VOLUME 3

EMPLOYER'S REQUIREMENTS

Section 5 - Electrical and SCADA Works

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5. GENERAL REQUIREMENTS FOR ELECTRICAL AND SCADA WORKS

5.1 Electrical General Requirements

5.1.1 Introduction

These requirements apply to all electrical works and equipment.

The following clauses shall specify general electrical requirements and standards of workmanship for the equipment and installations. General requirement clauses shall apply where appropriate except where particularly redefined in the individual specification clauses.

5.1.2 Electrical Power Supply

Purpose : Feeding of electrical power from the public electricity network to the RWMC

Location : Trace of the overhead power supply lines and Subotica RWMC

Drawings : Regional Waste Management Center (RWMC) - General Layout

Electrical power supply system is not provided. The provision of the power supply for the Subotica RWMC is partly in the Scope of the Delivery of this Tender. For the purpose of this Tender (both for the design and delivery) the Contractor can assume: (a) MV power connection will be realised from the connection point to the dedicated transformer substation, (b) power supply connection will be realised from the LV Switchgear Cubicles in the dedicated transformer substation (c) available power capacities will be sufficient for required power demands (d) during construction period Contractor will not have possibility to get electrical connection and he has to organize supply of electrical energy on his own.

The planned power capacity is considered sufficient for the future power demand. For all works on the power supply system, which includes works on LV connections, the Contractor shall carry out all coordination with the local electricity supply company according to the best possibility to realise the supply of electricity to the site. All costs necessary for the designing and construction (together with corresponding taxes), what includes 20kV power supply cable and installation of the high voltage equipment, measuring unit with the appropriate equipment for measuring consumption shall be included in the offer.

The power supply system will designed and built according to the technical requirements presented in Vol.3, section 2 of the present document.

5.1.2.1 Requirements for Power Supply System

After designing process line and defining ultimate power demands, the Contractor will make power supply system design for appropriate power supply of the RWMC. Provision of the reliable LV power supply in the terms of necessary reliability is under Contractor responsibilities. Contractor should respect the following requirements in regard to redundant power supply design:

1. 0.4 kV consumers within the plant are, as far as priority is concerned, divided in two groups:
    a. General consumers which should be fed by power transformer of the proper voltage & wattage, and
    b. special consumers which, in case of simultaneous distribution network failure are fed by proper power rated standby diesel generator. Contractor would

justify which consumers will be powered by this emergency diesel generator, which must include key pumping stations and sufficient oxygen to maintain a minimum biological process.

2. Consumers are directly fed from 0.4 kV main distribution switchgear in transformer substation or from 0.4 kV distribution boards, located around the plant in the vicinity of consumer groups, each group forming one functional entity
3. For RWMC power supply two transformer units in parallel should be envisaged, of which one alone shall be able to maintain the basic operations of the RWMC, until the operation of the other one is reestablished.

Status of RWMC power supply, including registration of the power energy consumption (i.e. production in the case of the power supply provision by diesel generator) has to be transferred to the Plant SCADA Station and included into system visualisation system.

5.1.3 MV Transformer Station

HV supply transformers for power supply to RWMC shall be for installation indoors and cast resin dry type, naturally air-cooled and thermal class F.

Standards:

Electrical design shall be done in line with Serbian standards and on the basis of internationally recognized standards..

The transformers for the RWMC shall comply with the requirements of relevant standards for indoor, naturally cooled types (AN) and thermal class F.

5.1.3.1 Main transformer station

For the purpose of power supply of the whole Centre, main transformer station shall be built near the eastern entrance to the Subotica RWMC. It shall contain oil transformer 20/0.4 V with rated capacity of 1,000 kVA and two additional places for the future transformers.

The transformers as well as the MV switchgear shall be able to utilize two external feeders that may change voltage during the life of the plan and therefore to operate at 10 and 20 kV.

The building shall consist of the following premises: rooms for transformers (one installed transformers and two rooms reserved for the future instalments), MV and LV distribution for Subotica RWMC, MV distribution of HEP and AKU-battery (accumulator) with switchgear. Within the construction of the reinforcement concrete floor slab in every room with transformer, openings for the pits for the oil shall be constructed. Above these pits, transformers will be placed on the stand which shall be mounted on the reinforcement concrete floor slab.

A system of auxiliary DC power supply is accommodated in a sheet metal cabinet (+DC) for wall mounting. The equipment installed in it will be as follows:

- HF rectifier 48 V, 8A
- Voltmeter for metering consumer voltage
- Signalling light, green "RAD" (in service)
- Signalling light, red "KVAR" (fault)
- ON/OFF switch for rectifier

- 2-pole automatic installation circuit breaker for rated current from 6 to 16A, rated voltage 127 V DC, with OF auxiliary contact, and C characteristic of switching off.
- Battery, four series connected and air-tight battery units, rated voltage 12 V, capacity 24 Ah.

Technical characteristics of the outdoor lighting unit:

-	Rated voltage		400/231 V
-	Rated current		150 A
-	Rated frequency		50 Hz
-	Rated short-circuit withstand current of earthing circuit	1s	2 kA
-	Mechanical protection		IP 00
-	Standards		IEC 60439-1

Electric equipment and metering equipment for electricity consumption shall be placed within the room of the MV and LV distribution. Reinforcement concrete slab shall have openings for passing of the cables.

On the facade walls of the rooms with transformers, on the side opposite of the wall where the doors will be placed, openings for the ventilations shall be constructed. They will be covered with protective bars and meshes.

Two cabinets with metering equipment shall be placed on convenient places. One will be for the purpose of measurement of the supply consumption (from the supply system) and the other will be for the measurement of the supply output (out from the landfill gas).

The dividing gadget shall be installed in the main cabinet with dividing equipment. Its purpose will be dividing the visible sections of the electric installations which will be supplied by power generator of the LV distribution network. This gadget shall be accessible for the purpose of protection from the recurrent voltage.

Power from the main transformation station shall be supplied to the following objects: area for collection and treatment of landfill gases, administration building, containers for the employees, service centre and outdoor lighting.

5.1.3.2 Rating

Transformers shall be sized for continuous operation at the maximum rating under the ambient conditions specified. Allowance shall be made for harmonics where non-linear loads (i.e. inverters) are connected.

The continuous full load rating of the transformer shall be based on the rating of the connected load whilst operating at maximum continuous output plus a margin of 10% for load growth. The peak short time rating of the connected load shall not exceed the name plate continuous rating of the transformer by more than 20%.

The transformers shall operate satisfactorily when connected to a supply with the following parameters:

Voltage variation of 6% of nominal applied voltage and frequency variation of 2.5% of nominal system frequency

Simultaneous variations of voltage and frequency shall not be in opposite directions.

The transformers shall be designed with particular attention to the suppression of harmonic voltage, especially the third and fifth, so as to eliminate wave form distortion and any possibility of high frequency disturbances reaching a magnitude as to cause interference with communication circuits.

The spare of free capacity shall be at least 20%.

5.1.3.3 Paint Requirements

The paint specification shall be suitable for the environment in which the transformer is to be located. The finish colour shall be the manufacturer's standard.

5.1.3.4 Windings

The primary windings of all transformers shall be closed delta connected. Unless specified otherwise by the Serbian Electricity Company, the winding configuration shall be Dyn5.

The secondary windings of all transformers shall be star connected with the star/neutral point brought out to the low voltage terminal box.

The star/neutral point of the secondary windings shall be solidly earthed.

5.1.3.5 Tap Changing

Off-circuit tap changing equipment shall be provided on the primary windings. Tapping range shall be ± 2½, ± 5% of the principal tapping.

The switch shall operate on all three phases and only come to rest when the switch is in full contact. The mechanism shall be of robust construction, designed against risk of damage from short circuits, and having all contact surfaces of ample area for satisfactory operation during overloads. The switch shall indicate the ratio that has been select.

A padlock facility shall be provided for locking the tap change selector in any chosen position. A padlock and one key only, shall be provided.

5.1.3.6 Enclosure and basic equipment

The transformer shall be made as three phase transformer cast under the vacuum in epoxy resin with or without enclosure (IP00 or IP30). A vacuum cast coating shall be fire resistant.

Basic Transformer shall have at least four multi-direction rollers, four lifting lugs, haulage hoels on chasses, one (two) earthed locations, HV and LV connections bars, of circuits taping links on the highest voltage side and other auxiliary equipment

5.1.3.7 Main Terminal Boxes

HT cable boxes shall be designed for dry type terminations, and shall have adequate space to permit cores of cables to cross over if required.

It shall be possible to remove the cable boxes without breaking the cable seals. The primary and secondary terminal boxes shall be provided with gland plates, to suit the HV and LV cables. Non-magnetic gland plates shall be provided where single core cables are specified. All cable entries shall be on the bottom of the terminal boxes.

5.1.3.8 Fittings and auxiliary equipment

The following fittings and auxiliary equipment shall be fitted, where applicable, to cast resin transformers:

- Winding temperature indicator fitted with alarm and trip contacts, 2 sets N/C, (to be confirmed) for both alarm and trip settings
- Auxiliary terminal/marshalling box housing all terminals for the alarm and trip contacts from winding temperature units. The terminal box shall have a degree of protection IP 54 minimum. The Contractor shall provide all cabling between trip and alarm contacts and the terminal/marshalling box

5.1.3.9 Terminal Markings

Permanent terminal markings are to be mounted on primary and secondary terminal boxes.

5.1.3.10 Identification Labels

All transformers shall be provided with a white/black/white identification label mechanically fixed to the front of the transformer. Letter minimum size shall be 15 mm.

5.1.3.11 Works Tests (FAT-factory acceptance tests)

The Engineer shall witness the works tests and notice in writing shall be given of the date set for the tests.

- 'Routine Tests' as set out in the relevant Harmonised European Standard.
- Calibration and functional checks on winding temperature and indicating thermometer.

In addition to the above routine tests the transformers shall have been subjected to a temperature rise 'Type Test' as set out in the relevant Harmonised European Standard. A copy of all test results shall be sent to the Engineer.

5.1.3.12 Site Tests (SAT-Site acceptance tests)

The Engineer shall witness site tests and at least ten days notice in writing shall be given of the date set for the tests.

Site testing of transformers after erection and prior to the connection of site cables and commissioning shall consist of the following tests (where relevant to the type and size of transformer):

- Insulation Tests of Primary and Secondary Windings
- Winding Temperature Indicator Calibration and Functional Tests (to auxiliary terminal box)
- Dielectric Tests
- High Voltage Tests on Primary and Secondary Windings with cable links disconnected

The Contractor shall provide power required for testing purposes. This may involve the provision of a portable generating set.

5.1.3.13 Test Certificates

Original test certificates together with one typed copy of each certificate shall be handed to the Engineer no later than eight days after the tests have been completed.

5.1.4 MV switch boards and switchgear

This specification covers the supply and installation of a.c. switchgear for 1.000 Volts to 10.000 Volts (rated voltage 12 kV) systems, three-phase.

5.1.4.1 Design

The equipment shall be designed for operation from the front, except where necessary for the isolation of voltage transformers where rear access is required. LV and MV compartments shall be completely segregated.

MV switchboards with switchgear shall comprise either a single unit or a suite of such units. Each unit shall be cubicle type, single bus bar, with vertical or horizontal isolation.

It shall be possible to extend the board safely by installing additional units at either end or cabling up with existing units live except when making the bus bar connections.

5.1.4.2 Ambient Conditions

Unless otherwise specified the assembly and all the equipment provided shall be capable of satisfactory operation within the temperature limits of –20 °C to 40 °C outside and +5 °C to 40 °C inside with relative humidity of 80%.

5.1.4.3 Materials

Enclosures shall be constructed of folded and welded sheet steel (2 mm thick, min 1.5 mm front panels). Suitably insulated bus bars and earth bars shall be of high-conductivity, hard drawn copper, and all other main current carrying components shall be of solid copper.

5.1.4.4 Mounting

The equipment shall be freestanding floor mounted. Fixing shall be by not less than four holding down bolts for each unit.

5.1.4.5 Working Space

Clear floor space according to the minimum local electrical regulation's request but not less than 1000 mm shall be provided all round the equipment after allowing for withdrawal of component parts and projecting operating handles. It shall be possible to close any cover after withdrawal of a truck-mounted breaker in its line of withdrawal.

5.1.4.6 Earth Connections

Each switchboard shall be equipped with a suitably fully fault rated bar running the full length of the switchboard. The bar shall be made up of sections within each cubicle, bolted together to form the complete earth bar. The busbar shall be with provision for bonding to the site cables, and a main earth terminal. The integral earthing system for each unit shall be firmly connected to the earth bar or terminal. Bolted connections shall be tinned.

5.1.4.7 Safety Shutters

Automatic, padlockable, metal safety shutters shall be provided to cover the live HV busbar and circuit spouts during isolation (when a circuit breaker, voltage transformer or contactor is withdrawn).

They shall be positively driven in each direction and padlockable in the closed position. A self-cancelling latch shall be included in each shutter mechanism for testing and maintenance purposes. Shutters shall be labelled indicating whether they are busbar or circuit shutters.

5.1.4.8 Interlocks

Comprehensive mechanical and electrical interlocks shall be provided to prevent any mal-operation.

Integral mechanical interlocks shall be provided to prevent any operation of a circuit breaker, starter, isolator or earthing mechanism that could cause danger to either the operator or the system. Provision shall be made on each circuit breaker and starter to padlock the carriage in either the isolated or earthed positions and to prevent a carriage being inserted when the withdrawn position is selected.

Where required to meet operational restrictions as defined in the Particular Requirement mechanical key interlocks shall be fitted together with any necessary key exchange boxes.

5.1.4.9 Busbars and Busbar Connections

Busbars and connections shall be manufactured from high conductivity copper, with a constant cross section throughout the switchboard and capable of carrying the design fault level current.

Busbars and connections shall be resin encapsulated, enclosed in an air insulated compartment. Access to the compartment shall be via bolted removable steel covers fitted with 'HIGH VOLTAGE' warning labels in Serbian language. Busbar joints shall be tinned, bolted and insulated by suitable moulded and resin filled shrouds or pre-moulded joint covers.

5.1.4.10 Circuit Breakers, switch disconnecters, earthing switches

Circuit breakers if designed shall be vacuum or SF6 type. Circuit breakers shall be capable of clearing any fault condition which may occur in the system without damage to equipment or personnel.

Circuit breakers of the same pattern and rating shall be interchangeable.

Circuit breakers shall be of the vertical isolation, horizontal drawout pattern, complete with carriage earthing contact. The isolating contacts shall comprise an appropriate number of individually spring loaded fingers.

Vacuum circuit breakers shall comprise separate vacuum interrupters, which are designed to prevent welding of contacts and sharp current chopping during fault interruption and switching of motor loads.

Sulphur hexafluoride (SF6) circuit breakers shall comprise an assembly of SF6 gas filled interrupters, which are designed to prevent welding of contacts and sharp current chopping during fault interruption and switching of motor loads.

Operating mechanisms shall be as: Hand charged spring with manual release.

All operating mechanisms shall have mechanical 'ON' and 'OFF' indicators and

a manual trip device fitted with means for locking. Hand charged spring mechanisms shall have mechanical indicators to show 'SPRING CHARGED' and 'SPRING DISCHARGED'.

Operating mechanisms of the hand charged spring types should be arranged so that release of the springs to close the circuit breaker can only be achieved by a deliberate action. It shall not be possible for vibration or mechanical shocks to release the charged springs. Spring operated mechanisms shall be provided with volt-free contacts to give indication that the springs are charged.

To facilitate maintenance and adjustment of contacts, it shall be possible to 'slow-close' the circuit breaker but this operation shall only be possible in the fully withdrawn position. Any necessary operating handle or lever shall be supplied.

All circuit breakers shall be provided with interlocks to ensure that:

- The circuit breaker cannot be plugged in or isolated whilst it is closed; attempted isolation shall not trip a closed circuit breaker
- The circuit breaker cannot be closed until it is fully plugged in or completely isolated
- The circuit breaker cannot be closed in the service position without completing the auxiliary circuits between the fixed and moving portions
- The circuit breaker cannot be 'slow-closed' except in the fully withdrawn position
- With hand charged spring mechanisms, the springs cannot be discharged until they have been fully removed and disconnected
- With the circuit breaker plugged into an earthing location a lockable manual device on the operating mechanism shall only affect tripping

Where mechanical key interlocking is employed, tripping of a closed circuit breaker shall not occur if any attempt is made to remove a trapped key from the mechanism.

For incoming and outgoing cubicles SF6 switch disconnecter preferably will be used with earthing switches. The switch may be in position "Closed", "Open" or "Earthed" to provide natural interlocking system preventing incorrect operation. The fast acting mechanism shall be provided to improve closing and opening of the switch and make it independent on the action of the operator. All precautions measures against accidental over-pressure of the gas shall be provided

Medium Switchgear units shall be produced and assembled according to IEC standards as following:

- 60694: Common specifications for high-voltage switchgear and control gear standards
- 62271-200: A.C. metal-enclosed switchgear and control gear for rated voltage
- above 1 kV and up to and including 52 kV
- 60265-1: High voltage switches for rated voltages above 1 kV and less or equal to 52 kV
- 62271-105: High voltage alternating current switch-fuse combinations
- 60255: Electrical relays

- 62271-100: High-voltage alternating current circuit breakers
- 62271-102: High-voltage alternating current disconnectors and earthing switches

5.1.4.11 Protective Relays

Protective relays for circuit breakers shall, unless otherwise specified, be the electronic type installed in draw-out cases mounted in an instrument cabinet above the circuit breaker on the front of the panel.

Over-current, voltage and frequency protection shall be provided obligatory while Earth Fault Protection shall be recommended.

The protection shall be inverse, extremely inverse, definite time, instantaneous, directional or non-directional as appropriate to the circuit or circuits being protected.

5.1.4.12 Current Transformers and Voltage Transformers

Current transformers and voltage transformers for protection and instrumentation shall be designed in accordance with the IEC Standard recommendations (60044-1, 60044-8) appropriate for the application or relevant European norms.

Voltage transformers (according IEC Standard 60044-2) shall be protected by h.r.c. primary fuses, and by secondary fuses in each relay and metering circuit. The secondary circuits shall be kept as short as possible and separate leads used to connect the transformer to each relay and metering burden. A means of isolation of the primary shall be included and lockable safety shutters shall cover the fixed isolating contacts when the transformer is isolated.

5.1.4.13 Voltmeters and Ammeters

A voltmeter and ammeter shall be fitted to each feeder circuit breaker arranged to monitor phase and line voltages and line currents on the load side in conjunction with selector switches. Ammeter switches shall be make-before-break type to avoid open circuits in the C.T. circuits.

5.1.4.14 Type Tests

The high voltage equipment shall be type tested by a recognised type-testing organisation and copies of the type testing certificates shall be submitted to the Engineer.

5.1.4.15 Routine Works Tests

Routine works tests and inspection shall include the following:

- Power frequency voltage withstands tests on the main circuit.
- Voltage withstands tests on control and auxiliary circuits.
- Measurement of the resistance of the main circuit.
- Mechanical operating tests.
- Any other tests necessary to demonstrate compliance with the Requirements and drawings.

5.1.4.16 Training

The Contractor shall provide training in the operation of MV Switchgear in the manufacturer's works. Further training shall be provided on site.

5.1.5 MV Substation Provisions

5.1.5.1 Notices

Clearly visible notices shall be fixed to the outside and inside of each substation giving the following information

A. External - Outside the substation the notices shall state: The name of the substation; the voltage; a warning against unauthorised entry; how to raise the alarm in case of fire; how to send for an ambulance; and who keeps the key.

B. Internal - Inside the substation the notices shall state: Electric shock instructions; a warning against working without a permit; and any other applicable routine instructions.

C. Single-line Diagram - A single-line diagram of the power distribution system shall also be provided in a glazed frame fixed to the wall of each substation.

5.1.5.2 Tool Cupboard

A wall mounted tool cupboard shall be provided, in each substation, to store all operating handles and any special attachments for testing etc.

5.1.5.3 Logbook Cupboard

A wall-mounted cupboard with a drop down writing surface shall be provided in each substation to house the substation logbook. This cupboard may be combined with the tool cupboard.

5.1.5.4 Keysafe

Two lockable keysafes shall be provided in each substation. Each shall be provided with not less than 8 hooks. Each safe shall be manufactured from steel, shall be of rigid construction to prevent being forced open, and be capable of being locked by two padlocks.

5.1.5.5 Operating Handles

One set of operating handles not integral with the switchgear shall be supplied for each substation. Each handle shall be labelled with details of the substation to which it belongs and an instruction notice prohibiting its removal shall also be provided All operating handles and instructions have to be in both Serbian and English language..

5.1.6 CE-Marking and Conformity Declaration

Each plant component as pump, blower, valve, field instrument, switchboard, machinery, etc. shall be CE-marked in accordance with relevant Application of Council directive(s) and delivered with a Declaration of Incorporation according to Application of Council directive(s) i.e.:

- 89/392/EEC and reissued as 98/37/EC (Machinery)
- 94/9/EEC (ATEX)
- 73/23/EEC modified by Directive 93/68/EEC [CE Marking] (Low Voltage)
- 89/336/EEC (EMC)

The total RWMC including separation plant, composting facilities, sewage treatment, leachate aeration and sludge treatment, together with control system such as SCADA, switchboard(s) etc. and associated field instrumentation, must comply with the regulations of the Directive on Machinery" Council Directive of June 1989 on the Approximation of the laws of the Member States relating to Machinery 89/392/EEC. The RWMC equipment must be designed and installed in accordance with relevant harmonized standards.

The Contractor shall provide for the total RWMC a common CE-mark and a Declaration of Conformity according to Application of Council directive(s): 98/37/EC and later amendments annex IIA.

Declaration of Conformity annex IIA shall furthermore include a Risk Analysis with information required for the risk evaluation, which in turn allows judgements to be made on the safety of machinery according to EN 1050 (Safety of machinery-Principles for risk assessment).

5.1.7 Installation Standards

All electrical work must be carried out by personnel in possession of a current licence acceptable to the Authority, which permit the Contractor to carry out work on low voltage equipment and cabling.

Low voltage (< 1000V) electrical equipment and installations shall be carried out in accordance with the standards of RS and requirements of:

- European norm EN 60204-1, Safety of Machinery, Electrical Equipment of Machines
- EN 60079 –10 Classification of hazardous areas
- EN 60079 – 14 Electrical installations in hazardous areas (other than mines)
- Good practice for implementing the directive 1999/92/EC (Hazardous explosive atmosphere)
- European norm EN 60439-1 and EN 60439-3 for design of switchboards
- International Electro technical Commission IEC 364 series for building installation
- European norm EN ISO 12100-1:2003 Safety of machinery - Basic concepts, general principles for design - Part 1: Basic terminology, methodology
- Serbian Electrical Standards
- Medium Voltage and High Voltage >1000V installation according to BS (British Standard) EN, IEC and local standards.

Any particular requirements of the EN or IEC standards shall take precedence to any other standards.

The Serbian competent authority shall approve all electrical equipment. Contractor is obliged to incorporate requirements of the responsible authorities into the design and to complete the works accordingly.

5.1.8 Workmanship

Particular attention shall be paid to the appearance of the electrical installation, arrangements of which shall be agreed by the Engineer before the commencement of installation. The Contractor shall ensure that the installation is completed to the highest standard and neatness with respect to the visible cable runs and the arrangement and alignment of apparatus and fittings.

The general requirements for process equipment and electrical building services are given in specific clauses but the Contractor shall determine the quantities and locations of fittings and equipment and shall prepare surveys and detailed design with installation arrangement drawings. The final locations of all building services fittings and process equipment shall be agreed at site with the Engineer before installation.

The Contractor shall arrange for the switchgear and panel manufacturers to provide skilled labour for the supervision of off-loading, placing in position on prepared foundations, erection and commissioning of all switchgear and control panels.

5.1.9 Materials

All materials incorporated in the works shall be most suitable for the duty concerned and shall be new and of first class commercial quality, free from imperfection and selected for long life and minimum maintenance.

The use of dissimilar metallic materials in contact shall be avoided, but where unavoidable these materials shall be selected so that the natural potential difference between them does not exceed 250 millivolts. Electro-plating or other treatment of contacting surfaces shall be employed as necessary to reduce the potential difference to the desired limit.

All materials and material finishes shall be selected for long life under the climatic conditions at construction site. Materials used in ventilated or air-conditioned areas shall be selected to allow for the conditions expected in case of failure of the ventilation or air-conditioning equipment.

5.1.10 Protection and Finishes

Materials or equipment in the installation shall be adequately protected against corrosion. Except in the cases of proprietary equipment for which galvanizing would not be appropriate, steelwork shall be hot dip galvanized. Damage to galvanized surfaces shall be made good. Nuts, bolts, washers or other such fasteners shall be manufactured from non corrodible materials or suitably plated to provide protection against corrosion.

Tropical grade materials and panel components shall be used wherever possible.

5.1.11 Derating due to Climatic Conditions

All electrical equipment as switchboards, control gear, panels, cables, wiring etc. shall be derated for the specified site climatic conditions in accordance with the factors of the relevant design standards.

5.1.12 Polarity

The polarity of all apparatus used for the specified Works shall be arranged as follows when viewed from the front:

- For two pole apparatus, the phase or live pole at the top (or left hand side) and the neutral or earthed pole at the bottom (or right hand side). On plug and socket outlets, the polarity shall conform to EN/IEC or other approved standards as appropriate
- For three or four pole apparatus the phases in the order L1, L2, L3 and neutral reading from top to bottom or left to right in the case of vertical and horizontal layouts respectively

Phase colours and sequence shall be to Serbian regulations.

All cable cores shall be identified with phase references.

All non-flexible cables shall be connected between main switchboards, Motor Control Centre (MCC), distribution boards, plant and accessories so that the correct sequence of phase colour is preserved throughout the system.

On building services wiring installations, where more than one phase is incorporated on a common system in one room, the live cores shall be phase identified as appropriate and fittings and switch accessories shall be permanently labelled and segregated in accordance with the relevant clauses of the EN/IEC Regulations.

5.1.13 Safety Interlocks

A complete system of electrical and mechanical interlocks and safety devices shall be provided throughout the electrical installation for the safe and continuous operation of the plant in order to ensure:

- Safety of personnel engaged in operational and maintenance work on the plant
- Safety of the personnel engaged in operational and maintenance work in hazardous explosive areas on the plant
- Correct sequence of operation of the plant during start up and shut down
- Safety of the plant when operating under normal or emergency conditions

Interlocks shall be preventive and not corrective in operation.

The safety interlocks system shall be according to "Good practice for implementing the Directive 1999/92/EC (Hazardous explosive atmosphere)" and EN 954-1 "Safety of machinery – Part 1: General principles for design"

The Contractor shall be responsible for the preparation of interlocking schemes for the approval of the Engineer.

5.1.14 Labels and labelling of the plant

Components and equipment, e.g. isolators, starters, distribution boards, junction boxes, timers, fuses, etc., shall be clearly labelled to correspond with the appropriate schematic or wiring diagram.

Labels shall be fixed to equipment prior to Tests on Completion being carried out.

Labels shall be manufactured and fixed conform following:

- Labels on the face of control panels: - 3 mm thick transparent plastic, rear engraved, the colour shall be black letters on a clear background. On control panels with dark paint finishes, the background shall be white

- Labels within control panels, and labels external to buildings: - 3 mm thick laminated plastic, engraved to give black letters on white background
- Internal labels shall be visible and shall not be obscured by panel wiring, etc. Warning labels shall be engraved to give black letters on a white background, and be preceded by the lightning flash symbol in accordance with the standard
- Labels shall be fixed with countersunk chromium plated or stainless steel screws. Self-adhesive labels will not be accepted
- Internal labels designating components shall be fixed to non-removable equipment

5.1.15 LV Switchboards and Motor Control Centres

LV (Low Voltage) switchboards and MCC (Motor Control Centres) shall as far as possible be control centres manufactured by a single approved supplier and the construction of each individual panel shall be such that all components shall be selected for standardisation.

Fully type tested designs to the fault levels specified with ASTA or KEMA certification is required.

Low voltage switchgear (distribution boards) shall be designed and constructed in compliance with IEC 439-3, and control boards (MCC) etc., shall be designed and constructed in compliance with IEC 439-1. Form 3b barriers shall be adhered to all types of boards.

Switchboards shall be positioned so that the structure or contents of the building thereto do not obstruct access. A distance of not less than 900 mm shall be provided and maintained in front of every switchboard/panel board for the purpose of safety and effective operation and adjustment of all the equipment mounted thereon.

Where a switchboard incorporates rack–out switchgear, doors or hinged panels there shall be a clearance of not less than 1200 mm between any wall or immovable structure and the switchgear, doors, or hinged panels when it is in the racked–out or in open position.

Rear access switchboards and panels shall be provided with unhinged lift–off panels only. Hinged panels will not be permitted.

All apparatus shall be positioned on a switchboard so that there is ample room for its safe and effective operation and handling.

The maximum height of any operating controls shall not exceed 1700 mm above finished floor level.

LV switchgear shall be suitable for extending at either end and arranged so that additional cubicles may be installed in position and cables only made off while the existing bus bars are not in operation. To gain access to the bus bar, for the purpose of extending, it may only be necessary to remove external end covers.

Each switchboard panel or section shall be fitted with a demountable metal cable termination gland plate positioned at vertical or horizontal level but with adequate space for termination of cables, conduits, etc. The gland steel plates shall be efficiently earthed to the panel earthing system by a separate earthing conductor. The base of the panels shall be provided with removable plates of PVC or steel type to seal the cable/conduit entry.

All switchboards shall be provided with lifting eyes, which shall be removable and replaced, at site, with chrome-plated screws.

5.1.16 Multi-Cubicle-Type Assembly

Cubicles shall be constructed of not less than 2 mm thick sheet steel and be of a totally enclosed welded construction with covers and hinged front doors interlocked as specified. Panels shall be arranged for front access only.

Low voltage switchgear and control boards and individual enclosures for installation in indoor locations shall have a minimum protection enclosure of IP54.

Cubicles shall be easily accessible for maintenance purposes. Barriers shall be included between cubicles if necessary to ensure safe maintenance on any out–going circuit when the remainder of the board is live.

Cubicles shall not rely on any removable portion for their rigidity.

All live terminals of equipment mounted on cubicle doors and/or enclosure covers shall be adequately screened unless protected by an interlocked isolator. Separate conductors shall efficiently earth all doors and hinged covers.

All terminations for out–going cables, including lighting fittings, socket outlets, etc. shall be provided with terminals. Termination at fuse switches and miniature circuit breakers will not be acceptable.

Switchboards and panel boards shall be complete with the necessary interconnections, small wiring, labels and copper bus bars, the interconnections being referenced to indicate phases, and they shall be properly earthed.

Where interconnections occur between various panels, the Contractor shall ensure that wire/terminal numbers have identical references.

5.1.17 Interlock

Interlocks shall be provided so that it is not possible to gain access without tools to any compartment containing uncovered live connections unless all such equipment inside the compartment is isolated from the supply.

Where access to low voltage enclosures is necessary with equipment energised from an external source all equipment, terminals shall be fully shrouded to prevent accidental contact and warning labels shall be fitted. Safety barrier shall have a minimum degree of enclosure IP2x.

5.1.18 Switchgear Earthing Works

Single enclosures shall be provided with an earth stud or earth bus bar. Multi- cubicle type enclosures shall be provided with a continuous earth bus bar, which shall extend over the full length. Each cubicle shall be bonded to the earth bus bar.

The earth bus bar shall be provided with two terminal assemblies for connection to the installation main earth terminal.

The short-time rating of the earth bus bar and connections shall be not less than that of the associated equipment, or the maximum through-fault current of the power source. The temperature rise of the bus bar and connections under fault conditions shall not cause damage to the connections of any equipment to which they may be connected.

Earth terminal bolts or studs shall be brass and shall not be less than 8 mm diameter.

5.1.19 Main Switches

The main switch or switches of every installation shall be marked as such and shall be identifiable from other switchgear by grouping, colouring or other suitable means, such as to render it (or them) easily located in an emergency. When there is more than one main switch in any building, each shall be marked to indicate which installation or section of the installation it controls.

In a cubicle main switchboard, the main controlling switch (or switches) shall be located in their own section, completely segregated from all other parts of the switchboard with front access.

All main switches on main switchboards (of either cubicle type or otherwise) shall be so located, that a minimum distance of 900 mm exists from the finished floor level to the bottom of the switch or connection straps, whichever is the less.

5.1.20 Distribution Sections

Distribution sections shall contain miniature circuit breaker outgoing ways for the required circuits plus approximately 20% of spare ways. Miniature Circuit Breakers (MCB's) shall be insulated moulded case, non-adjustable, magnetic and thermal tripping type. MCB's shall comply with EN/IEC standards for isolating and switching. MCB's shall have a rated current and category of duty of not less than M4 or as otherwise specified to match the fault rating of the switchgear. Back-up fuses shall be provided as required, but the ratings of the MCB's must be correctly co-ordinated with the fuse to achieve the necessary degree of fault co-ordination. Loads on distribution sections shall be balanced between the three phases as far as possible.

5.1.21 Bus bars and Bus bar Connections

All busbars and busbar connections shall be of hard drawn high conductivity copper. Busbars shall be insulated throughout their lengths by means of PVC sleeving.

Busbars shall be enclosed in a separate chamber and shall be continuous over each shipping section. Busbar compartments shall be rated for operation in the ambient conditions without forced ventilation.

Busbars and connections shall be identified by phase coding and adequately supported by suitable insulators. The whole installation shall be mechanically and electrically designed to withstand the full fault capacity. Live connections to and from busbars shall be either fully insulated or suitably screened and any covers screening the busbars and connections shall be provided with adequate warning labels. Easy access shall be available to the busbars for future connections.

All busbars and connections shall be rated for continuous operation. The dimensions of the busbar copperwork shall be of one size throughout the complete panel and the busbars shall be the same rating as the incoming supply switch unless stated otherwise in the Particular Requirement. Riser bars shall be of the same construction and be fault rated to the same level as the main busbars. The rating, supports and bracing of main connections between main circuit switching mechanisms and busbars shall be designed for operation at the same short-time withstand current rating as that specified for the busbars.

The Contractor shall provide type test certification for the busbar and primary connection short circuit withstand and thermal performance. Current transformers shall be bar type, to EN 60044-1 accuracy and output mounted on the cabling side of the ACB or MCCB.

5.1.22 Cable Boxes, Gland Plates and Terminations

The arrangement of cable boxes, gland plates and terminations shall permit easy installation. Cable gland plates shall be manufactured from sheet steel for multi-core cables and non-ferrous material for single core cables. Gland plates shall be mounted not less than 300 mm above the base of the enclosure.

Space for cabling within terminal enclosures shall be not less than that stated in EN norms. Adequate space shall be provided for the termination of oversize cables.

When the cable gland is remote from the cable terminals, purpose made cable tray or trunking shall be provided within the enclosure for securing or accommodating the cable cores.

Terminals for small low voltage power and auxiliary circuit application shall be fully insulated, and shall be of pillar type with indirect pressure plates unless otherwise approved by the Engineer.

Terminals in a common compartment associated with different voltages or circuit types shall be segregated into clearly identified groups. Barriers shall be provided between each group.

Terminals shall be provided for the connection of all cable cores and, where applicable, core screen drain wires.

Not more than one core of internal or external wiring shall be connected to a terminal. Where duplication of terminals is necessary, purpose made solid bridging links shall be fitted.

Terminals, which remain energised when the main equipment is isolated, shall be shrouded and fitted with a warning label.

5.1.23 Auxiliary Switches

Auxiliary switches for indication, protection, interlocking and supervision purposes shall be readily accessible and enclosed in a transparent dust proof cover.

Adequate secondary disconnection shall be included between the fixed portion of a circuit breaker and the moving portion.

Spare auxiliary contacts, one normally open and one normally closed, shall be provided on each unit.

5.1.24 Auxiliary Wiring and Terminal Blocks

Wiring used for internal connections shall be capable of withstanding, without deterioration, the conditions on site, due allowance being made for such temperature conditions as may arise within any enclosure.

Butyl rubber/CSP insulated cables or alternatively PVC insulated cables shall be suitably derated if necessary.

Single-strand wire shall not be used. Wires shall not be less than 1.5 mm2 total cross-sectional areas. Both ends of every wire shall be fitted with full ring interlocking ferrules of white insulating material. Letters and numbers shall read from terminal outwards and shall correspond to the appropriate wiring diagram. Crimped on terminal connectors shall be fitted to all wire ends.

Unless otherwise specified or approved, wiring may be coloured as EN 60204 and IEC 446 or as follows:

Phases:	Red, Yellow, and Blue
Neutral	Black
A.C. Control	Grey
D.C. Control	Black/White
Earth	Green/yellow

Wiring shall be supported in insulated cleats or cable trunking.

Wiring passing between cubicles, which may be separated for transport, shall be taken to terminal blocks, mounted near the top of each cubicle, separately from those for external cable connections.

The bus bar chambers of the equipment shall not be used as trunking for small wiring.

Connections to apparatus mounted on doors or between points subject to relative movement, shall be made in flexible wires, arranged so that they are subjected to torsion rather than bending.

All terminal blocks for the connection of auxiliary wiring shall comprise shrouded anti-tracking mouldings of melamine phenolic or comparable material. Terminals for auxiliary wiring shall be screw pillar type with indirect pressure plates complying to EN 60947: Part 1.

The Contractor shall submit for the Engineer's approval, samples of the types of wires, numbered ferrules, and terminal washers or lugs, if appropriate, which he proposes to use.

5.1.25 Indicating Lamps

On AC operated circuits, indicating lights shall be of low voltage type with self- contained transformers or LEDs indicator. The lamps shall operate at not greater than 90% rated voltage to ensure long life.

On DC operated circuits suitably rated resistances shall be connected across each lamp operating contact.

Lights shall be well ventilated and be designed to permit the removal of the lamp glass and lamps from the front of the unit.

Lamps units shall be of the "push to test" type to facilitate testing, or a separate "LAMP TEST" button for the whole control board/switchboard shall be installed.

5.1.26 Indicating Instruments and Meters

All indicating instruments and meters shall be flush mounted and generally of the same appearance throughout. They shall comply with relevant standards and shall be of industrial grade accuracy. They shall be sealed against the ingress of moisture and dirt.

Indicating instruments shall be of 270° scale type and shall have an external zero adjustment. They shall be positioned so that they can be easily read and the dial centres shall be not less than 400 mm and not more than 1700 mm above finished floor level. Instruments shall be fitted with an adjustable pointer or shall be inscribed on the scales to indicate the normal circuit rating for the associated circuit.

All indicating instruments shall have a square front appearance with width dimensions not less than 96 mm.

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Ammeter or kW-meters fitted in a motor winding circuit shall be provided with adjustable red pointers.

All instruments shall be mounted adjacent to the relevant circuit breaker, switch or starter, unless separate panel suites are specified herein.

At points of connection of instrument and meter potential circuits to LV bus bars, fuses shall be provided to protect the auxiliary wiring. For cubicle gear, these fuses shall be housed within the cubicle and be readily accessible. Additional fuses to clear individual instrument faults shall be provided and accessible from the front of the cubicle where specified.

5.1.27 Low Voltage Fuses

Low voltage fuse links shall be to EN 60269-2-3. A complete schedule of all fuses in the panel shall be affixed in a convenient position in the panel.

Fuse link carriers and bases shall be fully insulated and shrouded type, the design of which shall prevent contact with "live" parts while the fuse carrier is being, or has been withdrawn.

Fuse holders and bases shall be manufactured of moulded plastic. Ceramic material will not be accepted.

5.1.28 Current Transformers

Current transformers shall comply with EN 60044-1and shall be of the wound primary or bar primary type according to the ratio required. Current transformers shall be suitably rated and designed to carry out appropriate metering and protection functions as indicated.

The rated burden of current transformers shall not be less than the sum of burdens of all relays, instruments and related loads.

Unless otherwise specified current transformers shall be of Class 1 accuracy for use with measuring instruments and Class 5P for protection circuit duties.

Identification labels giving type, ratios, rating, output and serial numbers shall be fitted. Duplicate rating labels are to be fitted on the exterior of the mounting chambers suitably located to enable reading without removal of any cover. Labels shall be supplied for multi-ratio current transformers indicating the connection required for alternative ratios.

Bar type current transformers shall be supplied in preference to those with wound primaries. Current transformers short-time current ratings shall relate to the full fault level for one or three seconds as applicable and shall be not less than that of the switchgear in which they are incorporated.

Removable links shall be located on each phase of the switchboard primary conductors to enable easy current transformer maintenance and replacement.

One secondary terminal of each current transformer shall be earthed through a bolted link located in the switchgear instrument/relay panel.

5.1.29 Extra Low Voltage Supplies

Where extra low voltage supplies are required for illumination and power supplies (hand lamps, installation liable to flooding, portable hand tools, etc.) they shall be obtained via a portable step–down transformer with a 220 V primary winding and secondary winding at 24V.

5.1.30 Fault Level

Fault level shall be calculated and defined for three levels. First level will be for the main LV switchgear directly connected to the low voltage side of the transformer. Complete switchboard shall be manufactured to comply in total with a short circuit rating to calculated value in kA for duration of one second minimum.

With transformer distribution cut–out, the minimum short circuit rating for Main

Distribution Boards and MMC shall be the highest calculated value chosen between them expressed in kA and for distribution. Distribution Boards shall be not less than 10 kA.

All small wiring for controls, voltmeter supplies, etc., that originates from the main and sub–main bus bars shall be protected by means of bus bar mounted cartridge fuses suitably rated for the purpose intended. The maximum size of fuse used shall not exceed 20 amps.

5.1.31 Protection Relays

Protective relays shall be provided, for fault and overload protection, to operate circuit breakers.

The Contractor shall ensure that the form of protection proposed also meets the requirements of the project country regulations.

The Contractor shall be responsible for ensuring that all details relating to the protection systems shall be submitted to the Engineer for approval and no work shall commence until such approval has been received in writing.

An approved manufacturer shall manufacture all protective relays. They shall be suitable for climate and site conditions and fully sealed against the ingress of moisture and dirt.

Relays shall be suitably rated to operate at the specified DC auxiliary circuit voltage and shall have output contacts suitable for operation of the switchgear tripping mechanisms and associated alarm and indication systems.

Secondary injection shall be easily possible by means of purpose-made voltage and/or current plug-in type test terminal blocks which automatically open or short circuit the integral voltage transformers or current transformer respectively and provide terminations for the test supply. Disconnection of any permanent wiring will not be acceptable.

Each individual element of the relays shall incorporate a visual operation indicator, which shall be reset by operating an external reset button mounted on the front of the relay case.

Each relay shall be complete with panel mounting Works and terminals for external circuit connection. Protection relays and associated equipment shall be as detailed in the specific clauses and as determined by the Contractor.

5.1.32 Protection of Motors

Protection of motors for hazardous areas shall comply with relevant clauses of EN 60079-14.

For motors rated less than 2.0 kW, three single pole thermal overloads with phasing protection shall be provided.

For all motors rated above 2.0 kW three single poles thermal overloads and three single poles, wound magnetic adjustable overloads with phasing protection shall be provided or alternatively the motor shall be protected by a three phase motor protection relay.

The Contractor shall respect all specific requests from manufacturer of process equipment regarding protection of motors.

5.1.33 Over current and Earth Fault Protection Relays

Relays to be used for this duty shall incorporate selective Inverse Definite Minimum Time (I.D.M.T.) and Definite Time characteristics. Relays shall be arranged 2 pole over current and 1 pole earth fault or 3 pole over current and separate 1 pole earth fault to suit 3 phase 3 wire and 3 phase 4 wire system application respectively.

Inverse time characteristics shall be standard inverse or very-extreme inverse to meet the power system protection scheme requirements and shall fully comply with EN/IEC norms. Relays shall be of the static electronic pattern. Current and line settings shall be adjustable by integral switch or plug assemblies of approved pattern.

Relays shall be suitably rated to operate at the specified DC auxiliary circuit voltage and have output contacts suitable for operating the tripping mechanisms of the associated circuit breaker and initiating alarm and indication systems.

5.1.34 Direct Motor Thermal Protection

Where specified, motors shall be provided with embedded thermal switches or thermistors with a protective relay operating in the contactor circuit.

Thermistor protection on motors fitted with internal thermal devices shall be arranged such that in the event of device operation, a lock out function to prevent automatic re-start upon temperature reduction is operated. The tripped indication shall also operate.

Thermostat protection relays shall be ambient temperature compensated and have external manual reset Works.

5.1.35 Low Voltage Circuit Breakers

Circuit breakers shall be rated for controlling loads for maximum circuit operation and 400V 3 phases 50 Hz. 4 wire operation under the specified site climatic conditions.

All low voltage circuit breakers shall be housed in control boards, which comply with Particular Technical Requirements and shall not reduce the degree of protection to less than IP54.

Low voltage circuit breakers shall comply with IEC 60947-2 and UL 508 / CSA 22-2 No. 14 IEC 60664-1 IEC 60947-2, IEC 60947-2 EN 60947, shall be moulded case or open construction (metal clad casing) design.

Circuit-breakers shall be Utilisation Category B and shall have a service short- circuit breaking capacity not less than 50 percent of the rated ultimate short- circuit capacity.

Circuit-breakers shall be suitable for isolation and shall be to Over voltage Category IV to EN 60947-1

The rated current specified in the specific clauses shall be that with the circuit- breaker mounted within a switchboard. The service short circuit breaking capacity shall be not less than the maximum power system fault level.

Unless otherwise specified, air circuit-breakers shall be used for rated currents of 630A and above. Moulded case circuit breakers shall be provided where specified in the specific clauses.

Circuit breaker closing mechanisms shall be of the independent type. It shall be possible to manually charge power operated closing mechanisms. Works shall be provided for padlocking in the OFF position.

Each pole of moulded case circuit-breakers shall be fitted with a bi-metallic thermal element for inverse time delay protection and a magnetic element for short-circuit protection. The thermal element shall be adjustable. Adjustments shall be made simultaneously on all poles from a common facility. Thermal elements shall be ambient temperature compensated. Where available, the thermal magnetic elements shall be interchangeable.

Unless otherwise specified, air circuit-breakers shall be fitted with a solid state protection system. The protection system shall be fully self-contained, needing no separate power supply to operate the circuit-breaker tripping mechanism.

Accessories such as shunt trips, under-voltage releases, auxiliary contacts and motor mechanisms shall be manufactured to allow easy installation.

Closing mechanisms shall be suitable for operation at 80% of the nominal solenoid supply voltage.

Closing and tripping batteries shall comply with the relevant clauses of the Particular Technical Requirement.

Auxiliary contacts for the indication of breaker state shall be provided.

Incoming feeder circuit breaker panels shall be provided with a purpose designed, separate earthing device. The device shall be arranged to earth either the cable box or the bus bar side of the circuit breaker, and shall be stored in a suitable robust container, which shall include a permanently fixed instruction label giving details of assembly and use.

Auxiliary jumper connections, as necessary, shall be included.

5.1.36 LV Switches Disconnectors & Fuse Switches Combination Units

Switches, disconnectors, switch-disconnectors and fuse-combination units shall comply with EN 60947-3 and shall be suitable for uninterrupted duty.

Switching devices shall be suitable for isolation and shall be to over-voltage

Category IV to EN 60947-1. Unless otherwise specified, the Utilisation Category for switching devices shall be AC-23A for alternating current and DC-23A for direct current.

Operating mechanisms shall be of the independent manual type with provision for locking in the OFF position.

Fuse links for use in fuse-switch devices shall comply with relevant standards. Combination units shall be contained within a metal enclosure and shall be fitted with an earthing terminal or equivalent to enable the enclosures to be earthed irrespective of any means of connection such as is provided for attaching armouring or other metallic covering of the cable supplying the combination unit.

The enclosure shall be constructed so that the cover cannot be opened until the switch is fully opened and that when the cover is opened, a component examiner can override the interlock and operate the switch. After such operation, the cover shall be prevented from closing with the switch position indicator in a false position.

Switches and fuse switch units for switchboard installation shall be flush mounting.

Switches shall be provided with mechanical ON/OFF indicators and operating handles. Means shall be provided for locking the switch in the OFF position only.

The fuse shall either include a suitable fuse carrier or it shall be capable of isolation. If the fuse carrier is included, it shall be such that when it is being withdrawn normally or when it is completely withdrawn, the operator is completely protected from accidental contact with any live metal of its fuse link, fuse contacts and fixed contacts.

If the fuse is capable of isolation, it shall be interlocked with the switch so that isolation is complete before the fuse enclosure can be opened. In addition, the switch shall be prevented from closing while the fuse cover is open.

5.1.37 Motor Starters General

Each starter shall comply with EN 60947-4 and unless otherwise specified shall be class 12, utilization category AC3. Motor starters for hazardous areas shall comply with relevant clauses of EN 60079-14. The starter cubicles are required to form part of a motor control centre (MCC) and shall comply with the relevant clauses of EN 60439-1 for Form 3b switchboards.

The cubicles shall be easily accessible for be easily accessible for maintenance purposes and shall be damp and dustproof to IP54. Each motor starter shall be of a rating to carry the full load current of its rated duty at its most severe load conditions.

Motor starting contactors for reversing, star/delta, auto transformer, and similar shall be mechanically and electrically interlocked.

A timer system shall be provided in the control section of the cubicle (through PLC) to ensure that no two motors start simultaneously under normal operating conditions and particularly following a power failure. The timer system shall allow the duty motors to start or be started in the relevant duty sequence, prior to other motors becoming available for start. Time period between motor starting or becoming available for starting shall take into account the method of starting of the motor.

Motor starters shall have Type 2 short-circuit co-ordination. The circuit breaker, contactor and overload relay combination shall have undergone and passed all the tests specified for full Type 2 co-ordination.

All components, i.e. relays, contactors, timers, controllers, etc., shall be identified within the panel by indelible labels, mounted adjacent to the component, relating them to the schematic diagrams.

Starter sections shall be separate from the control sections where possible. Motor starters shall include the following:

1. Suitably rated lockable TP&N moulded case circuit breaker, with magnetic and thermal overload, or fuse switch, interlocked with the section door closed in both the ON and the padlocked OFF positions
2. Suitably rated direct on line or assisted starting system
3. Status monitoring and control signals as necessary for interfacing with the PLC/SCADA system
4. Anti-condensation heater, thermostat, fuse and link, controlled through auxiliary contacts of the main Contactor
5. Overload relay with single phasing and under voltage protection

6. Set of main and auxiliary terminals and a 15% spare capacity
7. Suitably rated 96 mm2 120° scale door mounted ammeter with upper scale compressed for motor starting
8. Door mounted hours run meter, non re-settable type, to 99,999.9 hours
9. Door mounted push buttons for lock off stop, start and overload reset
10. Door mounted indicating lamps for failed, running, stopped and available
11. Door mounted selector switch for hand/off/automatic control
12. Motor heater fuses and links
13. Facility in starter for automatically switching heater OFF when motor starts and ON when motor stops
14. Control supply MCB and links

Emergency switching controls, overloads and fault signals shall stop the Plant immediately and maintain the Plant in the failed state until the reset pushbutton is operated.

The types of starters for motors of various ratings shall be generally defined based on process requirements or as detailed below:

Motor Power Kw	Motor Type	Type of Starter
Up to and incl. 7.5Kw	Any	Any type appropriate to the motor and duty
Above 7.5kW and up to 30 kW	Squirrel	Star/Delta or soft start (variable speed driver)
	Wound Rotor	Rotor resistance
Over 30Kw	Squirrel Cage	Soft start (variable speed driver)
	Wound Rotor	Rotor resistance

Control Selection Switch

Unless particular requirements for selection switches are detailed in the Beneficiary's Requirements each starter shall be provided with a 'Local/Off/Remote/Auto' control selector switch. The following terminology shall apply:

LOCAL	Local to selection switch
REMOTE	Remote from selection switch
AUTO	Control from automatic controls

Manual operation shall override automatic controls except those provided for the protection of the drive.

Stop/Start push buttons shall be provided to operate Plant in Local and Remote mode.

Hours Run Counters

Hours run indicators shall be flush mounted, six digits, synchronous type.

Pushbuttons

Start pushbuttons shall only be effective in selected circuits, primarily hand control circuits.

Stop (lock off) buttons shall be effective irrespective of the position of the selection switch.

Reset button shall only operate when the fault condition has been cleared.

Starter Telemetry

For Telemetry, each starter shall provide the following signals as volt free contacts:

Motor Running Motor Failed Motor Available

Each signal shall be provided as an independent volt free change-over contact and shall be wired to a terminal strip in the control section.

Outgoing feeders

Feeder sections shall be provided with door interlocked moulded case circuit breakers.

The circuit breakers shall be complete with electronic over-current and earth fault protection. Under-voltage relays shall not be provided with these circuit breakers.

A single phase ammeter and CT's shall be provided on the dead side of each circuit breaker.

Fuses

Switchgear and fuse boards shall be fitted with fuse carriers designed to accept HRC cartridge type fuses to BS 88 class Q1, and shall be of the bolted type.

Fuses for motor circuit protection shall be to category of duty 415 AC 80.

Fully isolated fuse holders and neutral links shall be fitted inside enclosures where required and sufficient space for easy withdrawal shall be provided. Holders containing links shall be coloured white, whilst those containing fuses shall be coloured black.

Labels shall be provided giving the circuit identification and the fuse rating.

Three fuses of each rating used within the installation shall be provided as spares. These fuses shall be securely clipped on the inside of the door of the distribution board or starter section.

Direct on Line (DOL) Starters

Direct on line starters shall comply with EN 60947-4, and unless otherwise specified shall be intermittent duty class 12.

Star Delta Starters

Star delta starters shall comply with EN 60947-4, and unless otherwise specified shall be intermittent duty class 12. The utilization category shall be AC3.

Variable Speed Drives (Inverters)

The variable speed driver shall comply with IEC/EN 61800-5-1, IEC/EN 61800-3 and shall be of the AC inverter type based on the pulse width modulation principle of operation, capable of controlling the speed, torque and current of standard AC squirrel cage motors.

Inverters shall be selected to ensure that the harmonics generated within the system are within the limits allowed for the system and do not cause interference with plant or equipment connected to the system. The amount of variation of the output wave from a pure sinusoidal wave shall be such as to enable any motor driven by the inverter to be continuously operated to at least 90% of its rated output on a normal 400V 3ph supply.

Electromagnetic current compatibility is required with mains disturbance protection according to EN 61800-3 + Amendment A 11.

They shall be a six pulse solid state electronic pulse width modulated variable frequency supply system, adequately rated to have 10% reserve capacity when continuously driving the motor at the highest load. Drives rated at 100 kW and over shall as a minimum be twelve pulse types. Wherever possible, the installation and equipment shall be designed to limit or avoid harmonics as opposed to employing harmonic filtering.

Motors Protection

Protection of motors for hazardous areas shall comply with relevant clauses of EN 60079-14.

Motor starter circuits shall incorporate as a minimum a thermal overload protection relay with inherent single phasing protection. The relay shall be adjustable and shall be calibrated terms of motor full load current.

Motor protection shall be generally as detailed below; any variation to this will be detailed in the Particular Requirement.

Motor Size	Type of Protection
> 2 kW	Thermal overload relay
2 kW – 30 kW	Thermal overload relay + magnetic adjustable overload relay with phasing protection
30 kW	Full electronic monitoring and indication of faults

Auxiliary contacts shall be provided for indication, and a minimum of one set of spare volt free changeover contacts shall be included.

Overload relays shall be manually reset by means of an over current reset button, coloured red or black, mounted on the face of the starter section. This reset button shall electrically reset the overload relay

5.1.37.1

5.1.37.2 Individual Starters

Starters for hazardous areas shall comply with relevant clauses of EN 60079-14

Each individual starter shall be fed separately and advisable shall contain the following:

A. 1 No. Three Pole and neutral (T.P. & N.) externally operated fault making, load breaking isolating switch interlocked with the cubicle door with provision for using a padlock to hold it in the "OFF" position only. Isolator handles shall not be removable. The isolator shall be provided with suitable number of auxiliary contacts

B. 1 No. T.P. & N. moulded case circuit breaker

C. For DOL starting, 1 No. triple pole magnetically operated contactor with magnetic blow–outs or arc chutes and no–volt release

D. For Star–Delta Starting, 1 No. triple pole magnetically operated contactor with magnetic blow–outs or arc chutes and no–volt release

E. For Star-Delta starting, 1 No. set of magnetically operated, electrically and mechanically interlocked, star and delta contactors operating under electrical or pneumatic automatic timing devices with adjustable operating periods

The following equipment shall be provided in each starter section:

A. 1 Set Motor protection equipment

B. 1 No. Power factor correction capacitor with protective fuses

C. 1 No. Adjustable time delay relay or sequence starting (0 -10 minutes)

D. 1 No. Normally open, volt–free contacts for local and remote running indication

E. 1 No. Normally open volt–free contact for remote overload alarm indication

F. 1 No. Set of terminals for remote emergency lock-stop and remote indication lamps

The following equipment shall be mounted on the front of each starter cubicle door:

A. 1 No. Ammeter in motor circuit, fitted with suppressed scale to read motor running and starting current

B. 1 No. kW meter in motor circuit, fitted with suppressed scale to read motor running and starting power. (For motors above 15 kW)

C. 1 No. Pilot lamp "Motor in Operation" (lamp initiated by the final contactor stage)

D. 1 No. Pilot lamp "Overload Tripped". v) 1 No. Overload reset pushbutton

E. 1 No. "Off-Local-Automatic" selector switch

F. Set Stop/Start pushbuttons for operation under hand control

G. 1 Set Component labels

5.1.37.3 Inverters

The inverters shall be delivered with the newest technology including digitalized control system, menu programming, display for reading of faults and operation conditions.

The program system for the inverters shall be simple so that input of all data can take place without other equipment than the operation unit in the frequency converter. After programming of the unit, it must be locked with a code or similar.

It must be possible to read all alarms in a display or with lamps. Regardless of the type of fault that may arise, it must be possible to transmit this alarm via a joint fault signal to the

SCADA system. In the event of critical faults in inverter, motor or pump etc., the inverter must cut out.

The inverter unit shall provide a variable voltage/frequency supply to the pump set over the duty range. The inverter itself shall be built into an enclosure that meets IP2X acc. to EN 60529 with the main control panel doors open.

Inverters for hazardous areas shall comply with relevant clauses of EN 60079-4

The Contractor shall obtain from the Electricity Company the necessary written approval for the use of the equipment to be supplied and shall furnish the Engineer with copies of the data given to the Electricity Company and of the written approval received. In the event of problems in service, apparently attributable to the effects of the equipment, either on the plant or on the external electricity network, the Contractor shall provide and operate an automatic harmonic analyser to establish whether or not the equipment complies with the terms of the Electricity Supplier's approval. The Contractor shall be responsible for rectifying any shortfalls identified.

It shall be a six pulse solid state electronic pulse width modulated variable frequency supply system, adequately rated to have 10% reserve capacity when continuously driving the pump motor at the highest load.

It shall be capable of operating within the specified panel without exceeding any maximum temperatures dictated by the equipment manufacturer with ambient temperatures up to 40°C. Adequate precautions shall be taken to prevent the protective fuse devices blowing due to incoming mains supply transients.

All the components of the inverters shall be easily accessible for both test and maintenance purposes and there shall be built into the various components and circuits test facilities which either automatically indicate a failure or indicate a failure to a diagnostic test facility.

The amount of variation of the output wave from a pure sinusoidal wave shall be such as to enable any motor driven by the inverter to be continuously operated to at least 90% of its rated output on a normal 400V 3ph supply.

Electromagnetic current compatibility is required with mains disturbance protection according to EN 61800-3 + Amendment A11.

The ramp type acceleration/deceleration facility shall have a range to cover accelerating from zero to full speed variable from 0-10 sec's to 0-120 sec's with a similar facility on the deceleration range.

The inverter unit shall itself incorporate a diagnostic display for status and fault diagnostic purposes. The diagnostic display shall be readable with the compartment door closed and the isolator in the on position.

The following protection features shall be included:

- Instantaneous clearance of over-current, over-voltage, inverse time overloads and earth leakage protection for the inverter/motor
- Phase sequence indication, phase of fuse failure, and under voltage protection
- Thermal protection of power circuits from excess temperatures. Built-in adjustable over speed or over frequency protection.

The inverter shall be connected to the 400V supply by a triple pole contactor. A facility to temporarily wire the motor as a DOL starter in the event of inverter failure shall be provided. A triple pole thermal overload with single-phase protection and manual reset shall be provided.

When fan cooled units are used, the fan should run whenever the drive is in operation. This shall be achieved by interlocking the fan supply with the line contactor.

5.1.38 Actuator Starters

Where required, penstocks and valves shall be operated by means of electrically driven actuators with integral reversing starters.

Each actuator shall be fully weatherproof (IP56) and fitted with an anti-condensation heater, upper and lower limit switches and torque switches. Where actuators are installed in below ground chambers or other locations which could be flooded then the actuator enclosure shall be rated IP68 and suitable for being submerged under the maximum head of water that may occur at that particular location.

Motorized valves for hazardous areas shall comply with relevant clauses of EN 60079-14.

Each actuator shall be adequately sized to suit the application and be continuously rated to suit the modulating control required. The operating gear of all penstocks shall be capable of opening or closing the valve or gate against an unbalanced head equal to the maximum working pressure. All actuators shall have adequate torque margin to operate the valve under all conditions including seating and unseating loads and sticking after long periods of non-use.

The gearbox shall be oil or grease filled, and capable of installation in any position.

Alternative hand operation shall be possible, and the hand wheel together with a suitable reduction gearbox if necessary, shall be of adequate dimensions for easy operation by two men. The motor drive shall be automatically disengaged when under manual operation. Hand wheels shall be rotated clockwise to close the valves, and shall be clearly marked with the words "OPEN" and "CLOSE" with arrows in the appropriate directions. The rims of hand wheels shall have a smooth finish.

All actuators with the exception of rising spindle penstock actuators shall be equipped with indicators showing the position of the valve or penstock. A transparent PVC cover shall be fitted to protect the thread of the rising spindle type penstocks.

All operating spindles, gears and headstocks shall be provided with adequate points for lubrication.

The motors shall be provided with integrally housed starters and shall be sized to provide an adequate margin to prevent overloading. The motor torque rating shall be at least 10 percent greater than the maximum torque requirement of the actuator at rated voltage

The starter housing shall be fitted with contacts and terminals for power supply, remote control and remote positional indication, and shall also be fitted with internal heaters so as to provide protection against damage due to condensation. The heaters shall be switched "ON" when the starters are "OFF" and shall be switched "OFF" when the starters are "ON".

Where remote indication of valve position is required, for instance on flow control valves, then the actuator shall provide a 4-20mA signal.

Each starter shall be equipped as follows:

- Three Phase (TP) magnetically operated line contactors with no volt release and electrical and mechanical interlock (2 No.)
- TP Thermal cut out device (1 No.)
- 400/120 V, Control Circuit Transformer fully protected by fuses on primary and secondary circuits (1 No.) for remote control supply; or 400V AC to 24 V DC.
- Set of "Open", "Close" and "Stop" buttons (1 No.)
- 1 No. Local Off Remote switch with padlocking facilities (1 No.)
- 1 No. Set of Torque and limit switches for "Open" and "Close" positions (1 No.)

- Sets of Auxiliary limit switches in each direction (3 No.)
- Valve position indicator (1 No.)
- Indicating lamps indicating "open", "closed" or "in transit" (1 Set)

5.1.39 Automatic Control

The motors in some applications will be required to operate in a predetermined sequence and starters should include suitable auxiliary relays and contacts.

All starters, which are not PLC controlled, shall contain a timer, fully adjustable between 0-30 minutes, which shall only permit the drives to start in a staggered sequence on restoration of supply after an electricity supply failure.

5.1.40 Power Factor Correction Capacitors

The power factor shall be corrected to 0.95 lagging for all motors rated above 10 kW. Unless otherwise specified in Particular Technical Requirements, 3- phase unit power factor correction shall be provided for each motor circuit. On LV motor circuits the capacitors shall be housed in its respective starter compartment. Where due to space limitations the capacitors cannot be housed within the starters, they shall be installed in separate compartments adjacent to and fully interlocked with their respective starters.

The rating of capacitors shall be selected to correct the power factor of the motor when the associated drive is operating at its maximum duty point. Should the rating of the capacitor exceed 85% of the magnetising knar of the motor, it shall be switched by a separate contactor, interlocked and controlled automatically with the motor line contactor.

The capacitor(s) shall be connected after the line contactor but before the motor protection overloads, generally in accordance with the motor starter schematic diagrams.

All capacitor circuits shall have three separate protection fuses housed within the respective starter compartments.

The capacitors shall be of the oil or synthetic mineral oil impregnated type with paper or paper and plastic, film dielectric in an oil tight steel tank complete with discharge resistances. A metal enclosed terminal box with a bolted or screwed cover shall be provided with cable entry sealing Works.

A label shall be fitted on all capacitors warning that discharge resistances are fitted. All capacitors shall comply with relevant norms.

Capacitors containing polychlorinated biphenyls will not be accepted.

5.1.41 Electric Motors

Motors at 40°C ambient shall be of the squirrel cage induction type suitable for direct–on–line starting, with starting current not exceeding 6 times full load current unless specifically detailed in the relevant Section as an alternative arrangement.

Care must be taken in selecting the type of motor in relation to the starting characteristics of the driven load. Although a direct–on–line squirrel cage motor may be suitable in respect of starting current limitations, the starting torque may be insufficient and a motor of wound rotor construction (slip ring) could be required. Conversely, where a mechanical overload device is employed, it may be necessary to limit the starting torque of the motor thus ensuring the overload device can be set to give maximum protection to the plant.

All motors shall be suitable for operation at 400 Volts, 3 phases 50 Hz. supply and shall comply with EN or IEC Standards.

Motors for hazardous areas shall comply with relevant clauses of EN 60079-14

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Motor frames for indoor use shall conform to a degree of enclosure protection not less than IP54. Motor frames for outdoor use shall conform to a degree of enclosure protection not less than IP55.

Totally enclosed motors shall be provided with means of breathing and drainage.

Motor frames for submersible pumps submersible pumps shall conform to a degree of protection not less than IP68.

All motors, exclusive submersible pumps, shall be suitable for operation in the site climatic conditions and in ambient temperature up to 40°C.

The rotors shall run in ball and/or roller bearings and the weight of the rotor shall be carried by ball thrust bearings incorporated in the motor body. Bearings shall have a minimum rated life of 6 years (50,000 hours) and have provisions for adequate lubrication.

The bearing caps on the non–drive end covers of the motors shall be arranged so as to allow a speed check to be taken.

The efficiency and power factor of the motors shall be high over a wide range of load conditions and the motors shall be designed, manufactured and tested in accordance with relevant EN norms.

All continuous operations motors < 30 kW, which have operating time more than 5000 hours per year shall be energy efficient motors and fulfill the EFF1 requirements.

All windings shall have Class F insulation with Class B temperature rise limitations and this requirement is in addition to any adjustments necessary for the high ambient temperature at Site. A winding connection diagram shall be supplied permanently affixed to the inside of the terminal box or cover.

In addition to standard rating and performance data, motor nameplates shall include details of class of insulation, temperature rise and type of enclosure.

Motors shall be S4 duty type and capable of a minimum number of 15 starts per hour unless specifically detailed elsewhere in the appropriate section of the Requirements.

All motors shall be capable of developing a minimum starting torque of 150 % of the full load torque. It may be necessary, however, to limit the starting torque on some drives and this shall be achieved by the form of starter and method of starting.

The motors shall be commercially silent in operation and run free from vibration. The rotors shall be balanced both statically and dynamically and shall be tested and adjusted for dynamic balance both in an approved manner.

The site rating and normal ratings of all motors together with all performance data shall be provided to complete all the various schedules of particulars.

Terminal boxes shall be provided with glands suitable for XLPE or insulated wire armoured, PVC sheathed cable. The motor stool base, where appropriate, shall be drilled at works, vertically below the terminal box gland for the passage of the cables and the edges of the hole slightly countersunk or the hole bushed.

Termination boxes and terminals shall be of suitable dimensions to accept appropriate oversized cables in accordance with the schedules of particulars.

All motors drives shall be labelled to correspond with their respective starters. Arrangements shall be made with the manufacturer so that the Engineer may witness motor tests if so desired. Triplicate copies of motor test certificates shall be provided for approval. Additional copies shall be provided and included in the Operating and Maintenance Instructions.

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5.1.42 Emergency Stop Push Buttons

Emergency stop push buttons with mushroom heads, stay put type shall be provided adjacent to all motors as specified in EN 418 and EN 1050. Emergency switch-off for hazardous areas shall comply with relevant clauses of EN 60079-14.

Once operated the motor shall remain locked out until both the push button twist to release mechanism, and the "emergency stop reset" push button on the control panel have been operated.

The emergency stop push button shall be direct acting on the motor circuit, i.e. no intermediate devices shall be utilised.

Emergency stop push buttons shall be mounted on a suitable framework arrangement at a height of 1m and in a position to be accessible for emergency operation by the works personnel.

5.1.43 Cables, general

All cables used in the construction of the electrical installation unless otherwise specified, shall be in compliance with the relevant IEC and Serbian Standards:

Cables for hazardous areas shall comply with relevant clauses of EN 60079-14

All cables shall be of suitable voltage grade, with stranded copper conductors, selected for the climatic conditions specified and shall be derated by the approved factors laid down in the latest issue of relevant norms. The selection of all cables and derating factors shall be based on the following:

- Ground temperature
- Thermal resistivity of soil
- Cable depth LV (0.8 metres)
- Cable depth, Control and Instrumentation (0.8 metres)
- Cable grouping in accordance with the relevant tables
- Cable in air in accordance with the relevant tables

Each cable shall be of sufficient rating for its duty under normal, fault and site installation conditions. To assess the rating and cross–section required for each cable, the following factors must be considered as a minimum:

- Fault level
- Conditions of ambient temperature relevant to method of laying.
- Voltage drop
- Voltages drop in motor circuits due to the starting method.
- Over current settings of circuit breakers
- Short-circuit current settings of circuit breakers or fuses
- Disposition of cabling, whether in air, ducts or trays/ladders

Where cables are run in conduit any requirements of the EN standards must be complied with.

Where a neutral conductor is required, its cross–sectional area shall not be less than that of the phase conductors, unless otherwise specified. Each and every mains supply cable shall be provided with an individual earth continuity conductor (PE), which shall be not less than that of the phase conductors, unless otherwise specified. The PE conductor can either be

one core of a multicore cable or a separately run; PVC insulated (yellow–green) stranded single core cable sized in accordance with the EN standards. The use of cable armouring, conduits, water or other service pipes as the only means of an earth continuity path is strictly prohibited.

Each cable shall be supplied in lengths suitable for a continuous run, as no through joints will be permitted in any cable run without the prior consent and written permission from the Engineer.

Prior to dispatch to site, the supplier shall pass to the Engineer, in triplicate, copies of the cable manufacturers test certificates for approval.

5.1.43.1 LV Cables

All LV power cables shall be of the thermoplastic insulated type of either polyvinyl chloride (PVC) or cross linked polythene (XLPE). These shall Conformity according to Application of Council LV directive(s): and manufactured in accordance with Cenelec HD 603 and IEC 60332-1. They shall be of 600/1000V grade and comprise stranded copper conductor, PVC or XLPE insulated with suitable bedding, steel wire armoured and sheathed overall with extruded PVC. Where single core mains cables are to be installed these shall be provided with aluminium strip wire armouring. All LV cables shall be from an approved manufacturer.

Steel wire armouring is required for underground cables.

5.1.43.2 Small Wiring

Small wiring cables for use on power, lighting, ventilation etc. shall be 600/1000V grade and a minimum conductor size of not less than 1.5 mm2 cross sectional area. All conductors shall be stranded. Steel wire armouring is required for underground cables.

The cables shall manufactured in accordance with Cenelec and Conformity according to Application of Council LV directive(s)

Low voltage, 600/1000V power cables shall be plain annealed copper conductors with XLPE insulation, bedding tape, SWA or aluminium armour and PVC outer sheath, complying with standards IEC 60227, IEC 60245, IEC 60287 and IEC 60502. Where non-armoured power cables are provided, they must be mechanically protected by means of rigid or flexible metallic conduits.

A as long as a TN-S earthing system will be provided for the whole plant, power cables shall be 5 wires or 4+1 wires type.

The cross-sectional area of the neutral conductor (N) shall not be less than that of the phase conductors, unless otherwise specified. Power cables shall be provided with an individual earth continuity conductor (PE), which shall be the same as the phase conductors, or less according the calculation results, but not less than half of the phase cross section. The PE conductor can either be one core of a multicore cable or a separately run, PVC insulated (yellow-green) stranded single core cable sized in accordance with the EN standards. The use of cable armouring, conduits, water or other service pipes as the only means of an earth continuity path is strictly prohibited.

Lighting, heating and small power cables for internal installations shall be PVC insulated stranded copper conductors, run in conduit, trunking or other suitable means of mechanical protection.

Lighting, heating and small power cables for external installations shall be stranded copper conductors with XLPE insulation, SWA and PVC over heath complying with IEC 60502.

Fire alarm circuits shall be run in MI cable. MI cable shall have stranded copper conductors, copper outer sheath and red coloured PVC over sheath.

Unless otherwise specified by the equipment manufacturer, signal cables shall be PVC/SWA/PVC multi-pair cables. Conductors shall be single strand 0.9 mm diameter. An overall screen shall be provided.

5.1.43.3 Control and Instrumentation Cables

Control and instrumentation site cables shall be shielded and have polyethylene or PVC insulation. These shall be manufactured in accordance with Cenelec and Conformity according to Application of Council LV directive(s)

Each cable shall have its individual cores identified along their entire length by permanently printed numerals or letters. At every point of termination, core identification shall be carried out using an approved system of ferrule markers. At points of interconnection of wiring at which a change of numbering is unavoidable double ferrules shall be provided on each wire.

Any change of numbering shall be recorded on the wiring diagrams of the equipment at which the change is made.

Where it is proposed to use junction boxes for the marshalling of control and instrumentation cables to a common item of equipment, etc., any such junction box shall be of the wall mounting type, purpose made, complete with double terminal blocks of the pressure plate pattern.

All incoming wires shall be identified with core ferrules in accordance with the system schematic and cable diagrams. Prior to the installation of any junction box, the Contractor shall submit to the Engineer full details of the box and proposals for its use and only commence installation on the receipt of written approval from the Engineer.

Steel wire armouring is required for underground cables.

5.1.44 Cabling Method for Electrical Power

Every cable shall be installed in accordance with the relevant codes of practice and shall be neatly run in all situations.

When more than one cable is to be terminated at an item of equipment, particular care should be taken to ensure that cables to that equipment are routed from a common direction and each is terminated in an orderly and symmetrical fashion. Its cable number, as noted within the schedules shall permanently identify each and every cable at each end. The identification label shall be of adequate size and style to a pattern approved by the Engineer and shall be securely fixed to its relative cable.

Where cables enter or leave structures or panel plinths, the ducts shall be sealed at the points of entry or exit. Caulking shall be carried out with an approved compound and followed by not less than 40 mm of epoxy resin, two mix–cold waterproof compounds or a weak sand/cement mixture as directed by the Engineer. This shall include any spare ducts. The Contractor shall be responsible for temporarily sealing all cable ducts into structures during the installation stage to prevent accidental flooding of the structures.

During caulking care should be taken to ensure that the serving and/or armouring of any cable is not damaged.

In the event of any armouring or serving fault being made it will be the responsibility of the Contractor to repair or make good any such fault to the satisfaction of the Engineer. Where any such fault occurs, these shall be made known to the Engineer and subsequently recorded on the final record drawings.

All power cables shall be connected to switchboards and the like, in such a manner that the correct phase sequence, phase number and colour coding are preserved throughout the systems.

The PVC and XLPE insulated LV cables shall have their cores identified, as follows:

No.1 Phase	as	L1
No.2 Phase	as	L2
No.3 Phase	as	L3
Neutral	as	Blue or N
Earth	as	Green or Green/Yellow

Single core power cables shall have their cores identified as follows:

Phase	as	Brown
Neutral	as	Blue
Earth	as	Green or Green/Yellow

All cable conductors shall be terminated in suitable copper lugs or brass thimbles using an approved compression tool.

Under no circumstances shall the use of hand crimpers be permitted.

All cables shall be delivered on robust cable drums which shall bear the full details of manufacturer, size, length and insulation and shall be offered to the Engineer for inspection prior to installation.

Straight through joints will not be permitted except where a route length is in excess of a maximum drum length in which case the Engineer is to be notified.

At the terminals of rotating machines, each cable core shall have core ferrules to match the notation of each connection terminal of each machine.

Wherever it is required to remove the PVC sheath of a cable e.g. at a point of termination, the minimum length necessary shall be removed and the exposed conductor, sheath or armouring shall be adequately covered by an adhesive PVC tape or a PVC sleeve.

All LV cables whilst on their drums shall be adequately sealed at each end against the ingress of moisture. When a cable is cut from a length on a drum the drum length shall be immediately sealed. All cables once cut and laid shall be terminated in their final position or effectively sealed. All cables shall be drawn from the top of its drum, which shall be jacked and positioned for easy draw off in relation to its final position of installation. Where a long length of cable is drawn from its drum, cable rollers or skid boards shall be used.

The general routing of cables shall be as generally indicated on the Contract drawings but the final routes shall be those agreed with the Engineer prior to any cable installation work being carried out. All cables shall be installed in strict accordance with the Requirements.

5.1.45 Cable Trench Work

The Contractor shall prepare drawings giving the exact requirements for all cable trenches, detailing the width and depth of each trench and detailing road crossing cable ductwork to be provided. The drawings shall be prepared in conjunction with the Engineer and shall be approved in writing before issue to site.

The laying of all cables shall satisfy the following requirements:

- Cable depths shall be assessed from the finished ground level unless otherwise directed by the Engineer.
- Before laying in cables the Contractor shall inspect the trench works to ensure that the trench bottom is of a smooth and firm contour and free from broken stones or rocks.
- Cable bedding within the trenches shall be formed by a 75 mm sand layer.
- Cables shall be laid with adequate separation and shall be "snaked" to avoid tension during backfilling operations and subsequent settlement.
- Before sanding and backfilling, all laid cables shall be inspected by the Engineer and a further inspection made following sanding and tiling.
- After cables have been laid, they shall be covered by a further 75 mm of sand which shall be well tamped around the cables.
- After sanding, concrete cable covers and red warning tapes shall be placed as required.
- The Contractor shall ensure that cable covers are undisturbed and that large rocks, stones and the like are eliminated from backfill spoil.

5.1.46 Cable Tray Work

The Contractor shall supply and erect all required cable tray work.

The following points are to be taken into account in selecting routes for cable trays:

- Number of drive, power and control cables to be located on each cable tray.
- Separate cable tray works for machinery (EN 60204-1) and building installations (IEC 364)
- The avoidance of existing pipe works and pipe works required for future extensions.
- The avoidance of maintenance areas of machinery, pipes, etc.
- The avoidance of unnecessarily long runs of cable.
- Tray runs to be at high level as far as possible with droppers to plant items.
- The tray to be arranged vertically as far as possible.

The cable tray shall be manufactured from heavy duty, hot dip galvanized mild steel complete with approved type fixings and installed in accordance with manufacturer's instructions to permit maximum expansion.

Support brackets shall be constructed from galvanized steel, heavy-duty type, and installed at a maximum of 1 200 mm centres. Fixings of these brackets will depend on the tray loading.

Bends, tees and junction pieces shall be of standard design and have an inside radius of not less than 300 mm.

The trays shall be of adequate width for cables to be laid flat and not bunched.

All cables shall be saddled or cleated in position as they are installed along the route.

Cables on vertical trays shall be securely fixed at 600 mm maximum spacing. Cables on horizontal trays shall be fixed at suitable intervals to ensure a neat and orderly installation.

Particular care should be taken on vertically rising tray work, and adequate cable fixings shall be supplied to ensure security and distribution of load.

5.1.47 Cables installation

Cables shall be installed in accordance with manufacturer's recommendations.

Cables shall be installed in continuous lengths between definite terminal points. Joints shall not be allowed without the written approval of the Engineer.

Cables shall be installed using cable tray, cable cleats or in ducts.

Cables with PVC insulation or outer sheath shall not be installed in the proximity of polystyrene materials.

Segregation of cables in trenches, on cable trays, in conduit, in trunking, or in ducts shall be in accordance with IEC 61537. Particular attention shall be taken to ensure the correct segregation of intrinsically safe circuits.

Cables shall be installed using an adequate labour force together with drum jacks and cable rollers. Mechanical means of pulling cables shall not be used unless a torque limiting device is fitted.

Every cable shall be installed in accordance with the relevant codes of practice and shall be neatly run in all situations.

When more than one cable is to be terminated at an item of equipment, particular care should be taken to ensure that cables to that equipment are routed from a common direction and each is terminated in an orderly and symmetrical fashion. Its cable number, as noted within the schedules shall permanently identify each and every cable at each end.

Where cables enter or leave structures or panel plinths, the ducts shall be sealed at the points of entry or exit.

In the event of any armouring or serving fault being made it will be the responsibility of the Contractor to repair or make good any such fault to the satisfaction of the Engineer. Where any such fault occurs, these shall be made known to the Engineer and subsequently recorded on the final record drawings.

All power cables shall be connected to switchboards and the like, in such a manner that the correct phase sequence, phase number and colour coding are preserved throughout the systems.

Straight through joints will not be permitted except where a route length is in excess of a maximum drum length in which case the Engineer is to be notified.

At the terminals of rotating machines, each cable core shall have core ferrules to match the notation of each connection terminal of each machine.

Wherever it is required to remove the PVC sheath of a cable e.g. at a point of termination, the minimum length necessary shall be removed and the exposed conductor, sheath or armouring shall be adequately covered by an adhesive PVC tape or a PVC sleeve.

5.1.48 Cable Supports

Cables, except those laid in ground, run in horizontal cable troughs or in ducts, shall be firmly supported and fixed.

Cables clipped to cable trays shall be supported at intervals not exceeding 500mm. Cable cleats shall be installed at distances as recommended by the manufacturer.

Single runs of PVC armoured cables shall be supported using PVC cable clips. Multi-cable runs of PVC armoured cables shall be fixed onto heavy gauge galvanized steel cable trays and supporting steelwork.

Non armoured PVC cables shall be installed in conduits or trunking.

5.1.49 Cables identification

Cables and cable cores shall be identified at both ends by means of sleeve bands bearing the cable/core reference number which shall relate to the reference number shown on the drawings. Where multiple cables are laid in troughs, ducts, clipped on tray over long runs through several rooms in buildings, or laid in ground close together, intermediate markings to identify specific cables shall be applied.

Where cables are installed in ducts, the cables shall be identified with the cable reference number within each cable draw chamber.

The identification label shall be of adequate size and style to a pattern approved by the Engineer and shall be securely fixed to its relative cable.

5.1.50 Building Services

5.1.50.1 Builders Work

The Contractor shall be required to mark out all necessary holes and chases in the course of carrying out the installation and be responsible for the correct positioning of all fixings. All cutting away and grouting in of fixings in brick and concrete work and the making good shall be carried out by the Contractor. The Contractor shall arrange for the general requirements necessary for the electrical installation such as floor ducts, chases, etc., to be carried out at various stages of building work to ensure continuity of construction. In all cases the Contractor shall drill and plug walls, ceilings, floors, etc., and provide any special fixings for securing conduits, cables, etc.

5.1.50.2 Conduit Systems

Approved conduit systems shall be rigid steel conduits with metric threads and for flexible steel conduit and adaptors, as appropriate. All rigid steel conduit and fittings shall be screwed and hot dip galvanized, inside and outside.

In all plant buildings and structures, conduit shall be fixed to the surface of the wall or concealed in the floor screed when they cross the floor. Conduit shall be concealed in those locations where the wall or ceiling finishes as shown on the drawings or detailed in specific clauses make this possible.

All conduits shall be installed in an approved manner and arranged with adequate ventilation and drainage where necessary. Where practicable, all bends or sets, shall be formed in the conduit itself. Inaccessible junction boxes shall not be used.

The whole of the conduit system shall be completely swapped through to remove any loose matter or dirt before cables are drawn in. Where conduits connect to switch boxes, draw-in boxes, etc., the conduits must have a machined faced socket, screwed on to the end which when tightened, is flush with the outside of the box. The conduit is then to be secured to the apparatus by means of a hexagon smooth bore brass bush screwed from the inside of the apparatus into the conduit socket, in order to make a sound and tight mechanical joint. Conduits secured by locknuts in plain drilled holes will not be permitted.

All exposed threads shall be cold galvanized after installation.

Surface run conduits shall be supported at intervals in accordance with the following schedule:

Size	Interval
20 mm	1.2 m
25 mm	2.0 m
30 mm	2.5 m

Where bends and sets occur in the conduit run, the conduit shall be securely fastened at a distance of 250 mm on either side of the diversion.

Standard junction or adaptable boxes shall be provided at all junctions and at sharp changes of direction, in addition to any special positions where they are called for by the Engineer. Steel or malleable cast iron inspection couplers may be used in long runs to facilitate drawing in cables.

Only continuous lengths of buried conduit shall be installed between boxes, no joint boxes being allowed in the floor screeds. Conduits crossing expansion joints shall be fitted with couplings of approved manufacture, with an earthing clip at each side of the coupling, connected by the correct size of tinned copper stranded wire.

The ends of conduits laid or set in formwork prior to concreting, shall be temporarily sealed off with a coupler and a solid brass plug.

Installations of conduits shall be made on the exterior surface of buildings shall be done only after acceptance of the Engineer.

Fixing to surfaces of walls shall be by means of spacer bar saddles securely fixed by screws. Where conduits are concealed or laid in construction floors they shall be held in position with substantial fixings of make and pattern approved by the Engineer.

Conduit shall be of the screwed pattern galvanized by the hot dip process. All conduit fittings not carrying accessories shall be supplied with flat covers, fixed in position with round head brass screws. Each fitting shall be supplied with a neoprene gasket.

Adaptable boxes shall be constructed of minimum 3 mm sheet steel or best quality cast iron, finished as previously detailed for conduit fittings and sized to prevent the undue packing of cables.

Weatherproof boxes and accessories shall be used outdoors and where indicated in the Requirements.

Conduit shall be installed such as to permit complete rewiring, without the need to carry out builders works. No single conduit serving single phase socket outlets, lighting points and switches shall contain more than one phase.

5.1.50.3 Flexible Conduits

Where the conduit system terminates at any equipment requiring a non–rigid connection, a flexible conduit shall be installed of the PVC or PVC sheathed metallic type, fully watertight with purpose made connection adaptors.

Each flexible connection shall include not less than 400 mm length of flexible conduit.

5.1.50.4 Lighting Switches

Indoor surface switches shall be of minimum enclosure standard IP44. Where appropriate, they shall be of the multiple phase type and where possible shall be arranged in multi–gang boxes.

Outdoor lighting switches shall be of minimum enclosure standard IP54. Rear entry shall be provided to allow concealed conduit installation.

Switches for flush mounting shall comply with Serbian standards. Switches controlling fittings in toilets, washrooms, bathrooms, etc., shall be suitable for ceiling mounting, pull cord operated or shall be in accordance with this clause and installed outside the rooms.

Special care shall be taken to ensure that all switches are securely fixed, truly vertical and that flush mounted switches are flush with the wall finish so that the overlapping cover plates seat on to the rims of the boxes.

5.1.50.5 Lighting Fittings

Lighting fittings shall be complete with all supports, suspensions, flexible cables, pendants and plugs. They shall be connected to the main circuit wiring with flexible cables of a minimum conductor size of 1.5 mm2 insulated with silicon rubber or PVC.

Break joint rings shall be used in conjunction with batten holders, ceiling roses or back plates mounted on to a flush installation.

Standard fluorescent lighting fittings shall have two suspension fixing points. All lamp holders for flexible pendants shall be of the all-insulated skirted pattern with cord grips suitable for batten or wall mounting and shall be of similar pattern. All lamp holders shall be of the Edison screw pattern.

All fluorescent tubes shall be of an approved manufacture and standard white. They shall be suitable for the lighting fittings in which they are installed and of correct voltage.

Lighting which is not performed with standard fluorescent lamps shall be done with compact fluorescent lights (CLF) and should have the European Energy Label rating of A.

The Contractor shall supply and install all lamps for the entire lighting fitting installation, and shall replace all burned out lamps up to the time that the Engineer takes final acceptance of the Works. The Engineer shall approve the lighting layouts and fittings.

5.1.50.6 Socket Outlets

Socket outlets for installation in plant areas shall be manufactured by an approved manufacturer and in accordance with relevant Serbian Standards. Casings shall be produced from a thermoplastic material suitable for industrial application.

230 Volt sockets, shall be non–switched, 10 amp, 2 pole & PE and IP 54

400 Volt sockets shall be switched, mechanically interlocked, 16 amp, 3 pole and neutral and PE Protection enclosure IP54.

5.1.50.7 Control Cabinets

Where local starter panels are called for, each shall be provided with a fully metal or reinforced glass fibre construction cabinet. The cabinets shall be adequately sized to house the respective panels and be provided with front opening, hinged, lockable, access doors. Back panels shall be of a durable material. The base of the cabinet shall be complete with a gland plate and the necessary ventilation devices. Construction shall be to a minimum of IP54.

5.1.50.8 Distribution Boards

All distribution boards shall be of totally enclosed, metal clad pattern, manufactured in accordance with EN 60439-3.

The enclosure shall be made from zinc coated mild steel sheet formed to a clean line and complete with a lockable hinged cover with gasket. Removable plates with conduit knockouts shall be provided at top and bottom.

The maximum height of any operating controls shall not exceed 1700 mm above finished floor level.

All distribution boards shall be complete with an isolator of the rating and phase as the fuse switch at the supply source.

Doors shall be fitted with suitable gaskets and shall be easily removable to preserve the finish and simplify installation. Each distribution board shall be arranged for top or bottom cable entry and shall be provided with ample cable termination plate and chamber, to enable

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cables to be neatly glanded with tails grouped and terminated on to the appropriate internal terminations.

Distribution boards shall be wall or floor mounted and shall, when specified, incorporate on-load incoming supply switch disconnectors complying with EN 60947-1 which shall be of the front-of-panel operated type, with an "ON/OFF" indicator and capable of being padlocked in the "OFF" position. Distribution boards shall incorporate cartridge fuses, or combinations of single pole and neutral and triple pole miniature circuit breakers.

Miniature circuit breakers (M.C.B.'s) shall comply with relevant EN or IEC norms. They shall be fitted with thermal overload and instantaneous magnetic short circuit protection. Earth leakage protection, when specified, shall be current operated

Back-up fuses shall be fitted to provide the specified rupturing capacity, but the ratings of the M.C.B.'s must be correctly co-ordinated with the fuse rating to achieve the necessary degree of discrimination.

Each bank of M.C.B.'s/fuses shall be clearly identified with its appropriate phase reference/code, and the mounting framework for the banks of M.C.B.'s/fuses shall be easily removable to simplify installation. Adequate phase barriers and shields shall be fitted to ensure that after installation and wiring, all bare terminals and wires are covered, to prevent accidental contact with live conductors during the normal procedure of fuse changing and resetting of M.C.B.'s.

All neutral bars shall have a separate terminal for each fuse way within the distribution boards.

5.1.51 Earthing general

The metal framework of all electrical and associated equipment, exposed building steelwork, metal enclosures and associated screenings, supports, doors and any other metalwork that is not normally used to conduct electricity shall be effectively earthed at all times. Particular care shall be taken where moving parts are involved that they are earthed in any normal position, e.g., circuit breaker carriage, cubicle or substation door. A suitable flexible connection shall be provided for continuity between each and every moving parts.

5.1.51.1 Earthing Systems

Generally earthing system shall be formed by zinc coated laid in the building foundation and connected to the reinforcement by welding.

A main earth terminal bar shall be provided for each earthing system of each section of the power system or building installation to which all main earth conductors, earthing leads, neutral earth connections, switchboard earth bars, frame earths, and electrode nests, etc. shall be connected. Connections shall be readily accessible for test purposes.

Each main earth terminal bar shall comprise a wall mounted mild steel channel supported on non-ceramic insulators and of a length to accommodate all connections.

Earthing and equipotential bonding conductors of each earthing installation shall be a ring or radial system and shall be adequately sized for maximum fault current and the minimum cross section requirements of main earthing systems shall be 25 mm².

The armour wires on main cables shall be solidly bonded and earthed to provide additional earth paths. Particular care shall be taken on cable termination boxes, to ensure that the cable armour is adequately bonded to the associated item or plant.

Particular care shall be taken to ensure earth continuity across items of equipment situated within a cable run. Should the design of such equipment not give an adequate and lasting continuity through its structural body, then additional earthing clamps and conductors shall be provided to independently bond the cable sheaths together.

Joints and terminal boxes in underground cables (if approved by the Engineer) shall be bridged by tinned copper of adequate cross section, bonded to the cable sheath.

Earthing systems shall be performed according to IEC 60364 and the Serbian norms.

5.1.51.2 Protection of Earthing Systems

The complete earthing system shall be protected against damage by corrosion where necessary.

5.1.52 Lightning Protection

5.1.52.1 Structures and Buildings

All structures and buildings shall be provided with lightning protection in accordance with relevant EN/IEC Standards as IEC 61024, IEC 61312-1 and the Serbian Standards.

The design of lightning protection for hazardous areas shall comply with relevant clauses of EN 60079-14. Each structure shall be provided with one or more lightning arresters mounted at the highest point.

Lightning conductors shall be routed as directly as possible avoiding acute bends. The installation shall generally comply with the requirements for earthing conductor installation.

5.1.52.2 Lightning Protection Devices for Plants

The Contractor shall provide lightning and surge protection devices in accordance with relevant Serbian Standards and IEC 60664-1. This shall ensure isolation and automatic resetting of the parts of the system being subjected to high surge currents devices shall be un-fused.

Lightning protection shall be selected to provide the highest degree of protection possible, for the circuit being protected, i.e. the clamp voltage shall be the lowest possible commensurate with normal operation of the circuit.

Each lightning protection unit shall be earthed to an individual earth electrode, as directly as possible, without inductive loops and equipotential bonding to the nearest earth reference bar. A single unjointed earth cable shall be utilized.

Individual lightning protection units shall bolt directly onto a lightning earth bus bar. Cables and cores containing the circuits to be protected shall not be looped or grouped together until the circuits subject to induced lightning energy have passed through the protection units.

Where two or more lightning protection units are mounted on the same DIN rail mounted earth bar, the earth cable shall be sized as follows:

a) Cable length less than 6 metres - 10 mm^2

b) Cable length greater than 6 metres - 16 mm^2

The whole assembly shall be mounted inside an insulated box, if not already mounted separately from other equipment, close to the chosen earth termination in order to achieve a short, straight connection.

Lightning protection units which are mounted in an enclosure supplied with an ac electrical power supply which utilize DIN rail mounted earth bars shall have the earth bars insulated by means of a proprietary standoff, or the DIN rail insulated in an approved manner from the electrical power earth or any earthed conducting surface.

The route for the earth conductor system shall be as far away as possible from the vicinity of signal- and LV cables.

The earth conductor shall be copper, no smaller than 16 mm² in section, and its route shall be as short and direct as possible, in any case no longer than 10 metres. The cable run shall be straight, but any bends that are necessary shall have a long radius.

The Engineer shall approve the earth termination and the method of connection.

5.1.52.3 Earth Electrodes

The Contractor could provide an earth electrode system in some cases where lightning protection unit, Motor Control Centre, control board, distribution board etc. provides for the facility of lightning surge diversion equipment. If applied the system shall be equipotential bonding to the main protective conductor system at the common point of connection of the distribution system, which it serves.

Earth electrode systems shall be provided where specified in the particular requirements. Where lightning protection is specified to be provided, the Contractor shall provide an earth electrode system in full accordance with the relevant code of practice.

5.1.52.4 Earth Electrode Installations

Earth electrode installations shall connect earthing conductors to the general mass of the earth. The installation shall comprise earth rods, mesh or a combination in order to obtain the required earth electrode resistance.

Earth rods shall be of proprietary manufacture 16 mm outer diameter, made up of sections of 1.2 metres long with internal screw and socket joints and fitted with a hardened steel tip and driving cap. They shall be driven into the ground to a minimum depth of 2.4 metres.

The Contractor shall for each main earthing system provide a minimum of two earth rods or other electrode, and the conductor brought back to the main earth bus bar for each.

Connections to the electrodes shall be made as to be easily accessible for periodic inspection and shall be protected against mechanical damage and corrosion. The actual connection to the earth rod shall be by means of a purpose made non-ferrous clamp and shall be made below ground level, in a concrete inspection pit, having a removable cover.

When the installation has been completed, soil resistivity or other tests shall be carried out and witnessed by the Engineer, in order to ensure that the required earth loop impedance figure of less than 5 ohms is attained.

5.1.53 Uninterruptible Power Supplies

Uninterruptible power supplies (U.P.S.) shall be provided for equipment which does not have intrinsic back-up when loss of power supply would cause an unacceptable level of corruption of important electronically stored data, disruption of process control programmes or damage to electronic components.

A U.P.S. shall, where practicable, be used when environmental considerations preclude the use of a standby generator.

Where standby generation has been provided to prevent loss of electronically stored data, disruption of process control programmes or damage to electronic components, such equipment shall be further protected by provision of a U.P.S. between the generator and the equipment to absorb supply variations.

All U.P.S. systems shall be supplied at 230V, and shall have an output voltage of 230V. The Rated Output and Duration shall be as detailed in the Particular Requirements. One side of the output shall be connected to earth. Fuses or MCB's shall protect the output.

There shall be a synchronous changeover from mains to the U.P.S. in the event of a mains failure.

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The U.P.S. shall be housed in a wall mounted or floor standing enclosure and shall have a degree of protection to IP54. The enclosure shall have a door interlocked isolator. The following instrumentation shall be provided:-

I) Input Volts

II) Input Current

III) Output Volts

IV) Output Current

V) Output Frequency

All battery terminals and wiring shall be fully protected and segregated from other wiring to prevent inadvertent short circuits.

It shall be possible to maintain the U.P.S. in complete safety without shutting down the works.

When designing an U.P.S. preference should be given, where possible, to systems that do not utilise lead acid batteries and cadmium containing batteries..

5.1.54 Labels

All external and internal labels shall be engraved multi-layered plastic affixed with chrome plated screws.

Each switchboard, control panel, distribution board, compartment door, etc., shall have a title label and each door mounted component or control shall have a function label.

Every internal component shall be identified and each fuse shall be labelled with identification, fuse type, fuse current.

Compartments with doors not interlocked to an isolator or removable covers having access to live parts shall have an external label affixed thereto: - "DANGER LIVE TERMINALS" - black letters on a yellow background.

A list of label inscriptions shall be submitted to the Engineer for approval before manufacture.

Notwithstanding that wording of labels and notices and suchlike in this Section is written in English, all danger and warning labels throughout the Works shall be provided in both the Serbian and English.

5.2 Standby Generator

Purpose : Emergency power supply to key elements of the RWMC, and for maintaining basic operations and safety conditions, during interruption of public electricity supply

Location : Energy Block and Main LV Distribution

5.2.1 Generator

The standby generator shall be a diesel engine generator set standby rated. The generator shall be sized based on site conditions detailed in the particular specification. System voltage of 400 Volts AC, three phase, four-wire, 50 hertz.
The generator shall be sized for maximum voltage drops on motor starts.
Voltage regulation shall be +/- 1.0 percent for any constant load between no load and rated load.

Frequency regulation shall be ISO-synchronous from steady state no load to steady state rated load. Random frequency variation with any steady load from no load to full load shall not exceed plus or minus 0.25 %.

The engine-generator set shall be mounted on a heavy duty steel base to maintain alignment between components with bonded rubber anti-vibration pads, positioned between the engine and alternator support feet and the baseplate or between the baseplate and the floor. The base plate shall incorporate an integral sump tray sized to take the full lubricant and coolant volume of the generator plus 10 %. The sump tray shall have two float switches, one to shut down the generator and the other to close the solenoid valves on the fuel tank outlet should a high level in the sump be detected.

The base shall incorporate a battery tray with holding down clamps.

5.2.2 Engine

The engine shall be a multi-cylinder water-cooled industrial 4-cycle diesel engine. Running speed shall not exceed 1,500 rpm. The rating of the engine at its minimum tolerance level shall be sufficient to drive the alternator and all its accessories.
The engine shall have the ability to cold start, without any preheat, when ambient temperatures are 0°C. The engine shall be chiefly supplied with:

- Close control electronic governor;
- An engine driven, mechanical, positive displacement fuel pump;
- Fuel filter with replaceable spin-on canister element;
- Full flow lubrication oil filters with replaceable spin-on canister elements and dipstick oil level indicator;
- Replaceable dry element air cleaner with restriction indicator;
- Fuel solenoid, energized to run;
- Skid-mounted radiator and cooling system rated for full load operation in 40 °C ambient as measured at the generator air inlet. The radiator shall be provided with a duct adapter flange. The equipment supplier shall fill the cooling system with a non-alcohol based antifreeze mixture, containing corrosion inhibitors;
- Rotating parts shall be guarded against accidental contact in accordance with CE requirements;
- Thermostatically controlled water jacket heater, which is automatically turned off when the engine is running;
- An electric starter capable of three complete cranking cycles without overheating;
- Positive displacement, mechanical, full pressure, lubrication oil pump;
- Flexible and fixed supply and return fuel lines to and from the fuel and day tank;
- Engine mounted battery charging alternator, 37 ampere minimum, and solid-state voltage regulator. The alternator/regulator shall be charge rate sensitive.

The engine, in conjunction with the control gear shall provide automatic shutdown in the event of:

- High cooling water temperature;
- Low lubricating oil pressure;
- Generator overload/earth fault/phase failure;
- Engine failure;
- Engine failed to start (initiated after 3 attempts);
- Engine overspeed;
- Frequency change (low to high);
- Fire valve operation.

It shall also be fitted with oil pressure and coolant temperature gauges.
In the event of a shutdown occurring as a result of any of the items listed in the preceding paragraph, a fault lamp relevant to the fault shall be illuminated. The lamp shall remain illuminated and restarting shall be inhibited until remedial works have been implemented and the control system reset. Text displays are also acceptable.
The engine shall be supplied with the correct quantity and grade of lubricating oils and antifreeze solution, with corrosion inhibitors, for protection at temperatures down to minus 50 °C. The thermostatically controlled water jacket heater shall operate on 220 volts, 1 Phase, 50 Hz. The Contractor shall include all costs for connection to the mains supply.
The engine starting system shall be 12 or 24 volts. Heavy-duty low maintenance batteries shall be supplied with the engine. The batteries shall be complete with fully shrouded terminals. The starting system provided shall be capable of permitting a minimum of 3 x 20 second cranking periods to the engine after the batteries and engine have stood for a 24 hour period at a temperature of 0 °C, with the engine heating system inoperative.
All drain points for lubricant and coolant shall be extended for easy access and positioned so that drainage may be carried out easily into a container with a minimum height of 200 mm.

5.2.3 Alternator

The alternator shall be synchronous; four pole, revolving field, brushless, self exciting, self regulated. The voltage shall be 400 volt, 3 phase, 4 wire, 50 Hz, star connected. The alternator shall have a minimum protection index of IP 23. It shall be air cooled by a direct drive centrifugal blower fan, and directly connected to the engine with a flexible drive disc.
Radio interference suppression shall be provided. The system shall comply with the Electromagnetic Compatibility Directive 89/336/EEC.
The stator windings shall be two thirds pitches to reduce the production of harmonics and shall be adequately braced and supported to prevent distortion or movement by short circuit faults, motor starting, load acceptance etc.
All insulation system components shall meet the temperature limits for class H temperature rise. The alternator shall be chosen so that the temperature rise is no greater than class F limits under continuous maximum site loads.
A solid-state automatic voltage regulator shall maintain the terminal voltage. Alternator voltage output shall be within the limits specified.
The generator shall be capable of delivering rated output (kVA) at rated frequency and power factor, at any voltage not more than 5 percent above or below rated voltage.
The terminal box shall be easily accessed. Adequate clearance shall be allowed for the installation and removal of phase and neutral conductors. The requirement to remove other equipment to gain access to the terminal box will not be accepted.
The Generator Set Main Circuit Breaker shall be supplied with a 3 pole main circuit breaker: set-mounted and wired, moulded case type with electronic trip unit for overcurrent and earth fault protection.

5.2.4 Control Panel

An enclosed control panel shall be mounted on the generator set with vibration isolators. The generator set mounted control panel shall include the following features and functions:
Three-position control switch labelled RUN / OFF / AUTO.

In the RUN position the generator set shall manually start, and accelerate to rated speed and voltage.

In the OFF position the generator set shall immediately stop, bypassing all time delays. This position is also used to clear a fault and allow restarting the generator set after it has shut down for any fault condition.

In the AUTO position the generator set shall be ready to accept a signal from a remote device to start and accelerate to rated speed and voltage.

Generator Set AC Output Metering:
The generator set shall be provided with a metering set with the following features and functions:

- Analogue AC Voltmeter, dual range, 90-degree scale, 1.5% accuracy.
- Three No. Analogue AC Ammeter, dual range, 90 degree scale, 1.5% accuracy;
- Analogue frequency/RPM meter, *45-65* Hz, 1350-1950 RPM, 90-degree scale, +/- 6% accuracy.
- Seven position phase selector switch, with OFF position, to allow meter display of voltage in each generator phase.

Digital meters are acceptable in place of analogue.

Generator Set Alarm and Status Display:

The generator set shall be provided with alarm and status indicating lamps to indicate existing alarm and shutdown conditions. The lamp condition shall be clearly apparent under bright room lighting conditions.

The generator set control shall indicate the existence of the following alarm and shutdown conditions on the display panel:

- Low oil pressure (shutdown);
- High coolant temperature (shutdown);
- Low coolant level (shutdown);
- Emergency stop operated (shutdown);
- Overspeed / overfrequency (shutdown);
- Battery charge alternator failed (alarm);
- Underspeed / underfrequency (shutdown);
- Set failed to start (shutdown);
- Low fuel level (shutdown).

Engine Status Monitoring:

The following devices shall be provided on the generator set control panel:

- Engine oil pressure gauge;
- Engine coolant temperature gauge;
- Number of hours of operation (hours);
- Battery voltage (DC volts).

Control Functions:

The control system provided shall include a cycle cranking system, which shall be for 3 cranking periods of 20 seconds each, with 10 second rest period between cranking periods. Fail to start shall be indicated by operation of the appropriate alarm indication lamp.

The control system shall include an engine governor control, which functions to provide steady state frequency regulation as noted elsewhere in this specification.

Alternator Control Functions:

- The generator set shall include an automatic voltage regulation system, which is matched and tested with the governing system provided.
- Voltage adjusting potentiometer, to adjust voltage +1- 5% from rated value;
- Control system including an earth fault-monitoring relay;

- Control Interfaces for Remote Monitoring;
- Common alarm contact set to indicate existence of any alarm or shutdown condition on the generator set.
- One set of changeover contacts to indicate generator set is ready to load. The contacts shall operate when voltage and frequency are greater than 90 % of rated condition.

5.2.5 Battery Charger

A two-rate 230 Volt, 1 phase, 50 Hz battery charging system shall be provided with the generator. The following criteria shall apply:

- Constant potential trickle charge output to maintain the battery in a fully charged condition.
- A boost charge facility.
- The Charger shall be able to recharge a fully discharged battery in 24 hours.
- The Charger shall be charge rate sensitive and suitable for permanent connection to the battery.
- The charger may be wall mounted or incorporated into the generator control panel.

5.2.6 Earthing

The star point of the alternator shall be connected, via an accessible bolted test link, to the chassis and all other exposed conductive parts of the standby generator. All exposed conductive parts of the standby generator shall be connected to the main earthing terminal using a main equipotential bond. The standby generator shall be additionally connected to a separate earth electrode system, if applied.

5.2.7 Telemetry

The following volt free telemetry signals shall be made available.

DESCRIPTION	SIGNAL
Generator	Running
Generator	Start Failure
Generator Engine	Low oil pressure
Generator Engine	Overspeed
Generator Engine	Common Fault Alarm
Generator Engine	High temperature
Battery Charger	Faulty
Battery	Low Voltage
Generator	Auto Selected
Generator	Manual Selected
Fire Valve	Operated

5.2.8 Fuel Supply

A bulk fuel oil storage tank shall be provided and installed. The tank shall incorporate an integral sump. The sump shall be covered but will allow access for inspection. No drain shall be provided from the sump. The sump shall be sized for a minimum of 110% of the tank contents. The tank must be pressure tested before installation.

The bulk storage tank and all associated pipework shall be installed above ground. All pipework shall be wrapped in Denso tape to provide insulation and retard corrosion.
A vent must be installed on the tank to relieve the air pressure created by filling the tank as well as preventing a vacuum within the tank when fuel is consumed. The vent must terminate within the sump.

The fuel delivery line shall be adequately sized to allow for any friction losses between the bulk fuel storage tank and the generator and shall be kept as short as possible. It should be no smaller than the fitting sizes on the generator and for long runs or extremely low ambient temperatures the size shall be increased to ensure adequate flow. The feed to the generator shall be by gravity. The delivery line shall incorporate a water separator.
The tank shall be of mild steel welded construction suitable for the storage of fuel oil.
The fuel tank and integral pipework shall allow for differential movement upon filling between the tank and sump.
The fuel storage tank shall be provided, but not limited to, with the following:

- Pump to be used to pump the tank empty and for periodic removal of water/sludge.
- Level switch for overfill alarm.
- Level switch for low level alarm.
- Level switch for low low level cut off

All valves and connections shall be clearly and permanently labelled and shall be within the sumped area. The overfill switch shall have an audible alarm located at the tank filling point.
The fuel lines shall be of any fuel compatible material and of sufficient strength .The tank shall be fitted with the following:

- Hydrostatic contents gauge, scaled in liters, complete with isolating valve for maintenance;
- 80 mm ventilation pipe terminating within the sump;
- 2 inch filling line extended to the base of the tank fitted with a 2 inch BSP parallel threaded filling connection point with a brass threaded end cap, including lockable isolation ball valve;
- Spill return connection point at the top of the tank;
- Fuel draw off point complete with isolation valve, 25 micron inline filter and two normally closed solenoid valves in series. The solenoid valves shall close on set shut down or sump alarm. The draw off point shall be 50 mm above the bottom of the tank.
- No drain connection shall be provided on the tank.

An emptying connection shall be provided on the top of the tank, with an internal pipe made from copper or galvanized steel down to just above the base of the tank. Fuel lines shall provide dual containment and be provided with water and sedimentation traps in addition to generator filters. The containment shall be sealed at the generator end and open into the bulk tank sump. Fuel lines shall be kept as short as possible and shall be lagged and trace heated. The fuel return line/vent pipe from the generator shall be of the same material as the delivery line and shall enter at the top of bulk fuel storage tank and contain no shut off valves. This line shall be installed with a minimum amount of bends or dips to prevent an air lock forming in the system.
The fuel delivery line shall be connected to the fuel draw connection at the bottom of the bulk fuel storage tank. Flexible fuel lines shall be used to make final connections between the fuel delivery line and the generator to avoid any potential damage that could be created by vibration. All connections shall be threaded; clips or clamps shall not be used.

5.2.9 Fire Protection

A dead-weight fire valve shall be installed in the fuel line where it enters the generator building/enclosure. The fire valve shall be operated by fusible links over the alternator and engine. All necessary pulleys and tensioning springs to interface with the fire valve shall be supplied and installed. In the event of a fusible link melting the fuel supply to the generator shall be isolated, the engine shall shut down and a signal shall be generated providing volt-free contacts to the telemetry system.

5.2.10 Exhaust System

The selection, sizing and fixing on site of all sections comprising the exhaust system, including the silencers, shall be suitable for the installation and duty specified. A flexible connection shall be provided where the exhaust system interconnects with the engine.
Bend radii in an exhaust pipe should be a minimum of 1.5 times the inside diameter. The exhaust pipe should be routed in a path offering the least amount of turns or bends to keep back pressure to a minimum.

All pipes shall be well supported and springs or other dampers are to be used at points of high vibration. Due to heat radiation from the exhaust pipes, all pipes should be located a minimum of 250 mm from combustible material. At points where the piping passes through a wall or roof a metal thimble guard larger in diameter than the exhaust must be installed.
The outlet of the exhaust shall be cut off at a 30-45 degree angle and provided with an open mesh grill to prevent birds or vermin entering. An exhaust pressure actuated rainflap shall be used on vertical outlet pipes.

The level or height at which the outlet is situated should be sufficient to prevent fumes and odours from becoming an annoyance or potential hazard.
Long sections of piping shall include water legs and drain traps at their lowest points so that water does not reach either the silencer or engine. A slight slope downward from the silencer to the water leg or drain trap shall be added to ensure the proper removal of water.
Long piping runs shall be divided into sections separated by additional flexible connections. Any insulation material used for a flexible connection shall allow for the expansion and contraction of the connections due to temperature changes.
The exhaust system shall be designed to reduce noise levels to less than that specified in the tender documents.

Where the system is within the confines of the building 50 mm thickness mineral wool thermal insulation with aluminium cladding shall be applied to the pipework and silencers
Where any part of the exhaust system can be touched during normal operational conditions adequate lagging/insulation shall be supplied and installed to prevent bums.

5.2.11 Diesel Unit Housing

5.2.11.1 Diesel Generator Room

Emergency diesel generator and its engine will be placed in the power block building. The indicative position of the power block building is shown on the RWMC Layout Drawing DWG 5.3, position 29. Design requirements are given in Volume 3, Section 4. The building elements shall be suitably reinforced to prevent mechanical damage and shall be of rigid construction, comprising thermally insulated, fire retardant walls.
All panels used in the construction shall be joined using stainless steel bolts and the joints sealed with a non-biodegradable mastic sealer.
Doors shall open outwards and be provided with panic bars and door stays. Door fittings shall be stainless steel. Door locks will be free issued to the Contractor.
The generator room shall be sufficiently large to provide 1 meter of clear space around the generator and in front of any control panel door.
The generator room shall be adequately ventilated. All necessary louvers shall be supplied for the ventilation and airflow through the radiator. The louvers shall incorporate mesh to prevent the access of animals or birds. The louvers shall be weatherproof and if specified on the Technical Schedule include a system that will automatically open the louvers when the generator starts and close after generator shuts down, otherwise louvers shall be permanently open. Radiator air should not be depended on to move the louver vanes. Louver free area shall not be less than 65% of the total area of the opening and the overall size shall be matched to the airflow requirements of the engine when operating at full load condition.

Where required to meet the external noise levels specified, air inlet and discharge acoustic attenuators shall be provided suitable for mounting to the weather louvers. The attenuators shall be designed to meet the airflow requirements of the generating set at the ambient conditions specified.
A fire retardant flexible connection shall be installed between the engine radiator and the discharge attenuator/louver as required to prevent the recirculation of cooling air within the plant room.
The Contractor shall supply and install the following equipment in the generator room:

- Fluorescent lighting to provide illumination to a minimum level of 300 Lux.
- One wall mounted 3 kW fan assisted heater complete with a tamperproof electronic thermostat, temperature range 0~25 C. A tamperproof electronic timer with adjustable time ranges to provide heat for a pre-set period. The timer to be manually initiated. The timer shall incorporate "ON" and "OFF" push buttons together with a status indicator. A frost override is not required.
- 2 no. 13 Amp 2 gang switched socket outlets each protected with 30 mA RCCD.
- Emergency battery backed lighting shall be provided for safe egress only.
- Electrical services within the generator room shall be enclosed in heavy duty high impact plastic conduit or cable trunking. All fittings shall be metal clad pattern. The final position of all equipment to be approved before manufacture.
- The generator room shall be designed so that the generator can be removed with the room in position

5.3 Lighting

5.3.1 Indoor lighting installation

5.3.1.1 General

The illumination levels for working lighting inside the buildings and outdoor shall be according to the relevant standards. Voltage drop shall be less than 4%.

The evacuation lighting will be carried in the areas such as stairs, corridors etc. according to the relevant standards.

All lighting will mainly be carried with fluorescent fittings. The degree of protection for the fittings will be:

- in process rooms IP 44
- in technical rooms IP 34
- in aggressive rooms IP 65 or Ex-protected when needed

Types and models of the lighting fittings and lamps shall be approved by the Engineer.

Connection boxes for light installations must be codes in accordance with the feeder code.

5.3.1.2 Lighting equipment

Shop drawings and product data

Submit certified copies of photometric test data for each luminaire type. Photometric data to include total input watts, candlepower summary, candlepower distribution, zoned lumen summary, luminaire efficiency, coefficient of utilization table, lamp type, ballast type and manufacturer, and lumen rating.

Ballasts

Fluorescent ballast: energy efficient type, electronic.

- Rating: 50 Hz, voltage as indicated, rapid start lamps.
- Totally encased and designed for -15 to 50°C ambient temperature.
- Power factor: higher than 96%.
- Capacitor: thermally protected.
- Thermal protection: non-resettable on coil.
- Harmonics: 25% maximum THD including 49th for electromagnetic ballasts.
- Ballast Factor: greater than 0.90.
- Sound rated: Class A.
- Mounting: integral with luminaire.

Metal halide ballast.

- Rating: voltage as indicated, for use with 1-400 W or 1-250 W metal halide lamp.
- Totally encased and designed for 40 °C ambient temperature.
- Power factor: minimum 95 % with 95 % of rated lamp lumens.
- Type: constant wattage auto-transformer.
- Input voltage range: plus or minus 10 % of nominal.
- Minimum starting temperature: minus 29 °C at 90 % line voltage.
- Crest factor: 1.8 maximum current, 2.0 maximum voltage.

5.3.1.3 Execution

Install lighting fixtures.

Provide supports for lighting fixtures as detailed, as specified or as otherwise required by luminaire specified. Provide concrete inserts at points of luminaire support in unfinished areas where a concrete slab serves as ceiling.

Align lighting fixtures in rows, maintain heights and install lighting fixtures clear of other work.

Keep lighting fixtures covered and protected from construction dust and debris until building is broom clean and free of suspended dust clouds.

Do not install lamp in lighting fixtures until ready for testing and use. Obtain Engineer's approval before instalment of lamps.

When installation is complete, demonstrate operation to satisfaction of the Engineer.

Do not mount luminaire above pipes, ducts or equipment. In event of unavoidable tight locations, provide hangers to clear obstructions. Check layouts of other trades on job and plan cooperatively. Lighting fixtures in any room shall hang at one height. Obtain approval before any changes are made to layouts shown.

Provide steel luminaire studs, brackets and hangers. Where lighting fixtures are hung on chain hangers, provide chain of closed link type capable of supporting ten times luminaire weight. Use U-bolts for chain ends; S hooks are not acceptable.

5.3.2 Outdoor lighting installation

5.3.2.1 Standards

All equipment would be specified in this text is needing produced from the manufacturer which would be guaranteed the standardization of operational parameters and maintenance parameters , the spare parts and additional service and favour.

5.3.2.2 Products

Poles

Tabular Fe poles, height 12 m, anticorrosive protection with hot galvanization.

Lighting fixtures

Lighting fixtures with lamp Na VT 150 W.

Cables

Copper conductor with 1 kV PVC protection - Cu rope with cross-section 50 mm2.

5.3.2.3 Execution

Install poles according to the final design documentation.

Install lighting fixtures

- lighting fixtures with lamp Na VT 150 W on poles height ~~12~~ 10 m.

Install cables according to the final design documentation.

- Supply cable must be with copper conductors, with insulation and PVC armouring, nominal 1 kV current (according to the IEC 502 norm). Next to the supply cable, approximate ~~50~~ 16 mm2 cross-section copper rope or approximate 25 mm2 aluminium rope for ground is laid.
- Cable ends shall be equipped with cable head and prongs. To draw the cable into the structures, PVC pipes of 100 mm diameter and 2 m length shall be laid.
- Supply cable is laid directly into the excavated trench at the 80 cm depth. When the trench has been excavated, the cable is bedded into the 10 cm thick, fine sand or earth cradle, and covered by a 10 cm thick sand layer, first PVC band is laid on.
- Excavation material is then tamped in 20 cm layers. Second PVC warning band is placed at 20 cm depth from the terrain level. During cable laying, particular care shall be taken that permitted curve radius is not exceeded. Cable is bedded in the wavy manner into the trench in order to avoid later strains due to warming up or ground shifts. Therefore, the cable length should exceed the route length it is bedded in by approx. 1%.
- According to regulations, conducting of the low-current cable parallel to the telecommunication cable is allowed with 50 cm distance in between. In case lower distance is adopted, low-current cable is placed into iron pipes, and telecommunication cable into concrete ones.
- As a rule, crossing is executed under the 90° angle, but it can also be under a smaller angle which, however, must not be under 45°. Vertical distance between LV and TC cables at crossings is minimum 30 cm. LV cable is placed into an iron pipe, 2-3 m long and TC cable into a concrete pipe which is usually under the LV cable.
- LV cable running parallel to the water supply shall be at 50 cm distance. In case this distance cannot be achieved, cable must be placed into a concrete pipe. Passage across water flows is conducted by means of 3 m long pipes so that vertical distance is minimum 30 cm.

- LV cable running parallel to the sewer is conducted so that cable distance from sewer manhole cover midpoint shall be 2 m. Sewer crossing shall be executed in 3 m long concrete pipes, with 30 cm vertical spacing.
- Since cables have plastic insulation, temperature at which they are bedded shall be taken into account. It must not be lower than +5°C. In case bedding is done at lower temperatures, cables need be warmed up with agreement and approval by the Engineer.

Install wiring in the poles.

5.4 Instrumentation, Monitoring and Control

5.4.1 Introduction

This Section define the general requirements and standards of workmanship for the manufacture, supply, installation and commissioning of all instrumentation, monitoring and control equipment (excluding switchgear and motor control centres) and shall be applicable to these Works unless stated to the contrary in the Specific Requirements.

Where components or equipment forming part of the instrumentation, monitoring and control installation are not defined by Clauses in this Section, then the requirements of Particular Technical Requirements shall apply. Nonetheless the Contractor shall supply Plant that is fully operational.

The requirements of previous Sections shall, where appropriate, apply to all aspects of Instrumentation, Monitoring and Control.

5.4.2 Contractor's Responsibility

The Contractor shall be responsible for:

- all aspects of design, application and, where applicable, subsequent operation of the equipment, monitoring facilities and control circuits in accordance with the Requirements,
- liaison between sub-Contractors to ensure complete compatibility of all equipment at both component and system interface levels,
- overall systems engineering to ensure that all equipment, components and systems together form a consistent, rational and fully integrated instrumentation, monitoring and control installation,
- ensuring that each system is handed over complete in all detail and in perfect working order,
- the supply and installation of all components including signal isolators, amplifiers, converters, filters, line/equipment protection devices, voltage stabilisers, inverters, power supplies and similar items which may be necessary to achieve the correct functions as specified in the application clauses and to provide a safe and reliable installation; whether or not such items are specifically called for in the Requirements,
- protection on all relevant circuits and equipment against the effects of lightning and other induced voltages.
- the supply and installation of all interlocks, alarms and other facilities as the Engineer, may consider necessary to ensure safe and efficient operation ensure safe and efficient operation whether or not such items are specifically called for in the Requirements.

The approval by the Engineer of any drawing shall not absolve the Contractor from complete design responsibility.

5.4.3 General Design Requirements

The equipment shall be guaranteed suitable for operation under the prevailing environmental conditions and shall be designed:

- such that routine and occasional maintenance throughout its life shall be a practical minimum, compatible with the preservation of maximum reliability,
- to withstand the electrical, mechanical, thermal and atmospheric stresses to which it may be subjected under operational conditions, without deterioration or failure, and constructed to the highest available standards of manufacture, reliability, accuracy and repeatability.
- The design shall comply with the relevant clauses of EN 60204-1 and EN 60079-14
- Where more than one component or item of equipment is supplied to perform a particular function, all such items shall be identical and interchangeable.

The degree of protection for all equipment enclosures shall be in accordance with EN 60529 as follows:

- IP54 for indoor applications,
- IP65 for outdoor applications,
- IP68 for transducers, transmitters etc. and other equipment mounted within valve or meter chambers or similar locations (potentially submersible).

All equipment cabinets shall have lockable doors and any ventilation openings or louvres shall have effective dust filters. Any cooling fans shall have fan failure alarm contacts connected into the relevant alarm system.

External equipment shall be protected from direct sunlight by a well-ventilated cabinet, canopy or other approved type of sunshade.

Equipment in air conditioned locations shall be rated for continuous operation in ambient temperature up to 45°C.

External equipment and internal equipment not in air conditioned locations shall be rated for continuous operation over the ambient temperature range 0 °C to 50 °C. The above temperatures make no allowance for local temperature rises due to operation of the equipment itself or by adjacent equipment.

All equipment shall be protected against aggressive and/or corrosive environment.

All instruments shall be installed in the locations shown on the Contractor's drawings and where connections are to be made into pipelines, each installation shall be complete with the necessary manifolds, isolating valves, drain valves, test points, sample cocks, etc., as appropriate. In all cases it shall be possible to isolate and remove the instrument, and fit check gauges, or take samples as appropriate.

All analogue transmitters, receivers and direct wire transmission systems shall have a signal level of 0/4 – 20 mA or 0 –10 V.

All panel indicator lamps shall have a lamp test facility.

5.4.4 Installation Approval

Where there is no detail in the Requirements or associated drawings regarding the exact location or method of installation of measuring equipment, sensors, or other site mounted equipment, the Contractor shall submit details of his proposed installation to the Engineer for approval and obtain this approval before starting any installation work.

5.4.5 Testing and Commissioning

All equipment, including panels, consoles, pillars and all separate items shall be subject to inspection and full function test at the manufacturer's works. All equipment, sequences, programs and the like shall be proved and demonstrated to the Engineer as being in accordance with the application requirements.

Test Certificates, including characteristics covering the full operating range of measured variable against output signal, shall be provided for all instruments or sets of equipment measuring primary quantities.

Site testing shall include demonstration of the satisfactory operation of each system individually and the complete system as whole, before the start of main plant commissioning.

As an integral part of the setting to work and commissioning procedures, the Contractor shall ensure and demonstrate, to the Engineer's approval, that all items of equipment incorporating any form of variable setting (level electrodes, float switches, transmitters, trip amplifiers, meter relays, controllers, timer etc) have been adjusted to achieve optimum control of the process or plant operation.

5.4.6 Cables and Cabling

All signal and control cables shall be shielded.

All signal and control cables for PLC shall be shielded.

All multi–pair cables, except those connected to remotely controlled actuators, shall include a minimum of 25 % spare cores. This spare capacity shall be over and above any cores, which may be required for proposed future installations or extensions. Spare cores in addition to the above may be required in some cables to cater for the spare alarm channels.

There shall be a separate multi-core cable between each motorised valve actuator and the local distribution enclosure or control panel. All such cables shall include a minimum of 2 No. spare cores except those associated with actuators having remote control which shall have a minimum of 4 No. spare cores.

All cores, even spare cores, in the cables shall be connected to terminals in both ends.

5.4.7 Instrumentation and Control

All instrumentation, monitoring and control circuits and equipment shall be supplied adequately considering safety measures and preferably the voltage not exceeding 55 Volts to earth. These supplies shall be from one of the following:

- battery/charger unit, typically of 24 Volt nominal output, but under no circumstances exceeding 48 Volts nominal output
- double wound transformer having a fused primary, a 55–0–55 Volt secondary with the centre point earthed and each secondary line fused
- transformer / rectifier system, comprising a double wound transformer with a fused primary and a secondary having one end earthed, together with a full wave rectifier unit incorporating voltage stabilisation if necessary. The mean voltage of the rectified output shall not exceed the nominal output from the instrumentation battery/charger units

Equipment such as battery/chargers, no break and control power supplies, inverters etc. shall be supplied as necessary to maintain the required electrical supplies to essential instrumentation, monitoring and control systems which are to be kept in operation during a mains power failure. The essential equipment to be maintained during a power failure shall include mimic diagrams, alarm systems, data acquisition equipment and flow measuring, indicating, recording, integrating equipment or as otherwise detailed in the application clauses.

5.4.8 Remote Control Supplies

On remote control/indication circuits (such as occur with valves, penstocks, etc.) D.C. voltages and relays shall be used in all cases where the cable capacitance could be of sufficient magnitude to maintain AC. relays in an energised state. The Contractor shall be responsible for establishing where such DC operation of control/indication circuits is required and for providing a suitable supply at locations where instrumentation battery/charger supply is not available.

5.4.9 Construction of Panels

All panels for in-/outdoor shall comply with the relevant clauses of EN 60204-1 and EN 60079-14.

All panels, cubicles, cabinets, consoles, and desks together with any other types of enclosure (excluding motor control centres and switchgear) which form part of the instrumentation, monitoring and control installation shall comply with the requirements of EN 60204-1.

Removable earthed, metal gland plates shall be provided to accommodate all incoming/outgoing cables, and shall be fitted not less than 250 mm. above the floor level.

All equipment, other than front of panel items, shall be mounted on racks or fixing bars and not directly onto the panels.

Each enclosure shall be vermin proof but with the necessary provisions made for natural or forced ventilation.

All panel construction and arrangement details shall be approved before manufacture, and panels shall be subject to inspection.

5.4.9.1 Panels for Indoor Use

All instrumentation, monitoring and control panels, designed for use within buildings shall be constructed of prime quality, cold rolled and annealed mild steel or zinc coated sheet steel, of adequate thickness welded and braced to form a rigid structure. The minimum sheet steel thickness shall be 1.6 mm, with panel fronts and desk tops being thicker (2.00 mm, minimum.) to provide the necessary strength to prevent bowing. Panel fronts shall be flat and free of bow and ripple. External corners and edges shall be rounded to give a smooth overall appearance. No design involving the use of externally visible assembly bolts or screws will be accepted. Equipment mounting panels shall be not less than 2 mm. thick and shall be strengthened and/or braced to avoid any distortion or vibration. Equipment mounting plates and brackets shall if necessary were hinged to provide quick and easy access to equipment securing screws, terminals and wiring.

Doors and access panels shall be adequately braced or strengthened to avoid any buckling or twisting. Doors shall be of folded and welded construction mounted on lift–off hinges, with one hinge engaging before the other. Where necessary, removable access covers secured by quick release fasteners shall be provided. All doors and access panels shall close onto neoprene or soft rubber sealing strips, which shall be held in place mechanically, and not by adhesive. All doors shall be lockable. Where "walk–in" panels or structures are provided, these shall be fitted with lockable car type handles operable from inside even when locked.

Surface preparation and finish shall be in accordance with the "Preparation and Painting of Plant", with all internal surfaces finished in white. The external colour shall be as advised by the Engineer.

The design and construction shall be such as to provide an enclosure of superior quality, which shall match all other panels in the same location in style, appearance and finish. In cubicles for PLC (Programmable Logic Controllers) the equipment shall be designed for + 0

°C and + 40 °C and the relative humidity minimum 85% but at all times also for the meteorological conditions on the Site.

5.4.9.2 Panels for Outdoor Use

All instrumentation and control cubicles, kiosks etc. designed for use outside shall be preferably manufactured having walls of double skinned, resin bonded fibreglass, with a totally encapsulated infill of non-corroding alloy.

Box section steel shall be encapsulated into door edges and doorframes. Hinges shall be of high tensile, non–corroding alloy with stainless steel pins and through fixing bolts. Large plane surfaces shall have adequate reinforcing to ensure rigidity.

The doors shall be complete with latching handles and locks. All door catches and locks shall latch onto steel reinforced surfaces. The doorsill shall be protected by a non–corroding alloy material.

Colour impregnated gel coats backed by coloured resin shall be used to ensure maintenance free and "colour fast" finishes. The finish colour, both internal and external shall be gloss white.

Door mounted meters and transparent windows shall be of glass, which shall be protected from harmful direct sunshine by orientation or other approved means.

All internal equipment shall be mounted on supports built into the fibreglass structure. Fixing bolts through the skin will not be accepted.

5.4.10 Panel Wiring and Equipment

The requirements of this Clause shall apply to all cubicles, desks, cabinets, mimic diagrams etc. being provided as part of the instrumentation, monitoring and control installation, but not MCC (Motor Control Centres) or switchgear.

5.4.10.1 Panel Wiring

Panel wiring shall be carried out using cable installed in a neat, systematic manner, securely fixed and supported on insulated cleats or trunking, and arranged so as not to impede access to any internally mounted equipment.

Panel wiring for hazardous areas shall comply with relevant clauses of EN 60079-14

Analogue signal cables and D.C. control cables at voltages not exceeding 48 Volts (nominal), may be run together in the same cable bunch or trunking; but these cables shall be run separately from all other cables. In any cubicle, panel, or structure which is not fully enclosed (such as some mimic diagram structures), all cabling which is or may be at a voltage in excess of 55 Volts (nominal) to earth, shall be run in conduit.

For all cables, the sizing shall be fully adequate for the possible maximum loading, and derating shall be applied as appropriate for cable bunching and ambient temperature.

Identification ferrules shall be fitted to both ends of all wires, and shall be of the full circle type, threaded onto the cable such that all numerals are in line, and read outwards from the terminal.

Where stranded conductors are used, each end shall be fitted with a sleeved termination lug.

Terminations shall be restricted to one wire per terminal.

Cabling to door mounted equipment shall be protected in flexible cable conduit(s) and cleated to form a loom with a loop of adequate length to allow easy door opening without causing strain to the components or cable.

Sharp edges of cubicles, trunking, components etc., which may be in contact with cables, shall be protected to avoid damage to cable insulation.

5.4.10.2 Panel protection for electric chock

All terminals and all live parts (on equipment) which are or may be at a voltage in excess of 55 Volts (nominal) to earth, shall be enclosed by a protective cover, and carry a warning label stating the actual voltage.

For panels and enclosures covered under this section, the maximum potential between any two points within the panel or enclosure shall not exceed 250 Volts.

Terminals and equipment which are supplied from other sources and which may remain live when the panel isolators are opened shall be adequately protected and clearly labelled to this effect.

Adequate fuse protection for circuits and sub–circuits shall be provided and arranged such that any fuse failure causes the minimum disruption to controls and indications, and that any such fuse failure cannot create an unsafe operating condition. Fuses shall be of the HRC cartridge type and be mounted within fuse carriers. Ceramic fuse carriers and bases will not be accepted. All neutral links shall be bolted connections.

5.4.10.3 Panel Earthing

A copper earthing bar shall be provided and bonded electrically to the main frame. It shall be provided with suitable brass screw terminals for the connection of the metal cladding, instrument frames, gland plates, cable tray, the armouring of all incoming cables and the site earthing system.

5.4.10.4 Panel Heating

Each enclosure shall be fitted with one or more heaters to prevent condensation and assist ventilation. The heaters shall be so arranged and located that no deterioration can be caused to any equipment or wiring. The surface temperature of any part, which may be accidentally contacted, shall not exceed 65°C. The heating circuit shall be supplied via a fuse, an isolator and an Off/Auto switch. In the "Off" position the heater shall isolate and in the "Auto" position the heater shall be controlled by a thermostat or humidistat. All switches and controls shall be mounted within the enclosure.

5.4.10.5 Panel Equipment

A fuse and isolating switch shall be provided for each incoming A.C. and D.C. supply.

Where instrumentation, monitoring or control equipment is to be operated on a.c. supplies derived from within the cubicle, a 110 Volt (55–0–55) control transformer (or transformers) shall be provided for this duty. Each micro– processor and/or programmable logic controller shall have its own control supply transformer.

Each cubicle other than terminal enclosures shall be complete with a distribution unit providing an adequate number of fused outlets at 110 Volts (55–0–55) for possible future requirements.

Cubicles for PLC shall be equipped with a two-way outlet 230 V, and a fluorescent lamp 18 W, automatically switch-on when the door is open. Both the outlet and the lamp shall be fused in the LV distribution board.

All items of equipment mounted within the enclosure such as relays, electrical transducers, indicators, recorders, switch fuses, terminals etc. shall be arranged so as to provide easy access, be securely fixed and clearly labelled as to their function, designation, and where applicable, the voltage.

Where meters and recorders are mounted on vertical front panels, the height of the instrument centrelines shall be within the following limits above finished floor level:

- Indicating meters: 1.35 m min. and 1.90 m max
- Recorders: 1.45 m min. and 1.85 m max

5.4.11 Terminals and Termination

Terminals for the connection of all incoming/outgoing cables shall be provided and comprise anti–tracking mouldings of melamine, phenolic or comparable material fitted on a purpose–built mounting rail. Screw clamps or bars, but not pinch screws shall secure the conductors.

All terminals used on circuits not exceeding 55 Volts (nominal) to earth, excluding power supplies and auxiliary drives, shall be of the disconnecting link type.

Every terminal shall carry a clear identity number. Terminals at different voltages shall be grouped separately, and each group shall be clearly labelled with its respective voltage and function. Each group shall be segregated with appropriate barrier to give a physical separation of 2 mm minimum.

Transparent protective covers complete with a voltage-warning label shall be provided on all terminals, which are, or may be, at a voltage in excess of 55 Volts (nominal) to earth.

Sufficient terminals shall be provided for terminating all cores of all cables (including spares) associated with the particular enclosure. The number of terminals shall be sufficient to cater for all anticipated requirements plus 20% spare terminals and 30% spare terminal rail. A minimum of 5 terminals and 50 mm of spare terminal rail shall be provided.

Terminals for connecting to incoming/outgoing cables shall be mounted vertically wherever possible, arranged to provide easy access and to enable ferrule numbers to be read without difficulty. Direct termination onto such equipment as distribution boards, fuses or miniature circuit breakers is not acceptable.

Terminal rails shall be back plate mounted only, the mounting of terminal rails on the sides, bottom or top of cubicles shall not be allowed under any circumstances.

5.4.12 Labels

All external labels for panels and other items where specified shall be clear Perspex, back engraved, filled and back painted the same colour as the panel. All labels shall have chamfered edges and shall be fixed with chrome plated screws or adhesive with two-component glue (epoxy).

All internal labels shall be engraved multi–layered plastic fixed with chrome- plated screws.

Every internal component shall be identified and each fuse shall be labelled with the identification reference, fuse type and fuse current rating.

Panels with doors not interlocked to an isolator giving complete protection shall have a label affixed to the door: "DANGER LIVE TERMINALS" with black letters on a yellow background. The relevant voltage shall be stated.

All labels shall be in Serbian language and English.

A list of labels with Serbian and English language inscriptions shall be submitted to the Engineer for approval before manufacture.

All socket outlets shall be clearly labelled to indicate their respective operating voltages. All junction boxes shall be clearly labelled to indicate the relevant cable reference numbers.

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5.4.13 Control Battery / Charger Equipment

This Clause covers the requirements for batteries and chargers, specified in the application clauses for the operation of control, instrumentation, alarm and monitoring equipment.

Where alternative A.C. supplies are available, provision shall be made for taking the supply to the battery charger from either source (e.g. from either side of the bus–section switch) with facilities for automatic change over from one source to the other in the event of failure of the supply source.

The battery and charger unit shall where possible form a composite unit and be housed in a single sheet steel, floor standing cubicle having adequate ventilation and separate compartments for the batteries (lower compartment) and chargers (upper compartment). Access to the batteries shall be via lockable, hinged doors, and to the chargers via removable covers.

5.4.13.1 Batteries

The batteries shall be Lead Gel or Absorbed Glass Mat (AGM) batteries of deep cycle type with a nominal output of 24 Volts, and shall be of adequate capacity to maintain full operation of the relevant load equipment plus an additional 10%, for a period of 2 hours during mains failure, assuming a normal charge condition at the start of the mains failure.

All batteries shall be suitable for the intended service under the prevailing site conditions.

5.4.13.2 Battery Chargers

Duplicate chargers one "Duty" and one "Standby", shall be provided and mounted on their own respective chassis in the upper cubicle compartment.

The controls for each charger shall be mounted on their own respective mounting plate and these, together with all controls and indicators projecting through the front of the upper compartment shall be positioned at a height not exceeding 1800 mm from floor level.

The front panel of each charger unit shall include:

- 1 No. "ON/OFF" Mains Isolator
- 1 No. Lamp to indicate "A.C. Supply On" (White)
- 1 No. Charger Ammeter
- 1 No. Lamp to indicate "Boost Charge" (Red)
- 1 No. Lamp to indicate "Float Charge" (White)
- 1 No. Lamp to indicate "Charger Failed" (Amber)
- 1 No. Lamp test pushbutton

Each charger unit shall also be provided with:

- 1 No. "Float/Boost" selector switch mounted internally
- 1 No. Set of A.C. supply fuses
- 1 No. Volt–free contact for duty charger failed alarm
- 1 No. Volt–free contact for low D.C. output voltage alarm
- 1 No. Volt–free contact for loss of D.C. output voltage alarm

The above volt–free contacts shall open under fault conditions and be wired to a terminal block and further to PLC.

The following items of common equipment shall also be provided and mounted on the front panel:

- 1 No. D.C. output voltmeter, scaled to indicate regions of "Low", "Normal" and "High" output voltages, by the use of different coloured sectors
- 1 No. D.C. output isolator Switch
- 1 No. D.C. output Ammeter
- 1 No. Duty/Standby selector switch (labelled "No.1 Duty, No.2 Standby/No.2 Duty No. 1 Standby")

The battery charger unit shall also be provided with one set of full capacity rated output D.C. terminals and fuses.

In the event of failure of the duty-selected charger, the standby charger shall be connected automatically and contacts for the remote alarm indication shall be provided. The alarm indicating failure of the duty charger unit shall remain on until the failed charger has been repaired and returned to operation.

Reversion from "Standby" to "Duty" charger shall be a manual operation. The chargers shall be of the solid state constant potential type, and shall be designed to regulate the charger output voltage to within ± 1% for a mains input voltage variation of ± 6%.

The D.C. terminal voltage shall be further regulated such that under "Float" or "Boost" charge condition the D.C. voltage does not rise to more than 10% above the nominal.

The charger unit shall also be provided with both short circuit and reverse polarity protection.

The charger when selected to "Float" shall be capable of restoring the battery to 75% capacity within 7–8 hours.

Under "Boost" condition the charger shall be capable of restoring a fully discharged battery to 75% capacity within 4–5 hours.

The cabinet shall be manufactured in accordance with the relevant clauses but with additional treatment to the interior surfaces to prevent any corrosion by battery chemicals and with environmental protection to in-/outdoor use.

For each battery/charger unit the Contractor shall supply a set of maintenance tools, equipment and spares, and for non–sealed batteries this shall include a re-sealable, 2 litre container of electrolyte, a pouring device and hydrometer; all of which shall be contained and secured within the charger cabinet.

The Contractor shall fix inside the cubicle a wiring diagram indicating and identifying all outgoing terminals, components and fuses.

Special precautions shall be taken in the sizing of the battery and charger for high temperature situations, and all equipment shall be adequately rated for the prevailing site conditions.

5.4.14 Plant Control and Indication Circuits

The requirements detailed in this Clause refer specifically to control/indication circuits associated with power actuated valves and penstocks, but shall apply equally to all other plant controls/indications where similar conditions occur.

Although two or more auxiliary or limit switches may initially be set up to give simultaneous operation, it is impossible to ensure that such simultaneous operation will be maintained over an extended period. To avoid the possibility of a system malfunction due to the above, the use of duplicate auxiliary or limit switches to provide the same effective status signal will not be accepted.

Where a valve or penstock status signal is to be used in more than one circuit (e.g. control and indication), one set of auxiliary or limit switch contacts only, together with a slave relay if necessary, shall be used to initiate the operation of all such circuits.

Plant Control and Indication equipment for hazardous areas shall comply with relevant clauses of EN 60079-14.

5.4.15 Differential Pressure Transmitter

Each differential pressure transmitter shall be of rugged construction, suitable for the application and:

- have an electrical output of 0/4 - 20 mA or 0 - 10 V proportional to the differential pressure
- be capable of withstanding a 100% overload (i.e. twice the differential pressure required for full output) without sustaining damage
- have fully adequate static pressure rating to withstand all possible surge pressures
- have stainless steel sensing elements
- have independent span, zero and damping adjustments
- have an accuracy within ± 0.5 % of span, repeatability within ± 0.2 % of span and a dead band not exceeding 0.2 % of the span
- be operable on a 2 wire system
- incorporate an output indicator

Each installation shall be supplied and installed complete with:

- sensing lines of stainless steel
- a 3 or 5 valve manifold as required,
- test point(s) with separate isolating valve(s)

5.4.16 Pressure Transducer Level Measuring Equipment

Pressure transducer level measuring equipment shall comprise a strain gauge or differential transformer type pressure transducer, a controller/transmitter and be complete with all necessary cable, conduits, etc., as detailed below. Differential transformer transducers are to be preferred for very low ranges. Each pressure transducer shall be enclosed within an all welded, stainless steel case not less than 19.0 mm in diameter and shall:

- have a single moulded cable which is securely bonded to the stainless steel case and comprising electrical connections, venting tube, strain cord or wire within the cable to obtain the necessary strength, and an outer covering suitable for the application
- be suitable for continuous immersion in all process fluids likely to be met in wet applications
- be constructed so that the sensor diaphragm is protected against damage by shock, debris, etc., without restricting the transference of pressure changes from the surrounding medium
- incorporate automatic temperature compensation
- withstand a continuous overpressure of up to 400% without sustaining permanent deformation or calibration change

The controller/transmitter shall:

- be suitable for mounting within a control panel

- accept the signal from the transducer and provide a 0/4-20 mA or 0 -10 V output proportional to level (gauge pressure), for indication and control
- include independent zero and span adjustments
- have a system checking module which will simulate the transducer output

The complete system shall provide accuracy within ± 0.75% of span with linearity better than ± 0.1%.

Pressure Transducer Installation

For installations in sumps and for similar applications where the depth is in excess of 3 m or where the available headroom over the sump is limited, the pressure transducer shall be installed within a 100 mm dia. G.R.P. tube to provide protection against mechanical damage to both the transducer and the cable. The G.R.P. tubing shall have an adequate number of holes and/or slots to allow it to fill and drain as the level varies. The tubing shall be fixed to the sump wall at intervals not exceeding 2.5 m.

For installations where the sump depth does not exceed 3 m, the sensor shall be supplied and installed as a rigid assembly comprising a stainless steel tube, a tube holder (both as used for control electrodes) and the transducer, with the cable passing through the tube. The transducer shall be a close fit, located completely within the tube at the lower end. The assembly shall be fixed at not less than two places to the sump wall and installed with the bottom of the tube just clear of the sump invert.

For all installations the cable between the transducer and the controller/transmitter shall be a continuous length, and kept as short as is reasonably possible. This cable shall be run in conduit and installed well clear of all AC. mains and power cables.

5.4.17 Electrode Level Control Equipment

Electrode level control equipment shall consist of a control unit or units and a number of electrodes, together with all brackets and fixings as required for the complete installation.

For all applications, sufficient electrodes and associated controls shall be provided to prevent "hunting" between the two states.

The control unit shall:

- have all live parts at a voltage in excess of 55 Volts to earth completely shrouded and fitted with warning labels
- have an output relay with double pole changeover contacts of suitable material for the application
- have a light emitting diode mounted on the front panel to indicate when the relay is energised
- have a lockable sensitivity control potentiometer
- be capable of operating at a distance of up to 100 m. from the electrodes
- have a voltage on the electrodes not exceeding 25 Volts

The electrode and holder shall comply with the following:

- the electrode holder shall be of the heavy duty type, fully weather-proof, constructed from die cast aluminium and provided with a mounting flange having a minimum of 4 No. fixing holes
- the electrode holder shall be designed to allow a minimum of 75 mm adjustment of the electrode length
- the electrodes shall be of stainless steel grade, having a minimum

- each electrode shall be firmly secured to avoid any movement due to turbulences or flow velocity. The securing brackets shall be of the same material as the electrode and shall be installed above top water level
- where the electrodes pass through securing brackets; they shall be protected by heat shrunk sleeving extending from 300 mm above the bracket to 300 mm below the bracket

5.4.18 Gas Alarms

Concentration in the vicinity of the hazardous areas shall be monitored e.g. by means of gas alarms. At least the following requirements shall be complied with:

- the substances likely to be present, the location of the sources, maximum source strength and dispersion conditions must be adequately known
- the instrument performance must be appropriate to the conditions of use, especially as regards response time , alarm level and cross- sensitivity
- no dangerous conditions may arise on failure or individual functions of gas alarm systems reliability
- the number of location of measuring points must be so chosen that the gas mixtures can be detected quickly and reliably
- have minimum two output relays with double pole changeover contacts of suitable material for pre-alarm and shut down of electrical equipment
- have an electrical output of 0/4-20 mA or 0 - 10 V proportional to 0-5% methane
- Gas alarms must fulfil the ATEX directive requirements for electrical equipment

5.4.19 Float Switches

Float switches shall be the pendant type with the float suspended on a flexible cable, such that with the float free of the liquid the float and cable hang vertically, but with a rising liquid level the float shall rise and tend to invert.

The float shall be of robust design and comprise a mercury switch having changeover contacts encapsulated in hard plastic foam and connected to a 3 core cable. The whole assembly shall be covered and hermetically sealed in Hypalon or similar material.

With the tilting action, which occurs on rising level, the contacts shall change over, but there shall be a dead band between opening one contact and closing the other, during which period both contacts shall be open. This dead band shall operate over an arc approximately 20° either side of the horizontal.

The contacts shall be rated for a minimum of 5 amps at 110 Volts. The voltage on the contacts shall not exceed 55 Volts (nominal) to earth.

In all applications the installation shall be complete with approved means of preventing the float (and lead) from movement due to wind or liquid turbulence.

Where float switches are to be used in applications under which they may be submerged during normal operation (e.g. pump control and/or low level alarm); they shall be attached to a weighted chain to minimise movement due to turbulence and also to provide a means of raising the units for maintenance and repair. All brackets, fixings etc. as necessary for the complete installation shall be provided. The chain/float assembly shall be installed such that the point of suspension is not less than 400 mm from any side wall.

5.4.20 Flow Switches

Flow switches for installation in pipe lines shall:

- be suitable for the maximum possible flow rate
- withstand reverse flow without sustaining damage
- have the operating set point adjustable over the range 20% to 100% of the normal flow
- have change-over contacts rated at 5 Amps 110 VAC (50 Hz) or 1 Amp at 24 Volts DC
- be complete with all fittings necessary to carry out installation in the pipeline, including waterproof cable gland
- have a metal housing compatible with the pipe material and rated for the system temperature and pressure
- be suitable for the application and process fluid in respect of the principle of operation and the material of the wetted parts

5.4.21 Pressure Switches

Pressure switches shall be of either the bellows or bourdon type, and shall be rated to withstand the maximum possible surge pressures.

The switches shall:

- have a signal pole change-over contact, with the contact material and rating suitable for the application
- have a calibrated set point adjustment which shall be lockable to prevent any movement due to vibration
- have a switching differential adjustable between 5% and 25% of the set point adjustment range
- have all wetted parts compatible with the process fluid

5.4.22 Indicating Meters and Meter Relays

All indicating meters and meter relays for use in control and instrumentation panels, control desks, mimics etc. shall comply with this Clause and the appropriate sub–clauses. All meters and meter relays:

- shall comply with IEC 512 to accuracy Class 1 for instruments having a d.c. input and accuracy Class 1.5 for instruments having an a.c. input
- except those having digital, indication, shall have a linear scale, with clear graduations and markings
- shall have the units of the measured variable and any multiplying factor clearly marked on the scale plate or its equivalent
- shall be flush mounting with matt or semi–matt black bezel
- shall match all other instruments on the same panel or on similar panels in the same room as regards style, finish and appearance
- intended for installation within a control room shall be fitted with anti–glare or low reflectivity glass
- intended for installation on an inclined surface shall be suitable for that application, and when so mounted, the accuracy shall be maintained over the full range
- accept input signals of 0/4 - 20 mA or 0 - 10 V

5.4.23 Digital Indicators

The digital indicators shall have

- a minimum 4 digit display with floating decimal point and shall display positive and negative readings
- display digits approximately 14 mm high
- have standard DIN format 96 x 48 mm
- accept a 0/4 - 20 mA or 0 - 10 V input and display in the relevant engineering units
- have a sampling rate not less than 10 per second
- include a remotely initiated display hold facility
- be powered from the 24 Volt battery supply

5.4.24 Meter Relays

Meter relays shall incorporate one or two adjustable set point contacts for alarm or control.

The set point shall be visible and adjustable from the front and the signal output shall be via volt–free change–over contacts of suitable material and rating for the application.

5.4.25 Trip Amplifiers

Trip amplifiers or analogue alarm relays may be single or dual set point instruments as required and shall:

- accept input signals of 0/4 – 20 mA or 0–10 V
- have switched outputs with changeover contacts of suitable material and rating for the application
- have a set point (or points) which is infinitely variable over the whole input range by means of a lockable knob calibrated 0 – 100 %
- have a dead band or hysteresis of not less than 3 % of input span

The units shall be located within the cubicle and mounted so that they are easily accessible for adjustment of set points.

Trip amplifiers required to continue in operation during a period of power failure shall be supplied from the instrumentation system battery, either directly or via an inverter.

5.4.26 Integrators and Counters

The integration equipment shall comprise an integrator and a 6 digit numerical display unit or counter.

The integrator and counter may be combined into a single unit, or the integrator may be mounted remotely from the numerical display unit.

The counter shall be flush mounting with a matt or semi-matt bezel, and shall match all other instruments on the same panel as regards style, finish and appearance.

If a counter reset facility is provided, this shall be arranged such that accidental operation is impossible, and should preferably not be located on the front panel.

The integrator shall accept a 0/4 - 20 mA or 0 - 10 V signal proportional to flow. Integrators required continuing operating during a period of power failure should be supplied from the instrumentation system battery, either directly or via an inverter.

A low signal cut-off facility shall be provided on all integrators, and this shall be adjustable over the range 0.5 % to 5 % of the flow.

Integrated flows shall be in cubic metres and this, together with the measurement designation and any multiplying factor shall be clearly marked on the face of the counter, or on a matching label immediately below the counter.

The Contractor shall submit his proposals for integration rates and multiplying factors for approval by the Engineer.

Predetermining Counters

Where a liquor sampler is to be function of flow and/or where indicated in the application clause, the relevant integrator shall incorporate a predetermining counter having a minimum of 3 digits. The predetermining counter shall be on the front of the instrument with thumb-wheel setting facilities and shall operate such that a relay with changeover contacts is energised when the preset quantity is reached. The relay shall remain energised for approximately 1 second, following, which the counter shall automatically reset, and start counting again.

5.4.27 Control and Interposing Relays

All control and interposing relays, except those used for lamp switching, shall operate on a supply not exceeding 55 Volts (nominal) to earth and shall:

- operate reliably over the range +10% to 0 20% of the nominal supply voltage
- be of the plug-in type complete with plastic cover and retaining clip
- have vacuum impregnated coils and be suitably treated for operation under the specified environmental conditions
- have contact material suitable for each application
- have relay bases of the front connected, screw clamp type,
- incorporate indication of energisation/de-energisation

All relays operating on a d.c. supply shall have a surge suppression diode connected directly across the coil.

Mixed voltages shall not be connected to the contacts of any relay.

All relays and the associated wiring shall be protected by suitably rated fuses. Relays having different contact arrangements or coil voltages shall not be interchangeable. A permanent means of identification shall be fixed to each relay base and this identification shall be in accordance with the circuit diagram reference.

Where voltages from a remote source (i.e. voltages which cannot be readily isolated from within the cubicle), are connected to a relay or associated terminals, fuses etc., the Contractor shall ensure that all such live parts are fully shrouded and that appropriate warning notices are fitted.

The Contractor shall be responsible for ensuring that a.c. relays cannot be held in due to capacitance effects on long switching lines. Where such a possibility exists, a d.c. supply shall be provided.

5.4.28 Discrepancy Switches

Where illuminated control switches are used to provide discrepancy indication, the circuits shall be arranged such that the lamp is energised via a flasher unit. This flashing discrepancy indication shall operate if the switch is not fully activated or if the controlled item is not in the position shown by the switch blade.

The switches shall be of the type having a rotary action to select the operation and a push button action to initiate the operation.

All discrepancy switches shall be included with a lamp test facility.

5.4.29 Illuminated Push-Buttons and Status Indicators

All lamp indicators (except discrepancy switches) located on instrumentation and control panels, mimics, desk or consoles shall:

- be of similar size and appearance
- have bezel dimensions of not less than 24 x 36 mm
- incorporate two lamps
- be included within a lamp test facility
- be supplied complete with the required engraving on the screen
- be supplied from the local instrumentation power system or the local instrumentation system battery, unless stated to the contrary

5.4.30 D.C. Operated Lamps or LED

All D.C. indicator lamps or LED shall have diodes in series to prevent reverse current when making lamp tests.

5.4.31 A.C. Operated Lamps

In applications where a battery supply is not available, status indicator lamps shall be operated on available A.C. supplies. For these applications the indicator shall be a low voltage lamp supplied via a transformer incorporated within the light unit. The lamps shall have a voltage rating higher than the transformer secondary.

5.5 Testing, Inspection and Pre-Commissioning of Electromechanical Equipment

5.5.1 Works Testing and Inspection Costs

The Contractor shall offer all items of Plant for inspection examination and witness testing and shall give the Engineer four weeks' notice that the equipment is ready for operation and of his intention to carry out tests.

If the tests are beyond the resources of the manufacturer, he shall make arrangements for these to be carried out elsewhere. Any variation of this requirement shall be agreed and confirmation in writing obtained from the Engineer.

The Contractor shall carry out tests as stated in the current appropriate European or International Electro-technical Commission Standards (EN, IEC or BS), performance tests and such other tests as are necessary, in the opinion of the Engineer, to determine that the Works comply with the Requirements, either under test conditions in the manufacturer's works, on site or elsewhere.

Where tests and inspection have been completed to the Engineer's satisfaction and when the test certificates, curves, etc. have been checked, the Engineer shall confirm acceptance in writing and the plant shall not be incorporated in the Works or delivered until this acceptance has been received.

Where witness tests are not required, the test certificate and performance curves shall be forwarded to the Engineer within two weeks after instructions to waive witness tests have been received. On each test certificate, sufficient information to enable the Engineer to issue a release certificate, including the Contract number of the Requirements and details, shall be given for ready identification of the material or equipment to which the certificate refers. No inspection or passing by the Engineer of the Work, Plant or materials covered by the Contract, whether carried out or supplied by the Contractor, shall release the Contractor from any of his obligations under the Contract.

The Engineer reserves the right to require the Contractor to meet any extra costs which are occasioned by failure of the Contractor to comply with the above testing and inspection requirements including the provision of test certificates, curves, sub-orders, etc., or which in the opinion of the Engineer are due to insufficient care having been taken by the Contractor or his Sub-Contractor before presenting the Plant for inspection or test. If unauthorised delivery has taken place, the Contractor may be required to arrange for the plant to be returned to the manufacturer for inspection and/or witness testing at the Contractor's expense.

Any equipment used in the testing of the Plant shall in all respects comply with the appropriate safety regulations and/or requirements regarding electrical apparatus for the safety of the Plant and the men working thereon.

Full details of the method of testing proposed for each item shall be submitted to the Engineer.

The Contract prices shall include for the costs of all works tests, including temporary erection, labour, materials, instrumentation, stores, fuel and power used, as may be required during all inspections and tests and for the provision of certified records and curves.

The Contract Prices shall also cover all the costs during works testing including accommodation, travelling expenses and all reasonable expenses, incurred by the Engineer, allowing for individual inspection visits each of a duration of three days.

The above periods are deemed to exclude any necessary re-inspection visits arising from any abortive inspection visits, resulting from the Contractor's failure to comply with the requirements of this Section.

5.5.2 Test Instruments

The manufacturer shall satisfy the Engineer as to the accuracy of all the instruments used for the tests and if required shall produce recent calibration tests, or otherwise have them calibrated at his own expense by an independent authority.

Test - instruments for hazardous areas shall comply with relevant clauses of ATEX directive 94/9 EC and Good Practice for Implementing Directive 1999/92/EC.

Kilowatt hour meters shall be checked for correct rotation and creep tests shall be carried out to ensure that the meter is inoperative with voltage alone if the secondary of the current transformers is left connected with the primary current interrupted.

5.5.3 Test Certificates

Test certificates shall be provided giving a detailed record of all electrical and mechanical tests carried out on the equipment and material including lifting equipment, tanks, pressure vessels, cables and cabling both in the manufacturer's works and at Site.

Copies of certificates of all works hydraulics tests shall be provided.

The Contractor shall obtain and submit to the Engineer and to other parties as may be directed, within two weeks of completion of any witnessed tests, test certificates and curves of all items certifying that they have been satisfactorily tested and describing and giving full particulars of such tests.

Copies of test certificates of major items shall be included in the Operating and Maintenance Instructions..

5.5.4 Facilities Hydraulic Tests

All equipment subject to waste water or water pressure including pressure vessels, pumps, pipes, fittings and valves, shall be hydraulically tested to the pressure where specified or to at least 1,5 times the maximum working pressure.

Certificates of tests for all items shall be submitted.

Any of the hydraulically tested items shall be subject to the Engineer' random item proof re–test and notice of testing dates shall be submitted to the Engineer.

5.5.5 Facilities Inspection, Test and Guarantees

Schedules of Particulars shall be prepared for the following items by the Bidder with Guaranteed Particulars and efficiencies of the equipment offered at the duties specified, and these will be binding and may not be varied except with the consent in writing of the Engineer.

Full witness testing to the relevant standards and to prove guarantees given will be required for the following items:

- Pumps with capacities of more than 10 l/s
- Blowers (to be factory tested as well)
- Waste Separation equipment
- Composting equipment
- Wastewater and leachate treatment equipment
- Water supply equipment (Potable and Technical)
- Pumping stations
- Control/Switchgear Panels
- Circuit Breakers
- Power Factor Correction Capacitors
- Process Control and Indicating Instruments
- Electrical Measuring Instruments and Meters
- All Programmable Logical Controllers (PLC)

In addition, all other items of equipment not subject to witness testing shall be temporarily erected at the manufacturer's works, tested for satisfactory operation and offered for inspection. Certified copies of the manufacturer's test readings shall be submitted to the Engineer prior to packing for shipment.

Such inspection, examination, or testing, shall not release the Contractor, manufacturer or supplier of any item from any obligation.

Whilst the Engineer shall be provided with facilities for witness testing and/or inspection of all items of equipment at the manufacturer's works, he may at his discretion advice that the tests shall proceed in his absence, the tests shall be made as if in his presence, and duly certified copies of test readings shall be submitted.

Where items of equipment are of identical size and duty it may be required, at the Engineer's discretion that a reduced number of the items be subject to witness tests, however, this shall not relieve the manufacturers from the requirement of carrying out the performance tests on all items prior to offering for witness testing.

If after inspecting, examining, or testing any material or equipment, the Engineer shall decide that such items or any part thereof is defective, or not in accordance with the specification or performance requirements, he may reject the said items or part thereof, giving to the manufacturer within a reasonable time, notice in writing of such rejection, stating therein the ground upon which the said decision is based. All retesting shall be at the manufacturer's expense.

As and when the Engineer is satisfied that the equipment shall have passed the required tests he shall notify the Contractor in writing to that effect.

5.5.6 Pumps

Each pump (bigger than 10 l/s) shall be witness tested as an integral unit for a capacity of 50 %, 100 % and 110 % of the rated capacities (duty points). The tests shall include efficiency curves for the above capacities - both for the motors and for the pumps. Curves for motors may be based on the supplier's efficiency ratings.

5.5.7 Blowers

Each blower shall be witness tested as an integral unit for a complete sequence of operation for capacities of 80 %, 100 % and just below the opening of the relief valve. The witness test shall obtain the guarantees of performance for each item of equipment.

Impellors of centrifugal air blowers shall be dynamically balanced and then over speed tested to 15 % above the maximum continuous service speed.

The assembled blower units shall be proved mechanically by testing at contract service speed.

Full tests shall conform to the appropriate requirements of relevant standards

Tests shall be completed and witnessed at the manufacturer's works using a pipe-works system as required by the agreed code for aerodynamic testing.

Blower testing shall be undertaken using the driver motor, which will be coupled, to the blower on site.

The manufacturer's test drive motor may be used subject to the Engineers written approval. Adequate reason for this option shall be supplied to the Engineer with the request to use other than the final drive motors to be used on site.

Where variable volumetric output is required, the blower and motor shall be tested in combination with the control system, which will ultimately be used for this purpose on site.

5.5.8 Mechanical aerators

The aerator efficiency shall be tested at the Manufacture's test facility on Standard Aeration Efficiency according ASCE.

The Standard Aeration Efficiency of the aerator when measured in a square tank under standard conditions shall be > 2 kg O_2/kWhr acc. to ASCE

5.5.9 Waste Separation Equipment

Each piece of equipment in the waste separation line will be tested for motor ratings and operational characteristics, while the whole line will be performance tested during the commissioning tests.

5.5.10 Composting Equipment

Each piece of equipment in the composting line will be tested for motor ratings and operational characteristics, while the whole line will be performance tested during the commissioning tests.

5.5.11 Weighbridge

The weighbridge shall be tested for accuracy and correct performance of hardware and software.

5.5.12 Biogas closed flare

As there will be no gas available at the time of commissioning, the flare shall be factory tested before installation.

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5.5.13 Control/Switchgear Panels

All electrical equipment shall be delivered with CE-marking in accordance with low voltage directives e.g.:

- Factory built assemblies of low voltage switchgear and distribution boards shall be tested in accordance with EN 60439
- Factory built assemblies of low voltage switchboards, control gear, control boards and Motor Control Centres (MCC) shall be tested in accordance with EN 60439 and EN 60204-1
- Low voltage, circuit breakers, miniature circuit breakers, moulded case circuit breakers, air-breakers, switches, fuses, contactors, relays, terminals, battery charger and all other electrical equipment shall be delivered with CE-marking in accordance with low voltage and EMC directives

All low voltage switching devices of current rating 100 A or greater shall be subjected to measurement and recording of circuit resistance. The test shall comprise measurement, at the main terminals of each pole with the contacts fully closed, of D.C. voltage and current (at 100 A or greater). The values of resistance for any two similar examples from a particular manufacturer's range shall not differ by more than 20%.

5.5.14 High Voltage Devices

High voltage equipment shall be tested in accordance with EN or IEC standards

Additionally low voltage and high voltage switchgear and control gear assemblies shall be tested for the following:

A. Measurement of main circuit resistance

The resistance of each pole of each main circuit from the cable terminal to bushes (with all intervening switch contacts fully closed) shall be measured and recorded. A similar measurement and record shall be taken along the length of each bus bar (with bus-section switch contacts fully closed). The tests shall comprise the measurement of D.C. voltage and current and calculation of resistance.

B. Inter-changeability

All components of the same rating and construction, designated as drawout or plug-in shall be demonstrated as being interchangeable.

C. Protection and control circuits

For all forms of current transformer protection the following information shall be made available to the Engineer before the time of inspection:

- Current transformer magnetising curve
- Recommended relay setting
- Calculated primary operating current at this setting
- Calculated through-fault stability values where applicable
- Values of any stabilising and setting resistors employed in the systems

As far as possible, based on the completeness of the circuits, in the final manufactured form within manufacturer's premises, the satisfactory operation of associated control and protection circuits shall be proved by the following tests:

- To ensure the correct operation of all current operated protection relays and direct acting coils at the recommended setting by primary current injection
- To ensure the correct polarity between current and voltage elements of power relays, meters and instruments

- To ensure the correct operation of D.C. operated auxiliary protection relays, such as Buchholz protection relays at normal operating voltage by stimulated operation of associated remote relays
- To ensure the correct operation of control circuits at normal operating voltage by operation of local control switches and simulation of operation from remote control positions

Note: Checking the operation of all protection relays and control circuits shall be carried out with all closing and tripping circuits energised at their normal rated voltage.

D. Instrument and metering equipment

- Indicating ammeters shall be checked for calibration at 0.25, 0.5and full scale deflection by primary current injection testing
- Indicating voltmeters shall be checked for normal voltage readings by secondary voltage application
- Where possible, integrating kWh- and kVar meters shall be tested for correct operation. Tests shall be carried out to ensure that the meter is inoperative with voltage alone, with the secondaries of current transformers connected and the primary current interrupted
- All instruments shall be subject to the manufacturer's normal work tests and shall be certified

E. Supervisory and control equipment

- In order that any control scheme can be tested in its entirety, the Contractor shall provide a test assembly comprising an adequate number of switches and lamps as a means of simulating external signals and loads

5.5.15 Transformers

If it is decided to supply transformers they shall be routine tested at the manufacturer's works (FAT – factory acceptance test) in accordance with relevant EN/IEC standards. The Engineer will require witnessing the following tests:

- Measurement of winding resistance
- Ratio, polarity and phase relationship
- Impedance voltage
- Load losses
- No–load losses and no–load current
- Insulation resistance
- Induced over-voltage withstand
- Separate source voltage withstand

Further witness tests shall also be carried out in accordance with the following:

- Impulse voltage withstand

If the manufacturer can provide evidence covering impulse voltage withstand tests for transformers of similar type and design, Type Test certificates will be acceptable.

- Temperature rise

Where transformers of identical design and rating are being supplied, only one unit needs to be subjected to the full Temperature rise test and Type Test certificates supplied for the duplicate units.

5.5.16 HV Power Factor Correction Capacitors

Tests to include HV, dielectric withstand, phase to earth - measurement of dielectric loss and loss angle capacitance and verification of kVar.

5.5.17 Process Control and Indicating Instruments

All flow, level and process measurement controllers, transmitters, recorders, indicators, vacuum and pressure gauges shall be subject to routine tests in accordance with relevant EN/IEC standards.

Test Certificates shall be provided against each item of equipment.

5.5.18 Electrical Measuring Instruments and Meters

Tests to ensure accurate operation of all meters, voltmeters and kilowatt- and kVar hour meters shall be undertaken in accordance with relevant EN/IEC standards.

5.5.19 Programmable Logical Controller (PLC)

The Contractor shall be responsible for testing all items of equipment comprised in the PLC system for correct operation.

5.5.20 Coordination of Site Testing Programme

The Contractor shall be responsible for coordinating the programme of site testing of all items and to ensure that all parties concerned are present during any tests to obligate their responsibilities.

5.5.21 Cable Tests during Installation

During the period of site installation, the Engineer will carry out inspection of the works to ensure the standards of workmanship meet the Requirements and are to his satisfaction. In the event of any part of the cabling installation failing to meet these requirements, the Contractor will be informed immediately and shall remedy the deficiency to the satisfaction of the Engineer.

The Contractor shall:

1. Inform the Engineer prior to the testing of the cables and shall be responsible for liaising with any other Contractor to whose equipment the cables may be terminated to ensure that all parties concerned are aware of the impending tests, to guarantees the safety of personnel and that the isolation of any equipment has been completed. Any special isolation or preparation required to be carried out before cable testing can be completed, will be carried out by the Contractor responsible for that equipment. All tests shall be carried out by the Contractor but shall be supervised by the Engineer.
2. Provide D.C. test equipment and apply (after isolation) in the presence of the Engineer, the following D.C. test voltages on all cables between cores, cores and sheath and cores and armour.
3. High voltage cables if needed
    - XLPESWA PVC 12,000/20,000 Volt grade cable between cores and between any core and screen/armour 76,000 Volt
    - XLPESWAPVC 5,800/10,000 Volt grade cable and 3,500/ 6,000 Volt grade cable between any core and between cores and screen/armour 25,000 Volt/15,000 Volt

- LV cables 600/1000 V Polyvinyl chloride (PVC) or cross-linked polythene (XLPE 600/1,000 Volt grade cable between cores and between core and armour 3,500 Volt

4. Demonstrate correct phasing out of cores in all cables throughout the works and test the insulation of all the cables, both between the cores and between the cores and earth, during installation using an approved test instrument.
5. Conduct soil resistivity tests in the presence of the Engineer to obtain the most suitable location for the earth electrode system.
6. Demonstrate to the Engineer that the resistance of the earth electrodes to earth conductor continuity and earth installation is in accordance with the specified requirements.

Tests shall be performed from each major item of plant, by using an "Earth Megger" and auxiliary return conductor.

If any portion of the works fails to pass the tests, another test of the failed portion shall be repeated within a reasonable time upon the same terms and conditions.

Certificates of all testes carried out shall be provided giving full details and description of each test.

5.5.22 Tests on Completion

After erection is completed and the equipment is running satisfactorily after primarily setting to work the Contractor shall notify the Engineer that he is ready to demonstrate the performance of the facilities. Such demonstration is referred to herein as Site Testing, which shall be witnessed by the Engineer. The Contractor shall then test fully all items of equipment and shall include provision and arrangement of:

1. All skilled and qualified operating and test staff for the testing of all equipment.
2. Provisions and disposal of all services, lubricants, and fuels and electricity.
3. All measuring and testing instruments to demonstrate equipment operates to the fulfilment of the works tests.

All tests shall be carried out by the Contractor under the supervision of and to the satisfaction of the Engineer, as follows:

1. Lifting Equipment

Each installation inclusive of rails and beams shall be tested on site with test loads, provided by the Contractor, to prove that the whole is capable of satisfactorily lifting 25% above its rated load (lift in centre of gantry where applicable) and certificates of site tests shall be provided.

2. Pumps

Each set tested for capacity, head power consumption and mechanical reliability.

3. Dosing Equipment

Each set shall be tested for dosing the specified volumes. Efficiency of mixing shall be determined by taking samples and analysing for dissolved agent after 15 minutes, 30 minutes and one hour after start of mixing.

4. Electrical Plant and Power Systems

For electrical plant and power systems the Tests on Completion shall comprise pre-commissioning tests as detailed below, prior to energisation from the power supply system, followed by energisation and demonstration of the operation of the plant and

associated protection and control systems to the specified performance requirements and maximum operating and load duties.

On energisation a certificate of temporary acceptance will be issued for all Plant operating at 1000 V and above. Certificates of temporary acceptance will be issued for equipment on lower voltages on satisfactory demonstration of on-load operation.

All tests shall be carried out by the Contractor under the supervision of and to the approval of the Engineer, and shall comprise:

A. Switchgear and Motor Control Centres

Insulation testing

Power frequency pressure tests shall be carried out on all equipment for operation on systems above 1000 Volts.

For systems up to 1000 Volts equipment insulation tests shall be carried out at 500 Volts using an approved test instrument.

These tests shall be carried out with all circuit breaker/contactor panels closed in the circuit position, between phases and phase to earth. All secondary small wiring circuits shall be similarly tested.

Mechanical tests

All mechanical tests specified for conducting on manufacturer's premises are to be re-checked to ensure satisfactory operation of the plant in the final erected state.

Protection and control circuits

The satisfactory operation of all current operated protection circuits over their whole operating range shall be tested by secondary current injection, where primary injection tests have been previously carried out on manufacturer's premises.

Primary injection tests shall be carried out on restricted earth fault circuits, after pilot circuits have been completed, for stability and fault conditions. On transformer differential protection circuits where primary injection was not possible at the place of manufacture, the completed relay circuits are to be fully tested by secondary injection, and simulated fault conditions. Stability tests are to be carried out using normal load conditions after the system has been completed and energised.

Instrument and metering equipment

Tests shall be carried out to ensure the correct operation of current and voltage operated indication instruments when energised by the actual supply system.

Continuity of earth conductors

Continuity tests shall be carried out on the earth conductor within the switchboard, such tests being by current injection.

This does not exclude testing of the main earthing systems.

B. Power Transformers (if applicable)

Samples of insulating oil shall be taken from each transformer at top and bottom levels and from every container and subjected to dielectric strength tests.

Buchholz surge relays shall be tested after completion of pilot cables by stimulated oil level changes at the relay. Buchholz gas relays shall be tested with pilot cables connected by mechanical operation of contacts.

On-load tap changer equipment shall be tested to ensure correct operation from associated control relays mounted on the switchgear relay panels by voltage injection on the control relays.

C. Rotating machines (motors and generators)

Before the application of electric power the machine windings, the insulation resistance shall be tested (with a suitable insulation resistance tester) and shall be greater than the manufacturer's minimum recommended figure when corrected for site winding temperature. Any necessary drying out the windings on site shall be in accordance with the manufacturer's recommendations.

Before rotating any machine under power, the mechanical alignment of the shaft with the driven load (or driver) shall be checked (and adjusted if necessary) and shall be in accordance with the manufacturer's recommended figure.

Before mechanically coupling any machine to the driven load, the direction of rotation shall be checked.

Before running any machine on-load, all heavy current connections shall be checked for correctness of make-up and tightness.

5. Diesel -/Gas Generator Sets

Tests shall be carried out in accordance with relevant EN/IEC standards, under the control of the Contractor's staff and supervision of the Engineer. The purpose of the tests on completion shall be to confirm the works tests and each engine and generator shall be tested to verify the particulars given in the Technical Schedule. Each set shall perform the guaranteed duty for a period of up to 4 hours or as the Engineer may determine.

6. Bulk Fuel Storage Tanks

Prior to being put into service, each tank and associated equipment shall be subjected to a sustained pressure of 0.7 N/mm2 to ensure that the installation is sound and shows no leaks or distortions.

7. Earthing Systems

Test that the resistance of the earthing networks and electrodes are within the specified limits and in compliance with the Regulations of the local power company.

8. Pipeworks

All pipeworks erected at site shall be hydraulically tested, following erection to at least 1.5 times the maximum working pressure. The Contractor shall provide the necessary equipment including any temporary blank flanges, which may be required to isolate equipment.

The Contractor shall make his own arrangements for the supply and disposal of water used for testing which shall be obtained from a source approved by the Engineer.

The final test shall be applied in the presence of the Engineer.

The Contractor shall be responsible to the Engineer for testing of the welders and inspecting and testing of welded joints together with the supervision of the making good of any welding defects.

The Contractor shall provide all the necessary facilities, labour and equipment for the proper execution of the inspections and bend testing. The Contractor shall allow for two sets of bend tests.

Cast Iron pipelines shall be tested in lengths between manholes or valve pits or such shorter lengths as the Engineer may direct or permit.

Fittings required for temporarily closing the openings in pipelines to be tested shall be properly designed for the purpose and shall be adequately strutted to withstand the pressure applied.

9. Electrical Equipment and Installations

The Contractor will in addition be responsible for arranging and carrying out such witnessed or unwitnessed tests and inspections as may be required by the Local Power Company and obtain and hand over to the Engineer their certificate of approval of the complete electrical installation.

10. Building Services

The Contractor shall demonstrate that the building services installations conform to the Requirements and applicable local regulations.

The tests shall include but not be limited to:

A. For lighting installations

Demonstrate that the illumination levels conform to the specified values.

5.5.23 Pre–Commissioning and Maintenance

Following the successful testing of all equipment and when water becomes available, the Contractor shall be responsible for providing all skilled personnel for the trial operation of the Facilities.

5.6 SCADA and PLC equipment

All SCADA, microprocessor and programmable logic controller (PLC) equipment will comply with this Clause and the Microprocessor relevant sub-clause.

For SCADA, computers, micro-processors and similar solid state equipment, status inputs and outputs will be isolated by opto-isolators or an approved alternative and analogue inputs will be as differential inputs with a high common mode rejection by the input circuits. Individual noise filtering will be provided as necessary for each application. Series mode rejection and over-ranging protection will be fully adequate.

Components will be mounted on high grade flame retardant printed circuits boards which will comply with the relevant part(s) of IEC249, have gold plated edge connections, be equipped with test points to facilitate checking of major functions and have mechanical keying to prevent accidental insertion of an incorrect card.

The power supply unit will be suitable for operation on a supply having a voltage variation +6% and a frequency variation of □2%. The power unit will have an isolated output and incorporate protection against voltage spikes on the mains supply, over-voltage and short circuit.

The equipment will be maintained in operation during a period of mains failure, either drawing power from the emergency distribution system or from a separate UPS system, as appropriate. Each system unit will include spare installed capacity of not less than 15% of each type of input and output module, together with a minimum of 20% spare system logic capacity.

All systems and equipment will include diagnostic and automatic self test routines with volt-free contacts to initiate an alarm in the event of a malfunction.

5.6.1 SCADA Equipment

All SCADA equipment provided throughout the whole system will be of same type and operate so that spares are interchangeable and a fully integrated, compatible system is provided. The system will operate in a manner so as to minimize time delays in signalling particularly control signals, to an acceptable level.

The SCADA system configuration will be as detailed in Vol. 3, section 2 of the present specifications..

The equipment will be microprocessor based and of modular design, providing expansion capabilities and ease of maintenance. It will be designed for high reliability with test points and indications on the function boards. Multiple processors will be used, one for each main task within the system.

The SCADA system will be completely digital and operate on time division multiplex. The design will be such as to minimize the effect of line induced interference and will incorporate high security error checking, giving multiple error detection. In the event of data word error or line failure, the last valid scan will continue to be displayed.

A "SCADA failed" alarm will be initiated in the event of a telemetry equipment fault resulting in loss of valid data transmission. On restoration of SCADA transmission, the system will automatically return to normal working. The system configuration will be such that the failure of any outstation will not prevent the remainder of the system from operating correctly.

5.6.2 PLC Equipment

All computers, micro-processors, PLC's and similar system elements provided throughout the whole system will operate so as to provide a completely compatible system with all peripherals, programs, program development units, file management routines, data storage facilities and similar facilities being common to all elements.

All equipment will be fully programmed in accordance with the requirements of the Special Technical Conditions. All programs, in the form of flow diagrams or logic circuits will be submitted to the Service for approval not less than 6 weeks before the equipment is to be inspected.

In all cases the facility will be provided for modifying the program, altering set points and adjusting time settings while the equipment is "on line". There will be a permanently connected means of accessing set points and timer settings.

All equipment associated with an operator interface will utilize a high level, Service oriented language to permit programming, editing and similar functions by engineers and operators.

5.6.3 Lightning Protection Devices

The Contractor shall provide lightening and surge protection devices at each PLC on each communications circuit, base station and at all other parts of the radio network to ensure isolation and automatic resetting of the system being subject to high surge currents. Devices shall be unfused.

5.7 Electrical list of EN / IEC standards

During designing and execution of the works Contractor has to keep in mind that relevant standards and testing have to be used according to applicable standards where standards of RS will prevail. EN and IEC or any other standard applied have to be more demanding if applied.

The EN Standards referred to European Standards

The IEC Standards referred to have been issued by the International Electro-technical Commission

EN 418	Safety of machinery - Emergency stop equipment, functional aspects - Principles for design
IEC 512	Electromechanical components for electronic equipment; basic testing procedures and measuring methods - Part2: General examination, electrical continuity and contact resistance test, insulation tests and voltage stress tests
EN 954-1	Safety of machinery - Safety-related parts of control systems - Part 100 Guide on the use and application of EN 954-1:1996
EN 1037	Safety of machinery - Prevention of unexpected start-up
EN 1050	Safety of machinery - Principles for risk assessment
EN 1088	Safety of machinery - Interlocking devices associated with guards - Principles for design and selection
EN 50085	Cable trunking and ducting systems for electrical installations
EN 50086	Conduits for electrical installations
EN 50110-1	Operation of electrical installations
EN 50265-1	Common test methods for cables under fire conditions - Test for resistance to vertical flame propagation for a single insulated conductor or cable - Part 1: Apparatus
EN 50265-2-1	Common test methods for cables under fire conditions - Test for resistance to vertical flame propagation for a single insulated conductor or cable - Part 2-1: Procedures - 1 kW pre-mixed flame
EN 50281-1-2	Electrical apparatus for use in the presence of combustible dust -- Part 1-2: Electrical apparatus protected by enclosures. Selection, installation and maintenance
EN 60034-1	Rotating electrical machines - Part 1: Rating and performance
EN 60034-5	Rotating electrical machines - Part 5: Degrees of protection provided by integral design of rotating electrical machines (IP code) – Classification
EN 60049-1	Instrument transformers - Part 1: Current transformers
EN 60073	Basic and safety principles for man-machine interface, marking and identification - Coding principles for indication devices and actuators
EN 60076-1	Power transformers - Part 1: General
EN 6076-5	Power transformers - Part 5: Ability to withstand short circuit
EN 60079-10	Electrical apparatus for explosive gas atmospheres – Part 10: Classification of hazardous areas
EN 60079-14	Electrical apparatus for explosive gas atmospheres. -- Part 14: Electrical installations in hazardous areas (other than mines)
EN 60127-1	Miniature fuses -- Part 1: Definitions for miniature fuses and general requirements for miniature fuse-links
EN 60204-1	Electrical equipment of machines - Part 1: General requirements

IEC 60227-1	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V - Part 1: General requirements
IEC 60227-3	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V - Part 3: Non-sheathed cables for fixed wiring
IEC 60227-5	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V. - Part 5: Flexible cables (cords)
IEC 60228	Conductors of insulated cables
IEC 60245-1	Rubber insulated cables - Rated voltages up to and including 450/750 V - Part 1: General requirements
IEC 60245-3	Rubber insulated cables - Rated voltages up to and including 450/750 V - Part 3: Heat resistant silicone insulated cables
IEC 60245-4	Rubber insulated cables - Rated voltages up to and including 450/750 V - Part 4: Cords and flexible cables
EN 60269-1	Low-voltage fuses - Part 1: General requirements
EN 60269-2	Low-voltage fuses - Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application)
EN 60269-3	Low-voltage fuses.- Part 3: Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications)
IEC 60287	Electric cables - Calculation of the current rating
EN 60298	Specification for a.c. metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV
EN 60309-1	Plugs, socket-outlets and couplers for industrial purposes. - Part 1: General requirements
EN 60309-2	Plugs, socket-outlets and couplers for industrial purposes. - Part 2: Dimensional inter-changeability requirements for pin and contact-tube accessories
IEC 60331	Tests for electric cables under fire conditions - Circuit integrity
IEC 60332-1	Tests on electric cables under fire conditions - Part 1: Test on a single vertical insulated wire or cable
IEC 60332-3	Tests on electric cables under fire conditions - Part 3: Tests on bunched wires or cables
EN 60335-2-41	Safety of household and similar electrical appliances - Part 2-41: Particular requirements for pumps for liquids having a temperature not exceeding 35 °C
EN 60335-2-53	Safety of household and similar electrical appliances - Part 2-53: Particular requirements for sauna heating appliances
EN 60417-1	Graphical symbols for use on equipment - Part 1: Overview and application
EN 60417-2	Graphical symbols for use on equipment - Part 2: Symbol originals
EN 60439-1	Low-voltage switchgear and control gear assemblies - Part 1: Type-tested and partially type-tested assemblies
EN 60439-2	Low-voltage switchgear and control gear assemblies - Part 2: Particular requirements for bus bar trunking systems (bus ways)
EN 60439-3	Low-voltage switchgear and control gear assemblies - Part 3: Particular requirements for low-voltage switchgear and control gear assemblies

	intended to be installed in places where unskilled persons have access for their use- Distribution boards
EN 60439-4	Low-voltage switchgear and control gear assemblies - Part 4: Particular requirements for assemblies for construction sites (ACS)
EN 60439-5	Low-voltage switchgear and control gear assemblies - Part 5: Particular requirements for assemblies intended to be installed outdoors in public places - Cable distribution cabinets (CDCs) for power distribution in networks
EN 60446	Basic and safety principles for man-machine interface, marking and identification - Identification of conductors by colours or numerals
EN 60447	Man-machine interface (MMI) - Actuating principles IEC 60449 Voltage bands for electrical installations of buildings IEC 60479 Effects of current on human beings and livestock
IEC 60502	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV)
EN 60529	Degrees of protection provided by enclosures (IP Code) EN 60570 Electrical supply track systems for luminaires
EN 60598	Luminaires
EN 60598-2-18	Luminaires - Part 2-18: Particular requirements - Luminaires for swimming pools and similar applications
EN 60598-2-22	Luminaires - Part 2-22: Particular requirements - Luminaires for emergency lighting
EN 60598-2-23	Luminaires - Part 2-23: Particular requirements – Extra low-voltage lighting systems for filament lamps
EN 60598-2-24	Luminaires - Part 2-24: Particular requirements - Luminaires with limited surface temperatures
EN 60617	Graphical symbols for diagrams.
IEC 60621	Electrical installations for outdoor sites under heavy conditions (including open-cast mines and quarries).
IEC 60664-1	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests
EN 60695-2-1	Fire hazard testing - Part 2-1: Test methods - Glow-wire test methods
IEC 60702-1	Mineral insulated cables with a rated voltage not exceeding 750 V. Part 1: Cables
IEC 60702-2	Mineral insulated cables with a rated voltage not exceeding 750 V. Part 2: Terminations
EN 60707	Flammability of solid non-metallic materials when exposed to flame sources - List of test methods
IEC 60724	Short-circuit temperature limits of electric cables with rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV)
EN 60742	Isolating transformers and safety isolating transformers
IEC 60800	Heating cables with a rated voltage of 300/500 V for comfort heating and prevention of ice formation

EN 60898	Circuit-breakers for overcurrent protection for household and similar installations
EN 60900	Hand tools for live working up to 1000 V a.c. and 1500 V d.c.
EN 60903	Specification for gloves and mitts of insulating material for live working
EN 60947-1	Low-voltage switchgear and control gear - Part 1: General rules
EN 60947-2	Low-voltage switchgear and control gear - Part 2: Circuit- breakers
EN 60947-4-1	Low-voltage switchgear and control gear.- Part 4-1: Contactors and motor-starters - Electromechanical contactors and motor-starters
EN 60950	Safety of information technology equipment
EN 60984	Sleeves of insulating material for live working
IEC 60989	Separating transformers, autotransformers, variable transformers and reactors.
EN 60998-2-1	Connecting devices for low-voltage circuits for household and similar purposes - Part 2-1: Particular requirements for connecting devices as separate entities with screw- type clamping units
EN 60998-2-2	Connecting devices for low-voltage circuits for household and similar purposes - Part 2-2: Particular requirements for connecting devices as separate entities with screwless-type clamping units
EN 61000	Electromagnetic compatibility (EMC)
EN 61008	Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs)
EN 61009	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBO's)
IEC 61024-1	Protection of structures against lightning - Part 1: General principles
IEC 61034-1	Measurement of smoke density of cables burning under defined conditions - Part 1 Test apparatus
IEC 61034-2	Measurement of smoke density of cables burning under defined conditions - Part 2: Test procedure and requirements
EN 61046	D.C. or a.c. supplied electronic step-down convertors for filament lamps - General and safety requirements
EN 61048	Auxiliaries for lamps - Capacitors for use in tubular fluorescent and other discharge lamp circuits - General and safety requirements
EN 61082	Preparation of documents used in electrotechnology
EN 61131-1	Programmable controllers - Part 1: General information
EN 61131-2	Programmable controllers - Part 2: Equipment requirements and test
IEC 61140	Protection against electric shock - Common aspects for installation and equipment
IEC 61200-53 TR2	Electrical installation guide - Part 53: Selection and erection of electrical equipment – Switchgear and control gear
IEC 61200-413 TR3	Electrical installation guide - Part 413: Protection against indirect contact - Automatic disconnection of supply
IEC 61312-1	Protection against lightning electromagnetic impulse - Part 1: General principles

IEC 61643-1

EN 61346	Industrial systems, installations and equipment and industrial products - Structuring principles and reference designations
EN 61557	Electrical safety in low voltage distribution systems up to 1000 V a.c. and 1500 V d.c.- Equipment for testing, measuring or monitoring of protective measures
EN 61558-1	Safety of power transformers, power supply units and similar - Part 1: General requirements and tests
EN 61558-2-4	Safety of power transformers, power supply units and similar Part 2-4: Particular requirements for isolating transformers for general use
EN 61558-2-6	Safety of power transformers, power supply units and similar Part 2-6: Particular requirements for safety isolating transformers for general use
EN 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 1: General requirements
IEC 61643	Surge protective devices connected to low-voltage power distribution systems
IEC 60664-1	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests
EN 61800-3	Adjustable speed electrical power drive systems - Part 3: EMC product standard including specific test methods