers must request samples of all accessories, fittings and apparatus proposed for use in the works to be submitted for approval. Only those items that are accepted may be installed on site. Submit the manufacturer's product data for proprietary equipment, including:

- a. Technical specifications and drawings.
- b. Verification Reports.
- c. Performance and rating tables.
- d. Recommendations for installation and maintenance.
- e. Schedule of proposed major products that are not specified as proprietary items.
- f. Product certification.

14.4 Acceptance

The University will only accept projects as complete when all of the above have been carried out, submitted and verified.

The above standards are not an exhaustive list of the relevant requirements. The consultant/contractor must incorporate all relevant standards and Authorities requirements into project specific design, documentation and installation.

15 Document Amendment History

Revision	Amendment	Commencing
001	First Issue	16 August 2013
002	<p>Second Issue - Amendments</p> <ul style="list-style-type: none"> a. As-Built drawings clause 5.3 now includes Lightning Protection and Earthing & Bonding drawings; b. Asset labelling clause 5.7.1 added; c. Summary of Meter Requirements clause 5.23.4 added; d. Meter Labelling clause 5.23.5 added; e. Electromagnetic Interference clause 5.27 added; f. Shop Drawing clause 6 added; g. Safety in Design clause 7 added; h. Deemed to Comply University Standard Switchboard Types 1-5; <p>New Forms added to the website;</p> <ul style="list-style-type: none"> i. UI Design & Construct Checklist Form (UI-ENG-F009). 	18 September 2015
3.0	<p>Third Issue - Amendments</p> <ul style="list-style-type: none"> a. Project Definition stage added at 5.1. referring to Project “Gate Paper” and requirement for site inspection / briefing. Requirement for “Return Brief” formalised. b. Overall document review to identify any areas where the requirements showed an excessive cost / benefit; <ul style="list-style-type: none"> i. Triggers for Reuse of existing electrical equipment identified, and performance specified. ii. Addition of cheaper cable baskets for final sub circuits. iii. Consideration of alternative potentially cheaper new proprietary cable support systems, with caution pending need for greater installer experience / diligence. iv. Switchboards; Major amendments to embrace faster cheaper Modular Switchboard construction, which is now mature in Australia, and to cover new Australian switchboard standard AS NZS 61439-2016, Parts 0, 1 – 9. v. Distribution Board types simplified, and standard drawings deleted c. Documents required for Submission & Approval updated, tightened up, aggregated and clarified. d. Safety in Design legislation reinforced. e. Commissioning Checklists added. f. Supersession of Codes & Standards between project initiation and execution is addressed. A major issue immediately and ongoing given long project gestations. g. Scope / Technical cover increased to include; <ul style="list-style-type: none"> i. UPS (Uninterruptible Power Supply) for critical systems. 	26 August 2020

Revision	Amendment	Commencing
	<ul style="list-style-type: none"> ii. Active Harmonic Filters for curative retrofit. iii. Diesel generator fuel storage and pipework systems principles and technical requirements. iv. Power Quality Metering provided for input supplies to larger buildings to record Supply problems in detailed memory. h. Addresses the major new electrical Australian Standards released 2017/18 which have major impact on design, installation, commissioning and cost; <ul style="list-style-type: none"> i. Power Tariff Metering is now statutory property of the Retailer and must comply with their requirements. ii. AS/NZS3000-2018 Australian Wiring Rules. iii. AS/NZS3010-2017 Generator / PV Installations iv. AS NZS 61439.1-2016 Switchboard Design & Manufacture v. AS/NZS1940-2017 Diesel Fuel handling & storage i. EPO (emergency power shut off) for labs and workshops revised. <ul style="list-style-type: none"> i. Quantity of EPO buttons required amended. ii. User EPO Reset project specific technical solutions required. j. Warning labelling for the Emergency Services identifying Alternative Power Supplies in buildings is added. k. Defects period maintenance; clarified Thermal Scanning of switchboards and added basic Harmonics Power Survey for large installations. l. Retrofit of RCDs to exiting installations discussed, including scope limits and latent defects. m. Asset Standard Owner is now COS. 	

16 Attachments

ATTACHMENT 1- SWITCHBOARD SHOP DRAWINGS