QUEENSLAND Urban Utilities

ABN 86 673 835 011

Low Voltage Variable Speed Drives

TMS1406

Standard Technical Specification

Revision Control

Revision Number	Date	Revision Details	Responsible Officer
03	Dec 2015	Initial Issue – supersedes PSE-SSM018 version 03	Steve Bourke
04	Jan 2016	Issue for Use – Stakeholder comments updated	Steve Bourke

Contents

1. Scope

This specification details the minimum technical requirements for design, manufacture, installation, inspection and testing of Low Voltage Variable Speed Drives for Queensland Urban Utilities facilities.

The VSD units may be specified for supply in any of the following forms:

- Incorporated into a switchboard or panel,
- Supplied loose as a self-contained assembly,
- As a chassis for assembly into a switchboard by others.

1.1 Definitions

In this document, the following definitions apply:

Project Documentation	Governing technical documents for the specific item(s) for the specific works included or referenced in the Contract
Contractor	The entity bound (including sub-contractors appointed by the contractor) to execute the work having responsibility for design, manufacture and supply, delivery, documentation and other functions as further defined in the documents related to the work.
Contract:	The agreement between QUU and the Contractor to which this specification pertains.

1.2 Acronyms and Abbreviations

AC	Alternating Current
AS	Australian Standard
CPU	Central Processor Unit
CT	Current Transformer
DC	Direct Current
ELV	Extra Low Voltage
EMI	Electromagnetic Interference
FAT	Factory Acceptance Test
IEC	International Electro-technical Commission
HV	High Voltage
I/O	Input / Output
IP	Ingress Protection
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers

ITP	Inspection and Test Plan
LV	Low Voltage
LCP	Local Control Panel
MCC	Motor Control Centre
NC	Normally Closed
NO	Normally Open
MCCB	Moulded Case Circuit Breaker
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
PLC	Programmable Logic Controller
PPE	Personal Protective Equipment
PTC	Positive Temperature Coefficient
RCD	Residual Current Device
RFI	Radio Frequency Interference
RPEQ	Registered Professional Engineer Queensland
RTD	Resistance Temperature Detector
RTU	Remote Telemetry Unit
QUU	Queensland Urban Utilities
SCADA	Supervisory Control and Data Acquisition
SAT	Site Acceptance Test
SI	International System
SLD	Single Line Diagram
THDI	Total Harmonic Distortion Current
THDV	Total Harmonic Distortion Voltage
VSD	Variable Speed Drive
VT	Voltage Transformer

1.3 Reference Documents

Document Number	Title
CHE135	Pre factory inspection test sheets checklist
CHE305	Standard Variable Speed – Sewerage Pumping Station (FAT)
TEM336	Power System Analysis Guidelines
TMS62	Preferred Equipment List – Electrical and Instrumentation
TMS76	Corrosion Protection for Electrical and Mechanical Equipment

	and Structures
TMS1151	Preferred Equipment List – Control Systems
TMS1200	Electrical Installation - Technical Specification
TMS1202	Control System Implementation for Network Assets
TMS1203	General Requirements for Hazardous Area Installation – Technical Requirements
PRO307	Procedure Drafting Guidelines – Contract Requirements
PRO395	SEQ Water Supply and Sewerage- D&C Code Asset Information QUU Addendum
	SEQ Water Supply and Sewerage Design & Construction Code (SEQ WS&S D&C Code)
WI58	Arc Flash Assessment and PPE Selection

2 Standards and Regulations

All equipment and workmanship shall conform to the most recent requirements of the relevant statutory Local, State and Commonwealth Authorities and current applicable Australian Standards. Alternatively, where no Australian Standard exists, work shall conform to the most current and applicable International standard.

Where conflict exists between different Codes, Standards or Regulations, the most onerous conditions of specification shall apply unless accepted otherwise in writing by QUU.

The Contractor shall not deviate from the provisions of the relevant standard without first obtaining agreement in writing from QUU Superintendent.

Particular standards and regulations relevant to the work include but are not necessarily limited to the following:

2.1 Australian Standards

The equipment shall be designed, manufactured and tested in accordance with the latest edition of all relevant Australian and International Standards, Codes and Regulations except where modified by this specification.

AS/ISO 1000	International System of Units (S.I.) and its Applications
AS 1029	Part 1, Low Voltage Contactors (Up To and Including 1000 V AC)
AS 1042	Direct Acting Electrical Measuring and Indicating Instruments and their Accessories
AS 1202	Part 1, DOL Motor Starters Part 5, Semiconductor Starters
AS 1275	Metric Screw Threads for Fasteners
AS 1394	Safety Signs for the occupational environment
AS1627.4	Metal Finishing – Preparation and Pre-treatment of Surfaces – Abrasive blast cleaning of steel
AS 1775	Air Break Switches, Isolators and Fuse Combination Units (Up to and Including 1000 V AC and 1200 V DC)
AS 1930	Circuit Breakers for Distribution Circuits
AS 1939	Classification of Degrees of Protection Provided by Enclosures for Electrical Equipment
AS 2005	HRC Cartridge Fuses, up to 1000 V
AS 2053	Conduits and Fittings for Electrical Installations
AS 2064	Limits and methods of measurement of electromagnetic disturbance characteristics of industrial, scientific and medical (ISM) radiofrequency equipment
AS 2184	Moulded Case Circuit Breakers

AS 2692	Busbars and Busbar Connections
AS 3000	SAA Wiring Rules
AS 3008.1.1	Electrical Installations – Selection of Cables – Cables for Alternating Voltages up to and Including 0.6/1kV – Typical Australian Installation Conditions
AS 3111	Approval and Test Certification for Miniature Overcurrent Circuit Breakers
AS 3133	Approval and Test Specification – Air Break Switches
AS 3135	Approval and Test Specification – Semi-Enclosed Fuses for a.c. Circuits
AS 3147	PVC Insulated Cables and Flexible Cords
AS 3167	Protective Isolating Transformers
AS 3439.1	Low Voltage Switchgear and Control Gear Assemblies Part 1 - Type Tested and Partially Type Tested Assemblies
AS 3808	Insulation and Sheathing Materials for Electric Cables
AS 3947	Low-Voltage Switchgear and Controlgear
AS 4070	Recommended Practices for Protection of Low Voltage Electrical Installation and Equipment in MEN Systems for Transient Over Voltages
AS 4024	Safety of Machinery(all parts)
AS 60044	Instrument Transformers
AS 60146	Semi-conductor Convertors
AS 60269	Low Voltage Fuses
AS 60529	Degrees of Protection Provided by Enclosures (IP Code)
AS 60947	Low-voltage Switchgear and Controlgear
AS 61000	Electromagnetic Compatibility (EMC)
AS 61558.1	Safety of power transformers, power supplies, reactors and similar products – general requirements and tests

2.2 International Electro technical Commission (IEC) Standards

IEC 60050	International Electro-technical Vocabulary
IEC 60051	Recommendation for Direct Acting Indicating Analogue Electrical Measuring Instrument and their Accessories
IEC 60228	Conductors of Insulated Cables
IEC 60255	Electrical relays
IEC 60332 all parts	Flame Test On Single Insulated Wire/Cables and Bunched Wires/Cables
IEC 61800	Adjustable Speed Electrical Power Drive Systems
IEC 62061:2005	Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems

2.3 Institute of Electrical and Electronics Engineers (IEEE) Standards

IEEE 519	Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

2.4 Regulations

The current regulations and statutory requirements of the State of Queensland, Australia, shall be complied with, including:

- Queensland Electricity Act 1994
- Queensland Electricity Regulations 2006
- Queensland Workplace Health and Safety Act 2011
- Queensland: Environmental Protection Act – 1994
  - Environmental Protection Regulation 2008
  - Environmental Protection (Air) Policy 2008
  - Environmental Protection (Noise) Policy 2008
  - Environmental Protection (Water) Policy 2008
- Building Code of Australia Volume 1 and 2
- Supply Authority Conditions of Supply and Consumer Metering
- Workplace Health and Safety Regulation 2011
  - Work Health and Safety (Codes of Practice) Notice 2011
- Electrical Safety Act 2002
  - Electrical Safety (Codes of Practice) Notice 2013
- Electrical Safety Regulations 2013
- Professional Engineers Act 2002

2.5 Units and Language

AS/ISO 1000 (metric SI system) shall be used. All documentation and correspondence shall be in the English language.

2.6 Sub-Contractors

The Contractor shall disclose, at the tender stage, all sub-contractor or sub-supplier they intend to use as part of the equipment package supply. The Contractor shall not sub-contract any work to any party without the prior written consent of QUU. It shall remain the Contractor's responsibility to audit and co-ordinate the performance of their sub-contractors with results being disclosed to QUU.

All requirements applicable to the Contractor are applicable to sub-contractors or sub-suppliers. QUU reserves the right to attend the premises or otherwise of any sub-contractor or sub-supplier used in the engagement of the equipment package.

2.7 Contractor Exceptions

The Contractor shall be responsible to submit, together with the Tender, a list of deviations or exceptions to this Specification. In the absence of any exceptions, it will be construed that the Contractor fully complies with this Specification.

2.8 Order of Precedence

In the event of any conflict arising between this Specification and other documents listed herein, refer comments to QUU for clarification before design or fabrication commences.

The order of precedence that applies is as follows:-

- The Contract or Purchase Order Scope or Work
- Project Data Sheets
- This Specification
- Project Drawings
- International Codes and Standards

3 Electrical Design Criteria

3.1 Operating Conditions and Design Life

The VSD and associated equipment shall be designed for minimum life duration of 20 years in the environment and for the duty specified herein and on the Project Documentation. The equipment shall also be suitable for a minimum of 5 years normal continuous operation without maintenance at the duty specified herein and on the Project Data Sheets.

All equipment will be required to operate continuously at full load for 24 hours per day, 365 days per year under the climatic conditions detailed in this specification. All equipment shall be designed to perform this duty safely and without being attended.

VSD's will be located both indoor and outdoor depending on the application.

3.2 Site Climatic Conditions

The VSD project specific datasheet and relevant Project Documentation will define the installation location for the VSD.

Location	South East Queensland	
Altitude	Above mean sea level.	0-150m
Ambient Temperature	Minimum	-5°C
	Maximum (dry bulb)	45°C
Relative Humidity	Minimum	26%
	Maximum	100% condensing
Solar Radiation	Black bulb design temperature - minimum mechanical design temperature for equipment exposed to solar radiation	85°C

Note: Corrosive environments are locations where H_2S gas or other corrosive chemicals and gasses can exist under normal operating conditions and can be both indoor and outdoor areas. This is not limited to and is applicable to all wet wells installations. All areas including inside air conditioned switch rooms at Sewerage Treatment Plants are considered corrosive environments. All materials installed shall be suitable for the environment.

3.3 Operating Requirements

3.3.1 General

The equipment ratings shown on the drawings are the required ratings after all derating factors have been applied.

All components of the VSD and associated power and control circuit components shall be selected and installed so that all circuits can operate simultaneously at the full load rating shown on the drawings at the worst climatic extreme detailed in Clause 3.2 of this specification.

The full load rating for motor circuits shall be taken as the motor full load current while the rating for other circuits shall be the circuit breaker rating.

Unless specified otherwise the load capacity of the VSD rating shall be a minimum of 120% of the connected motor rating for 60 seconds for variable torque loads (fans, centrifugal pumps). The VSD rating shall be 150% of the connected motor rating for 60 seconds for constant torque loads (positive displacement pumps, belts, converters etc).

The VSD shall be keypad programmable with the ability to remotely mount the keypad if required, and shall have 'password' or function protection to prevent unauthorised changing of VSD parameters.

3.3.2 Fault Level

VSD's shall be protected against faults on the incoming mains and DC convertor, by either HRC fuses, semi-conductor fuses or MCCB's with the necessary interrupting capacity for the specified fault level and backup clearing time. The fault protection devices shall be supplied and installed in accordance with the VSD manufacturer's recommendations.

VSD's supplied as complete assemblies (ie. in separate free standing enclosures) may be fitted with fault protection devices built in.

VSD's supplied as chassis units shall have recommended upstream protective devices as nominated by the VSD supplier.

3.4 Utility Data

The electrical system will have the following voltage levels:

High Voltage Power Supply	33 kV AC, three phase 3 wire, 50 Hz, 11 kV AC three phase 3 wire 50 Hz, 6.6 kV AC, three phase 3 wire, 50 Hz
Low Voltage Supplies	3 ph, 4 Wire, 400 Volt +10,-6% 50 Hz ± 2%, MEN System Voltage Unbalance <5%
Single Phase Power Supplies	230 V AC, +10,-6%, 2 wire, 50Hz ± 2%,
Control Power Supplies:	UPS 230 V AC, single phase 2 wire, 50 Hz

	Regulated 24 V DC
Special Purpose Power Supplies	Regulated 48VDC and 110VDC

The equipment shall be designed to operate continuously under the following conditions:-

- HV Distribution: Steady State Voltage ± 5% nominal voltage
- LV Distribution: Steady State Voltage +10,-6% nominal voltage
- Steady State Frequency ± 2.5% nominal frequency
- Transient Voltage ± 20% nominal voltage
- Transient Frequency ± 5% nominal frequency
- Total harmonic voltage distortion < 5 %

3.5 Workmanship and Personnel

Personnel engaged in the manufacture of VSD panels shall be accredited, suitably experienced, competent and skilled in the particular field of work in which they are engaged. All works shall be completed by or under the direct supervision of fully qualified tradespeople holding trade qualifications and certificates adequate for the work and licensed under the Queensland Electricity Board regulations.

Persons employed in the design, manufacture and testing of the VSD's shall be directed by experienced qualified supervisors who shall be responsible for the works and for ensuring that the Contractor's personnel are conversant with and comply with QUU's specifications.

Welders shall be suitably qualified and accepted by QUU's Representative prior to commencing any welding works.

QUU reserves the right to inspect all works and direct re-work in the case that the works are not in compliance with the project specifications or commensurate with acceptable trade practice.

3.6 Weather and Ingress Protection

All VSD enclosures shall be Ingress Protection (IP) rated as specified in the Project Documentation.

VSD's are susceptible to damage or failure due to moisture and dust ingress and the enclosure containing the VSD shall be IP rated as follows unless otherwise specified:

- For outdoor installation - minimum IP56
- For indoor installation - minimum IP44

All outdoor equipment and installations shall be suitable for un-protected exposure to the weather, direct sunlight and hose-down cleaning. Where specified in the Project Documentation weather hoods and/or sun-shades shall be provided for UV and weather protection.

3.7 Materials and Equipment

All materials shall be new and unused, free of defects and shall be supplied with relevant certification and documentation. The defects liability period for all VSD's and associated components shall be 12 months from date of commissioning completed to QUU's satisfaction.

All Contractor supplied equipment shall be of manufacturer, type and model as specified in TMS62 Preferred Equipment List– Electrical and Instrumentation and TMS1150 Control System Preferred Equipment List. The Contractor shall not deviate from these requirements without prior written approval from QUU. Where the materials are not specified the Contractor may offer standard materials suitable for the application, environment and operating conditions. Non-specified equipment shall be of the same type, grade and quality as similar items specified in the Project Documentation. Corresponding parts of similar equipment shall where possible be interchangeable.

The Contractor shall maintain up to date inventory list of all components and consumable and procure additional materials as required well in advance so as not to delay the manufacturing schedule due to shortage of materials.

All components shall be of standard manufacture and readily available from suppliers unless specified otherwise in the Project Documentation. All equipment to be supplied shall be sourced from local OEM (Original Equipment Manufacturer) Authorised Distributors within Australia.

The selected components shall be suitably rated for the application with particular attention given to the following:

- Process conditions
- Power rating
- Voltage rating
- Frequency rating
- Duty rating
- IP rating

All equipment and materials shall be new and comply with the relevant specifications, regulations, codes and standards.

All components and materials supplied by the Contractor shall be free from:

- Asbestos
- Ceramic fibre
- Chlorofluorocarbons
- Polychlorobiphenyls (PCB) and their isomers
- Radioactive materials (unless specified otherwise in Project Documentation)
- Mercury

3.8 Heat Loss

The Contractor shall provide details at the time of quotation listing the heat generated by all the equipment contained in the enclosure across the full operating range of the VSD.

3.9 Reliability

At the time of quotation the Contractor shall include a listing of data for the VSD and the associated components with the following information:

- Mean Time Between Failure (MTBF),
- Mean Time To Repair (MTTR),
- Overall MTBF of the VSD.

The methodology used to derive this data shall also be provided.

The information is not required to be provided where the VSD proposed is as per the TMS62 Preferred Electrical and Instrumentation List.

4 Design and Performance Requirements

4.1 General Design

The VSD and associated equipment shall be designed and manufactured with an emphasis on safety, reliability and maintainability. Comprehensive diagnostic systems shall be an integral part of the equipment design. Circuits shall be designed and laid out for ease of fault finding and servicing.

Control circuits shall be designed so that they are "fail safe". Failure of a circuit component(s) shall cause power circuits to open, control circuits to generate signal stops and cause equipment to go to a safe condition. Fuses shall not be used in circuits where blown fuses would cause transmission or reception of erroneous signals or reference voltages.

Where the VSD is to be utilised with existing motors, the Contractor shall advise of the suitability and compatibility. Any investigations required to do so shall be allowed for by the Contractor.

4.2 Rating and Protection

All the equipment shall be designed for continuous operation at full load under the applicable environmental conditions. All electrical equipment shall be to the latest proven design available at the time of manufacture.

All equipment used shall be of a rating suitable for the duty it is to perform and capable of withstanding the maximum electrical fault conditions which can be applied to it, without damage. Fault conditions shall include, but not be limited to, overloads, short circuits and ground faults.

Provision shall be made in the design to prevent, as far as practical, the occurrence of an arcing fault by provision of the following:

- adequately rated components,
- suitable insulation techniques,
- adequate creepage and clearance distance,
- suitable interphase barriers,
- suitable cable terminations.

The suitability of the equipment and the effectiveness of the protection systems shall be supported by calculation and by protection grading curves showing all energy sources, protective device operation curves and short time ratings of contactors and cables. Supporting documentation shall be provided for all source data. A single line diagram shall show all cables, contactors, circuit breakers, fuses, overloads, over current relays and earth leakage relays, their sizes, load and fault ratings.

All equipment that has an interrupting capacity less that the short circuit capacity of its supply shall be protected by fault current limiting fuses.

4.3 VSD Accessories

The Contractor shall design, supply and install suitably rated VSD accessories including isolation transformers, input reactors, output reactors and termination filters as required to meet the Contractors stated VSD performance specifications. Such VSD accessories shall be sized and selected by the Contractor taking into account QUU's power supply characteristics and the intended arrangement of equipment, load characteristics and intended cabling.

4.4 Electro Magnetic Interference (EMI)

The VSD shall not generate noticeable radio or television interference, nor create electromagnetic interference on the control signal input circuit, internal firing circuit of other control equipment and protection devices.

The VSD shall be provided with on board or external RFI filters at the power supply input. The filters provided shall ensure that the VSD and filter combination complies with the requirements of AS 2064-1997 Group 1 Class A for conducted emissions or Class B for VSD's connected to the same 415 volt supply as domestic residences.

The installation and earthing of the VSD's shall be done to ensure compliance with the requirements of AS 2064-1997 Group 1 Class A for radiated emissions.

All VSD's proposed shall be complete with OEM's recommended installation instructions to enable the Contractor to comply with the statutory requirements for EMI.

Documentation to demonstrate compliance with AS 2064 shall be available for review upon request by QUU.

All cabling and wiring shall be carried out so as to prevent disturbance of sensitive circuits by electromagnetic and radio-frequency emissions with the use of VSD's.

Installation of VSDs shall be carried out in accordance with the OEM's recommendations, including requirements for connection of screened cables between VSD and associated motor.

Installation of cabling, wiring and components for control, instrumentation and communications shall be carried out with particular attention to:

- earthing,
- cable / wiring routes,
- segregation / separation,
- shielding.

4.5 Audible Noise Emissions

For the full operating range of the VSD, audible noise emissions from the VSD and associated cooling fans all equipment running simultaneously shall not exceed 70 dBA one (1) metre from the source with panel doors closed. The Contractor shall provide a noise frequency analysis for the entire operating range of the VSD, by a competent testing authority accepted by QUU

4.6 Corrosive Gas Atmospheres

Unless specified otherwise the Contractor shall supply the VSD and associated electronic components with conformal coating. This is applicable to both outdoor and indoor locations for installation of the VSD.

4.7 General Performance

The output waveform of the VSD shall be such that motor derating of a standard AC induction motor is not required when operating the driven load by the VSD.

The VSD shall be capable of starting into a rotating motor including reclosing the isolation contactor, without tripping.

The VSD shall be provided with adjustable starting torque settings for hard to start loads, and with a selection of Volts/Hz patterns to ensure optimum operation of the motor/VSD combination.

The VSD shall be provided with:

- Independently adjustable minimum/maximum speed limit adjustments.
- Minimum of two preset speeds selected by digital inputs.
- Automatic restart after momentary power failure.
- Torque limiting feature to prevent VSD tripping due to a temporary over current situation.
- Slip compensation for maintaining constant motor speed at all loads.
- Adjustable acceleration and deceleration times with settings 0 to 1200 seconds minimum.
- Auto reset of the VSD after either operator preselected or supplier factory set fault conditions. In either case, the Contractor shall nominate the fault conditions which are auto reset by the VSD and those which may be reset by the operator.
- Integral electronic thermal overload.
- English language LCD display for programming and fault identification.
- Provision in the control circuit for switching of a bypass contactor (ensuring tha. all VSD isolation and interlocking functions are provided) without synchronising going to or from bypassing. After bypassing, the VSD shall delay restart of the motor so restarting involves ramping up of speed. Contractors shall provide descriptions of bypass options where proposed.

- Capacity to auto-reset/restart for up to three times or, as an option, to have manual local reset/restart or remote reset/restart via communications link.
- Immunity to transient voltage dips or total loss of supply voltage. The Contractor shall nominate performance level offered.
- Minimum of two (2) jump frequencies to mask one or more specific speed zones, to avoid driven machinery resonance.
- Microprocessor control system for the complete unit, including firing control.
- Re-programmable in the field via an inbuilt keypad with integrated digital display and programming terminal (notebook PC) connected to the VSD communications port.

Programmable acceleration and deceleration rates selectable by:

- volt free contacts,
- communication link,
- keypad at the VSD.

Motor deceleration shall be controlled by a braking resistor where specified in the Project Documentation.

The following shall be considered normal requirements unless specified otherwise in the Project Documentation:-

- Speed accuracy (stability) ±1% from no load to full load,
- Maximum speed 50 Hz,
- Motor slip compensation,
- Starting torque capability to suit load application,
- For the power system conditions stated, the VSD shall provide programmable functions to ensure that maximum rated load can be developed by the motor at specified conditions.

5 Manufacturing Requirements

5.1 Cabling, Wiring and Equipment General Arrangement

Equipment in the VSD starter panel shall be arranged to allow adequate space for the installation and termination of all internal and external wiring. There shall be a suitable amount of space between the internal components to allow easy access for maintenance on the equipment, including the removal of failed equipment without the need to disassemble adjacent equipment.

All cabling and wiring shall be accessible. All wiring shall be one continuous length from terminal to terminal. Splicing, jointing or teeing shall not be accepted.

Common wiring between compartments (i.e. 24VDC, 0V etc.) shall be configured such that removal of a wire (or loose wiring) within one compartment shall not cause loss of connection to other compartments.

Electronic protection equipment requiring connections to AC supply, current transformers, voltage transformers, baluns and the like, shall wherever possible, be directly connected to such equipment.

A minimum 50mm shall be maintained between each terminal row and any cable ducts to provide sufficient clearance for fanning of conductors for termination and for affixing ferrules for wire identification.

Equipment shall be mounted on a gear tray and not directly to the external metalwork of the enclosure in such a manner so that all equipment can be removed without unbolting the gear tray. Self-tapping screws for fixing equipment to gear trays is not accepted.

Terminals shall be mounted on rails that are attached to a gear tray.

All outgoing power wiring shall be arranged to allow the use of a clip-on ammeter for testing purposes.

Where practical, all field cables shall be terminated on the same side of the terminal blocks within the VSD enclosure.

Terminal strips shall be mounted vertically to facilitate ease of cable termination and identification of terminals.

Terminals for the connection of field cables shall be located as close as practical to the point of entry of the cable into the enclosure. Where possible, terminals shall be located to prevent field cables (or cores part of) being routed through a compartment for termination into another compartment.

All cabling and wiring between compartments shall be routed through suitably sized holes cleanly punched in the metalwork and protected with grommets or similar to prevent insulation damage.

5.2 Cabling and Wiring Containment

All cabling and wiring within the enclosures shall be neat, firmly secured and enclosed within PVC cable ducts. Wiring looms or spiral wraps shall not be permitted except for wiring connections to hinged equipment (doors etc.). All cable ties shall be installed with an approved tensioning and cutting tool.

Where ducts are mounted upside down, the wiring shall be cable tied/supported to prevent the duct lid being forced open by the weight of wiring upon it.

Ensure minimum clearance of 100mm is maintained between cable ducting and gland plates.

The use of terminations as the only means of wiring support is not permitted.

Self-adhesive wiring supports shall not be used.

Cable ducts shall be side slotted PVC and shall have positive continuous (or clamping) edges on both the wiring channel and the cover.

All cable ducts shall be sized to have minimum of 30% spare duct capacity for future expansion (including provision for field cabling)

All wiring within a cable duct shall be insulated for the highest voltage within the cable duct.

5.3 Cable and Wire Detail

All wiring and cabling shall be low smoke emission, halogen free, stranded flexible tinned copper conductor and be flame retardant in accordance with the requirements of IEC60332.

Control cables for analogue signals to the VSD shall be shielded twisted pair cables with the screen of the cable bonded to the panel instrument earth at one end only. All other panel wiring shall be multi-stranded single core copper 0.6/1kV V105 grade PVC insulated with a minimum cross sectional area of 1.0mm^2 for instrumentation, 1.5mm^2 for control and minimum 2.5mm^2 for power wiring.

CT wiring shall be sized against the related circuit breaker burden and shall be a minimum cross sectional area of 4.0mm^2.

Multi-pair cables with multi-strand 0.5mm^2 conductors shall only be permitted for wiring to control system high density I/O modules within enclosures.

Plugs and cables supplied with standard equipment items shall not be modified and shall be installed in the panel as per the OEM's recommendation.

5.4 Wire Insulation Colour Coding

Insulation colours for internal wiring shall be as detailed in the following table and in accordance with AS/NZS 3000:

Description	Colour
AC – 3 Phase A	Red
AC – 3 Phase B	White
AC – 3 Phase C	Dark Blue
AC – 3 Phase Neutral	Black
AC – 1 Phase Active (230V)	Red (ferruled '230Vac)
AC – Neutral (230V)	Black (ferruled '230Vn)
AC – CT & VT Phase A	Red
AC – CT & VT Phase B	White
AC – CT & VT Phase C	Dark Blue
AC – CT & VT Neutral	Black
12VDC (Positive)	Orange
12VDC (common)	Violet
12VDC (signal)	Grey
24VDC (Positive)	Orange
24VDC (common)	Violet
24VDC (signal)	Grey
Earth	Green/Yellow
Instrumentation, 4-20mA(+)	White (twisted pair)
Instrumentation, 4-20mA(-)	Black (twisted pair)
Instrumentation, Triad – 3rd Core	Red
Electrode Wiring	Salmon
Intrinsically Safe Wiring	Light Blue

5.5 Wire Numbering

Panel wiring shall be numbered at each end with the wire numbers as detailed on the schematic and wiring diagrams.

Where practical, wire numbers shall commence within 20mm of the termination.

All alpha-numeric characters used for wire numbering shall be in English.

Wires shall be marked using indelibly printed ferrules in clear plastic push-on ferrule holders and shall be clearly read without moving the ferrule holder.

Wire numbering shall be similar or equal to Grafoplast SI2000 system.

Wires connected directly in series or parallel shall have the same ferrule number, all wires shall be uniquely numbered. Ferrules shall be arranged to read from left to right and from bottom to top.

Wire numbers for wires running external to compartment shall have the appropriate prefix.

Ferrules and holders shall be unaffected by moisture.

Ferrules shall require disconnection of the wire to remove the ferrule.

Ferrule holders shall be sized to suit the wire and shall not rotate freely around the wire.
Hand printed, 'C' type clip-on or adhesive ferrules are not acceptable.

Earth wires connected to the control panel earth bar shall be identified with a dedicated wire number and wire numbers assigned shall be updated to the panel schematics and/or other Project Documentation where not already indicated.

When wiring numbers change (i.e at connections between equipment) a clear system of coding is to be used at the change point and details shall be clearly marked on the drawings.

The wire number conventions for existing installed control panels at the particular site shall be adopted for all new control panels at the same site, unless specified otherwise in the Project Documentation.

5.6 Segregation and Shrouding

Within electrical enclosures segregation of cabling and wiring shall be achieved through the use of either physical distance or slotted PVC cable ducts.

Polyphase power cabling, wiring and terminations shall be physically segregated from small panel wiring and associated equipment.

Wiring and terminations of voltages greater than ELV shall be separated from ELV control and instrument signal wiring.

Terminals with circuits operating above ELV shall be segregated using removable shrouding that fully surrounds the terminals.

The shrouds shall be a clear transparent insulating plastic with a fully visible red/white/red warning label. Warning labels on shrouds shall contain the text

"Danger XXX Voltage", where XXX is the maximum voltage level behind the shroud.

Different voltage levels on banks of contacts of individual devices shall be avoided where practical.

5.7 Protection of Line Side Conductors

All supply conductors of voltages greater than ELV to the line side of the incomers, switches, circuit breakers and other switching devices shall be fully insulated or provided with IP2X covers or shrouds.

5.8 Door and Escutcheon Wiring

Flexible wiring shall be provided to equipment mounted on doors, escutcheons or similar hinged moving equipment. The wiring loom shall be clamped to retain the loom in position and to prevent any strain or rubbing of the wiring for the full travel of the door or escutcheon.

Spiral wrap, split tubing or similar shall be installed to provide mechanical protection for door and escutcheon wiring looms.

LV components and wiring are not permitted to be mounted on VSD access doors or escutcheon panel unless formally accepted otherwise by QUU.

5.9 Transportable Sections

Where equipment shall be split for transport, the internal wiring between transport sections shall terminate at a row of dedicated marked terminals located on one side of the break.

The disconnected wiring between transport units shall be crimped (with termination pins/lugs), loomed together and clearly marked for easy identification and on-site connection into the terminal blocks located in the adjacent transport unit.

5.10 Labelling and Identification

All equipment within the control panel enclosure shall be clearly labelled for positive identification with the design documentation.

All potential hazards within the electrical enclosures shall have warning labels provided indicating the voltage level.

Equipment identification labels shall be QUU assigned tagnames or as defined on the P&ID, schematic, wiring or general arrangement drawings.

All identification and warning labels shall be in English.

Labels shall not be secured to ducting or electrical equipment items. Labels shall be positioned adjacent to the relevant equipment and to provide unobscured visibility from outside the enclosure.

Each strip of terminals shall be clearly identified with a group label. In addition, each terminal in the strip shall be labelled with a unique number.

All terminals shall be equipped with provision for affixing individual terminal numbers. A non- adhesive, vibration resistant system shall be used for affixing individual terminal numbers.

The control panel shall be labelled with QUU assigned equipment tag number and title in accordance with the Project Documentation. Labels shall be installed as per the label schedule drawing for the control panel. Control Panels installed in public accessed areas shall have QUU Danger label fixed to the external door.

In addition every exterior and interior device, including terminals, terminal strips, fuses, switches, test blocks, indication lamps, relays and other equipment, shall be identified by a label fixed near the device and oriented so that it is readable from the appropriate access door. The label shall include a unique alphanumeric identification code. Equipment labels shall be fixed so as to not be obstructed from view by panel wiring.

All device labels, other than proprietary legend and escutcheon plates on devices, are to be engraved from white/black/white ABS plastic laminated engraving material.

External labelling is to be fixed by stainless steel threaded screws. Labels longer than 30 mm shall have clearance fixing holes to allow differential expansion of label and mounting. Where labels are mounted on standoffs they shall be suitably backed to prevent breakage.

Labels shall be provided to indicate the main isolator for each voltage level in the control panel. In addition labels shall be provided on exterior of the control panel front door indicating the voltage levels inside the panel and where each voltage source is isolated upstream of the panel. The label shall indicate the upstream switchboard and circuit breaker number and label shall be engraved black text on white background.

Isolated neutral circuits where present in the panel shall be identified with a warning label.

Label letter height shall be generally as follows:

VSD Panel QUU Equipment Number: 30 mm

VSD Panel Title: 20 mm

Max Voltage Level and Upstream Isolation: 20 mm

Equipment Labels: 5 mm

Pushbutton Designation: 3.5 mm

A label list shall be submitted for approval to QUU prior to manufacture.

Labels not approved by QUU shall be replaced at no cost if required by QUU.

Label colouring shall be:

- Internal labels W/B engraved ABS PLASTIC to the label schedule.
- Warning labels R/W engraved ABS PLASTIC to the label schedule.

First letter = Background colour, Second letter = Lettering colour.

- Emergency Stop pushbutton labels shall have yellow ring with black lettering.

Internal labels on gear trays or escutcheon panels shall be secured by M3 chrome plated metal threads or glued into position. Double sided tape shall not be accepted for fixing labels.

CB's to be identified with individual labels as per the label schedule.

External labels are to be 1mm thick 316 grade s/steel secured by M3 316 s/steel metal threads.

All internal and external labels are to have bevelled edges.

5.11 Danger and Warning Labels

All removable covers and protective shrouds which give access to exposed busbars or live terminals shall be labelled with red/white/red labels marked

"DANGER 400VAC ISOLATE ELSEWHERE.

Equipment connected to the line side of a switchboard incoming switch (eg. voltmeters) shall be marked

"DANGER - LINE SIDE CONNECTION – ISOLATE ELSEWHERE

5.12 Primary Nameplate

The primary name plate shall be fitted in a prominent location and secured by stainless steel screws or rivets. The following information shall be given in all cases:

- Queensland Urban Utilities
- Project Name
- Purchase Order or Contract number
- Equipment Title
- Equipment Tagname

5.13 Manufacturer's Nameplate

The switchboard rating plate shall be fitted in a visible position. Entries on the rating plate shall be indelibly marked, by etching, stamping or engraving. The following information shall be given in all cases:

- Manufacturers name and Company Logo
- Type, Model and Serial Number
- Standard to which VSD panel is manufactured
- Certified Weight
- Date of Manufacture
- Nominal Operating Voltage
- Nominal Operating Current
- Rated short circuit time withstand current
- Rated peak withstand current

5.14 Earthing

All parts of the VSD panel which are required to be earthed shall be effectively connected to the control panel earth bar. All earth conductor connections to the earth bar shall be secured with two screws. Screw holes shall be drilled and tapped. The earth bar shall be provided with suitable termination facilities for the connection of the earth conductors on all incoming and outgoing cables and shall be provided in each terminating zone.

The earth bar shall be colour-coded with green/yellow bands at maximum 300 mm intervals. The earth bar shall be tapped and fitted with bolts, washers and spring washers to accommodate the earth connections for all incoming and outgoing cables, with 20% spare connections.

All metal parts of the panel shall be bonded to the control panel earth bar.

All doors and escutcheons, fitted with control and/or indicating equipment shall have an independent flexible earth strap with mounting bolt and nut, or stud welded to the door.

All secondaries of current transformers shall have one lead earthed.

All metal cases of instruments, relays, selector switches, etc. shall be connected by an unbroken insulated earth wire of minimum size 2.5mm^2 to the earth bar. The earthing connections shall be arranged so that removal of one component shall not affect continuity of the earthing conductor associated with any other component. Earth conductor insulation shall be coloured green/yellow.

Earthing of RFI Filters shall be bonded to the filter using flat copper strap, and earthed at a point no greater than 300 mm from the filter.

An isolated instrument earth bar with 20% spare capacity shall be provided in the marshalling terminal section. The instrument earth bar shall be bonded to the main earth bar in the panel with a single 4mm^2 G/Y PVC cable.

Earthing of the VSD unit and other associated components shall be installed strictly as per the OEM's installation instructions.

5.15 Locks and Handles

For outdoor VSD enclosures Closetrade - Swing Handle HW-HAND-FLUSH-SS-MS874 with Closetrade - 3 point lock rod set HW-CAM-3PL-SET-3B4500-RG006-1-316SS shall be installed.

Lockwood Barrel Locks are to be fitted with Key Codes RC496A, RC496AB, RC496ABC refer to QUU for clarification as to where each is required. Where there is 3 point of closing handles only one to be lockable.

5.16 Lockable T Handles

For indoor VSD enclosures Lockable 'T' handles shall be chrome plated and keyed L & F 92268

5.17 Indoor VSD Panels

5.17.1 Enclosures

VSD panels located indoors in non-corrosive environments shall be minimum IP44 and completely self-supporting fully welded rigid structure, constructed from formed zinc annealed mild sheet steel, of minimum thickness 2.0 mm, free from rust, dents and any surface defects.

Equipment gear trays shall be a minimum 2.0 mm thick mild sheet steel for those panels up to an area of 500 mm x 500 mm. Where panels are larger than 500 x 500mm a 3 mm thick gear tray shall be provided, supported by studs of adequate size welded to the case.

Large equipment mounting panels, exceeding 1000 mm in any direction, shall be secured by a minimum of six welded studs and nuts.

Heavy equipment shall be supported by separate independent framework and shall not rely on the enclosure sheeting.

All nuts, bolts and studs shall be cadmium plated mild steel.

Equipment shall be arranged in the panel to permit easy removal of all components without interference to the structure, other components or cable entry. Consideration to the weight of VSD unit and allowance in design for removal of the VSD unit using a lifting device or other methods shall be provided.

Equipment shall not be mounted on the side walls of the panel.

Where VSDs are specified wall mounted, the VSD shall consist of a completely enclosed, minimum IP44, self-supporting frame bolted together to form one assembly.

5.17.2 Doors and Escutcheons

Doors and escutcheons shall be constructed from formed zinc annealed mild sheet steel, of minimum thickness 1.6 mm, free from rust, dents and any surface defects. Door sealing shall be achieved by 120 degree return on case, sealing against neoprene gasket glued to the inside of the door.

Stiffeners shall be fitted to all doors with dimensions in excess of 1000 mm high and 450 mm wide, or as required. Doors and escutcheons shall open a minimum of 100 degrees for equipment access, and shall be fitted with door stays.

All doors and escutcheons shall be fitted with chrome plated pintle hinges. A minimum of three hinges shall be fitted if the door or escutcheon is over 900 mm in height.

All doors shall be held closed with chrome plated lockable 'T' handles. For doors up to 450 mm high, one 'T' handle is sufficient. For doors above 450 mm and up to 900 mm high, two 'T' handles are sufficient and doors over 900 mm high shall have three 'T' handles or a Tri-lock. The same rules apply for escutcheons which shall be secured with panel key locks Emka 1/4 turn 1000-U142.

All doors and escutcheons shall be effectively earthed to the control panel case by means of flexible earth connection not less than 4 mm2 fixed to a welded M6 bolt.

At least one off document holder shall be provided to inside of control panel front door.

Control equipment other than indicating lights, push buttons, digital display and the membrane keypad and LCD display shall not be mounted on the enclosure door.

5.17.3 Plinth

Plinths shall be a minimum 75 mm 'U' channel, hot dipped galvanised. Plinth to have M12 clearance holes for bolting to the floor, and 50 mm diameter holes for inserting lifting bars, pipes to be welded between holes to stop the entry of vermin into the base of the panel, alternatively fit galvanised covers over holes after installation. The plinth shall be installed with toe facing out.

5.17.4 Paint Treatment

The surface of mild steel control panel metal work shall be degreased and cleaned with solvent, then coated with electrostatically applied powder coat in accordance with paint manufacturers' recommendations.

Internal and external surfaces shall be RAL7035 to AS2700, gear trays and escutcheons shall be gloss white.

5.18 Outdoor VSD Panels

5.18.1 Enclosures

VSD panel enclosures for all outdoor locations or corrosive environments shall be minimum IP56.

Panel material is to be minimum 3mm Marine grade Aluminium (5251) or 2 mm SS316. Pacified welds shall be provided throughout SS316 cubicles. All sheet metal edging is to be de-burred.

All panels are to be folded, "Pulse MIG" & "TIG welded with all visible seams and joints fully welded, free from splatter and ground smooth where needed.

All equipment shall be removable via the front access doors.

Equipment shall be arranged in the panel to permit easy removal of all components without interference to the structure, other components or cable entry. Consideration to the weight of VSD unit and allowance in design for removal of the VSD unit using a lifting device or other methods shall be provided.

Equipment shall not be mounted on the side walls of the panel.

All panels located in outdoor locations exposed to the weather shall be provided with a sloped rain hood.

5.18.2 Doors and Escutcheons

External doors and covers are to be fitted with Emka 1011-207 self-grip seal.

M6 Earth studs are to be fixed to the interior of all doors and hinged escutcheons and on adjacent cubicle interior surfaces.

Door stiffeners are to be SS316 and a minimum of 3 mm and of sufficient strength to prevent being deformed when subjected to reasonable loads.

All doors shall be held closed with stainless steel lockable 'T' handles. For doors up to 450 mm high, one 'T' handle is sufficient. For doors above 450 mm and up to 900 mm high, two 'T' handles are sufficient and doors over 900 mm high shall have three 'T' handles or a Tri-lock. The same rules apply for escutcheons which shall be secured with stainless steel panel key locks Emka 1/4 turn 1000-U142.

All doors and escutcheons shall be effectively earthed to the control panel case by means of flexible connection not less than 4 mm2.

Hinges shall be Selectrix HIB650ss-316 Stainless steel.

SS316 star washers are to be fitted under all hinge screws.

All escutcheons are to open to a minimum of 90°.

At least one off document holder shall be provided to inside of control panel front door.

Control equipment other than indicating lights, push buttons, digital display and the membrane keypad and LCD display shall not be mounted on the escutcheon door inside the front access door.

5.18.3 Plinth

Plinths for panels installed in non-corrosive areas shall be a minimum 75 mm 'U' steel channel and hot dipped galvanised.

Control panel plinth shall be 160x60 channel T6 Grade Aluminium in corrosive areas. The aluminium plinth paint coat system shall comply with TMS76 Corrosion Protection for Electrical and Mechanical Equipment and Structures.

At installation the control panel plinth shall be levelled using chemical anchors with SS316 threaded rod and jacked high enough to prevent the plinth being contact with water ponding. The spacing between the concrete slab and the plinth shall be filled with a non-hydroscopic, non-shrinkable material to prevent corrosion and ingress of vermin.

Plinths to have M12 clearance holes for bolting to the floor, and 50 mm diameter holes for inserting lifting bars, pipes to be welded between holes to stop the entry of vermin into the base of the board, alternatively, fit galvanised covers over holes after installation. The plinth shall be installed with toe facing out.

5.18.4 Paint Treatment

Aluminium and stainless steel surface preparation shall be finished smooth and all exposed welds are to be cleaned, descaled, and all surfaces are to be degreased. Surfaces pre-treatment is to be in accordance with AS1580 and AS3715 using Novox LF acid etch cleaner, Novacoat 12 conversion coating and clean water rinses.

Apply Dulux Alphatech 3000 powder coat to the manufacturer's recommendations.

Alternative surface preparation and paint coating systems will only be accepted where QUU has provided written permission to deviate from this specification.

Cubicle and external components are to be coloured Dulux Mist Green (36648) matt finish.

Interior items (mounting panels, escutcheons, etc.) are to be coloured Dulux Bright White (32166)

Minimum Dry Film Thickness on all surfaces is to be 50 microns.

5.19 Inspection and Access Covers

Inspection and access covers shall be manufactured from the same material as the control panel exterior enclosure. In addition the following shall apply to Inspection and Access covers:-

- Lift-off covers shall be fixed with M8 studs and stainless steel dome nuts and stainless steel "D" Handles are to be fitted.
- Small covers shall be fitted with M6x1.0 flat head closed end rivet nuts.
- Fitted with seals attached to the cubicle.
- Fixings are to be fitted at no more than 100mm spacing.
- Maintain a 50mm clearance from section dividers.
- Shall not be split.
- Shall not be earthed.

5.20 Ventilation

All VSD panels shall have a ventilation design calculation completed before manufacture commences. The calculation shall demonstrate that the maximum temperature inside the panel shall not exceed the maximum temperature rating specified by the component manufacturers:

The calculation shall allow for the following criteria:-

- Ambient temperature of 45°C unless specified otherwise in Project Documentation
- Black Body Solar Radiation Gain at 85°C
- Component heat dissipation
- Still wind conditions

The ventilation calculation approved by an RPEQ and undertaken using QUU approved modelling software shall determine the ventilation methods required. The ventilation methods in order of preference are as follows:-

1. Natural ventilation.

2. Solar Heat shield bolted to external walls and shields shall be theft proof.

3. Forced Ventilation fans shall be N+1

Air intake and exhaust outlets shall be provided with SS316 mesh screens and air filters to prevent vermin ingress with screens and filters removable for cleaning. Screens and vents must be removable from inside the enclosure without need to unbolt the gear tray or remove equipment from the gear tray to gain access. For indoor VSD panels a dry type heavy duty air filter shall be easily demountable and accessible without opening the door; and contained in a rigid frame for routine cleaning.

For outdoor VSD panels external metal hoods shall be provided to vents and air intakes to maintain IP rating of the overall enclosure.

Hot air from the outlet vent(s) shall not be exhausted over the front of the VSD panel where persons will access the controls and digital display. The fans shall pressurise the enclosure and be located at the bottom of the VSD enclosure. The fan shall be mounted directly behind an inlet vent provided with a grille or equivalent. The air flow shall be directed over the electrical equipment.

Where forced ventilation is proposed a thermostat shall be provided inside the panel to provide control of the ventilation fans and a second set of thermostat contacts shall provide over temperature warning alarm to the local PLC. The thermostat warning temperature setting shall be set to below the maximum design temperature for the components in the panel and maximum setting is 50°C. The ventilation fans shall ideally start when panel temperature reaches 35°C and stop the fans at 25°C.

In addition to above the VSD shall provide internal over temperature protection. At a factory set protection temperature, the VSD shall trip and display the cause of the trip by indication on the digital display and operate an internal over temperature alarm relay contact for monitoring by a PLC.

5.21 Panel Ventilation Fans

The Contractor shall provide rugged and high efficient fans, with at least 5000 hours bearing life for cooling of the VSD panel interior. The internal fans may operate from 240V, 50 Hz supply. External fans on larger VSD's shall be tamper proof and preferably driven by three phase motors with IP54 housings. Panel ventilation design shall allow for N+1 redundancy in the number of fans. Air conditioning cooling of the panel is not accepted.

5.22 Cooling and Heat Sinks

VSD integral heat sinks protruding through the rear wall of the enclosure are preferred for VSD'S with heat losses of 1kW or greater, per unit. The heat sinks shall be guarded to prevent accidental contact with hot surfaces. Heat sinks that can become live due to a VSD fault condition shall be guarded by an earthed metal cover with minimum IP40. Heat sink design shall allow adequate access for cleaning and inspection.

5.23 Gland Plates

Gland plates shall be single piece, 5 mm aluminium. A 3mm thick aluminium gland plate can be accepted only where all cables proposed to be installed in the gland plate have less than 32mm diameter glands. Gland plates shall be sized for 50% spare cable access in future.

The gland plate shall be effectively earthed to the control panel earth bar. The Contractor shall fit 25 mm wide neoprene gaskets to all gland plates, secure with 6 mm bolts at maximum 150 mm centres.

Cable glands are to be fitted with the compression side installed inside the cubicle.

5.24 VSD Mounting Arrangements

5.24.1 Chassis

VSD units supplied as a chassis only shall have holes suitable for screws to hold the weight of the VSD unit in transport and handling. The holes shall be positioned to allow unobstructed access for the use of fixing tools during installation.

5.24.2 Self-Contained

Self-contained VSD enclosures shall have externally accessible mounting lugs minimum 4 off, 4 mm thick, on the vertical sides for bracing to a wall or other structural framework. Holes shall be drilled 13 mm or larger for bolting to the supports. The Contractor shall determine bolt size and drilling for heavy units.

5.24.3 Panel

For panel mounted VSD units the Contractor shall ensure that the VSD and other associated equipment in the panel is installed in strict accordance with the OEM's recommendations and in such a manner that all necessary electrical clearances are observed and that the rating of equipment is not impaired either thermally or electro-magnetically by the proximity of other equipment or cables.

No items of equipment which is to be operated or viewed by an operator (pushbuttons, switches and meters) shall be mounted more than 1900 mm or less than 400 mm above floor level. It shall not be necessary to open any door or remove any cover to operate or reset equipment that is required for normal operation.

No piece of equipment shall be mounted behind other equipment or in any manner denying free access for removal or maintenance.

Items of equipment or terminals shall be no closer than 300 mm measured vertically from outgoing gland plates.

When designing the VSD panel the Contractor shall make consideration for access and egress around the panel at the location it will be installed. The panel opening door swing shall not obstruct escape routes, walkways or access to plant or equipment.

5.25 Spare Capacity

Unless otherwise specified by 'Layout' drawings issued with the Project Documentation, spare space shall be provided in the VSD panel equivalent to 20% of the total gear tray space available.

Adequate space shall be provided in the panel to allow for the inclusion of RFI filters at a later date, should these be required.

Mounting of equipment on side walls of the panel is not permitted.

5.26 Serial Communications and Fieldbus Cabling

Profinet cabling shall be routed directly between Profinet communication ports and end devices. Profinet communication cables shall not to be terminated on intermediate terminals.

Equipment such as meters, motor protection relays, circuit breakers and the like which are specified to be part of a serial communications link (whether copper or fibre) shall have communication wiring installed as per the manufacturer's instructions, using the manufacturer's proprietary connectors and cables.

All copper communication cabling shall be installed in accordance with industry best practice installation guidelines and to reduce EMI disturbances.

5.27 Termination of Control and Instrumentation Cables

All control and instrumentation wiring to the VSD unit and the control panel shall be terminated at equipment terminals using pre-insulated, crimp type, bootlace pins or lugs.

Terminations relying solely upon solder are not permitted.

No more than one wire shall be terminated in either side of the terminal.

Separate pins or lugs, as applicable, shall be used for each conductor and screen wire. Screen wires of twisted pair instrument cables shall have a clear sleeve fitted before the pin of lug is fitted.

Pins and lugs shall be suitable for copper conductors.

Pins and lugs shall be sized to suit the conductor size.

A method of stripping insulation that does not risk damage to the conductor shall be employed.

Pins and lugs shall only be crimped with the pin or lug manufacturer's approved crimp tool.

Provision shall be made on the length of the wire at each terminal to permit cutting and remaking of the wire termination at least once without interference with the main run of the wire and loom.

Terminals shall be rail mounted, clip-in, tunnel type and shall incorporate vibration resistant, captive pressure screws which shall not bear directly on the wire.

Knife gate marshalling terminals with minimum size for 0.5mm^2 conductors shall be installed for all control and instrument cable cores. Fused terminals are

accepted and where fuse terminals are provided the Contractor shall provide minimum 10 off spare unused fuses inside the panel.

Terminals shall be suitable for copper conductors.

Terminals shall be rated minimum 600V.

Terminal block insulation shall be of a non-grid, non-hygroscopic, non-tracking, non-flammable material.

Terminal shall have minimum ingress protection rating of IP2X to prevent accidental contact during inspection and maintenance.

Terminals shall be sized to suit the conductor size and current rating (minimum of 0.5mm^2 conductor).

Multiple level or tiered terminals shall not be used.

Push-in clamp type terminals can be provided on the VSD unit only. Separately mounted terminal blocks/strips shall be provided for each voltage level.

Separately mounted terminal strips shall be provided for different wiring applications including control, instrumentation and power wiring.

Adjacent groups of terminals shall be separated from each other using space, barriers or earth terminals.

Terminals shall be arranged such that all cores (including spare cores and screens) of multicore and twisted pair cables fan out and terminate in a logical sequence onto consecutive terminals of a common terminal strip. The terminals strip group label in this case is the same as the cable tag number. Terminating screens of instrument cables direct to the instrument earth bar is not accepted.

Terminals for internal wiring shall be arranged such that all 'commons' or 'positives' are grouped together and bridged with a continuous link on consecutive terminals.

Each strip of terminals shall be clearly identified with a group label. In addition, each terminal in the strip shall be labelled with a unique number.

Terminal strip labels and numbers shall be defined on the relevant drawings and Project Documentation.

Sufficient terminals shall be provided to terminate all cores (including spare cores and cable screen wires) of multicore cables and instrument cables.

Each terminal strip shall have at least 30% spare terminal space (including provision for field cabling).

All unused ancillary control and monitoring channels on control equipment items within the control panel shall be wired to terminal strips for future use.

Barriers shall be installed on each side of groups of terminals used for termination of spare cores.

All PLC and RTU digital and analogue I/O channels shall be wired to marshalling terminal strips (including installed spare cards) for connection to field cabling.

Field cabling associated with RTD's can be connected directly to the control system analogue input channel.

Where more than one wire is to be connected to one side of a terminal for looping purposes, multiple adjacent terminals and preformed links or combs shall be provided.

Terminal strips shall be arranged such terminal screw slots and terminal numbers are visible from outside the compartment to facilitate ease of wire termination.

All cables entering the control panel shall be individually glanded and only bottom access to the control panel enclosure is accepted unless otherwise accepted by QUU.

Where cables or wiring terminate into plug connectors, such connectors shall be equipped with retaining devices to prevent accidental disconnection.

Surge barriers shall be installed in the control panel for control circuits and instrument loops where indicated in the Project Documentation. The field cables shall connect direct to the surge barrier terminals. Surge barriers shall be provided as per TMS62 Preferred Equipment List – Electrical and Instrumentation. Neutral conductors on load side of the surge barriers shall be identified and isolation maintained from unprotected power supply neutral conductors.

Coaxial antenna cables shall be protected by coaxial surge protectors suitable for the frequency of operation of the antenna system. The surge protector shall be securely bonded to the control panel earth bar. Contractor shall ensure coax connectors and cable glands are not over tightened which can cause deformation to coax cable and signal attenuation.

5.28 Termination of Power Cables

Three phase input power cables to the VSD shall be separated from the output power cables from the VSD by a minimum of 300 mm. Power cables shall be terminated as per the VSD OEM installation instructions.

Generally, power cables with conductor size 16mm^2 and above shall be connected directly to the equipment terminals using bolted lugs with space provided to enable the installation and termination of such cables. Provision shall be allowed for termination of neutral conductors with the same cross sectional area as the active conductors.

For instances where intermediate terminals are required for the termination of power cabling with conductor size of 16mm^2 and above then moulded stud

type terminals shall be used with minimum 300mm clearance above the gland plate and respecting the minimum bend radius of the field cables.

Individual cores of cables up to and including 10mm^2 may be terminated on screw clamp/pressure plate type tunnel terminals where required due to space constraints or other physical limitations. In such cases, raised insulated barriers shall be inserted between terminals for individual phases of a three phase supply. Such terminals shall incorporate vibration resistant captive pressure screws.

Cabling and wiring terminating at stud and screw type terminals shall be fitted with crimp type ring tongue terminals.

In all instances lugs and terminals shall be suitable for copper conductors and shall be sized and rated to suit the conductor size and current rating.

All LV power terminals shall be rated minimum 1000V.

Terminal block insulation shall be of a non-rigid, non-hygroscopic, non-tracking, non-flammable material.

Terminals shall have a minimum ingress protection rating of IP2X to prevent accidental contact during inspection and maintenance.

When more than one wire is to be connected to one side of a terminal for looping purposes, multiple adjacent terminals and preformed links or combs shall be provided.

Wherever crimping is necessary, compression tools recommended by the manufacturer of the crimp type terminals shall be used. Where hand operated, the tools shall be of the type which do not release until full compression is applied.

Power operated crimping tools with hexagonal crimping dies shall be used on conductors in excess of 16mm^2.

Terminals for neutral circuits shall be sized to suit conductors of the same size as the active conductor.

Polyphase cabling and wiring shall be coloured at the terminations to distinguish phase or polarity. Colours shall be permanent and shall not fade over time.

5.29 Termination of CT and VT Cabling

Test terminals and short circuiting disconnect links shall be provided in all on protection secondary circuits to facilitate secondary injection testing for CT circuits. These terminals shall be readily accessible and suitably protected with a removable clear shroud.

CT circuit wiring connected to circuits external to the enclosure shall be provided with captive-type shorting links at the outgoing terminal.

Test terminals shall be provided for VT circuits.

5.30 Miniature Circuit Breakers

The control circuit supply voltage for VSD panels shall be 24VDC unless specified otherwise in project documentation.

Where the VSD panel is fed from an LV control supply the main isolator for the panel shall be shrouded and segregated from ELV components. The upstream LV protective device for the control power supply shall have a 30mA RCD. RCD's shall not be installed on the line side of UPS's and in this case a range selectable earth leakage relay shall be installed for equipment protection. The fault current rating of CB's and all other equipment shall be suitable for the prospective fault current level at the point of installation in the power network.

Where the LV control supply is not fed from an UPS a surge protection device shall be installed at the VSD panel. The surge diverter shall be fuse protected and rated at 50kA (8/20 micro seconds) and offer bi-directional protection and be current rated for the connected load.

All power supply feed cabling for electrical enclosures shall be connected to a main circuit breaker prior to connection with any electrical equipment. The circuit breakers (and/or terminals if required) shall be located in close proximity to the entry point of the cable to alleviate the need for running the cable through the cabinet.

All miniature circuit breakers (MCBs) shall be suitable for copper conductors and rated for uninterrupted duty.

MCBs shall be equipped with both inverse time delayed thermal protection for overcurrent and instantaneous magnetic trip protection for short circuit protection.

LV MCB's shall incorporate earth leakage protection unless specified otherwise in Project Documentation.

In all instances, the MCBs shall be selected to suit the connected cable and load applications in terms of duty, rated current, short circuit breaking capacity and load characteristics (instantaneous tripping curves to suit resistive loads, motors, fluorescent lighting etc).

Single pole AC MCB and two-pole DC MCB's for control power shall be provided unless otherwise approved by QUU.

The main CB or main isolator, status and operating facility shall be visible and accessible from the front of the panel. MCB's shall be equipped with clear labelling to indicate whether they are ON or OFF.

In all instances MCB's shall be individually pad lockable in the off position. This facility shall be a proprietary proven robust arrangement for accepting standard scissor locks/hasps for group isolation purposes.

Where specified in the project documentation, MCB's shall include voltage free auxiliary contacts for control system monitoring.

MCB's shall be mounted on rails that are attached to the gear tray or directly unto busbar chassis assemblies via terminal screws for distribution boards. The distribution of each voltage level shall be in a common area of the control panel and segregation installed between different voltage level distribution sections.

Where more than one wire is to be connected to one side of an MCB for looping purposes to adjacent MCBs, preformed proprietary link bars or combs shall be provided.

MCBs shall have a minimum ingress protection rating of IP2X to prevent inadvertent contact during inspection and maintenance activities.

MCBs shall incorporate captive terminal screws and metal lock dogs provided for each CB and isolator in the panel.

A typed legend in a plastic clear folder shall be provided for all levels of voltage distribution in the panel and fixed to the inside of the control panel front door.

5.31 Indicating Lamps

Indicating lamps shall be flush mounted and designed so as not to rotate even if the retaining nut is not fully tightened. The fitting shall be secured to the panel independently of any bezel which needs to be removed for lamp changing.

The status of indication lamps shall be visible from a wide viewing angle.

Lamp holders and lenses shall be designed to dissipate continuously the heat produced by the largest lamp that can be fitted, without deterioration or discoloration.

Lamps shall protrude from the front of the fitting far enough to be readily gripped with the fingers for change-out.

Lamp nominal voltages shall be at least 110% of their supply voltage. LV circuit lamps are not permitted.

Lamps shall be cluster LED type with internal voltage drop resistor.

Colours for indicating lamps shall be:

- Green: Motor Stopped / Off
- Red: Motor Running / On

- White: Healthy/Lamp Test / Ready
- Amber: Fault / Trip/ Alarm/ Caution

All lamps operating at the same voltage shall be interchangeable. Lamps operating at different voltages shall not be interchangeable.

VSD panels that incorporate indicator lamps shall include a common or integral push-to-test pushbutton to test operation of all the lamp circuits.

5.32 Actuators, Push-buttons and Control Switches

The functional requirements of all actuators, push buttons and control switches shall be defined on the relevant projects drawings. All actuators, push-buttons and control switches shall be heavy duty, oil tight and fully rated for the operating conditions and specific application. The device and method of installation shall be selected to maintain the IP rating of the enclosure. Devices shall be selected from TMS62 Preferred Equipment List Electrical and Instrumentation.

All push-button switches, except emergency stop push-buttons shall have a full shroud to prevent inadvertent operation. Emergency stop pushbuttons shall be of the mushroom head, latched type, manually reset and coloured red. Emergency stop push-buttons shall have a guard rings rather than full shrouds.

Colours for actuators and pushbuttons shall be:

- Green: Start /Jog/ Close/ On
- Black: Process Stop / Normal Off
- Red: Emergency Stop/ Emergency Off
- Blue: Reset

5.33 Emergency Stop Circuits

Emergency Stop circuits installed for VSD's shall be Category 2 in accordance with AS4024 Machinery Safety code standard. The Contractor may reduce the Category of the emergency stop circuit where the Contractor has provided a risk assessment to AS4024 and a design report to validate the reduction in Category. The design report shall be approved by an RPEQ Electrical and the risk assessment must be conducted with QUU participation.

Emergency Stop circuits for dry well and wet well submersible pumps have been risk assessed and are accepted as Category 1. There is no requirement for further risk assessment and design report for Category 1 Emergency stop circuits on these pump station sites.

6 TECHNICAL REQUIREMENTS

6.1 Harmonics Mitigation

The VSD design shall comply with harmonic distortion limits as stipulated in IEC 61800-3. The VSD supplier shall provide the harmonic frequency spectrum of THD current and THD voltage emitted for the full operating range of the VSD when connected to the power system.

The Contractor shall provide a Harmonic Design Report as per TEM336 Power System Analysis Guidelines for the VSD's proposed. If the accumulated harmonic distortion levels are calculated to exceed the following limits at the point of installation of the VSD's in the LV network then series reactors or other harmonic filters shall be provided by the Contractor.

- THDV exceeds 5% or
- THDI exceeds 5% or
- Individual Frequency Harmonic Distortion Voltage exceeds 3% or
- Individual Frequency Harmonic Distortion Current exceeds 3%

It is the Contractors obligation to provide a design that meets QUU's harmonic distortion limits specified. The cost of supply, installation and testing of harmonic filters shall be included in the Contractor's bid proposal as an option to be confirmed if required during detail design.

Upon completion of VSD commissioning the Contractor shall provide a record of actual harmonics recorded when the VSD's are operating over the load range, 25%, 50%, 75% and 100%. These records shall demonstrate all the harmonic conditions stated above are met at the LV bus where VSD's are connected.

6.2 Filters

A dv/dt filter shall be provided at the VSD unit where the dv/dt at the motor terminals is calculated to exceed 500V µ sec. The Contractor shall provide the dv/dt filter sizing calculation during detail design of the VSD.

The Contractor shall guarantee that nuisance tripping of upstream earth leakage protection systems shall not be attributed to the operation of the VSD for its full operating range.

Coil suppressors are to be fitted to each contactor and relay used in the VSD to eliminate electrical noise from these devices.

On VSD's where DC link reactors are used, cabling to and from the reactors shall be as short as possible and kept segregated from all other panel wiring. The current rating of cabling to and from the DC reactors is to be a minimum of 1.5 times the full load current of the VSD.

6.3 Controls, Status Indication and Software Requirements

6.3.1 Configuration General

The VSD shall be capable of being configured for the particular application in which it is used, utilising network programming protocols.

Programming of all functions shall be possible from the front panel without the use of external equipment. The VSD shall also be capable of being configured from a standard PC running the configuration software. The Contractor shall include supply of this software and any programming cables and accessories required.

The VSD shall retain the programmed settings when isolated from its power supply for maintenance purposes or in the event of a power failure.

6.3.2 Communications

The VSD shall be provided with a communications port capable of connecting to the local control system using one of the communication protocols:-

- Profinet
- Profibus
- Modbus TCP/IP
- Serial Modbus

All status and control parameters available at the VSD shall be accessible over the communications link.

6.4 Display of Running Parameters

The following shall be accessible individually via the keypad and display and also over the communications link:

- All fault indications
- Output frequency (Hz),
- Output Speed (rpm),
- Motor actual speed (rpm)
- Reference frequency (Hz),
- Output current per phase,
- Output voltage per phase,
- Power KW, KVARS,
- Power Factor
- VSD Internal Temperature
- Input signal status - run/stop/fault,
- Output signal status - run/stop/fault,
- % load and
- % torque.

6.4.1 VSD Control

Unless specified otherwise in the project documentation the VSD shall have digital inputs and outputs as follows:-

Analogue Inputs:

- 4-20 mA DC analogue input programmable for speed reference,
- 0-10 VDC analogue input programmable for speed reference

Analogue Outputs:

- 4-20 mA DC analogue output proportional to motor shaft speed,

Digital Inputs:

- run at speed reference 1,
- run at speed reference 2,
- emergency stop,
- interlock,
- forward direction select,
- reverse direction select,
- electrical fault remote reset,
- manual/auto selection.

Digital Outputs:

- VSD healthy,
- running (volt free contact),
- invertor fault (volt free contact),
- input fault (overcurrent etc.),
- output fault (motor overload etc).

The number of spare unused input and output signals shall be at least 20% of each I/O type unless specified otherwise in the Project Documentation.

6.4.2 Input Contactor

Electrical power to the VSD can be supplied by an input contactor which shall be hardwired to the following for tripping of the motor:

- Thermistor relay circuit
- Emergency Stop circuit

Note: Input contactor is not required where the VSD is provided with the safe torque off feature.

6.4.3 Speed Control

The VSD shall be capable of varying the motor speed using a local panel mounted potentiometer hardwired to the VSD as well as a remote 4-20mA

control signal. Speed reference signal shall also be provided over the network communications port on the VSD.

6.4.4 Settings

VSD shall be supplied with proprietary diagnostic and setting software developed specifically to the VSD.

The maximum and minimum operating speed shall be programmable from the front panel of the VSD.

The acceleration ramp rate from start up to the minimum speed setting shall be programmable. This setting shall not affect the acceleration and deceleration rates within the control speed range at any other time.

6.4.5 Alarms

Alarms may be integral with the monitoring and diagnostic arrangement but shall have the following minimum features:

- A remote common alarm signal (programmable by the user)
- An alarm log system indicating sequence of alarms with time stamping.

6.4.6 Fault Indications

Pre-trip information shall be able to be recalled from the VSD fault memory even in the event that the VSD loses its power supply. The following fault signals, alarms and trip indications shall be available on the digital display of the VSD and from the communication port on the VSD:-

VSD input side:

- overcurrent,
- over voltage,
- under voltage and
- supply phase failure

VSD output side:

- overcurrent,
- earth fault,
- electronic motor thermal (inverse) overload protection,
- loss of load,
- inverter overload,
- thermistor trips and
- RTD trips

VSD Internal:

- DC Bus over voltage protection (against regenerative voltages),
- DC Bus under voltage
- VSD over temperature,
- Braking resistor overheating and
- Microprocessor or CPU fault,
- Back-up battery failure.

6.5 Diagnostic Features

The VSD microprocessor on board control system shall have diagnostics capability, with memory of the last three faults (or more), available on command via the keypad as well as fault readout and remote control and interrogation capability via the communications link.

The keypad shall allow access to authorised persons only (password protected) to configure and read the following data:

- Current limit,
- Acceleration and deceleration rates,
- Hold speed settings, jump or speed range masking and any other related speed control features,
- Overload or invertor firing fault,
- Motor overload settings.

6.5.1 Access Security

Provision shall be provided to prevent normal operator access to the VSD's configurable settings and local keypad controls.

In particular, the following set points and controls shall be capable of only being accessed by authorised persons during commissioning and fault finding:-

- Minimum and maximum frequency setting,
- Acceleration and deceleration ramp rates,
- Configurable alarm point settings,
- Local (key pad) speed control,
- Local (keypad) start / stop control,
- Other parameters that can affect drive performance.

6.6 Protection

6.6.1 Configuration General

The VSD shall be fitted with all necessary internal protection to ensure safe operation of the unit.

The Contractor shall provide a list of protection settings for VSD's so that these can be verified and witnessed by QUU during the Factory Acceptance Test.

The VSD shall include provision for thermal monitoring and protection of the associated motor by monitoring the output motor current and protecting the motor against overloads. Reset of VSD faults shall be manual from the key pad as well as remote via communication link to the VSD communications port or using hardwired digital input to the VSD.

The VSD shall trip under the following fault conditions:

- Converter and inverter stage power and control circuit failure,
- Earth fault on the output,

- Output single phasing,
- Fan failure and/or high enclosure temperature.

The VSD shall be capable of being tripped via the communications link.

The Safe Torque Off feature specified in Section 6.6.7 shall be used where safety related functions are required.

6.6.2 Motor Protection

Motor protection shall be included in the VSD as follows:

- Motor current thermal overload protection
- Temperature winding high alarm and trip (RTD / thermistor)
- Stalled / Locked rotor protection
- Unbalanced current protection
- Starts per hour
- Instantaneous earth fault

6.6.3 Earth Leakage Protection

Unless specified otherwise in the Project Documentation the output of VSD shall have earth leakage protection scheme enabled.

6.6.4 Motor Thermistor Overload

The VSD shall have provision for PTC thermistor protection. A separate thermistor relay is also acceptable.

Trip reset shall be manual from the VSD front panel and remote using the communications port on the VSD.

6.6.5 Temperature Detectors

The VSD unit shall have inbuilt RTD type temperature protection and indication devices.

Unless specified otherwise in the Project Documentation the VSD unit shall also have an integrated RTD relay for direct inputs of external RTD signals from devices installed in the motor windings and bearings.

Trip resets shall be manual from the VSD front panel.

Vertically mounted motors will have RTD elements on thrust bearings.

RTD temperature elements installed in motors will be PT-100 platinum resistance type to IEC 60751 and shall incorporate 3 wire terminations at the VSD.

Where utilising an existing motor, the Contractor shall confirm compatibility of existing temperature elements with the VSD proposed and allow to replace with suitable temperature elements as required.

6.6.6 Main Isolator

Unless specified otherwise in the Project Documentation each VSD starter shall be supplied with an isolator which shall switch the incoming power supply (3 phase) and auxiliary power supplies. The status of the isolator shall be monitored by the local control system.

The isolator shall be rated to full load current of the VSD and shall be manually actuated by an external handle with the enclosure door or escutcheon closed. The operating mechanism shall be suitable for independent manual operation. The isolator unit shall be provided with padlocking facilities for padlocking the operating handle in the OFF position

The VSD shall not be damaged when the isolator is operated while VSD is operating and motor is running.

Any parts inside the VSD starter enclosure which remain live after the isolator is switched off shall be IP2X shrouded against accidental contact and shall be adequately labelled.

The enclosure or escutcheon door shall be mechanically interlocked to prevent closing the switch when the door is 'Open' or opening the door when the switch is 'Closed'. An interlock defeat mechanism shall be provided and shall be operable only by authorised personnel.

6.6.7 Safe Torque Off

Unless specified otherwise in the Project Documentation, the VSD shall support the Safe Torque Off (STO) function according to IEC 61800-5-2:2007 and IEC 62061:2005.

The STO may be used where power removal is required to prevent an unexpected start and typically only for Emergency Stop functions. The STO function shall not be used as a method of isolation to access the VSD or motor.

The Contractor shall provide the following data on the VSD Project Data Sheets:

- Probability of Dangerous Failure on Demand (PFD),
- Probability of Dangerous Failures per Hour (PFHd),
- Safe Failure Fraction (SFF),
- Hardware Fault Tolerance (HTF),

7 QUALITY ASSURANCE, INSPECTION AND TESTING

The VSD shall be manufactured to quality assurance and manufacturing standards according to AS 9001. Any deviation from the requirements of these standards shall be stated in the tender proposal.

7.1 Quality Assurance

The Contractor shall demonstrate that they operate a quality system in accordance with an internationally recognised standard. The effectiveness of the quality system and the Contractor's compliance with it shall be subject to monitoring by QUU and in addition, may be audited following an agreed period of notice.

The Contractor shall submit a quality control program for QUU review at the time of Tender. The Contractor shall provide facilities for, and cooperate with, QUU inspectors during manufacturing, assembly and testing.

7.2 Inspection and Test Plan

All materials and workmanship will be subject to progressive inspection and testing by QUU at both the Contractor's workshop and site. QUU reserves the right to reject any material, which does not comply with the specifications, set forth herein or which contain defective materials or workmanship. Rejected materials shall be promptly removed at the expense of the Contractor and shall be replaced as soon as practical at no cost to QUU.

The Contractor shall at all times provide QUU with free access to the workshop facility for the safe and convenient inspection, examination, and testing of any part of the Work, including the relevant materials and documentation.

The Contractor shall submit with their Tender, Inspection and Test Plans (ITPs), which shall define the proposed inspection and testing activities. The Contractor shall be responsible for confirmation of conformance to the ITP's.

QUU typical check sheets are provided for information and do not necessarily meet all the minimum requirements of this specification:-

- cable Pre factory inspection test sheets checklist.
- CHE305 Standard Variable Speed – Sewerage Pumping Station (FAT)

The Contractor may utilise alternative documentation for inspection and testing, however all documents shall be approved by QUU in writing before the inspection and testing tasks commence.

Refer to TMS1202 Control System Implementation Network Assets – Section 8 for minimum requirements for inspection and testing of VSD's and associated control system software.

7.3 Type Test

Type tests establishing the performance criteria of the VSD and enclosure shall be carried out in accordance with the requirements of AS 60146 and AS 3439.1.

The type test certificates may include the following tests:-

- Main electronics shall have been completely tested and configured before being installed into the completed VSD
- Short time current tests on busbars
- Temperature rise tests
- Type 2 coordination test between contactors and short circuit protection motor starters.
- Verification of making and breaking capacity
- Mechanical operation of circuit breakers, and switches

Type tests for circuit breakers and contactors shall be carried out in accordance with the relevant Australian Standards. Where type tests have been carried out previously on identical plant, copies of these test certificates may be accepted. These shall be submitted to QUU for acceptance prior to contract award.

The Type Test certificates should be held in the name of the company manufacturing the VSD panel. VSD panels manufactured to a fully type tested design shall be preferred over panels with partial type test design.

This specification details performance and construction requirements for VSD panel. Should any requirement of this specification require the Contractor to deviate from the Type Tested design, then the Contractor shall specify this in their offer. Otherwise, it will be assumed that the VSD being offered is both a Type Tested design and a design which complies with this specification.

7.4 Routine Test and Factory Acceptance Test

Routine tests in accordance with AS 60146.1.1 and other relevant Australian Standards shall be performed at a minimum except where stated otherwise in the Project Documentation.

The Contractor shall provide written notice to advise QUU within 10 business days prior to the commencement of testing so that testing may be witnessed by a representative of QUU. QUU will not attend the factory testing until the FAT Plan and supporting check sheets have been accepted by QUU.

Certified test records, consolidated in the FAT Report for each VSD panel shall be provided immediately after completion of the tests. The test records shall clearly describe the details of the tests and the test results. All supporting calculations shall be provided.

The routine and FAT shall include but not limited to the following:

- Completeness check

- Quality of the manufacture
- Checking of rating plates
- Testing of all protection devices as primary or secondary injection test
- Insulation resistance tests
- Special tests when required and mutually agreed with QUU
- Busbar systems shall be Ductor tested across all individual connections
- Dielectric tests
- Earth continuity tests
- Measure the contact resistance of the main current carrying paths including the main busbars, bus-section breakers etc. and verify acceptable values
- Primary injection to demonstrate correct ratio and polarity of CT's and correct operation of instrument and protection circuits
- Functional check of circuit breaker and switch operation and control circuits including local and manual controls and simulation of remote controls
- Functional test of all interlocking between switches and doors

Power circuits insulation shall be tested using a 1000 V 'Megger' or approved equivalent voltage test unit. Control wiring shall be tested at 500 V only.

Semiconductor equipment and sensitive electronic components shall not be voltage tested.

High current micro-ohm resistance tests shall be carried out individually on all joints in the main circuit supply including connections to each outgoing unit. For outgoing units larger than 150 A, all power connections in the outgoing unit shall be tested. Resistance measurements shall be recorded and examined for inconsistent and unusually high readings.

Acceptance by QUU of any equipment does not relieve the Contractor from any of their performance guarantees or other obligations under the Contract or purchase order.

7.5 Inspections

Equipment shall be checked against the QUU accepted design documentation to ensure that the correct type, rating and number of circuits has been installed. The design drawings shall be updated to properly reflect the finished VSD panel and copies of the drawings forwarded to QUU.

The following items shall be checked:

- sealing of fully welded seams is satisfactory;
- equipment mounting and cable supports to ensure adequate fixing and bracing;
- operating handles and interlocks for correct functioning;
- clearance and creepage distances and degrees of protection;
- doors and access covers for sealing;
- bolted and screwed connections for tightness and adequate contact;

- label text against relevant schedules.

7.6 Functional Checking

All control wiring in the VSD panel shall be checked for correct connection and marked off on the schematic drawings. The drawings shall be amended to reflect the final connections of the control panel as despatched from the workshop.

If QUU carries out spot checks of the completed panel and discovers inconsistencies with the test records or drawings provided, then the Contractor shall retest the entire VSD control panel in the presence of the QUU Representative.

All circuits shall be energised at their operating voltage and pushbuttons, and indicating lights and switches installed to fully simulate all field devices. Each feature of the circuit shall then be checked by operation of the switches and pushbuttons.

Analogue circuits shall be injected with a variable input signal equivalent to its specified input and the signal shall be varied over its entire range to test the operation of the VSD speed control and local display indicators. In the case of VSD output signals shall be monitored and the setpoints where configured checked for correct operation including the operation of any associated alarms.

Each VSD supplied shall be functionally tested with a small 3 phase motor connected and supplied by the Contractor. The VSD's shall be programmed to suit the test motor and all operating functions shall be checked with the test motor in operation. The VSD communication link and remote control and monitoring of the VSD over the network shall be fully tested. Refer to TMS1202 Control System Implementation for Network Assets for specific requirements of FAT testing the VSD control system.

At the completion of the FAT the VSD settings for the motor to be connected at site shall be programmed in the VSD by the Contractor. Parameter settings for the test motor and site motor shall be provided in the FAT Report for each VSD.

The Contractor shall provide RPEQ approved marked up red-line drawings and FAT report that contains completed test and inspection sheets within 5 business days of completing the FAT. A complete copy of the red line drawings shall be placed inside the switchboard enclosure and delivered to site with the VSD panel.

7.7 Site Acceptance Testing and Commissioning

Site inspections, site acceptance testing (SAT) and commissioning will be carried out to check the correct installation and prove the operation of the VSD control circuit, in accordance with the Contractor's recommended SAT and commissioning procedures. Where specified in the Project Documentation

the Contractor shall provide a SAT Plan, Commissioning Plan as well as supervision of the site works, which shall include but not limited to:-

- Verification of the installation work e.g. check mechanical installation, check electrical installation including all cables, terminations, identification, check external controls and interfaces.
- Perform SAT to the QUU accepted SAT Plan
- Insulation resistance tests
- Secondary injection tests
- Functional test to prove the operation of items.
- Adjust all necessary settings, e.g. VSD configuration settings
- Verify the operation of all (remote) trips, controls and output signals.

The Contractor shall submit a list of all test records and configuration settings for all parameters associated with the VSD and other equipment contained within the VSD panel.

Refer to TMS1200 Electrical Installation Specification and TMS1202 Control System Implementation for Network Assets for additional requirements for undertaking SAT and commissioning of VSD's.

On completion of the site installation of the equipment, and before the equipment has been put into regular use, QUU may repeat selected tests. Should any equipment fail any tests, the Contractor will be notified of such failure and the cost of replacements, repairs, and further SAT shall be covered by the Contractor.

The Contractor shall provide all testing of the site installation works to AS3000 and includes circuits to existing equipment fed from the new or modified switchboard. The Contractor has an obligation to advise QUU in writing of all existing circuits and equipment that does not meet AS3000 current standard, along with a certificate of conformance for the installation works completed by the Contractor.

8 Packing, Handling and Shipping

The Contractor shall be responsible for preparation for shipment including: packing, protection, preservation, labelling and marking of all items.

All test certificates shall be shipped with all lifting equipment, spreader bars, slings and shackles.

VSD starter panels shall be manufactured and tested at the factory, and shall be shipped completely assembled.

All equipment shall have been fully tested and inspected prior to packaging. No packaging activities shall commence without the prior consent of QUU. QUU shall be notified of the dates of packaging with sufficient notice to allow attendance for completion of inspection and release certificates without affecting the required delivery schedule.

No equipment shall be allowed to leave the Contractor's premises without such certificate being signed, or a written waiver issued.

Temporary storage arrangements prior to site delivery shall be provided by the Contractor and included in the Contract works. The storage location, preservation and duration of storage allowed shall be agreed prior to Contract award with QUU.

9 Documentation

9.1 Prior to Award

The Contractor shall provide the documentation specified in the Project Documentation with the Tender submission.

9.2 Documentation After Contract Award

After the award of the Contract, the Contractor shall supply the documentation specified in the Project Documentation. The VSD and associated equipment procurement and manufacture shall not commence until the design documentation has been accepted by QUU. Design services shall be performed under the supervision of an RPEQ with relevant experience in the design discipline. All documents submitted to QUU for review shall have been checked and approved for issue by an RPEQ.

9.3 Drawings

The Contractor shall submit design drawings detailing the VSD panel construction. This shall include but not limited to the following:-

- General Arrangements(internal and external)
- Single Line Diagrams
- Schematics
- Termination Diagrams
- Installation Details
- Equipment List

Where VSD panel 'Layout' drawings are issued by QUU with the Project Documentation, they shall be used as a guide only; the Contractor shall remain responsible for the detail design of the panel and shall produce workshop drawings.

Drawings shall be submitted in accordance with

- PRO307 Procedure Drafting Guidelines – Contract Requirements
- SEQ Water Supply and Sewerage Design & Construction Code (SEQ WS&S D&C Code).
- PRO395 SEQ Water Supply and Sewerage- D&C Code Asset Information QUU Addendum

9.4 Equipment Lists

An equipment list shall be provided that details the equipment type, manufacturer, model number and quantity of every item of equipment being installed in the control panel. This shall include all minor equipment such as control relays, lamps and terminals.

9.5 Label Schedule

A label schedule shall be provided for all labels indicating label text and text size as well as label overall dimensions, colour, material and fixing method.

9.6 Manuals

The contractor shall provide Operations and Maintenance (O&M) Manuals for all new equipment. This includes two (2) hard copies and one (1) electronic copy in pdf format on DVD. The O&M manual must be provides within 5 business days after the site commissioning is completed.

The Contractor shall provide the O&M manuals in compliance with SEQ Water Supply and Sewerage Design & Construction Code (SEQ WS&S D&C Code). The hard copy manuals shall be neatly presented in 2 ring binders, where hole punching is not suitable or the manual is not provided with supports the manual is to be restrained by use of document holder similar to Magi-clip DK3660 with annotated dividers separating the different sections

Loose sheets and drawings not forming part of individually bound booklets within the manual shall be protected in individual plastic pockets. A maximum of two single sided sheets shall be placed back to back in each pocket, allowing them to be read without removal from the pockets.

Each folder shall have the following identifying information on the front cover giving

- Project name,
- Switchboard Asset Tagname and Title
- Contract number and year of installation,
- Company name, address & phone number;

Electronic copy of O&M Manual shall be supplied on CD/DVD and be sorted in directories that reflect the layout provided in the hard copy manuals.

All files shall be in one of the following formats to allow QUU easily reprint portions or all of the O&M Manual.

- Adobe Acrobat (*.pdf)
- Microsoft Word (*.doc or *.docx)

- Microsoft Excel (*.xls or *.xlsx)

The following minimum information shall be provided in the O&M manuals:-

- Equipment schedule detailing the make, model and number of all separate items of equipment within the control panel. This shall describe exactly the equipment installed, including which manufacturer's options and accessories are included;
- Equipment manufacturer's maintenance information;
- Preventative maintenance schedule;
- Complete description of the VSD panel including all information shown on the rating plate;
- Details and names of equipment suppliers;
- Drawing list showing number, title and revision;
- Drawings including relevant Contract Drawings and
- List of spare parts provided
- FAT Report and
- SAT Report if site testing is included in the Contract scope or works
- VSD configuration parameter listing – hard copy and software copy showing individual parameters modified from factory default settings.

9.6.1 Generic Manuals

Vendor generic manuals shall be modified with strike thru text or highlighted text by the Contractor to indicate the actual equipment supplied and information contained in the manual must be specific to the equipment supplied.

10 Spare Parts and Special Tools

10.1 Spares

The Contractor shall provide a list of the following spares:

- Commissioning and start-up spares
- Recommended spares list for two years operation

The spares lists shall be itemised and priced with the Tender Proposal. QUU will advise the Contractor what spares will be procured.

10.2 Special Tools

The Contractor shall list and provide pricing for all necessary special tools, software licences, programming cables etc that are required to perform routine maintenance, operation and fault finding on the VSD and associated equipment with the Tender Proposal.

QUU will advise the Contractor what components will be procured.