WORK INSTRUCTION

General Electrical Specification

QMS-FS-WIN-62-014 Revision 0 – 14/02/2019

Revision History and Approval

Rev.	Nature of changes	Approval	Date
A	Draft for Review	Jim Pollard	10/08/2017
0	Approved	David Glavas	14/02/2019

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Appendices:

Standards and References

1 GENERAL

1.1 The Facilities and Services Division is required to maintain an overview of electrical services installed on all campuses, buildings, structures and facilities owned and managed by the ANU in the various states and localities of Australia. It is essential that anyone adding to or modifying any part of the electrical installation liaise closely with the Division for special conditions and requirements.

1.2 This document referred to as the ANU General Electrical Specification establishes a base level of quality and shall be read in conjunction with the Electrical Design Guide, Part 07 of the Campus and Building Requirement Manual which describes the design objectives for ANU electrical installations.

1.3 Consultants, designers or project managers who are engaged by the ANU may use the ANU General Electrical Specification if appropriate or alternatively provide a project specific electrical specification incorporating all the ANU's specific requirements.

1.4 In this document the Principals Representative (PR) shall mean the person in the Facilities and Services Division responsible for administering the electrical work and the Electrical Services Supplier (ESS) shall be the person carrying out the work.

1.5 The ESS must be in possession of valid written authorisation before they can perform electrical work on any ANU administered facility.

1.6 Should there be any discrepancy between the project electrical specification and the ANU General Electrical Specification, the project specification shall take precedence. Clarification however should be sought from the PR.

2 CONDITIONS OF CONTRACT

2.1 Practical Completion is the date as nominated by the PR when the Works are complete except for minor omissions and minor defects which do not prevent the Works from being used. Documents and other information that are essential for the use, operation and maintenance of the Works shall be supplied at the time of Practical Completion. The Defects Liability Period will start from the date Practical Completion is granted.

2.2 There are various contractual arrangements for performing work at the ANU and these are dependent on the complexity and value of the project. Details of the arrangement will be provided with the project documentation.

3 THE WORKS

3.1 The work comprises all labour, materials, equipment necessary to supply, install, test, commission and maintain during the 12 months defects liability period (except where varied), the complete installation as specified in the Project Scope of Works including all unspecified minor and obvious work to the satisfaction of the PR.

3.2 The standard 12 month defects liability period is varied for the following components:

- Five (5) year unconditional warranty on all components that are part of an LED luminaire (including exit and emergency luminaires) and including LED lamp(s), driver, housing, back-up emergency lighting batteries, fixings and any labour costs associated with repair or replacement.

4 OPERATING AND SERVICE CONDITIONS

4.1 Unless otherwise specified, the equipment, materials and installation of the work shall comply with the following criteria:

- Supply System Nominal Voltage: *400/230V 3 phase, 4 wire + 10% or – 6%*
  240V 1 phase, 2 wire + or – 10%
- Supply System Frequency: *50Hz*
- Supply System Earthing: *Multiple Earthed Neutral (MEN)*
- External Temperature Service Conditions: *Maximum 40 degrees C, Minimum –10C*
- Relative Humidity Service Conditions: *Maximum 95%*
- Overall voltage drop shall be in accordance with *AS60038.*

4.2 The above criteria refers to requirements in the Australian Capital Territory. Where statutory requirements in other states or territories vary from the ACT, refer to the Facilities and Services Division for a directive.

5 ELECTROMAGNETIC COMPATIBILITY (EMC)

5.1 The ESS should be aware of the problems caused by stray electrical and magnetic fields and good practice procedures in cable installation that reduce them.

5.2 Products that are prone to producing electromagnetic emissions are required to carry the Regulatory Compliance Mark which replaces the previous "C-tick" marking system as per the requirement of AS/NZS 4417.1 - Regulatory compliance mark for electrical and electronic equipment.

5.3 Variable speed drives shall comply with Australian EMC standards. Refer to the ANU VSD requirements as specified elsewhere in this document. Provide details of VSD drives or any other inverter equipment for approval before ordering equipment.

5.4 Power utility companies and Australian Standards stipulate maximum harmonic levels which apply at the customer's point of common coupling (PCC). Generally the maximum permissible harmonic levels are given in terms of % Total Harmonic Voltage Distortion (THVD) however, to achieve a reduction of THVD, the customer is required to reduce their Total Harmonic Current Distortion (THCD) through the use of harmonic mitigation equipment. Commonly THCD levels are required to be between 5-8%, however this may vary from state to state. *IEEE Standard 519 - Recommended Practice and Requirements for Harmonic Control in Electric Power Systems* and *AS/NZS 61000.3.6 - Electromagnetic compatibility (EMC)-Limits - Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems*; are two widely used harmonic limit standards, however other standards may also be relevant including AS/NZS 61000.3.2 - Electromagnetic compatibility (EMC)-Limits - Limits for harmonic current emissions (equipment input current = 16A per phase). Electrical consultants shall confirm harmonic requirements with the relevant local utility provider.

5.5 With regards to the ACT, Evoenergy have advised that the permissible distortion levels for the Evoenergy electrical network secondary distribution system are as described in the document "Evoenergy Conditions of Supply" and in the Australian Standard AS/NZS 2279.2 - Disturbances in mains supply networks - Limitation of harmonics caused by industrial equipment. The levels generally accepted are: (from AS/NZS 2279.2, Table 1) Total Harmonic Distortion on the voltage waveform (THVD) should be limited to 5% (individual harmonic ratio from odd harmonics should be less than 4%) on the secondary distribution system at the point of common coupling.

AS/NZS 2279.2 - Table 1

HARMONIC VOLTAGE RATIO LIMITS AT ANY POINT ON THE SYSTEM

(Including background levels)

Supply system	Voltage at point of common coupling	Total harmonic voltage ratio %	Individual harmonic voltage ratio %	
			Odd	Even
Primary & secondary distribution	< or = 33kV	5%	4%	2%

6 MATERIALS, STANDARDS AND WORKMANSHIP

6.1 It is a requirement of this specification that only good quality materials of new and current manufacture are used in University installations. To achieve this, the following standards and codes are to be complied with.

- AS/NZS 3000 (current edition) Electrical installations (known as the Australian/New Zealand Wiring Rules)
- National Construction Code plus appendices relevant to the state or territory.
- Local Authority and Supply Authority rules & regulations.
- The standards as identified throughout this specification.

6.2 The installation shall be complete with all materials and equipment necessary to make a safe and reliable installation that can be readily operated and maintained. All electrical work shall be executed in a safe, neat and workmanlike manner and be carried out by competent ANU authorised personnel under adequate supervision using appropriate safe work method statements where required.

6.3 Unless otherwise noted, maintain uniformity of type and manufacture throughout the specified installation, for example between the new work and existing work where an existing installation exists.

6.4 Certificates of Electrical Safety shall be submitted to the Regulatory Authority with a copy to the Facilities and Services Division for all modifications, alterations and additions to ANU fixed wiring.

7 CARE AND PROTECTION OF SUPPLIED MATERIALS

7.1 Inspect all materials, plant and equipment prior to installation or building-in and remove dirt, debris, swarf, filings, burrs and the like. Leave all unfinished work in a safe condition.

7.2 Provide adequate protection, to approval, for all equipment during construction. Seal off open ends of pipes and ducts with caps to prevent entry of foreign matter until the works have been handed over. Plastic sheet, paper and wood plugs are not acceptable. Provide plastic, cardboard, hardboard, or timbered protection to approval to protect items susceptible to scratching, bending or breaking. Maintain weatherproof and dustproof covers over all electrical, control and instrument components. Clean finger marks from reflective surfaces such as used in recessed downlights

7.3 Protect existing plant and equipment and existing building and structural elements against damage and deterioration during the course of the works. Provide plastic, cardboard, hardboard or timbered protection as appropriate and to approval.

7.4 When working indoors, provide drop sheets to protect floors, benches, equipment and personal property.

8 CHASING AND DRILLING

8.1 Consult and obtain approval from the PR before chasing walls, floors and concrete slabs. Some buildings on the Acton Campus have services such as low temperature heating water, electric heating elements and electrical conduits cast into floor slabs. Trace out all such services before drilling or chasing commences. All excavation, trenching and drilling to be in accordance with the F&S QMS document.

9 DRAWINGS

9.1 Drawings supplied with this specification are not to be regarded as working drawings, but indicate generally the proposed layout of the plant, systems and equipment. The ESS shall prepare or obtain from manufacturers and suppliers, all drawings and information necessary for fabrication, assembly, installation and commissioning of all plant, equipment and systems.

9.2 Where it is necessary to take site measurements to correctly locate work, responsibility for the accuracy of such measurements rests solely with the ESS.

9.3 Information or dimensions obtained verbally from others shall be confirmed in writing before being used in laying out or installation of this work.

9.4 Before placing orders or commencing manufacture of the equipment the ESS shall supply for review to the PR all working plans, detail drawings, automatic control and wiring diagrams, manufacturer's catalogue and performance characteristics and all switchboard and distribution board drawings. The ESS shall allow for 5 working days for drawing review.

9.5 Review of a submission is not to be construed as acceptance by the PR of responsibility for layout measurements or coordination with other trades, although every endeavour will be made to detect any obvious errors.

9.6 The requirements of submission of drawings and other information is intended to provide an opportunity for the PR to review the ESS interpretation of requirements and to minimise delays resulting from rejection of work on site.

9.7 Review of drawings by the Facilities and Services Division in no way relieves the ESS of their responsibility of meeting all the requirements of the contract drawings and specifications unless written instructions to the contrary are given in the review process by the PR.

9.8 Prior to granting Practical Completion of the Contract, the ESS shall supply to the PR a complete set of works-as-executed documentation. The drawings shall be computer-aided design (CAD) format as per standard ANU requirements. Symbols used on electrical drawings shall comply with Australian Standards.

10 SITE INSPECTION

10.1 The ESS shall visit the site to determine the full extent of the work before submitting a priced offer. Claims based on information that would have been known as a result of a site inspection at the time of submission will not be considered.

11 CONTRACT PRICE

11.1 The priced submission shall be a fixed lump sum not subject to rise and fall. During the contract period no claims will be paid for variations to labour rates, material costs, import duties, freight charges, currency exchange rates, or customs tariffs.

12 ACCESS AND WORKING HOURS

12.1 Working hours are restricted from 7.30am to 5.00pm Monday to Friday unless otherwise agreed in writing by the PR. After-hours access can be arranged and may be desirable in some stages of construction. Make all such arrangement and confirm in writing. All power shut downs shall be programmed after hours. Make allowance in the price submission for after-hours work. Where it is required to isolate power at substations make all necessary arrangements with the Supply Authority and pay for all associated Supply Authority costs.

13 INTERRUPTION OF ELECTRICITY SUPPLY

13.1 At the ANU many critical applications rely on a continuous electricity supply. Seek approval from the PR before disconnecting any supply, and provide a minimum of 5 days written notice of intention.

14 CONSTRUCTION PROGRAM

14.1 Where requested by the PR, a construction program shall be submitted for approval that indicates all major activities that are necessary for the works. The program shall indicate dates for completion of significant stages of each major activity of the works.

15 EXCAVATION WORKS

15.1 REFER TO THE F&S QMS DOCUMENT REGARDING EXCAVATION, DRILLING AND TRENCHING. All excavation work at the ANU shall be performed strictly in accordance with the ANU Excavation Permit procedures. No excavation shall proceed until the requirements of the documentation are met. Verify and obtain approval from the PR for all excavation routes before proceeding.

15.2 It will be the ESS responsibility to determine the existence of and verify the position of underground services before commencing excavation and further, to arrange repair by the responsible servicing authority at the ESS own cost, all damage caused to those services during the works.

15.3 The ESS is responsible for providing up-to-date services drawings for any new services installed as part of the excavation activity, and providing these to the PR at the completion of the works.

15.4 The trenches shall be backfilled with soil free from rocks and organic matter. The backfill material shall be placed in 300mm layers and compacted and the surface restored as near to the existing condition as possible. Provide a continuous warning tape at approximately 100mm directly above all underground cables. Allow for costs associated with replacing turf, bitumen, paving or concrete as required. If existing turf is to be reused make due allowance for maintaining the material in good condition until it is reinstalled.

15.5 It is the responsibility of the ESS to obtain the finished surface levels of the ground in areas where cable trenches are to be installed before the work is commenced. Suitable barriers and warning notices shall be provided for open trenches to protect the public at all times.

16 PENETRATIONS AND FIRE BARRIERS

16.1 All penetrations through wall, ceilings and floors shall be sealed after the installation of services. Where services are required to pass through fire rated barriers or zones they shall be sealed with approved fire rated material. Verify all penetrations with the PR before proceeding.

16.2 The ESS is responsible for providing up-to-date services drawings for any new services installed as part of the penetration activity, and providing these to the PR at the completion of the works.

17 SAMPLES, SHOP DRAWINGS, INSPECTIONS AND APPROVALS

17.1 Samples of each type of light fitting shall be submitted for approval. Catalogue pamphlets may be accepted in lieu of samples. Verify requirements with the PR. Shop drawings shall be submitted for approval before manufacture commences for all switchboards, lighting columns and other fabricated equipment. The drawings shall show dimensions, metal gauges, equipment, panel layout, labelling, cable numbers and the like detail.

17.2 If this specification requires any work to be specially tested, inspected or approved, timely notice shall be given of its readiness for inspection. If any such work shall be covered over without approval or consent it will be required at the ESS expense to be uncovered for examination.

18 REMOVAL OF REDUNDANT EQUIPMENT AND WIRING

18.1 All redundant material as identified in the contract documentation shall be physically removed from the installation and disposed of in an approved manner. Liaise with the PR who will make a decision if any material is considered suitable for retention and reuse. Materials that contain hazardous components such as PCB capacitors, fluorescent tubes, batteries and asbestos shall be disposed of by the contractor in accordance with the ANU Hazardous Materials Disposal Procedures. Where a circuit schedule or single line diagram is changed as a result of the Works as described in the contract documents, provide sufficient information to the Facilities and Services Electrical Supervisor who will arrange for a template circuit schedule and single line diagram to be made available for upgrade by the ESS.

19 LABELLING AND CIRCUIT SCHEDULES

19.1 Circuit reference labels of Traffolyte™ style with black letters/white background or other ANU approved non-deteriorating material, fixed by means of screws, rivets or glue shall identify every relay, push button, fuse, circuit breaker, switch, meter, indicator light, terminal block, motor and other apparatus ***including all power sockets and light switches***. Labels for power sockets and light switches shall be located adjacent to the accessory and shall refer to the switchboard origin and circuit breaker number e.g. **DB-1 CB32**. An approved alternative accessory labelling system is the Clipsal C2000 Series. An approved label showing the outlet circuit ID number shall also be mounted adjacent to each lighting socket in false ceilings.

19.2 All control circuit wiring shall be labelled at each end and in junction boxes by an approved non-deteriorating means with circuit reference numbers. All wiring shall be colour coded to maintain phase sequence identification.

19.3 A4 size typed circuit schedules as per standard ANU format shall be fitted inside the doors of all switchboards behind clear rigid plastic panels, and shall comprise the following:

- Circuit reference number
- Size and type of cable and rating of circuit breaker or fuse
- Description of circuit
- Name of switchboard.
- Name of switchboard feeding the board.
- Switchboard Reference Number.

19.4 A template for the ANU standard circuit schedule will be provided with the contract documents. Modify the template as necessary to record the circuit details for each switchboard and in addition to the printed copy in the switchboard, provide an electronic copy with works-as-executed documentation.

19.5 All main switchboards shall have located in near proximity an A2 sized copy of an up-to-date version of the electrical single line diagram mounted behind a rigid clear panel.

20 CORROSION

20.1 Take all necessary precautions with the supply and installation of all accessories, fittings and equipment specified to prevent corrosion. Make good or replace any component or accessory showing signs of rust or corrosion during the maintenance period in an approved manner without additional cost to the University.

21 EARTHING

21.1 Supply and install the complete earthing system for the installation including all necessary electrodes, cabling, clamps, test links and associated equipment in accordance with the requirements of AS 3000, the local Inspecting Authority and the Local Supply Authority. For new main switchboards provide a Traffolyte label indicating the exact location of the main earth connection.

21.2 The multiple earthed neutral (MEN) system is in use by the Supply Authority and the ESS shall observe all related requirements. Unless otherwise advised provide a MEN link in all new main switchboards.

21.3 Pay particular attention to the fault loop impedance requirements of AS/NZS 3000 2018 and submit test results confirming compliance during the testing and commissioning phase. Bond earth cables to each individual item of electrical equipment so that the earthing is electrically continuous. Provide an earth bond to the nearest water main service. Enclose earth wires with their respective circuit runs throughout their length.

22 CABLING, RETICULATION AND DISTRIBUTION SYSTEMS

22.1 General Requirements

22.1.1 All cabling shall comply with *AS/NZS 3000 2018: Electrical installations* and shall have a minimum protection compliant with *AS/NZS 3013 : Electrical installations - Classification of the fire and mechanical performance of wiring system elements*. Wiring methods and routes shall be discussed with the PR before work commences. Only approved materials shall be used. All supports and enclosures shall be suitable for the environment with galvanised steel and UV stabilised PVC used where exposed to the weather.

22.1.2 Power cables shall be kept separate from data cables in accordance with relevant standards. All wiring to fire and smoke control equipment, lifts and emergency services shall be fire rated and comply with requirements of *AS/NZS 3000: Electrical installations*.

22.1.3 Cables shall be run in configurations designed to reduce magnetic field effects. Single current carrying conductors shall be kept to a minimum.

22.1.4 Where cables pass under external walls of buildings they shall be enclosed in PVC conduits with long sweep radius bends. Provide PVC sleeves where cables are required to cross roadways or paved areas. Continuous lengths of cable shall be used. Unless otherwise indicated, no underground joints will be permitted.

22.2 Conductors

22.2.1 All conductors shall be annealed high conductivity copper conductors, in accordance with *AS/NZS 1125 : Conductors in insulated electric cables and flexible cords*. TPI and TPS cables shall be type V-75, manufactured in accordance with *AS/NZS 1125*. Conductors smaller than 2.5 mm² shall not be used except as detailed for switchboard control wiring. Single strand cables shall not be used.

22.2.2 All functional insulation of conductors throughout the installation shall be coloured for ease of identification. Colours used shall be red, yellow and blue for phase wiring, black for neutral, green - yellow for earth wires and brown for control wires.

22.2.3 It is not anticipated that any overhead aerial conductors will be used on ANU campuses. Obtain written approval from ANU Facilities and Services before installing any aerial reticulation.

22.3 Conduits, Pipes and Fittings

22.3.1 Where conduits or pipes are used as conductor enclosures they shall be complete with wiring boxes, bends, condensate traps, flanges, unions, locknuts, bushes, saddles and clips and expansion joints where required. All conduits shall comply with *AS/NZS 2053.1 : Conduits and fittings for electrical installations*.

22.3.2 Screwed steel conduit and fittings shall be no smaller than 20 mm diameter and no larger than 50 mm diameter.

22.3.3 Rigid PVC conduit and fittings shall be no smaller than 20 mm diameter and no larger than 50 mm diameter and shall meet the requirements of *AS/NZS 2053* for Class B - heavy gauge conduit.

22.3.4 Flexible connections to equipment shall be made of flexible steel conduit, in accordance with *AS/NZS 2053*, or flexible PVC corrugated non-metallic conduit which shall comply with *AS/NZS 2053*.

22.3.5 Where rigid PVC cannot follow an even profile, corrugated PVC may be used as discussed with the Supervisor. Under normal circumstances rigid PVC shall be used.

22.3.6 Conduit and pipe may be surface run in plant rooms, or in other areas as agreed with the Supervisor. Elsewhere all wiring shall be concealed unless approval is agreed with the PR.

22.3.7 Square off all conduit ends and internally ream after threading. Make all screwed joints with metallic based paint, before tightly butting and use pull through to internally clean all runs, before inserting cables. Unions shall be used at all butt joints, in preference to running threads.

22.3.8 Locknut conduit and pipe to all equipment and accessories. Fit two locknuts and an inside bush with sheet metal surrounds.

22.3.9 Field bends shall have a minimum bending radius of six times the enclosure diameter. Kinked or squashed enclosures are not acceptable.

22.3.10 Expansion joints shall be utilised between independent structures. Enclosures set in concrete shall have a diameter no greater than 1/3 of the slab thickness whilst they shall also be covered by at least 25 mm.

22.3.11 Obtain prior approval for conduit or pipe location routing clearances, before work commences.

22.3.12 Wiring boxes shall be located at a maximum linear route length of enclosure run of 20 metres.

22.3.13 Provide PVC insulated draw wires in all empty conduits.

23 SWITCHBOARDS

23.1 General Requirements

23.1.1 All switchboards shall comply with AS3000:2018 and latest amendments. Main switchboards in buildings and boards over 200A rating shall have a minimum Form of Separation of Form 2 to *AS/NZS 61439.1 : Low-voltage switchgear and controlgear assemblies*.

23.1.2 Main switchboards shall be fitted with TERCEL Isosurge or ANU approved equal surge diverting devices. The diverters shall comply with *AS 1307.2 : Surge arresters - Metal-oxide surge arresters without gaps for A.C. systems*. The surge arresters shall be connected to the load side of the main switch if applicable, be protected from fault currents, have an isolation facility from the active conductors and a means of failure indication visible without the need for tool access. Surge devices shall have an output capability for connection to the ANU Building Management System.

23.1.3 Unless otherwise indicated main switchboards if required to power essential equipment and services shall have a facility to connect to the ANU's mobile emergency power generation equipment.

23.1.4 Switchboards shall be made by an established manufacturer and be of the totally enclosed type. The boards shall contain a busbar assembly, separate neutral and earth bars.

23.1.5 Drawings of all switchboards shall be provided for approval before manufacture and type test certificates shall be provided upon request.

23.1.6 The switchboard shall be mounted where indicated on the drawings. The ESS shall ensure that there is sufficient space available and that the final position satisfies all statutory and Supply Authority requirements.

23.1.7 The switchboard shall contain all the equipment detailed on the drawings and shall contain 30% spare space unless specified otherwise.

23.1.8 The supply to the board shall be 400/230V, 3 phase, 4 wire, 50 Hz MEN solidly earthed. The short circuit rating is as indicated on the drawing. The ESS should note the Supply Authority's minimum short circuit requirements for main switchboards. Particular attention shall be given to discrimination and cascading in the switchboard design.

23.1.9 All busbars shall be of high conductivity copper with full size neutral identified with phase colours and so arranged as to facilitate future extensions. Busbars shall be insulated.

23.1.10 Wiring within switchboards shall be in PVC insulated stranded copper conductors neatly arranged and wherever practicable shall be contained in capped slotted plastic ducting. The boards shall incorporate adequate space for incoming and outgoing cables and shall have facilities for cable terminations. All cabinet cabling and small power cables shall terminate on a labelled terminal strip while larger cables shall enter and leave via appropriate cable glands. All larger cables shall be provided with suitable lugs.

23.1.11 Minimum sizes of stranded conductors to be used are as follows:

Internal Control Cubicle Wiring	*1.5 sq. mm*
Control Cabling	*1.5 sq. mm*
Power Cabling	*2.5 sq. mm*

23.1.12 Wire colouring shall be red, white, and blue for phases and black for neutral

for ELV AC	*pink*
for DC	*+ve white, -ve black*
earth	*green/yellow*

23.1.13 All control wiring shall be terminated with approved lugs, shall be numbered at each end and at any junction and shall be fitted with an approved ferrule type numbering system to conform to the numbering system on the wiring diagram.

23.1.14 All ACBs, MCBs, MCCBs, contactors, instruments, CTs and other components shall be as specified elsewhere in the documents.

23.1.15 All circuit breakers over 100 amps shall be labelled externally with screw on labels and smaller breakers shall be identified by an approved method. The rating of all breakers shall be indicated without removal of escutcheons or cover plates.

23.1.16 Each switchboard shall have a label designating origin of supply. A legend shall be fixed to the board containing circuit designations. On main switchboards a copy of the single line diagram shall be mounted in the switchroom.

23.1.17 All switchboards where required to have lockable doors shall be fitted with an ANU Facilities and Services Division standard access lock Lowe and Fletcher 92268.

23.1.18 All switchboards in fire egress routes shall comply with the requirements of the Building Code of Australia and be fitted with smoke seal door gaskets.

23.1.19 Time switches where required shall be of the electronic type and be fitted with battery reserve of at least 30 hours. Time switches shall be mounted so that the settings can be changed without removal of the escutcheon plates or exposure to live parts.

23.2 Metering

23.2.1 Refer to project documentation for metering requirements. All meters and current transformers shall be in accordance with the requirements of *Section 6 Building Management Systems* of the Campus and Building Requirements Manual. All meters shall be accessible without the need to use tools. METERING CT'S, POTENTIAL FUSES AND METERING TEST BLOCKS SHALL BE INSTALLED IN READILY ACCESSIBLE LOCATIONS FOR ON-GOING TESTING, COMMISSIONING AND MAINTENANCE OF THE METERING INSTALLATION.

23.2.2 The ANU BMS Supervisor will inspect the metering installation for compliance with the requirements of ANU documentation and will organise for the testing, commissioning and programming of the meters and data wiring connection to the ANU Energy Monitoring System.

23.3 Cabinet Construction

23.3.1 Switchboard cabinets shall be of the totally enclosed, continuously welded, metal-clad type fabricated from a minimum of 1.5 mm sheet steel with radiused corners and all visible joints ground smooth.

23.3.2 Doors where required shall be lift off type with chromium plated hinges, have double turned edges, be fitted with lockable latching bars where appropriate and shall swing through an arc of 135 degrees.

23.3.3 All necessary equipment shall protrude through turned edge escutcheons. Escutcheons shall hinged and be secured with captive screws.

23.3.4 All external cabinets shall be ventilated with louvered openings with gauze screens across openings.

23.3.5 Cabinets shall be designed to minimise hysteresis and eddy current losses.

23.3.6 Cabinets for outside installation shall have IP 54 protection and be mounted on galvanised metal supports bolted to a concrete plinth. External cabinets shall be fitted with anti-condensation

heaters rated at 100 watts per cubic meter of cabinet volume. An accessible thermostat shall be provided. Indoor cabinets shall have a minimum degree of protection of IP33 unless otherwise specified.

23.3.7 Before the application of external finishes, thoroughly rub down after fabrication and coat with etching type, rust-inhibiting primer. Finish with at least two (2) coats of an approved enamel or powder coat. All interior surfaces are to be finished with white enamel. Verify external paint colour before application.

23.3.8 All switchboards shall be left such that penetrations are sealed to prevent the entry of vermin.

23.4 Equipment

23.4.1 Circuit breakers of the miniature circuit breaker (MCB) type with SC rating up to 10 kA shall be used for all sub circuits in this installation and shall comply with *AS/NZS 3111 : Approval and test specification - Miniature overcurrent circuit-breakers*. Two phase and three phase circuit breakers shall be of the multiple type with a common tripping device. Circuit breakers with a rating of less than 6kA shall not be used on the ANU Acton Campus unless otherwise approved.

23.4.2 Large frame size moulded case circuit breakers with SC rating > 10 kA shall comply with *AS/NZS 61439.1 : Low-voltage switchgear and controlgear assemblies*.

23.4.3 All moulded case circuit breakers shall incorporate thermal-magnetic tripping and arc extinguishing features.

23.4.4 Shunt-trips where fitted shall be part of the circuit breaker.

23.4.5 All miniature circuit breakers on a switchboard shall be of the same manufacture. If the type of circuit breaker is not specified, TERASAKI or similar approved breakers shall be used.

23.4.6 For all new installations and switchboard upgrades, individual residual current device (RCD) protection shall be provided for all general purpose outlet and lighting circuits except for security, refrigeration, communication and similar circuits. RCDs shall comply with *AS/NZS 3190 : Approval and test specification - Residual current devices (current-operated earth-leakage devices)*. Earth leakage devices shall nominally operate at 30mA. RCD's shall be of the type that occupy one pole on the chassis and do not require the bus bar to be cut.

23.4.7 Combination Fuse Units where used shall be of the fault make load break type. All the live parts shall be shrouded and all exposed metal earthed.

23.4.8 Where high rupturing capacity fuses are installed provide spare fuses to 10 percent of the number of each of the different fuses used in this installation, or 4, whichever is the greater. Note that re-wire-able fuses are not permitted anywhere on University installations.

23.5 Control Panels and Mechanical Switchboards

23.5.1 These cabinets shall have a separate main isolator that can be isolated without access to any live parts. The load side wiring from the main switch shall be connected to bus bars with a separate fixing for each circuit. Switchboards shall be lockable with L&F 92268 key. Metering shall be as per the requirements of *Section 6 Building Management Systems* of the CBRM.

23.5.2 The fault level at the cabinet shall be ascertained and the equipment installed in the cabinet adequately protected.

23.5.3 The switchboards shall comply with *AS/NZS 61439.1 : Low-voltage switchgear and controlgear assemblies* and generally be of Form 1 construction.

23.5.4 Control circuits shall operate at ELV and comply with *AS/NZS 3000 : Electrical installations*. ELV circuits shall be fused and earthed.

23.5.5 Indicator lamps shall preferably be LEDs, and any panel with lamps shall have a lamp test facility.

23.5.6 All outgoing circuits up to 20 amps shall exit the board via a terminal strip. All terminals shall be labelled. All control wiring shall be labelled at each end and at any junction with an approved slide on ferrule system and terminated with approved lugs.

23.5.7 Each panel shall have a separate neutral and separate earth bar. Incorporate a double 10A power outlet in each mechanical switchboard for maintenance purposes.

23.5.8 All components in the panel shall be labelled with the circuit designation and function. The board shall be fitted with a legend detailing the circuits, indicating which switchboard feeds the panel and giving the drawing number of the wiring diagram.

23.5.9 All controllers, relays, contactors, etc., shall be DIN rail mounted and removable from the front. Self-tapping screws shall not be used. All cables in the panel shall be run in suitable PVC ducting.

23.5.10 The board shall contain spare space for 30% more miniature circuit breakers and control gear.

23.5.11 Provide interface relays for connection of the BMS to control panel/mechanical switchboard wiring.

23.5.12 Wiring and layout drawings shall be submitted to ANU Facilities and Services before manufacture begins.

23.6 Electric Duct Heaters

23.6.1 All electric duct heaters associated with mechanical plant shall conform to the electrical requirements as detailed in *AS/NZS 1668.1 : The use of ventilation and air conditioning in buildings - Fire and smoke control in buildings* and *AS/NZS 3102 : Electric duct heaters*. Note this includes at least a fan interlock, an airflow safety switch and a thermal cut out.

23.6.2 The heaters shall comply with *AS/NZS 1668.1*.

23.6.3 The contactor supplying the duct heater shall have an auxiliary contact that will be wired into the controls to ensure that the supply fan runs while the contactor is closed. (This is to ensure that the fan will continue to run if the heater contacts “welds in”).

23.6.4 A lockable on-load isolator shall be installed adjacent to each duct heater. Provide an isolation switch in the control circuit at the duct element box. Final wiring to the heating elements shall be in heat resistant tails.

24 LIGHTING

24.1 General Requirements

24.1.1 Refer to *Section 7 Electrical Services* of the CBRM for the general requirements of lighting at the ANU. Provide the complete lighting installation as specified, scheduled and shown on the drawings. The lighting installation shall be complete with luminaires, lamps and all necessary accessories and control gear.

24.2 Luminaires

24.2.1 Luminaires shall comply with the requirements of *AS/NZS 60598.1 Luminaires - General requirements and tests*.

24.2.2 Install light fittings square to the building details in straight lines. Thoroughly clean all light fittings immediately prior to the official handing over date.

24.2.3 All luminaires shall have an earthing conductor.

24.2.4 Plastic used for louvres, diffusers, etc., shall be UV stabilised.

24.2.5 Deliver light fittings to site protected against damage by suitable packaging and remove packaging only immediately prior to installation. Any light fittings deformed, scratched or otherwise damaged will be rejected.

24.3 Lighting Control Systems

24.3.1 Basic design requirements for lighting control systems are identified in *Section 6 Building Management Systems* of the CBRM. Where a proprietary lighting energy management system is used it shall be either ECS MLS, Cbus or other ANU approved systems. Refer to project documentation for details.

24.4 Road, Footpath and Pedestrian Crossing Lighting

24.4.1 Design requirements are detailed in *Section 6 Building Management Systems* of the CBRM.

24.4.2 Provide an RCD circuit breaker in each lighting column to protect and isolate each luminaire. The circuit breaker shall be accessible via the hand hole at the base of each lighting column. The cover plates for this equipment shall be secure and only accessible by the use of tools. Streetlight circuits shall circuited using 16 sq. mm single phase, neutral and 16 sq. mm earth conductors in 50mm conduit. The circuit shall be automatically controlled by the BMS system or other means.

24.4.3 Streetlight fittings, lamps and columns shall match existing equipment unless otherwise approved of by the PR. Obtain street light number labels from the F&S Electrical Supervisor and secure as directed. Record underground cable routes and column numbers on works-as-executed drawings.

24.5 Emergency Lighting

24.5.1 The emergency lighting installation shall comply with the relevant sections of *AS 2293.1 Emergency escape lighting and exit signs for buildings - System design, installation and operation* and the National Construction Code (NCC). Luminaires shall be manufactured and fully tested to the requirements of *AS 2293.3 : Emergency escape lighting and exit signs for buildings - Emergency escape luminaires and exit signs* and be the single point type complete with LED lamp, environmentally safe batteries (not NiCad), test button and battery charging. Emergency luminaires shall have extended warranties as identified in Clause 3 of this specification.

24.5.2 The emergency luminaires and exit signs shall be circuited such that they are automatically connected to their emergency power source upon failure of the electrical supply to the normal lighting in the designated area. Emergency lighting shall be separate from the normal lighting and shall consist of stand-alone luminaires. Exit signs shall use the “running man style” green/white legend.

24.5.3 Luminaires shall comply with the operational requirement of the battery being able to deliver code lighting for a period of 90 minutes. Emergency luminaires subject to water, dust or insect penetration (i.e. external fixtures) shall be Ingress Protection rated at IP65.

24.5.4 For new projects and refurbishments, an emergency lighting manual testing facility shall be provided in accordance with *AS/NZS 2293.1* in the appropriate distribution board.

24.5.5 Label each emergency and exit luminaire with a unique identifying number and record the number and location in a schedule included in the emergency and evacuation lighting operation and maintenance manual. The label shall be permanently fixed, indelible and readable at a distance of 1m. Label all circuit breakers controlling emergency and exit luminaires in accordance with *AS/NZS 2293.3*.

24.5.6 The emergency lighting system shall be Clevertronics or approved equal. Non-maintained emergency luminaires shall generally be the recessed “Spitfire” type. Exit signs shall generally be “edge

lit" type recessed where appropriate. Emergency luminaires shall have 5 year warranty from the date of Practical Completion.

25 ACCESSORIES

25.1 General Requirements

25.1.1 The position of power outlets, telephone outlets, thermal detectors, lights and switches as shown on the drawings are approximate only. The ESS shall be responsible for determining the final positions from the PR. No cost variation will be allowed for points finally located within 3 metres of the position indicated on the tender drawings.

25.1.2 Internally installed accessories shall be white, impact resistant and flush mounted over recessed wall boxes.

25.1.3 Accessories subject to the effects of weather, water or dust shall have Ingress Protection rated at IP56.

25.1.4 Refer to separate clause regarding accessory labelling.

25.2 Lighting Switches

25.2.1 All switch points shall be positioned on the lock side of door frames at a height of 1350 mm above finished floor level. Where switches fall adjacent they shall be ganged behind a recessed common flush plate, but no more than three (3) switches may be accommodated in any one plate unless indicated on the drawings. ***Light switches connected to different phases shall not be grouped under a common flush plate.***

25.3 Power Outlets

25.3.1 General purpose power outlets shall be 10A, 240V switched socket combination 3 flat pin type, suitable for inductive loads to *AS/NZS 3131: Approval and test specification - Plugs and socket-outlets for stationary appliances*. Outlets shall generally be mounted on the skirting duct or at a level of 450 mm above the finished floor level or 300 mm above bench tops where applicable.

25.3.2 As a general requirement for power circuits that contain no electrical space heating, up to 16 socket outlets may be installed on one 20 amp circuit (a double-ganged socket outlet shall count as 2 outlets).

25.3.3 Where 3 phase power outlets are required, these shall be 5 pin with active, neutral and earth cabling.

26 MOTORS

26.1 Electric motors shall conform to *AS 60034.1 : Rotating electrical machines* - normally 3 phase 4 pole squirrel cage induction machines. Motors shall normally be Totally Enclosed, Fan-Cooled (TEFC).

26.2 All motors exposed to weather shall have Ingress Protection rated to IP56.

26.3 All motors shall be provided with starters complying with *AS/NZS 60947.1 : Low-voltage switchgear and controlgear* rated for AC3 utilisation. Starters shall incorporate overload and single phase protection with manual reset.

26.4 Motors shall have pad-lockable local isolators complying with *AS/NZS 3000: Electrical installations*. Guards shall be installed to protect all moving parts.

27 VARIABLE SPEED DRIVES

27.1 General Requirements

27.1.1 The Variable Speed Drives (VSDs) shall be a dedicated HVAC engineered design, not a general purpose product. All VSDs shall be from the same manufacturer and series/type with a common operator keypad and display.

27.1.2 The VSD shall be contained within a minimum IP54 full integrated enclosure suitable for plantroom installation incorporating all the accessories necessary to meet this specification without using a secondary enclosure. Each VSD complete with any options necessary to meet this specification shall be fully tested at the manufacturer's works, including driving a motor connected to a dynamometer at full load during the automated test procedure. The VSD must conform to recognised International Standards and be manufactured to ISO 9001 quality standards.

27.1.3 The VSD shall be supported locally by the manufacturer who will provide full technical support and troubleshooting capability from their local facility. Spares holding and service support shall be provided locally by the manufacturer or their approved service partner.

27.1.4 The VSD shall be of the variable voltage, variable frequency type. It shall convert fixed voltage/frequency three phase AC mains supply input to variable voltage/variable frequency output for controlling the speed of three phase AC motors. VSDs that only control the output voltage will not be approved.

27.1.5 VSDs shall be suitable for use in either a stand-alone mode, complete with all necessary control functionality and protection, or as part of a centrally controlled system via a serial communication network to the BMS via an in-built EIA485 port or other high level interface as required.

27.2 Mains Supply, Motor and Application Compatibility

27.2.1 The VSD shall be rated for 3 phase, 415 V +/-10%, 50/60Hz +/-5% mains supply. The VSD shall comply with *AS IEC 61800.5.1 Adjustable speed electrical power drive systems - Safety requirements*. The VSD supplier shall confirm what type of short circuit input protection devices can be used for compliance with this safety standard. With the motor operating at rated nominal speed, full load the VSD shall be able to deliver full rated motor voltage (415V) and full rated motor power over the +/-10% mains voltage range.

27.2.2 The VSD shall be suitable for controlling any IEC standard design motor and shall not require the motor to be de-rated or cause the motor temperature to rise above the Class B rise expected on normal mains supply. If the VSD cannot maintain Class B temperature rise then the motor shall be oversized and de-rated or an external blower for cooling the motor shall be required.

27.2.3 The VSD shall be able to automatically tune itself to the motor to optimise motor performance and efficiency, improve start capabilities and compensate for motor cable variances. This function shall be carried out with the motor at standstill (i.e. without spinning the motor) and without the need to decouple the motor from the driven load.

27.2.4 The output voltage to frequency ratio shall be suitable for fan and centrifugal pump control. An automatic energy optimization function shall be incorporated to dynamically optimize the voltage to the motor throughout the operating range of application. This function is to ensure the magnetization of the motor is optimum at all speeds and loads to minimize motor energy consumption.

27.2.5 Where there is a requirement for variable speed chillers elsewhere in this specification the VSD supplied for chiller control shall comply with all paragraphs of this Variable Speed Drives section. The VSD shall have the capability to run the compressor type used in the chiller, be programmable for an output

voltage to frequency ratio suitable for the compressor type and include an automatic energy optimisation function to dynamically optimise the voltage to the compressor motor throughout the operating range.

27.2.6 The VSD shall minimise motor audible noise though the use of a self-adjusting switching frequency. The switching frequency shall be automatically adjusted to optimise motor and VSD operation while reducing motor audible noise. VSDs with fixed switching frequencies will not be approved.

27.2.7 For direct drive fan applications the VSD shall be capable of providing full motor torque at any selected frequency between 20Hz and nominal motor frequency while also providing an automatic energy optimised variable torque voltage/frequency curve for operation at reduced speeds below this selected frequency. The VSD shall be capable of controlling parallel motors of mixed ratings and allow disconnection of any motor whilst running without causing tripping.

27.3 Electromagnetic Compatibility - Harmonics

27.3.1 Within its enclosure the VSD shall include DC link harmonic filtering with both inductive and capacitive elements to control the mains borne harmonics to within the value prescribed by the electricity distributor.

27.3.2 VSDs not incorporating DC chokes should include 5% AC input chokes within its enclosure to give a similar harmonic reduction performance. If AC input chokes are used, the VSD manufacturer must advise the percentage voltage drop across them when the VSD is operating at full load. Incorporation of either DC or AC chokes should ensure the harmonic emission requirements of *AS 61800.3: Adjustable speed electrical power drive systems - EMC requirements and specific test methods* are complied with. For relevant powers the VSD shall also comply with *AS/NZS 61000.3.12: Electromagnetic compatibility (EMC) Limits*. The VSD shall exhibit near unity displacement fundamental power factor at all loads and speeds.

27.3.3 The VSD supplier shall provide details of all harmonic currents up to and including the 40th when operating at full load and provide an estimation of the total harmonic voltage distortion resulting at the point(s) of common coupling due to the installation of all the VSDs on the project. Details of the loads, supply transformer, impedances and other relevant supply network data will be supplied to enable this calculation to be made. If this estimation concludes the total harmonic voltage distortion is expected to be above the value prescribed by the electricity distributor the VSD manufacturer shall propose additional passive or active advanced harmonic filters to reduce the harmonic distortion to within the value prescribed by the electricity distributor.

27.4 Radio Frequency Interference:

27.4.1 The VSD shall be CE marked in accordance with the European Union EMC Directive legislation and C-Tick marked in accordance with Australian Communications Authority (ACA) regulations. Within its enclosure the VSD shall include a radio frequency suppression filter to ensure:

- The VSD complies with the conducted emission requirements of *AS/NZ 61800.3* Category C1 with 50m motor cable; OR
- The VSD complies with the conducted emission requirements of *AS/NZ 61800.3* Category C2 with 50m motor cable if at the time of submission for approval the electrical installer verifies in writing that they meet the definition of “professional” as per that standard.

27.4.2 The VSD manufacturer shall supply correct EMC installation recommendations to ensure compliance with this specification.

27.5 Immunity:

27.5.1 The VSD shall comply with the immunity requirements of *AS/NZ 61800.3* Second Environment levels.

27.6 Protection:

27.6.1 The VSD shall provide protection against the following conditions:

- *Output earth fault*
- *Output short circuit fault*
- *Loss of mains phase (programmable as described below)*
- *Loss of motor phase (3 phase measurement)*
- *Over voltage*
- *Under voltage*

27.6.2 The VSD shall monitor the output current on all three motor phases and the current protection feature shall be sufficiently fast to allow the VSD to survive a continuous short circuit on the output terminals without damage to any of the VSD components.

27.6.3 The output circuit shall be of such a design to allow unlimited switching of the motor circuit at any load or speed without interlocks and without causing damage to the VSD.

27.6.4 It shall be possible to program a current limit to protect the driven equipment from excessive overloads during either running or starting. If the VSD output current reaches this limit any further attempt to increase the current will cause the VSD to reduce its output frequency to reduce the load. If desired it shall be possible to program a timer which will cause the VSD to trip after operating in this current limit condition for the programmed time.

27.6.5 In order to ensure continued operation of equipment during extended periods of overload it shall be possible to program the VSD to periodically reduce its output current to a programmed value during these periods, allowing the VSD to continue to run the equipment without tripping.

27.6.6 A loss of mains phase function should protect the VSD from damage and indicate the phase loss condition. The VSD should be programmable so that during an input phase loss condition the VSD can trip and display an alarm, issue a warning while running at reduced capacity or issue a warning while running at set point speed.

27.6.7 The VSD shall not exhibit an inrush current when connected to the mains supply or given a start signal. The VSD shall model the motor in its software to predict motor overheating for use with motors not fitted with thermistors. When overheat is predicted an alarm or warning shall be initiated.

27.6.8 The VSD shall include a thermistor input as standard for use with motors fitted with thermistors to provide motor thermal protection without the need for external thermistor interface relays.

27.6.9 Galvanic isolation shall be provided between the VSDs power and control circuits in accordance with the PELV (Protective Extra Low Voltage) requirements defined in *AS IEC 61800.5.1 Adjustable speed electrical power drive systems-Safety requirements - Electrical, thermal and energy* to ensure operator safety and to protect the BMS interface. VSDs not including galvanic or optical isolation on both analogue and digital I/O shall include additional isolation modules.

27.6.10 The VSD shall not include any button on the keypad allowing the motor direction to be reversed.

27.7 VSD Ratings and Selection

27.7.1 The VSD shall be able to provide full rated output current continuously, 110% of rated current for 60 seconds and deliver 120% of rated motor torque for up to 0.5 seconds while starting. The VSD shall be selected such that its nominal current rating is greater than or equal to the motor's full load current.

27.7.2 The VSD shall be selected based on operating in a maximum peak ambient temperature of 50°C at its nominal current rating when used with Australian high efficiency motors as per *AS 60034.1*

Rotating electrical machines - Rating and performance. It shall be suitable for operation in conditions with a relative humidity up to 95%. To ensure continued operation of the plant during times of extreme ambient temperature conditions it shall be capable of operation at reduced performance in temperatures from -10°C to +55°C.

27.7.3 The VSD's efficiency shall be minimum 96% at 100% load and 94% at 50% load.

27.7.4 VSD acoustic noise shall not exceed the lower of the noise levels defined for motors elsewhere in this specification or the following measured at a distance of 1m from the VSD when operating at full load:

- *≤90kW 70dBA*
- *≥110kW 85dBA*

27.8 Control Functions

27.8.1 The VSD shall include a full 3-zone, 3 set point, and 3 feedback *proportional–integral–derivative* (PID) controller as standard to provide closed loop control of the driven equipment direct from up to 3 signal transmitters without the need for external signal conditioning. It shall be programmable to compare the feedback signals to a common set point or to individual set points. It shall be programmable to select either the maximum or minimum feedback signal as the controlling signal or to calculate the controlling feedback signal as the average of all feedback signals or the difference between a pair of signals. It shall incorporate an auto-tune feature to self-tune the P and I terms to facilitate easy commissioning. It shall be possible to apply individual scaling to each feedback. If this 3-zone controller is not included in the VSD, a comparable controller should be included with the VSD package.

27.8.2 The PID controller shall incorporate a flow compensation function to dynamically adjust the set point based on flow to automatically compensate for varying pressure drops in the system at different flow rates when using a sensor installed near the outlet of a pump, instead of out in the controlled system, as the feedback signal.

27.8.3 The VSD shall have three additional auto-tune PID controllers which can provide set point reset or control damper and valve actuators in the system.

27.8.4 A run permissive function shall be provided to accept a "system ready" signal to ensure the VSD does not start until dampers or other auxiliary equipment are in the proper state for VSD operation. The run permissive function shall be capable of initiating an output signal as a start command to actuate external equipment before allowing the VSD to start (e.g. damper actuator). If this function is not included in the VSD, comparable control circuits should be included in the VSD package.

27.8.5 The VSD shall automatically adjust the acceleration and deceleration rate to ensure "no trip" ramping in case too rapid acceleration or deceleration is called for. The VSD shall be capable of automatically connecting to a spinning fan, forward or reverse running, without tripping.

27.8.6 It shall be possible to program four bypass speed ranges to avoid operating at speeds/flows which result in mechanical or air resonance conditions. An automated procedure for setting these speed ranges shall be provided to simplify commissioning. It shall be possible to program a minimum of 8 pre-set speeds, selectable via digital inputs and the high level interface, to override the speed control signal for duties such as night setback, smoke extract and morning boost settings.

27.8.7 The VSD shall be able to automatically reset in the event of an alarm condition with the ability to program the number of reset attempts (up to 20 or infinite) and the time between each attempt.

27.8.8 The VSD shall have a programmable automatic "sleep" mode function complete with boost facility, which operates when loads are below minimum settings. When the VSDs speed is being controlled by its PID controller, it shall be possible to program a "wake-up" feedback value that will cause

the VSD to start. To avoid excessive cycling of the driven equipment, it shall be possible to program a minimum run time before sleep mode can be initiated and a minimum sleep time.

27.8.9 The VSD shall include a motor preheat function to prevent condensation forming in the motor during shutdown periods. The VSD shall display and log in non-volatile memory the total kWh consumed and total motor running hours without additional instrumentation and provide the facility to reset these counters.

27.9 Fire Safety Function:

27.9.1 The VSD shall have a digital input which can be used to override all other local or remote commands in the event of a fire command from the fire safety system. The VSD shall display Fire mode whenever this input is active.

27.9.2 The VSD should be programmable such that depending on the application and system design the fire command should force the VSD into one of the following operating states:

- *Start and run, or continue to run, at a speed in the forward direction.*
- *Start and run, or continue to run, at a speed in the reverse direction.*
- *Stop*

27.9.3 The speed/set point at which the VSD shall run when the fire command is active should be set by either a dedicated programmable pre-set reference or defined analogue input signal. All other pre-set references or analogue input signals should be ignored. The VSD should be programmable to allow operation in either open loop or closed loop, using its internal PID controller, when the fire command is active. When the fire command is active the VSD should operate as per the programmed function above overriding all of its warnings and alarms and motor protection features in order to secure continued operation until such time that the fire command is manually overridden or that a fire has rendered the VSD inoperable.

27.9.4 To meet different application and system design requirements the reaction of the VSD to serious fault conditions, such as earth fault or short circuit fault on the VSDs output, should be programmable to the following:

- *The VSD should trip but then continuously attempt to automatically reset and restart, even if that risks potential damage to the VSD*
- *The VSD should trip but require a manual reset*

27.9.5 To enable testing of the fire system without overriding the VSDs warning and alarm protection systems, it shall be possible to programme the VSD to temporarily respond to alarms as per normal operation when the test fire command is active.

27.9.6 All VSDs used as part of the fire safety system shall be configured to require a password before any parameter changes can be made. A real time clock shall be an integral part of the VSD.

27.9.7 Ten programmable time periods with individually selectable on and off functions shall be available. The clock shall be capable of initiating functions including start/stop, change of speed and change of set point (e.g. for night setback) and of controlling output relays for control of external equipment.

27.9.8 It shall be possible to program unique events that only occur during normal working days, others that occur on non-working days and others that occur on specific days and dates. The manufacturer shall provide a free PC based software to setup the calendar for this schedule.

27.9.9 It shall be possible to program preventative maintenance reminders based on date and time, VSD running hours and VSD operating hours.

27.9.10 When the VSD is integrated into the BMS via a high level interface it shall be possible to synchronise the VSDs clock with that of the system's master clock. With this synchronising function included, battery backup of the VSDs clock is optional. If the VSD is not integrated into the BMS via a high level interface, the VSDs clock shall be equipped with a battery backup.

27.9.11 The VSD shall be able to store application load profile data to assist in analysing the system demand and energy consumption over time.

27.9.12 The VSD shall include a cascade controller which allows the VSD, utilising its PID controller and output relays, to control a multi-pump system with the duty pump speed controlled and one or two assist pumps fixed speed.

27.10 Control I/O, Signals and Status Indicators and High Level Interface

27.10.1 As standard the VSD shall provide the following minimum programmable I/O points:

- *6 x digital inputs*
- *2 x digital outputs (provided by relays with changeover volt free contacts (rated for 240V AC) and on/off delay timers)*
- *2 x analogue inputs (each selectable for voltage or current signals, direct or reverse acting, with the minimum and maximum range independently scalable from 0-10V DC and 0-20mA)*
- *1 x analogue output (0/4-20mA)*

27.10.2 The VSD shall have the facility to expand its I/O capability through the addition of option modules. These should be available as factory mounted modules, with the complete VSD including the modules tested at the manufacturer's works and also available as simple field mounted options using rigid connectors to plug into the VSD. The following I/O points should be provided by these option modules:

- *Additional digital inputs*
- *Additional digital outputs including additional relay outputs*
- *Additional analogue inputs*
- *Additional analogue outputs (0/4-20mA and 0-10V DC)*
- *Pt1000/Ni1000 temperature sensor inputs*

27.10.3 It shall be possible to read the status of all digital and analogue inputs (including those on I/O expansion modules) via the high level interface making them available as remote inputs for the BMS.

27.10.4 It shall be possible to control all digital and analogue outputs (including those on the I/O expansion modules) via the high level interface making them available as remote outputs for control by the BMS. When controlled by the BMS in the event of the high level interface network failing the digital/analogue outputs shall override to a programmable default condition/value.

27.10.5 All digital inputs shall be programmable to the following functions as a minimum: ramp start/stop; coast stop; reset; hand start; auto start; pre-set speed select; external interlock; run permissive; fire mode.

27.10.6 All digital outputs shall be programmable to provide the following status signals as a minimum: ready; running; tripped/alarm; hand mode; auto mode. These signals shall also be available via the high level interface irrespective of the digital outputs' programmed functions.

27.10.7 Analogue inputs shall include a "signal loss" detection algorithm with ability to program the action after the loss of signal and a time delay to eliminate nuisance signal loss indications.

27.10.8 Analogue inputs shall incorporate a programmable low pass filter to compensate for electrical noise on the signal.

27.10.9 All analogue outputs shall be programmable to represent the following as a minimum: motor current; motor power; sensor feedback; motor speed; output from the additional PID controllers. It shall be possible to scale the minimum and maximum values of these outputs.

27.10.10 The VSD shall provide a fan operating status/interlock signal with the function deriving this signal capable of detecting the loss of running load indicative of mechanical failures resulting from a broken belt or coupling etc. To ensure against nuisance indications this function must be based on motor torque, not current, and must include a proof timer to avoid brief periods of no load from falsely triggering this indication. The VSD shall be programmable to signal this condition via a keypad warning, relay output and via the high level interface to the BMS. Only when the VSDs loss of load function complies with this clause completely can it be used in place of a differential pressure/flow switch for fan operating status/interlock.

27.10.11 The VSD shall provide a pump operating status/interlock signal with the function deriving this signal capable of independently detecting no-flow and dry pump conditions and operation off the end of the pump curve. To ensure against nuisance indications the no-flow and dry pump conditions must be based on motor power and speed. Proof timers must be included to avoid brief periods of any of the conditions being detected from falsely triggering this indication. The VSD shall be programmable to signal any of the conditions via a keypad warning, relay output and via the high level interface to the BMS. Only when the VSDs pump operating status function complies with this clause completely can it be used in place of a differential pressure/flow switch for pump operating status/interlock.

27.10.12 The VSD shall include a standard EIA485 communications port. The VSD shall be capable of connecting to the following high level interfaces for integration into the BMS network:

- *Johnson Controls Metasys N2*
- *Siemens Apogee FLN (P1)*
- *Modbus RTU*
- *LonWorks FTP certified to LonMark standard 3.3*
- *BACnet MSTP*

27.11 Installation, Commissioning and Service

27.11.1 All VSDs shall be installed in accordance with the manufacturer's recommendations and be located as close as possible to the motor being controlled. When the VSD is installed within sight and within 10m of the motor, as an alternative to the local motor disconnect switch specified elsewhere in this specification, the VSD shall incorporate a factory fitted mains disconnect switch with auxiliary contacts available for status indication.

27.11.2 The VSD shall incorporate a keypad with LCD alpha-numeric and graphical backlit display providing the following:

- *Hand-Off-Auto keys to start and stop the VSD and determine the source of control. It shall be possible to disable these keys or password protect them from undesired operation.*
- *Reset key to enable local/manual resetting of alarms.*
- *"Info" key to provide "on-line" context sensitive assistance for programming and troubleshooting.*
- *A red alarm light, a yellow warning light and a green power on light.*
- *Password protected keypad providing two levels of password protection.*
- *Display all information in clear language (e.g. Earth Fault). Numeric codes alone will not be accepted.*
- *Display five simultaneous meter displays/operating variables.*
- *Display set points and feedbacks (e.g. static duct pressure or condenser water return temperature) in appropriate engineering units (e.g. Pa, kPa, bar, mbar, in WG, psi, °C, °F).*
- *Display the value of each analogue input and output for system setup and troubleshooting.*

- *Display the status of each digital input and output for system setup and troubleshooting.*
- *Display the current date and time.*
- *Display of plant equipment identification name/number (e.g. AHU-B-4, SCHWP-3)*

27.11.3 The VSD shall include a quick setup menu with factory pre-set typical HVAC parameters provided. It shall also include individual Fan, Pump and Compressor menus specifically designed to facilitate easy start-up of these applications.

27.11.4 The VSD shall be capable of running with no motor connected for testing and commissioning.

27.11.5 The VSD shall store the last 10 alarms in an alarm log which remains available after a power cycle of the VSD. A description of the alarm and time and date of the alarm shall be recorded. The VSD shall have a standard USB port for direct connection of a PC to the VSD. The manufacturer shall provide PC software to enable the as commissioned configuration of the VSD to be simply saved and documented through the USB port.

27.11.6 The VSD shall have temperature controlled cooling fan(s) to minimize audible noise, minimize losses and ensure optimum fan lifetime. No rear access shall be necessary during normal servicing. Where VSD's are installed in external environments, provide suitable protection from the weather and solar radiation load.

28 INSPECTION, TESTING, COMMISSIONING AND HANDOVER

28.1 General Requirements

28.1.1 In addition to the statutory inspections, all electrical work conducted on University facilities shall be subject to inspection for compliance with the requirements of the contract documentation including this specification. The ESS shall give notice in writing to the Facilities and Services Division that the electrical work is ready for inspection. The PR will inspect the installation and if necessary produce a written list of non-compliances. ***The installation shall be fully commissioned and tested by the ESS using the testing guidelines in AS/NZS 3017 Electrical installations - Verification guidelines***.

28.1.2 Irrespective of any former tests, the installation shall fully comply with the Contract Documents before claims for final payment are met. The ***Practical Completion Check Sheet – Electrical Services*** (Refer to Appendix A) shall be used by both the ESS and the PR to verify that all of the contractual obligations of this documentation are met. A copy of the check sheet shall be signed off by both the ESS and PR and included in the O&M Manual.

28.1.2 Provide complete test and inspection facilities, both at the factory and the site, to ensure that the installation conforms to the requirements of the specification.

28.1.3 The ESS shall perform fault loop impedance checks and test the trip settings of all RCD's for all the works that the ESS is responsible for. The test requirements are detailed in Clause 8.3.10 of *AS/NZS 3000 Wiring Rules*. Test results shall be included in the O&M manual.

28.1.4 Provide copies of Certificates of Electrical Safety in the works-as-executed documentation.

28.1.5 Make known to the PR the results of all Supply Authority inspections, immediately upon receipt of same, in addition to meeting the cost of all repeat tests.

28.2 Works-As-Executed Documentation

28.2.1 On completion of the project works, supply initially a draft PDF electronic copy of works-as-executed documentation including drawings and operating and maintenance instructions for the use of personnel who will be operating and maintaining the plant. The documentation will be reviewed by the PR, changes made where necessary and returned to the ESS.

28.2.2 The full works-as-executed (WSE) documentation shall then be resubmitted in electronic format with DWG versions of any contract documents. The final submission of the WAE shall be in the format as detailed in the CBRM. Include in the WAE documentation any testing and commissioning data, ITP's, Certificates of Electrical Safety, hard and softcopy circuit schedules and the ANU Electrical Practical Completion Check Sheet signed by both the PR and the ESS.

28.2.3 The operating and maintenance instructions shall include procedures for electrical and mechanical plant (where appropriate) including a detailed description of the system, a maintenance and test schedule listing daily, weekly, monthly and annual requirements for the complete system. Include manufacturer's brochures and service information for equipment installed and list the name, address and telephone numbers of supply and service organisations.

28.3 Final Completion

28.3.1 The following requirements shall be fulfilled before the work can be considered as finally complete:

- *Final as installed drawings received.*
- *Final operating and maintenance manual received including test sheets.*
- *Zero outstanding defects.*

Appendix A: Practical Completion Check Sheet – Electrical Services

Serial	Description	Check
1	Regulatory Authority - Certificate of Electrical Safety Certificate.	☐
2	Emergency Lighting Installers Certificate.	☐
3	O&M manuals submitted.	☐
4	Hard and soft copy provided of ANU standard format circuit schedules for all DB's.	☐
5	Single line diagram in glazed frame adjacent to MSB.	☐
6	Accessories labelled in accordance with ANU requirements.	☐
7	Metering tested, commissioned and connected to the BMS system. Provide test certificate for each meter.	☐
8	Switchboard thermographic test results if applicable.	☐
9	Switchboards inspected for correct labelling to accessories and wiring.	☐
10	All fire penetrations sealed as per the requirement of the Australian Standards, conduits in cable pits sealed to prevent the passage of water.	☐
11	Location of main earth detailed on the MSB.	☐
12	Test certification for data and telephone installation submitted.	☐
13	Instructions to ANU staff for the operation of plant and equipment.	☐
14	Verification that all ITP's as determined in the contract documents have been supplied.	☐
15	Verification that all test results as required by the contract documents are recorded in a log book or O&M manual.	☐
16	Continuity of earth system, protective earthing conductors and bonding conductors as per AS/NZS 3000:2018, Clause 8.3.5.	☐
17	Insulation resistance in accordance with AS/NZS 3000:2018, Clause 8.3.6.	☐
18	Polarity in accordance with AS/NZS 3000:2018, Clause 8.3.7.	☐
19	Correct circuit connections as per AS/NZS 3000:2018, Clause 8.3.8.	☐
20	Verification of earth fault loop impedance (EFLI) required for automatic disconnection of supply in accordance with AS/NZS 3000:2018, Clause 8.3.9.	☐
21	Operation of RCD's as per AS/NZS 3000:2018, Clause 8.3.10.	☐
22	Luminaires correctly sealed to prevent the entry of insects.	☐
23	Removal of redundant services and associated works completed.	☐
24	Confirm the date when the Defects Liability Period commences (/ /)	☐

Project Officer

Name: _____ Signature: _____Date: ___ / ___ / ___

Electrical Worker or Contractor

Name: _____ Signature: _____Date: ___ / ___ / ___

Licence No.: _____