**Section 6 - Employer’s Requirements**

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**ABBREVIATIONS**

|  |  |  |
| --- | --- | --- |
| AC | - | Alternating Current |
| ADB | - | Asian Development Bank |
| AFNOR | - | Association Francaise de Normalisation |
| ANSI | - | American National Standard Institute |
| ASA | - | American Standards Association |
| ASHRAE | - | American Society of Heating, Refrigerating and Air-conditioning Engineers |
| ASME | - | American Society of Mechanical Engineers |
| ASTM | - | American Society for Testing and Materials |
| ASTME | - | American Society of Tool and Manufacturing Engineers |
| AVR | - | Automatic Voltage Regulator |
| BS | - | British Standard |
| BSEN | - | British Standard Euro Norm |
| CB | - | Circuit Breaker |
| CCR | - | Central Control Room |
| CEE | - | Commission Internationale de Réglementation en vue de l’Approbation de l’Equipement Electrique |
| CFA | - | Consolidated Freight Association |
| CI | - | Cold Insulation |
| CIRIA | - | Construction Industry Research and Information Association, London UK |
| CT | - | Current Transformer |
| CWI | - | Chilled-Water Insulation |
| DCS | - | Distributed Control System |
| DGU | - | Diesel Generator Unit |
| DIN | - | Deutsches Institut für Normung |
| DO | - | Diesel Oil |
| ELS | - | Emergency Lighting System |
| EPA | - | Environmental Protection Agency |
| EUROVENT | - | Comité Européen des Constructeurs de Matériel Aéraulique |
| EU | - | European Union |
| GIS-SWG | - | Gas Insulated Switch Gear |
| GPS | - | Global Positioning System |
| GRP | - | Glass-fibre Reinforced Plastics |
| HI | - | Heat Insulation |
| HFO | - | Heavy Fuel Oil |
| HRC | - | High Recovery Fuse |
| HV | - | High Voltage (­ 36 kV) |
| HVAC | - | Heating, Ventilation & Air-Conditioning |
| IEC | - | International Electric Commission |
| IFO | - | Intermediate Fuel Oil |
| ISO | - | International Standardisation Organisation |
| ISRM | - | International Society for Rock Mechanics |
| I&C | - | Instrumentation and Control |
| KKS | - | :Kraftwerk Kennzeichnungs-System (= Designation System for Power Plants) |
| LCP | - | Local Control Panel |
| LCB | - | Local Control Boards |
| LLC | - | Logical Link Control |
| LV | - | Low Voltage (< 1 kV) |
| MCC | - | Motor Control Cubicle |
| MMI | - | Man Machine Interface |
| MV | - | Medium Voltage (­1 kV < 36 kV) |
| MVR | - | Manual Voltage Regulating |
| NB | - | Nominal Bore |
| NFPA | - | National Fire Protection Agency |
| NLS | - | Normal Lighting System |
| NLTC | - | No Load Tap Changer |
| OHL | - | Over Head Line |
| OLTC | - | On Load Tap Changer |
| OPC | - | Ordinary Portland Cement |
| PC | - | Performance Certificate |
| PGC | - | Potential Gradient Control |
| PLC | - | Programmable Logic Control |
| PPI | - | Personal Protection Insulation |
| PQR | - | Procedure Qualification Record |
| P&I | - | Piping and Instrumentation |
| SCADA | - | Supervisory control and data acquisition |
| SIS | - | Swedish Standard |
| SLD | - | Single Line Diagram |
| SLS | - | Security Lighting System |
| SPT | - | Standard Penetration Test |
| SRPC | - | Sulphate Resisting Portland Cement |
| SSD | - | Saturated and Surface Dry- Condition |
| SWG | - | Switch Gear |
| TOC | - | Taking Over Certificate |
| TRD | - | Technische Richtlinien für Dampferzeuger (= Technical Guidelines for  Steam boilers) |
| UPS | - | Uninterrupted Power Supply |
| UTM | - | Universal Transversal Mercator (Co-ordinate System) |
| VDE | - | Verband Deutscher Elektrotechniker e.V. |

# Particular Specification – Electrical Works

## Foreword

The concept for the Fourth Power Development Project is for a power plant with ultimately three diesel generating units of 8 MW each. However, only 2 diesel generating sets have now been installed under the original project and now the third engine is to be installed under ADB financing. The present Employer’s Particular Requirements for Mechanical Works cover all Works and Supply of Goods financed under the ADB financing.

## Scope of Works and Supply of Goods

This specification covers all the electrical works to be carried out under this contract including design, supply, erection, testing and commissioning and any other required services to make the plant functional and complete in every respect. The required equipment, systems, materials, etc. are those necessary for the complete and proper execution of the contract on a turn-key basis contract and as generally shown in principle on Tender Drawings and/or stated in the General and Particular Technical Specifications.

The scope of the Electrical Works shall include, but not be limited to, the following:

### Generators

1. Single salient pole synchronous generators of approx. 8 MW, operating at nominal voltage of 11 kV, 50 Hz, driven by medium speed 750 rpm diesel engines, including brushless excitation system with rotating diodes, standstill heating and all related ancillaries;
2. Single generator control panels, complete with protection relays, automatic voltage regulators, generator control and excitation system, synchronization, load sharing, interface and all required supervision and alarms, at least to the extent of the existing units 8 & 9, for installation in the local control room;
3. Single diesel control panels, complete with all necessary monitoring, supervision and alarms, at least to the extent of the existing diesel generator units 8 & 9, for installation in the local control room [May be supplied as one common Diesel Generator control panel comprising of items b. and c.]

### Cabling

1. One (1) lot of medium voltage XLPE copper cables 6/10 kV for the connection of generator 11 kV main switchgear and generator earthing
2. One (1) lot of low voltage XLPE power cables 0.6/1 kV (copper)
3. One (1) lot of control and pilot cables

### Electrical Spare Parts

1. Complete sets of spare parts for all electrical equipment and machinery of the project, adequate for at least 10,000 hrs. operation, including AVR, governer controller, synchronizer and load sharing unit. all new spares should be

calibrated and have all required settings for operation.

All items are to be priced individually.

### Training Program

1. Generator workshop training
2. Switchgear workshop training
3. Site training

### Miscellaneous

The scope of supply shall include any other item required to make the plant/systems functional and complete in every respect. Such items shall be specified in detail with individual prices to be given for each item.

### Electrical Workshop Equipment

The following equipment is required for the electrical workshop to be established at the new powerhouse:

* One (1) signal generator
* One (1) three phase power analyser
* One (1) simulating module for PLC
* Two (2) Fluke ScopeMeter or similar (scope meter or similar to be requested by

by STELCO; model number to be given later)

Individual prices shall be quoted for each optional item.

### Generators and Auxiliaries

Single salient pole type diesel driven synchronous generators, including all related auxiliaries and ancillaries, shall be supplied, one for each diesel unit specified under the scope of the mechanical works.

The design of the generators shall be co-ordinated by the Contractor between the manufacturers of the generators and the diesel engines.

### Generator Capacity and Main Data

#### Capacity

The generator capacity, at the specified design temperatures, rated power factor and any subsequently specified condition, shall be 8 MW depending on the output of the selected diesel engine. The bid shall include the following diagrams:

* Generator capability diagram for operation at IEC standard conditions
* Generator capability diagram for MCR operation at site conditions within Zone A of fig. 13 of IEC 600034-1

### Main Data

|  |  |  |
| --- | --- | --- |
| Type: direct elastically coupled to diesel engine |  | 3-phase, synchronous |
| Rated capacity at IEC conditions: |  | as above, to be detailed in the data sheets |
| Maximum continuous rating (MCR) at design ambient conditions: |  | as above, to be detailed in the data sheets |
| Over-load capacity: 10% for 1 hr within 12 hrs. without undue temp. rise |  | as above, to be detailed in the data sheets |
| Rated voltage: | kV | 11 |
| Voltage regulating range: | % | ±5 |
| Rated power factor: | cosφ | 0.8 |
| Rated frequency:  Rated Speed:  Detailed in data sheets | Hz  rpm | 50  750 |
| Over-speed capability: | % | 120 |
| Rotor and stator insulation: | Class | F |
| Winding connection:  Terminals  Reactances (unsaturated):  Transient X’d  Sub transient X”d | approx. %  approx. % | star, leads brought out to 6  30  20 |
| Unbalanced load:  No-load S.C. ratio: | Approx. % | 8  0.6 |
| Excitation system |  | brushless with rotating  diodes |
| Type of construction: |  | acc. to manufacturer’s  design |
| Type of cooling |  | IC 21 |
| Degree of protection: |  | IP44 |

The design, construction, characteristics, and performance of the generators shall conform to IEC Standard 60034 and shall comply with the Employer’s General Requirements.

### Supervisory Devices

#### General

The scope of work shall comprise all devices necessary for the supervision of the generator. In the following the minimum scope is specified. Other devices deemed necessary by the Contractor shall be included.

#### Stator

The stator shall be equipped with 12 resistance-type temperature sensors Pt 100 with static alarm and tripping device for monitoring the winding temperatures. They shall be of the three-wire type, evenly distributed in the stator winding and be placed between upper and lower layer.

The terminals of the sensors shall be connected to surge protection devices that shall prevent excessive over voltages in case of failure of the stator winding insulation.

#### Rotor

The rotor shall be protected against single and double earth faults by a dedicated rotor protection relay [64N] to be installed in the local control panel. Single earth faults shall lead to an alarm only, whereas double earth faults shall trip the generator immediately.

The rotor temperature shall be monitored by means of the manufacturer's standard system providing the following features:

* Analogue signal, 0 - 150 C approx., for remote indication
* Static alarm and tripping device

#### Bearings

The bearings shall comply with the following:

* 2 resistance-type temperature sensors for each bearing (metal temperature)
* 1 oil level indicator for each bearing oil reservoir
* 1 oil flow switch for each bearing oil system
* 1 pressure switch for the oil system

#### Excitation System

Electrical protection and monitoring shall be provided for the individual systems and main components.

#### Fire Alarm System

Temperature and/or smoke detectors for fire alarm shall be provided as described under "Fire Alarm System". (Required smoke/heat detectors to be added to the existing new system)

#### Earthing and Short Circuiting Facilities

Earthing and short circuiting of the generator shall be possible at the associated 11 kV switchgear cubicle. It shall be electrically and mechanically interlocked in such a way that it can be operated only if the pertaining unit is not alive.

Provisions shall be made for short circuiting the three-phases for generator drying with approx. 80% rated current and/or for adjustment of the generator protection during 10 minutes with 120% rated current.

The generator earthing system shall consider a double earth fault (IKEE) according to IEC.

### Gen-set Local Control Panel

#### General

The scope of work includes the engineering, design, supply, installation, testing and commissioning of metal enclosed local control panels for of the generating set. The control panels shall be installed in the engine room. The panels shall be provided with ventilation by forced air. The air inlet openings shall be fitted with a labyrinth type filter and a second fine filter. The forced air system shall be designed with 100% spare capacity including redundant in-feed, which shall be switched on automatically if the main system fails. Voluntary pre-selection shall be possible by a selector switch.

The control equipment for the generator shall be designed to accommodate plug-in technique. The panels shall be complete with all necessary control, supervisory, monitoring and alarm equipment for the operation of the gen-sets and their excitation and voltage regulation systems. The control systems shall be designed to allow manual / automatic excitation and load control as well as local / remote control of the generators and excitation systems.

#### Excitation Control

The local control panel of the alternator shall be equipped with, but not limited to, the following:

* One set of automatic voltage regulators consisting of one main and one slave AVR, the characteristics of which have to match the particulars of the alternators, complete with matching units and power factor control units for back-synchronisation (Basler DECs 200 system or equivalent Basler type) or same as existing DG8 and 9.
* one (1) delta (AVR / MVR) indication
* one (1) set point indicator (should be able to see power factor, kW and kVAr in individual meters)
* one (1) ammeter and one (1) voltmeter to measure the DC output of the rectifier assembly (the system should show maximum kW, kVAr and kV)
* three (3) ammeters and one (1) voltmeter with change-over switch to measure the AC input of the rectifier assembly
* one (1) voltmeter with change-over switch for generator voltage
* one (1) rotor protection relay for rotor earth fault and rotating diode failure protection
* one (1) luminous panel for detailed fault indication (e.g. blowing of fuses, failure of individual diodes, failure of the ventilation system, over voltage protection, etc.). For group remote alarm indication and event recording, every alarm circuit shall have separate potential free contacts wired to a terminal board.
* control devices (on and off luminous pushbuttons, selector switches, etc.) for:
* set point adjuster to raise / lower AVR / MVR
* change-over between AVR and MVR
* key locked Local / Remote control selection
* ventilation system
* anti-condensation heating
* 4 – 20 mA signals and potential free contacts shall be available at the terminals for remote indication; terminals shall also be available to receive remote control commands. Transducers for KW, KVA and Kvar to give signals in the negative range so that operators and troubleshooting engineers can see when reverse real power or reactive reverse power from the generator set.

#### Gen-set Control

The local control panels of the gen-set shall be equipped with, but not limited to, the following:

(a) For the generator:

* three (3) ammeters
* one (1) voltmeter with change-over switch
* one (1) frequency meter
* one (1) cosφ meter
* one (1) kW meter
* one (1) kWh meter
* one (1) kVAr meter
* one (1) winding and bearing temperature indicator with selector switch

(b) For the diesel engine

* one (1) running hour counter
* one (1) engine speed indicator
* one (1) turbocharger speed indicator
* one (1) exhaust gas temperature indicator including selector switch for each cylinder

(c) Each panel shall have a set of controls consisting of at least the following:

* AMF controller
* Load sharing unit
* Gen-set Start – Stop
* Gen-set control Manual – Off – Auto
* Speed setting Lower – Raise
* Voltage setting Lower - Raise
* Emergency Stop

#### Synchronization System

Each generator shall be provided with its own full automatic synchronizing system. Initiation as well as interruption of the automatic synchronising / paralleling procedure shall be possible at any time at both the local and the main control room.

The synchronizing device shall be microprocessor based with plug-in type modules and shall have the following features without any need for additional options or software:

Easy programmable parameters such as:

* Paralleling time
* Response of the engine regulators
* Response of the generator voltage regulator
* Circuit breaker reaction time
* Full double channel hardware and software system enabling the following functions:
* Single channel operation in the event of any internal fault
* Self supervision / monitoring
* Connecting to zero voltage bus-bars
* Auto shut off function after successful paralleling
* Local operation, maintenance and diagnostics
* Full remote operation and supervision
* Auxiliary supply from the voltage transformers, otherwise double in-feed from different independent sources
* Automatic bus-bar voltage transformer selection, depending on the position of the 11 kV generator bus-bar isolator
* Programmable for easy use of the voltage transformer at bus 1 and / or bus 2 of the 11 kV SWG, otherwise interposing transformers shall be included
* Test mode

For each synchronising system, a synchro-check shall be provided as back-up.

Marshalling terminals / racks for later easy extension with a computerised control and supervision system shall be provided including potential free contacts and 4 to 20 mA output signals.

### Site Tests

#### Pre-Commissioning Tests

During erection and before start-up the following measurements and tests shall be performed as a minimum:

1. Visual inspection and dimensional check
2. Check of stator bore for exact roundness at the edges of the iron core
3. Checking of the uniformity of the air gap
4. Checking of the alignment of the ready assembled Diesel and generator shaft.
5. Checking of all bearing clearances
6. Checking of the bearing oil cooling installation for complete and correct assembly
7. Checking of the entire generator cooling system for complete and correct assembly
8. 12 hours hydrostatic pressure and tightness tests of all equipment containing/ carrying water, oil and compressed air
9. Measurement of the DC resistance of the field winding
10. Measurement of the stator winding DC resistance per phase
11. Megger test and HV test of the field winding
12. Megger test (1 min. and 10 min. value) of the stator winding and determination of polarisation factor
13. Operational tests of all generator auxiliary equipment, including calibration of related electric control instruments
14. Checking of measuring, alarm, and protection devices
15. Performance tests on the excitation system.

#### Commissioning Tests

The following commissioning tests shall be performed on each generator:

1. Test of shaft movement, bearing run and shaft eccentricity
2. Measurement of the short-circuit and no-load curves
3. Megger test and HV withstand test of the stator winding
4. Performance test of excitation system during no-load running
5. Functional test of generator protection relays
6. Primary injection test up to 110% rated current with short circuit at the 11 kV side
7. Determination of reactances and time constants as derived from specified measurements/tests
8. Measurement of shaft voltages
9. Balancing, over speed test and vibration measurement
10. Synchronisation with the Grid System
11. Load rejection tests at different load steps in order to check Diesel governor and AVR
12. Rated output test of the unit including temperature run
13. Diesel engine speed governor and generator excitation tests for parameters in accordance to ISO-3046
14. Measurement of the individual losses and determination of the efficiency in accordance with IEC 60034-2, ISO 8528, and ISO 15550
15. Measurement of power consumption of essential independent auxiliaries in accordance with ISO 3046, ISO 8528, and ISO 15550

## 11 kV MV Switchgear

### General Design Conditions and Data

#### Instrument Transformer

The rating of the instrument transformer shall comply with the requirements as specified, in particular as far as adequate accuracy, saturation factor, rated burden and insulation levels are concerned.

Particular reference is made to the relevant Protection Specifications.

Current transformers shall be designed for continuous thermal current rating equal to the current rating of the associated switchgear plus 20% over-load as well as for a short time current rating corresponding to the relevant fault level of the circuit, accuracy no more than 5%.

Current transformers shall not be mounted on the CB truck but in the fixed portion of the relevant compartment.

Potential transformers shall be of the cast resin insulated, single phase type.

#### Earthing Switches or Devices

Each feeder and each bus-bar shall be equipped with a three phase, hand operated earthing switch.

An interlock shall be provided to enable closing only if the relevant MV circuit breaker is in the draw out position and the remote feeding circuit breakers are open. Moreover, it shall not be possible to move in a circuit breaker truck when the earthing switch is closed.

### Protection Functions

#### Generator Protection

The following protection functions shall be provided as a minimum in accordance with relevant ANSI codes and IEEE recommendations:

[50/51] Definite and Inverse time over-current protection

[50N/51N] Definite and Inverse time earth fault protection

[46] Negative sequence / unbalanced power supply protection

[49] Thermal overload protection

[87G] Generator differential protection

[67N/67NC] Directional earth fault protection

[32P/32Q] Reverse power protection

[37P] Directional under-power protection

[40] Loss of field protection

[78PS] Pole slip

[50V/51V] Voltage restrained over-current protection

[21B] Under-impedance protection

[64G] Stator earth fault protection

[27R] Permanent under-voltage protection

[27] Under-voltage protection

[59] Over-voltage protection

[59N] Neutral voltage displacement protection

[47] Negative sequence over-voltage protection

[81H] Over-frequency protection

[81L] Under-frequency protection

Two trip relays

One trip supervision relay

One supply supervision relay

Trip matrix

## LV AC Power Distribution System

The Contractor shall supply, install, and commissioned all required LV main distribution and sub-distribution boards shall be by the Contractor. The switchgear, boards, and all other equipment related hereto shall meet the General Technical Requirements, as specified.

### Scope of Supply:

The Contractor shall provide:

Single LV AC switchboards for diesel engine auxiliaries, 400/ 230 V, 50 Hz connect to existing EAP10 feeder

### General Design Conditions and Data

#### General

The final number of boards, feeders, etc., as well as the required capacities and assemblies shall be defined by the Contractor according to the requirements of the equipment of his scope of supply. The Contractor shall in particular verify the required short-time withstand current of all LV equipment considering the present installation and future extensions. Reference is made to the tender single line diagram that is indicative only of the philosophy of the overall design.

The allocation of auxiliaries to different sections of each busbar and the interconnections between different boards shall be selected to achieve maximum plant availability and reliability.

A single failure shall not lead to a total plant shut down. Double in-feed to boards etc. shall be provided accordingly.

The Contractor shall submit a load evaluation for each individual switchboard and the entire plant in order to verify the adequacy of the available auxiliary supply.

#### Instrument Transformer

Instrument transformers shall be of the completely enclosed, dry cast resin type in accordance with General Technical Requirements.

#### Remote Indication and Control

All electrical measuring systems requiring remote indication in the control room shall be equipped with transmitters. All interfaces as required for remote control, monitoring, and alarm shall be provided.

#### Voltage Monitoring

Bus-bar voltage monitoring relays shall be installed in each LV switchboard and sub-distribution panel as follows:

* For AC systems: definite time delayed, three-phase under-voltage relay [27], adjustable in steps
* For DC systems: Instantaneous under-voltage relay [27], adjustable in steps.

#### Spare Compartments

Each LV AC and DC board shall contain at least 10% unequipped spare compartments, with a minimum of one, of each type of outgoing feeder. Such compartments shall be closed by steel panels/ doors.

#### Spare Feeders

Each LV AC and DC board shall contain at least 10% fully equipped spare outgoing feeders, with a minimum of one, of each type of feeder.

#### Outgoing Feeders to Individual Diesel Generator Auxiliaries (already supplied)

* One (1) circuit breaker with electromagnetic and thermal over-current release
* One (1) current transformer for feeders rated 63 A and above
* One (1) ammeter for feeders rated 63 A and above
* One (1) current transmitter for remote indication if required for process control.

For ratings of 25 A and below, the circuit breakers may be replaced by MCBs with electromagnetic and thermal over-current releases, provided the fault carrying capacity without additional pre-fuse will be adequate.

#### Tests at Site

The complete switchgear and the individual apparatus shall be tested on site as further described in the Particular requirements including setting and functional test of protection devices and synchronisation scheme.

## Cabling

### Scope of Supply

The scope of works shall comprise the supply, installation and commissioning of all medium voltage and low voltage power cables, control cables, pilot cables, fibre optic cables, cable terminals, sealing ends, cable racks, trays and ladders, supports, conduits, cable fixing material, etc., for the complete power station. It shall cover all equipment and works to form a complete, safe, and reliable plant.

The scope of supply comprises basically the following types of cable:

1. One (1) lot of medium voltage 6/10 (12) kV XLPE copper cables, for the connection of generator to the 11 kV main switchgear and earthing resistor
2. One (1) lot of low voltage XLPE copper cables 0.6/1 kV
3. One (1) lot of control cables
4. One (1) lot of pilot / fibre optic cables

### Design Requirements

#### General

The cables described in this section shall comply with the General Technical Requirements, as far as applicable.

The Contractor shall perform all relevant design and engineering of the complete cabling system and prepare the terminal diagrams, cable list, cable schedules, and the cable raceway arrangement plans.

The Contractor shall select the most suitable and effective cable passage and raceways ensuring that they do not interfere with other installations. Cables laid outdoors shall never be exposed to direct sun radiation.

#### Power Cables

The Contractor, taking into account site environmental and prevailing climatic conditions, shall determine the maximum continuous current carrying capacity of each individual cable type and cross section used. The applied load reduction factors are subject to the approval of the Employer

The Contractor shall submit for approval:

* Calculation of the continuous current rating of the proposed cables and their accessories
* Calculation of voltage drop
* Calculation of induced voltages in pilot and alarm cables installed in parallel with the power cables
* Report of own site measurements of induced voltages on pilot and alarm cable
* Calculation of earthing wire cross sections

The cross section shall be calculated by the Contractor subject to consideration of the following conditions:

* Maximum load current under most severe ambient conditions
* Maximum fault currents/ periods

#### Control Cables

All control, metering, instrumentation and I&C cables shall comply with the provision of the General Technical Requirements.

### Cable Sealing Ends and Terminations

The sealing ends used shall suit the severe ambient conditions by an increased creepage distance via an additional insulation cap. For outdoor sealing ends, a creepage distance of 40 mm/ kV line-to-line operating voltage shall be provided.

At all terminations of wires and cables, the insulation shall be neatly stripped without nicking the strands of the conductors. Cable lugs of adequate size shall be used for stranded conductors. Cable glands or clamps shall be provided to prevent any stress to the conductors or the terminals.

#### Grounding of Cable Screens

Cable sheath/ screens shall be solidly earthed at both ends via the station earthing system.

### Tests

The cables and their accessories shall be subject to acceptance tests, to be performed at the Contractor's premises and at site as applicable. The latest issue of IEC standards shall apply as far as not requested otherwise.

Before energising a cable circuit including all the accessories, tests shall be performed on the complete installation as described in the General Technical Specification.

## Lighting and Small Power

A complete lighting system, with the individual components being of approved type and constructed of best quality materials shall be supplied, installed, and commissioned.

### Scope of Supply

The scope of supply shall comprise, but is not limited to the following:

* Exhaust stack

### General Design Conditions and Data

The complete system as well as the individual apparatus shall comply if not stated otherwise with the requirements of the General Technical Requirements.

The Contractor shall prepare and submit to the Engineer for approval the installation drawings and illumination level calculations.

### Illumination Levels

The mean illumination levels shall be as follows with the indicated values referring to equipment in new conditions:

* Outdoor transformers, oil storage tank areas, etc. 30 lux
* Power house basement 60 – 150 lux
* Accessible cable trenches, cable floors 60 lux
* Outdoor operating areas 150 lux
* Battery rooms 150 lux
* Power house operation floor level and stair cases 200 lux
* Switchgear/ electrical rooms 250 lux
* Local control room 350 lux

Additionally, all local push button stations, control stations, control panels, instrument racks, hand operated equipment like valves, etc., shall - if required due to the low surrounding illumination levels - be illuminated separately by means of suitable fluorescent lamps, mounted on poles or at adjacent structures, so as to obtain at least 200 lux illumination level. The illumination level shall be measured as laid down in the General Technical Requirements.

#### Lighting Categories and Power Supply

The electrical lighting system shall be divided into the following categories:

* Normal lighting system (NLS), fed via the lighting sub-distribution boards
* Emergency lighting system (ELS) for the power plant control room, fed from the common plant safe AC system (about 30 % of the NLS system)
* Security lighting system (SLS), consisting of self-contained fixtures with batteries and chargers

Operation time in case of main supply failure shall be 3 hrs for the SLS as well as the control room ELS and 0.1 hrs for the remaining ELS

The following service voltages shall be used:

* Normal lighting system: 3-phase, 5 wire AC 400 / 230 V
* Emergency lighting system: either 110 V DC or self-contained DC supply fed by single phase AC 230 V
* Security lighting system: self-contained DC supply fed by single phase AC 230 V
* AC power socket outlets: 3-phase, five pins 400 V
* AC socket outlets: single phase 230 V

The power socket outlets shall be fed directly from the LV power distribution, supplying the concerned area and building services socket outlets shall be fed from the next lighting sub-distribution.

#### Accessories, Small Material

All necessary junction boxes, socket outlets, and switches shall be provided. The equipment may be surface mounted in technical rooms and outdoors but shall be flush mounted in the administration building and offices, etc. They shall be of white colour or light-grey colour.

Equipment for surface mounting shall be sealed against ingress of moisture. Each socket outlet shall have a grounding contact (PE) for protection purposes.

#### Compensation and Radio Interference

For compensation of the inductive current of the chokes, compensating capacitors have to be provided to obtain a power factor of about 0.9.

Discharge resistors of sufficient size shall be connected in parallel.

According to the IEC standards the equipment shall be furnished with radio interference suppressors, if applicable.

## Electrical Spare Parts

The scope of supply shall include complete sets of spare parts for all electrical equipment and machinery as under.

### Security / Maintenance Spare Parts

#### Security Spare Parts

The Security Spare Parts to be supplied as defined by Employer shall comprise all required spare parts which have to be in store in order to replace important items which may be expected to be damaged during normal operation, and whose non-availability would prevent the power plant from operation. They shall be recommended by the manufacturer and shall comprise:

1. At least one piece of any type of measuring, protection, indication, and alarm device installed in the plant (should provide at least one spare MV circuit breaker for generator and one spare circuit breaker for feeder)
2. At least one piece of each type of current transformers, voltage transformers, surge arresters, and MV circuit breaker for each three pieces supplied and installed
3. One complete set of spare fuses, lamps, relays, MCBs and other items required to keep the plant operational in case one of these items fails.

#### Maintenance Spare Parts

The maintenance spare parts are those required to perform regular maintenance on items requiring periodic maintenance.

Under this category the following parts shall be supplied with suitable packing and corrosion protection:

* 1 truck for 11kV switchgear for circuit breaker service and replacement

### Spare Parts / Consumables for 10 000 Service Hours

The Spare Parts / Consumables shall be recommended and offered by the Tenderer according to his equipment, comprising spare parts and all other materials which are required to perform correct maintenance and overhaul works for 10 000 running hours according to the instructions of the manufacturers of each plant component supplied under this contract.

## Training Program

The Tenderer shall propose to Employer for approval a comprehensive training program adapted to the specific requirements of the STELCO power plant in Male covering at least the following:

### Generator factory training

Training of electrical supervisors to be performed preferably at the generator manufacturers workshops / repair centres especially concerning generator and AVR fault finding, specific maintenance methods and procedures including measuring, performing of generator and AVR specific maintenance works including proper reporting.

4 Persons, one week each as “hands on” training on fault finding and AVR / speed governor setting tasks.”

Training shall also include governor, actuator and related hardware adjustments and electronic and software training. Also training shall be given on mounting and adjustment of all the sensors used in the engine and around the pipes and auxiliary devices. Theory of engine operation related to engine sequences like starting, stopping, slow turn, emergency stop shall be given.

### Switchgear workshop training

Training of electrical supervisors to be performed preferably at the Switchgear manufacturers workshops / repair centres especially concerning fault finding, maintenance, security check methods and safety procedures including measuring, performing of repair and overhaul works and proper reporting.

1 batch of 4 Persons, for one week as “hands on” training on real switchgear overhaul / repair / assembly tasks.”

### Foreign Training

All living, accommodation, food, transport expenses of the trainees during the period of training/study tour including airfares, incidental expenses, medical expenses, medical insurances etc. shall be covered by the Bidder including pocket allowance of US$100/day/person.

### Site training

#### General Plant Operation Strategy

The site training shall be on operation of the 11 kV switchgear and of the distribution feeders under fault conditions, load shedding programming and reconnection strategies. This general plant operation training shall be directed mainly to the plant operating staff and may be combined with the mechanical training.

#### Operation and Regular Maintenance

Training at site shall cover mainly the operation and day to day maintenance / regular maintenance aspects at least for the following items:

* Main generators including excitation and Automatic Voltage Regulators (AVR)
* Generator and switchgear control, protection and supervision system
* MV switchgear maintenance
* LV Switchgear maintenance
* DC power supply operation and maintenance
* Safe AC operation and maintenance
* Calculation of suitable setting values for protection relays.

# General Specification – Electrical Works

## General

The electrical equipment of any electrical, mechanical or civil installation being provided under this Contract shall fulfil the requirements of this Section and, as far as applicable, also those of Section 6.0 Sub-Clause 2.7 "Painting and Corrosion Protection".

All components shall be new and of an approved and reliable design. The highest extent of uniformity and Interchangeability shall be reached. The design shall facilitate an easy maintenance and repair of the components.

The equipment shall be pre-assembled to the highest possible extent in the Contractor's or Sub-Contractor's workshop including wiring of boards, desks, etc. and installation of internals.

All equipment shall be suitable for the prevailing extreme climatic conditions. If necessary, open air installed parts shall be protected against sun radiation by means of adequate shades. All equipment shall be of vermin proof and tropicalised design.

## Standards and Environmental Conditions

### Standards

The design and manufacture of all electrical equipment shall comply with the latest editions of the IEC Standards; particularly the following shall be applied to select electrical equipment:

− IEC 60034 Rotating electrical machines

− IEC 60038 IEC Standard voltages

− IEC 60044 Instrument transformers

− IEC 60059 IEC Standard current ratings

− IEC 60071 Insulation co-ordination

− IEC 60072 Dimensions of electrical machines

− IEC 60076 Power transformers

− IEC 60079 Electrical apparatus for explosive gas atmospheres

− IEC 60086 Primary cells and batteries

− IEC 60137 Insulated bushings for AC above 1000 V

− IEC 60156 Determination of electric strength of insulation oil

− IEC 60183 Guide to selection of HV cables

− IEC 60216 Thermal properties of electrical insulating material

− IEC 60227 PVC insulated cables for voltages up to 750 V

− IEC 60228 Conductors of insulated cables

− IEC 60255 Electrical relays

− IEC 60265 High voltage switches

− IEC 60269 Low voltage fuses

− IEC 60282 HV fuses

− IEC 60287 Calculation of the current rating of HV cables

− IEC 60296 Mineral insulation oils

− IEC 60331 Test for electric cables under fire conditions

− IEC 60332 Tests on cables under fire conditions

− IEC 60364 Electrical installations for buildings

− IEC 60376 Specification of SF6

− IEC 60439 LV switchgear and control gear assemblies

− IEC 60470 HV AC contactors

− IEC 60502 Power cables with extruded insulation for voltages >1 kV < 30 kV

− IEC 60529 Degree of protection provided by enclosure (IP Code)

− IEC 60598 Luminaries

− IEC 60617 Graphical symbols for diagrams

− IEC 60623 Vented NICD cells

− IEC 60664 Insulation co-ordination for equipment within LV systems

− IEC 60694 Common specification for HV switchgear and controlgear

− IEC 60702 Mineral insulated cables

− IEC 60909 Short circuit currents in three phase AC systems

− IEC 60947 Low voltage switchgear and controlgear

− IEC 61082 Preparation of documents used in electro-technology

− IEC 61140 Protection against electrical shock

− IEC 61660 Short circuit currents in DC auxiliary installations

− IEC 62271 High voltage switchgear and controlgear

− IEC 62305 Protection against lightning

In case an IEC Standard does not exist or does not cover the Scope of Supply, National Standards equivalent to German VDE or British B.S. acceptable to the Employer shall be applied.

In addition, the generating sets including control and switchgear shall be designed, manufactured, workshop and site tested, and commissioned in accordance with all applicable provisions of ISO Standards 3046, 8528 & 15550.

Any other standard not covered by the above provisions need to be submitted for approval prior to commencement of any design work

### Standard Voltages and Frequencies The following nominal values are applied:

− Transmission voltage 66 kV

− Distribution voltage 11 kV

− Generator voltage 11 kV

− Low voltage (3 phase, 4 wire system) 400 / 230 V

− Rated frequency 50 Hz

− Steady state operation frequency range +3% to - 5%

− DC voltage 110 V and 24 V

### Climatic Conditions

All electrical equipment shall be entirely suitable for the use under the site conditions as specified in Section 6.0 Clause 2.0 ‘Physical Data’.

## Generators

### General Design Conditions

#### General

The design, construction, characteristics, performance, and testing of the generators shall conform to requirements of the applicable IEC Standard. Rating and performance of the generators shall further be in accordance with ISO 8528.

All equipment shall be designed and manufactured under due consideration of the prevailing transport limitations.

The bid shall include adequate information regarding installation at site as well as regarding replacement of a faulty rotor at a later stage. The required crane capacity of the crane shall be advised.

All provisions shall be included to allow the measurement of the individual losses and determination of the efficiencies.

#### Studies and Calculations

At the earliest possible design stage, well ahead of the start of manufacturing, the Contractor shall perform and submit all necessary studies, such as for shaft oscillations, load oscillations, cyclic irregularity, and angular deviations to ensure:

* Adequate shaft diameter
* Clear definition of min. required inertia of the Diesel generator unit regarding:
  + Flicker-less light
  + operation of a single unit at an isolated grid
  + parallel operation with other Diesel units at the grid
  + adequate speed control

The inertia necessary for parallel operation shall be incorporated in the generator rotor and / or in the flywheel. The main technical data of the existing generator sets shall be available to the Contractor. The Contractor shall inform himself fully before executing the flywheel calculations. Those calculations are subject to the approval of the Engineer.

The Contractor shall calculate the range within which natural frequencies are to be expected. There shall be no forcing frequencies within 20% of either end of the range. Together with these calculations, the Contractor shall submit the transfer function blocks for the excitation and speed governor as applied for this project.

Each of the generators in conjunction with its excitation system shall be stable at all permissible loads on an isolated grid as well as in parallel with any of the other diesel generators within the power plant or with the existing generating sets at the Male' island.

The generator design and construction shall avoid undue or harmful vibrations and shall minimize noise and vibrations at all permissible operating conditions.

All parts of the generator shall be constructed to withstand all possible operation conditions. Tightening of screws and bolts shall be easily possible during maintenance works and a check on tightness shall be done after the trial run.

#### Stator

1. Frame and Housing

The stator frame and housing shall be of a rigid welded steel construction and completely assembled. The frame shall be of sturdy construction to carry the stator core, windings and attached ancillary installations. Stator frame shall form a self-contained structure capable of coping with all forces during normal and severest fault conditions and avoiding any kind of structural resonance. Besides the high resistance to deforming forces, the construction shall be sufficiently flexible to permit core dilatation and thus securely prevent buckling of the core.

The scope shall include all required embedded, supporting, and fixing materials.

1. Core

The stator core shall consist of non-ageing low loss silicon sheet-steel with a loss-coefficient of max. 1.1 W/kg at 1 Tesla. The laminations shall be insulated by means of a heat resistant varnish, uniformly applied to both sides of the low loss sheets hydraulically pressed and clamped after punching and removal of burrs to avoid any vibration. Vibrations of the core sheets shall securely be prevented during the service life of the generator. Measures are to be taken for dampening the vibrations of twice rated frequency. The laminations shall be equipped with cooling air ducts to ensure a uniform temperature rise over the entire core length. Cleaning of the ducts shall be possible without dismantling main parts of the stator casing

Anti-condensation heaters shall be installed in the lower part of the stator casing. The service life of the heater elements shall be more than 20 000 service hours.

1. Windings and Terminals

The entire stator winding shall be designed and insulated in compliance with the rated generating voltage, applying IEC class F insulation materials only. Impregnation shall be performed under vacuum. The stator windings shall be composed of multiple circuit windings made of high conductivity copper.

The shape, arrangement, and transposition of the conductors shall provide optimum electrical and mechanical characteristics. Design, materials, and manufacture shall comply with the most modern technology.

Four (4) resistance type temperature sensors per phase (one for spare) shall be installed at the hottest areas of the stator windings.

Adequate corona protection and appropriate contact with the slot surface shall be ensured. Wedges shall be securely fixed to avoid loosening or even moving out.

The end turns of the windings shall be designed to withstand all dynamic forces imposed by short circuits or connection of the unit under phase opposition without any permanent deformation or damage.

The line and neutral leads shall be brought out to terminals with highly flexible connections, suitably located on the stator frame. The connections between the windings and terminals shall be adequately insulated and supported.

Type and arrangement of the line terminals shall be suitable for terminating multiple single phase XLPE cables. Terminals and phase sequence shall be clearly marked.

#### Rotor

The rotor basically shall consist of the shaft with flange, salient poles, and fans, as required. The type, design and the construction of the rotor shall ensure that all parts withstand over speed stresses without permanent deformation or damage.

The complete rotor shall be balanced and shall withstand 120% rated speed whereby the mechanical stresses of rotating parts shall not exceed 70% of the yield point.

1. Shaft and Coupling

The design and construction of the shaft shall be co-ordinated between the Diesel and the generator manufacturers. The shaft shall be of high quality forged steel, carefully heat treated with bearing, sealing, and alignment reference surfaces accurately machined and polished conforming to standard tolerances coupled with an elastic coupling to the engine crankshaft.

The critical speed and vibration strength of all rotating parts shall be checked with the Diesel manufacturer and shall be verified by calculations.

All coupling dimensions shall be agreed upon by the Diesel and generator manufacturers.

The critical speed of the Diesel generator unit and the rigidity against vibrations shall be verified and confirmed by calculations.

The elastic coupling shall withstand all potential misalignment which may occur during engine operation including extreme loads resulting from short circuits or sudden load changes resulting from switching of large transformers, loss of load in the grid or sudden shutdowns of other gen-sets.

1. Poles and Windings

The field windings shall be of hard drawn copper and shall be insulated in class F against the core and adjacent coils, withstanding a test voltage of ten times the exciter voltage, but not less than 1500 V and not exceeding 3500 V. The winding connections between different poles shall be made by flexible tapes of adequate size. Insulation material and temperature rise shall be in accordance with the requirements for the stator windings. All possible stresses caused by over speed, shock load, etc. shall be considered.

A complete damper winding for direct and quadrature-axis damping of a reverse phase system of at least 20% consisting of solid copper bars firmly fitted to the damper rings made of hard copper with silver coated contact areas shall be provided.

#### Cooling System

The generator cooling system shall be of the self-ventilation open circuit type. The cooling air shall be drawn via washable fine filters from the machine hall. The design parameters concerning power house ventilation as detailed in the relevant sections shall be adopted. The cooling air shall be forced through the generator by axial fans arranged on the rotor.

The hot air shall be led through short air ducts towards the roof of the machine hall.

#### Bearings

The generator shall be provided with two sleeve guide bearings with forced oil lubrication. The necessary lubrication oil shall be supplied by the Diesel engine oil system.

High pressure jacking oil shall be provided for start-up and shut-down.

Special care shall be taken in the design of the bearing seals. No oil vapour shall enter the generator compartments. The system shall preferably be based on quenching air and vent-pipes with filters.

The bearings shall be adequately insulated to prevent harmful flow of shaft currents. Test points shall be arranged at an easily accessible location to allow regular checks on the existence of shaft currents. Above arrangement can be combined with the auxiliary brush gear provided for the rotor earth fault protection.

All provisions shall be included to permit loss measurement acc. to the calorimetric method. The Tender shall include detailed technical documentation on the proposed bearings.

### Excitation and Voltage Regulation System

#### General

The generator shall be equipped with a brushless excitation system that has proven reliable operation at all expected service conditions. The system shall be capable of providing a sufficient margin of stability under all steady and transient load conditions.

It shall obtain, together with the voltage regulator, a very sensitive and quick acting control of the generator voltage and reactive power. For impulse excitation (10 sec), at least 200% of the rated excitation at rated generator capacity shall be available. The exciter response at rated load of the main excitation unit shall be less than approx. 2 sec according to IEC. The excitation system shall also be properly designed for carrying out primary injection test of the generator protection system (up to 110% rated current with a short circuit at the 11 kV side).

The system shall be designed and adjusted at site in order to operate reliably and stable together with the existing generating sets under the load and operation conditions as they may occur in the isolated island network as actually existing in Male' as well as with an interconnected network as it will exist in the future. This will include very sharp load variations in case one of the engines fails as well as frequent switching operations on an empty cable network after black-outs. It shall allow operating the gen-set in peak load mode where it has to take all sudden load variations as well as in fixed load mode. For this reason the Contractor shall ensure a suitable design and setting of the engine speed governor as well as of the AVR such that the gen-set will be able to ensure reliable trouble free operation even under extreme load and power factor variations.

The scope of supply shall include all devices required for the excitation system including dry type excitation transformers, special current transformers, rectifier assembly, AVR, etc. High voltage apparatus shall be installed in metal enclosed cubicles complying with the technical requirement for MV, LV, and control switchgear.

The excitation system shall consist of brushless exciter machine mounted on the non-driving end of the generator shaft with the exciter stator fed by static excitation equipment. The exciter machine shall be mounted inside the generator housing. The machine shall be a rotating armature synchronous generator. The rotor of the exciter shall be equipped with a rectifier bridge for feeding the pole windings of the main generator. The diodes used in the rectifier shall be ample dimensioned so that only 60% of the rated current and 30% of the inverse voltage of the diodes shall be utilised if the unit operates at rated loads.

Resistors shall be connected in parallel with diodes to protect them against over voltages due to current commutation or due to false synchronization. The rectifier shall be equipped with monitoring devices indicating defect diodes and rotor earth faults. The monitoring devices shall be designed to allow remote indication and alarm signalisation. Slip rings for signal transmission shall not be permitted. The excitation energy for exciting the poles of the exciter machine shall be controlled by the automatic voltage regulator.

The power supply for the voltage regulator shall be effected by a voltage transformer and corresponding current transformers. The transformers shall be dry type cast resin insulated transformers. The excitation system shall supply the power needed to maintain a steady three phase short circuit current of at least two times the full load current.

Self excitation of the generator even after a short circuit across the terminals shall be ensured without any additional measures.

#### Voltage Regulation

The automatic voltage regulators shall be equipped with load dependent control being unaffected by frequency changes within the range of 45-52 Hz. Outside this range, the flux shall be limited by adequate voltage reduction. Over and under excitation protection shall be provided.

At constant speed, it shall ensure a steady state voltage accuracy within 0.5% related to the set reactive power characteristics curve between no load and full load and at power factors between 0.8 lagging – 1 – 0.9 leading. Soft start facilities to gradually build up the nominal voltage without significant overshoot after initial ‘switch on’ shall be provided. The generator voltage shall be adjustable within 5% of the rated voltage using a value-setting device.

The AVR droop shall be adjustable from 0 to 8% as required for single and parallel operation. The regulator shall be designed to meet the requirement for a quick restoration of voltage changes. When rated load is switched on, the voltage shall be fully regulated on average within 900 ms at maximum.

In addition to the automatic voltage regulator described, the generator shall have an excitation current control for manual adjustment of the excitation current (also suitable for primary injection test up to 110% rated current). The setting range shall be 0 – 110% of rated voltage. Changeover from automatic to manual control shall be done automatically if the automatic voltage regulator fails. The manual control circuit shall remain operative if the AVR returns to normal. Follow-up devices for bumpless changeover shall be provided. During this transition system should not fall instability.

### Inspection and Tests

#### General

The complete generators, components, and materials shall be inspected / tested as described below.

The principal requirements of generator testing procedure and conditions shall be governed by the relevant IEC Standards. All test equipment shall be provided by the Contractor.

#### Material Certificates

The Manufacturer shall deliver test certificates for all materials. The standards for material acceptance are based on the following codes:

1. Minimum requirement for important cast pieces: ASTM code class 2 or equivalent
2. Minimum requirement for important weldings: International Institute of Weldings Acceptance Code
3. Minimum requirement for ultrasonic tested sheet steel used for parts of major importance: Stahl – Eisen - Lieferbedingungen des Vereins Deutscher Eisen ¬ Huettenleute, class 2 or equivalent.

The Manufacturer shall submit material certificates for the following parts of the generator:

1. Rotor Shaft
2. Poles, Pole Endplates, Rods and Bolts for Laminated Poles
3. Stator and Rotor Winding Insulation Material
4. Bearings
5. Stator and Rotor Winding Copper
6. Stator Core

#### Workshop Acceptance Tests

The generator shall be assembled at the Manufacturer’s workshop to perform the following tests that may be witnessed by the Employer’s representative(s). Acceptance certificates for all tests shall be submitted:

1. Heat test run
2. Winding and coil tests
3. Rotor tests
4. No load and short circuit characteristics
5. Electrical measurements

## Electric Motors

### General

All motors shall be of approved manufacture and shall comply with the requirements of this Contract. They shall be complete with terminal boxes, cable glands and other accessories as specified. Each motor shall be fitted with adequate lifting hooks or eyebolts, as suitable. Motors of the same type must be fully interchangeable and shall conform - as far as applicable - to IEC standard motor dimensions. All AC motors shall be of the squirrel-cage type provided with either deep slots or double squirrel cages.

All precautions shall be taken to prevent any corrosion.

### Rating

The service voltages of the motors shall be as follows:

* LV (0.4 kV), AC, 3 phase, for all motors up to and including 160 kW
* LV (230 V), AC, 1 phase, may be used for motors up to and including 0.5 kW
* DC (110 V) for all motors required to work on the DC system

The rating of each motor shall be adequate to meet the requirements of its associated plant. The following basic criteria shall be applied:

A service factor, being the ratio of the installed motor output at design ambient conditions (rated output) to the required power at the shaft of the driven machine at its expected maximum load (power demand), shall be applied as follows:

**Power Demand Service Factor**

Up to 20 kW 1.25

From 21 to 55 kW 1.15

From 56 kW 1.10

AC motors shall be capable of operating continuously with its rated output (at design ambient conditions) at any frequency between 95% and 105% or at any voltage between 95% and 105% or at any simultaneous variation of voltage and frequency up to a total of 10% of the rated values. A transient over-voltage of 130% of the nominal voltage shall as well be sustained. Furthermore motors shall be capable to maintain stable operation when running at 75% nominal voltage for a period of 10 seconds.

The pull out torque shall be at least 160% of the rated torque for continuously loaded motors and 200% of the rated torque for intermittently loaded motors.

DC motors shall be capable of operating continuously under rated output conditions at any voltage between 90% and 110% of the nominal voltage. Unless otherwise approved, the speed drops between no load and full load shall not exceed 10% of no load speed. DC motors shall operate with a fixed brush setting for all loads.

### Starting

AC motors with rated output up to 47 kW shall be designed for direct on-line starting. Star/ delta starting, if required for a particular application, may be approved on request.

All motors shall be capable of being switched on / over to an infinite bus bar at 110% of the nominal voltage and with a maximum residual voltage of 100% at the motor terminals, even in phase opposition.

For starting the motors, a momentary voltage drop of 15% referred to nominal voltage shall be taken into consideration. The maximum starting current (without tolerance) shall not exceed the following values:

* 8 times of rated current for LV motors ≤200 kW
* times of rated current for DC motors (by means of starting resistors)

With 85% of the nominal voltage applied to the motor terminals, each motor shall be capable of accelerating its associated load to rated speed with a minimum accelerating torque of 5% of full load torque.

All motors shall be able to withstand six cold starts per hour, equally spaced. In addition, each LV motor shall be capable of enduring three successive starts with the motor initially at operating temperature without damaging overheating.

Motors required for frequent, automatic starting shall have an adequate rating which shall be subject to the Employer’s / Engineer’s approval. The Contractor shall state in the motor list the frequency of starts permitted in compliance with the motor design. The Contractor shall submit starting curves (temperature/ time) for all motors above 47 kW.

### Windings and Insulation Class

The insulation of all motors shall be of class F and shall be suitable for operation in damp locations, for occasional contact with corrosive gases and vapours and for the applied fluctuations in temperature.

The stator winding shall be suitably braced to withstand the forces due to direct-on-line starting and transfer conditions as mentioned before.

Inter-phase connections inside the machine shall be made at non-driving end and the winding connections and tails shall be non-hygroscopic. The stator winding shall have a sufficient cross section to withstand the maximum prospective fault current for the period of time determined by the protective devices.

The rotor winding shall be designed to give trouble free continuous service including repeated direct-on-line starting.

### Ventilation and Type of Enclosure

Unless otherwise specified, all motors shall be of the totally enclosed fan cooled type, protection class IP 55 according to relevant IEC Standard.

Motors installed outdoors shall be protected from direct exposure to sun. For this purpose, a suitable shed shall be provided. Motors of IEC size 132 and above shall be equipped with automatically controlled heating elements for protection against internal condensation during stand still periods as described under "Anti Condensation Heaters".

### Bearings

As far as applicable and unless otherwise specified, self-lubricating ball and roller bearings with solid races shall be provided for all LV motors as necessary. For vertical motors thrust bearings are required. All motors with IEC size 132 and above shall be equipped with a type of lubricator which permits greasing while the motor is running and which prevents over lubrication. Additionally, the bearings shall be fitted with grease nipples permitting the use of a universal grease gun.

Where sleeve bearings are being used, they shall be preferably of the self-lubricating type. If forced lubrication is required, it shall be arranged common to both, the motor and the driven machine and provisions shall be made to ensure lubrication during start-up and shut down operations without the necessity to start an auxiliary lube oil pump. Self-lubricated bearings shall be equipped with an easily accessible lubrication pot with overflow pipe and oil collecting vessel. The bearings shall further be protected and sealed against dust penetration and oil leakage.

In case of independent bearings, motor and bearing pedestals shall be fitted on a common base plate.

For the transport of motors equipped with ball or roller bearings, special bearing inserts shall be provided to prevent transport damage.

### Shafts and Couplings

Unless otherwise specified, the motors shall be provided with a free shaft extension of cylindrical shape with key and keyway according to relevant IEC Standard. The motor half-coupling shall be pressed on the motor shaft and shall be balanced together with it. A coupling guard shall be provided.

### Brush Gear and Commutators

Brush gear for DC motors shall be designed to ensure constant brush pressure. Carbon brushes shall be provided with high abrasion resistance. Each brush shall be independently adjustable but shall not require adjustment throughout its life. The brush holder shall not touch the commutator as the brushes wear, and current carrying through the pressure fingers will not be accepted. A sufficient number of brushes, not less than two per pole, shall be fitted to ensure that vibrations do not affect the commutation.

The minimum safe wearing depth of commutators shall not be less than 6 mm and the minimum safe diameter shall be marked.

### Terminal Boxes and Earthing

The terminal leads, terminal boxes, and associated equipment shall be suitable for terminating the respective type of cables. The terminal boxes shall be of ample size to enable connections to be made satisfactorily. The terminal boxes with the cables installed shall be suitable for connection to supply systems having the short circuit capacity fault clearance time determined by the motor protective devices.

A permanently attached connection diagram shall be mounted inside the terminal box cover. If motors are suitable for only one direction of rotation, this shall be clearly indicated. Terminal boxes shall be totally enclosed and designed to prevent the ingress of moisture and dust. All joints shall be flanged with gaskets of neoprene or similar material. For motors of IEC size 132 and above, the terminal box shall be sealed from the internal air circuit of the motor.

Depending on the size, LV motors shall be fitted either with an approved cable sealing and dividing box, or with a gland plate installed in the terminal box and drilled as required, with suitable fittings for the cable entry.

All winding ends shall be brought out to terminal blocks or stud type insulators. For earthing purposes, each motor shall have adequately sized bolts with washers at the lower part of the frame. In addition, each terminal box shall contain one earthing screw.

### Noise Level and Vibrations

In order to prevent undue and harmful vibrations, all motors shall be statically and dynamically balanced. Double amplitude values shall not exceed the values as stated in German VDI Regulations 2056, class "good".

### Motor List

The motor list to be issued by the Contractor shall include all aggregates driven by electrical motors (except final control elements such as control valves, dampers, etc. which are part of I&C lists) and shall contain at least the following technical data:

* Item (drive name)
* Code No.
* Location
* Driven machine data:
  + Design speed
  + Rated power demand
  + Kind of operation (continuous, intermittent, during plant start-up only)
* Motor data:
  + Manufacturer
  + Type
  + Type of cooling
  + Type of protection
* Nominal (nameplate) rating
* Rated output (considering the above specifications, in particular clause "Rating")
* Service factor
* Electrical design data as:
  + Rated voltage
  + Rated speed
  + Rated current
  + Power factor
  + Efficiency
  + Ratio of starting to rated current
  + Ratio of pull-out to rated torque
  + Frequency of permissible starts
* Bearings:
  + Manufacturer
  + Type and type number

### Tests

Each motor shall be factory tested and shall undergo a test at site. The Contractor shall submit certificates for all type test prescribed under IEC Standards. The following additional tests shall be performed under full responsibility of the Contractor.

Workshop Tests:

* Measurement of winding and insulation resistances
* No load current measurement
* Open circuit secondary induced voltage test at stand still (wound rotor)
* High voltage test
* Over-speed test (120% for 2 minutes)

Tests at Site (with motor coupled):

* Measurement of insulation resistance
* Measurement of shaft current.
* Measurement of motor vibrations
* At motors rated 47 kW or higher, in addition:
  + Oscillographic measurement of starting current (if not performed during workshop testing)
  + Measurement of starting period.

## MV Switchgear (Already supplied)

### Design and Construction of Cubicles

The MV switchgear cubicles shall be of type-tested design in accordance with the applicable IEC Standards. The minimum protection classes for cubicles shall be as follows:

* MV SWG in separate electrical rooms: IP42
* MV SWG on industrial floor: IP43

The MV switchgear shall be of the metal-clad type, rigidly constructed of braced rolled steel sections with recessed panels and substantial mounting frames for mounting of power and control cables. The panels shall be fabricated from sheet steel with a minimum of 2.0 mm thickness, with reinforcements where the sheet panels may be weakened due to large cut-outs.

The MV cubicles shall be mounted onto steel beams embedded into the floor. All required base frames, anchors, fixing bolts, and lifting eyebolts etc. shall be provided. Provisions shall be made for future extension of the switchgear assembly at both ends. All cubicles shall be tropicalised and vermin proof.

All sheet metal surfaces shall be cleaned, filled where necessary, primed and paint coated in accordance with the General Requirements for Painting and Corrosion Protection. The painting shall be scratch proof and shall be of such quality that damage of the paint during transport or erection can be easily repaired at site with original paint furnished with the cubicles by the Contractor. All bolts, screws, washers, etc., shall be corrosion protected.

The construction shall be such that the individual feeders of the switchgear are mechanically segregated from each other. In addition, the MV switchgear shall have segregated compartments for:

* each of the bus-bars
* the switching unit
* the voltage transformers
* the current transformers and power cable termination
* the control gear and protection.

All faults occurring in any of the segregated compartments are to be restricted to that area and, except for bus bar faults, shall not cause shut-down of any other feeder of the SWG other than the faulty one itself. If required, pressure relief devices shall ensure that impermissible pressures created during short circuits or heavy switching operations do not cause deformations or destruction of the relevant cubicle. The pressure relief shall be directed to the outside of the building

All MV switchgear cubicles shall have front access to the switching unit and relay compartment and rear access for easy cable connection works. All doors shall be hinged and fitted with a handle with lock or padlock. The opening angle of doors shall be locked at to about 100°.

Automatic safety shutters shall be provided to prevent accidental contact with live parts when the switching unit has been withdrawn from its operating position. These shutters shall be activated by the positioning of the switching device.

Opening the back or front door of any cubicle shall not expose the bus bars and access to the bus bars shall only be possible by removing bolted covers.

Floor openings under cubicles shall be covered and/ or sealed by the Contractor after laying cables, etc., so as to obtain fire proof (same class as the related floor) and vermin-proof installations.

Clearances between live parts and to earth shall be in accordance with the relevant standard specifications.

### Bus-bars

The main three phase bus-bar systems and the branch-bar connections shall be seized as specified in the Particular Requirements for Electrical Works. The bus-bars including the branches shall be capable of withstanding all electrical and mechanical stresses, which may occur at the point of installation due to short-circuit currents for the times specified in the Particular Requirements and relevant standards.

Bus bars shall be made of high conductive electrolytic copper conductors with the connection points suitably protected against corrosion. They shall be colour coded, rigidly supported on cast resin insulators or bushings and shall comply with the requirements of the relevant standard specifications. Provision shall be made for expansion and contraction of the bus bars resulting from temperature variations.

Connections of bus bars outside the bus bar compartment shall be insulated or shrouded to minimise the risk of hazardous accidental contact while working on other parts of the switchgear.

### Earthing

An earthing bar with a minimum cross section suitable to carry the design short circuit current of the board for 3 sec. shall run the full length of the switchgear. This bar shall be connected twice to the main earthing system. The Contractor shall connect to this bar all metallic parts not forming part of the live circuits and all instrument transformers to be earthed.

Each MV switchgear cubicle shall be provided with manually operated three phase earthing switch arranged downstream of the switching device. Further, manually operated earthing switches shall be provided for each bus bar section. Safety interlocks respectively measures shall be provided to prevent earthing of live parts.

### Circuit Breakers

The switching unit / circuit breaker shall be of the horizontal draw-out or disconnectable type.

The draw-out unit shall be mounted on trucks or slide in chassis having adequate guidance by greased, sturdy sliding rails or rollers. It shall be connected to the bus-bars by means of a

self-aligning plug and socket arrangement. Complete isolation of each circuit shall be attainable by drawing out the switching unit.

The contact surfaces of plugs and sockets shall be silver-plated and their design shall take into consideration the severe conditions of the site. They shall be amply sized and sufficiently strong to withstand maximum prevailing short circuits and carry continuously their normal rated current without damage or overheating of any kind.

The draw-out units shall have clearly marked service and test positions. A mechanical interlock is to be provided to prevent withdrawal of the unit unless the power circuit has been interrupted. The unit shall, furthermore, positively be locked in a test position before it is manually released for complete withdrawal. The test position shall permit local and remote closing and tripping of the relevant switchgear with the power contacts not energised, i.e. removed from the load circuit.

Barriers of heat resisting, non-tracking and insulating material shall separate the phases of the circuit breaker.

For draw-out switching units of more than 10 kg weight, a transportation carriage, adjustable to the respective installation heights shall be furnished.

Connections to the control circuits of the draw out unit shall be realised by plug and socket arrangements.

Circuit breakers shall be of the trip-free type, both mechanically and electrically, with a driving mechanism composed of a spring loaded, energy storing closing and tripping device. Spring loading shall be by electric driving motor, which shall be of the totally enclosed type.

Means shall be provided to prevent pumping while the closing circuit remains energised should the breaker either fail to latch or be tripped during closing due to the operation of a protective device.

Spring release closing mechanism shall be affected by means of a DC solenoid coil and by means of a mechanical pull out handle. Tripping shall be effected by means of a DC solenoid shunt trip coil and by means of a mechanical push-in button.

Each MV circuit breaker shall have a device to register the number of closing operations.

### Low Voltage Compartment

All terminal blocks/ points, relays and instruments, etc., shall be located so as to be safely accessible while the equipment is in service. Suitable touch protection shall be provided to prevent access to live parts whilst a cubicle door is open. All secondary wiring shall be arranged and protected by ducts or trunking.

Whenever the correct operation of instruments and relays makes it necessary, adequate vibration and shock absorbers shall be installed.

All cubicles shall be complete with lighting with door switch, socket outlet, cable end boxes/ glands, etc., internal wiring, terminal boards and accessories, as required.

Cubicles shall be equipped with resistance type space heaters with thermostatic temperature control giving an alarm locally on the front door of each cubicle and a group alarm (for each row of cubicles) in the remote control room.

Each cubicle shall be provided with a suitable mimic diagram.

* 11 kV red
* 0.4 kV dark brown
* DC yellow
* Earth black

Mimic diagrams to be arranged on switchgear cubicles shall be colour coded as follows: similar to RAL 3018 similar to RAL 8015 similar to RAL 1021 similar to RAL 9005

### MV Control

Each circuit breaker cubicle shall be provided with:

* One (1) green coloured push button for "ON"
* One (1) red coloured push button for "OFF"
* One (1) key operated selector switch SWG - REMOTE
* One (1) mechanical "ON/OFF" position indicator or one (1) white coloured signaling lamp for the "ON" position.
* One (1) amber coloured flashing signal lamp for fault signalization of any local protection equipment (tripping of protection relay or device, blowing of power fuse, tripping of miniature circuit breaker of control circuits, control voltage failure). This lamp shall remain lit until cancelled by resetting of the device leading to fault signalization.
* Alarms shall be repeated group-wise for the different distribution boards/ MCCs via
* the alarm system as specified, at the local and remote control rooms, as available, and on the event recorder.

The "OFF" control shall be effective independent of the selector switch position while the "ON" control shall be restricted to the set selector switch position.

All meters, indicators, switches, and the other different kinds of exposed components shall be flush mounted to the panel front.

All instruments and indication devices shall be fixed at levels not higher than 2 meters and control devices not higher than 1.8 meters.

### Interlocking System

Hard wired electrical ON/ OFF interlocking of incoming feeders, outgoing transformer and cable feeders, bus-bar coupler, and bus-interconnector shall be realised in the relevant switchgear cubicles. The interlocking system shall operate completely independent from any electronic device. Also a key interlocking system shall be provided between the circuit breaker, the bus-bar isolators and the earthing switch.

The basic interlocking principles are as listed below:

* All bus-bar isolators shall be interlocked with the associated circuit breakers and against each other.
* Change-over of any MV bus bar section to another supply source via an incoming feeder (either intentional or due to a failure) shall be effected by a synchronization device.
* Change-over of any MV bus bar section to another supply source via a bus-coupler or bus-interconnector (either intentional or due to a failure) shall be effected through a check-synchronising relay.
* Each transformer feeder shall be interlocked in such a manner that the LV circuit breaker can not be closed unless the MV circuit breaker is closed. If the MV breaker is tripped manually or automatically the LV breaker shall also be tripped automatically.

### Erection

Piping containing steam, water or oil shall not be permitted above electrical rooms and above electrical cubicles. Air conditioning ductwork shall not be arranged above electrical cubicles.

The minimum width of access for operation and maintenance works in front of any cubicle, between rows of cubicles and behind cubicles shall be 1000 mm. For the MV switchgear such clearance shall be applied if the C.B. truck is fully withdrawn. In case that such ways are longer than 6 m, entry from both sides shall be possible. The maximum escape way length in electrical rooms shall be 40 m.

### Tests

The workshop tests shall be performed as required by the applicable IEC Standards. For the individual switchgear apparatus (i.e. circuit breaker, load break switch, etc.), type and routine test certificates of the manufacturer shall be supplied.

At least the following tests shall be performed in the manufacturer's workshop on the individual apparatus and on the complete installation, respectively, all in accordance with the applicable IEC Standards:

* Visual inspection
* Megger tests
* Power frequency HV tests
* Dielectric tests of the auxiliary circuits
* Measurement of the main contacts resistance with DC
* Functional tests of the control circuits
* Check of the operational sequence
* Measurement of the measuring transformer's angle and ratio errors according to IEC Standards
* Functional tests of the protection equipment.

At least the following site tests shall be performed:

* Visual inspection
* Megger test (to include equipment as far as possible)
* Functional tests of controls, interlocks, instrumentation
* Setting of protection relays, adjustment by the primary injection method
* HV test as far as applicable.

## LV Switchgear

### Design and Construction of Panels

#### General

The LV switchgear and control panels shall be of type-tested design in accordance with the applicable IEC Standards. The minimum protection classes for cubicles shall be as follows:

* LV SWG and control panels in separate electrical rooms: IP42
* LV SWG and control panels on industrial floor: IP43
* LV SWG and control panels outdoors (with shed): IP55

The switchgear and control panels shall be of the metal-enclosed type, rigidly constructed of braced rolled steel sections with recessed panels and substantial mounting frames for mounting of power and control cables. The panels shall be fabricated from sheet steel with a minimum of 1.5 mm thickness, with reinforcements where the sheet panels may be weakened due to large cut-outs.

All panels shall be of the free-standing floor mounted type provided with ways and means for floor fixing and anchoring devices. All required base frames, anchors, fixing bolts and lifting eyebolts etc. shall be provided.

Panels installed in rooms provided with raised (computer) floor shall have a separate supporting structure made of angular steel profiles, fixed on the floor. Already existing computer floors shall be removed as required. After erection of the cubicles, the floor tiles shall be arranged such that they fit tight against the cubicles and can be removed easily, if required.

All sheet metal surfaces shall be cleaned, filled where necessary primed and paint coated in accordance with the General Requirements for Painting and Corrosion Protection. The painting shall be scratch proof and shall be of such quality that damage of the paint during transport or erection can be easily repaired at site with original paint furnished with the panels by the Contractor. All bolts, screws, washers, etc., shall be corrosion protected.

All panels shall have front access to the switching units and relay compartment and, if applicable, rear access for easy cable connection works. The opening angle of doors shall be locked at to about 100°.

Clearances between live parts and to earth shall be in accordance with the relevant standard specifications. All secondary wiring shall be arranged and protected by ducts or trunking.

Floor openings under cubicles shall be covered and/ or sealed by the Contractor after laying cables, etc., so as to obtain fire proof (same class as the related floor) and vermin-proof installations.

#### Design

If not required otherwise by the Particular Specification, the LV SWG shall be designed as follows:

1. LV distribution boards of 150 A rating and below and having fused/ MCB / MCCB outgoing feeders only shall be of the conventional, fixed mounted type. If such LV boards are combined power and control boards, metallic segregation between both sections shall be provided.
2. All other LV distribution boards shall be of modular technique with withdrawable circuit breakers for incoming and outgoing feeders as well as sectionalizers. The construction shall be such that the individual feeders of the board are mechanically segregated from each other. All faults occurring in any of the segregated sections are to be restricted to that area and, except for bus bar faults, shall not cause shut-down of any other feeder of the board other than the faulty one itself.
3. All MCCs shall be provided in draw out technique as specified. The construction shall be such that the individual feeders of the switchgear are mechanically segregated from each other. All faults occurring in any of the segregated sections are to be restricted to that area and, except for bus bar faults, shall not cause shut-down of any other feeder of the board other than the faulty one itself.
4. The fault current requirements of the individual distribution boards and components shall be calculated by the Contractor on the basis of the design data of components under consideration of the maximum acceptable tolerances of components according to standards.

All electrical switchboards, panels and cubicles shall be tropicalised and vermin proof. Cable entries shall be normally only from the bottom of the cubicle through individual cable glands for each cable. In case individual cables for each phase are used, metallic closing plates and cable glands shall be of non magnetic materials. Cable entry from top of the switchboards, panels and cubicles or through elastic rubber or plastic plates is not allowed. All switchboards, panels and cubicles shall be equipped with thermostatic controlled anti condensation heaters.

LV Panels and switchboards shall be equipped inside with British Standard single phase 230V switched wall sockets for 13 A fused plugs as well as lighting controlled through a reliable door switch.

#### Bus-bars

Bus-bars shall be seized as specified in the Particular Requirements for Electrical Works. The bus-bars including the branches shall be capable of withstanding all electrical and mechanical stresses, which may occur at the point of installation due to short-circuit currents for the times specified in the Particular Requirements and relevant standards.

Bus bars shall be made of high conductive electrolytic copper conductors with the connection points suitably protected against corrosion. They shall be colour coded, rigidly supported on cast resin insulators or bushings and shall comply with the requirements of the relevant standard specifications.

#### Earthing

An earthing bar with a minimum cross section suitable to carry the design short circuit current of the board for 3 sec. shall run the full length of the switchgear. This bar shall be

connected twice to the main earthing system. The Contractor shall connect to this bar all metallic parts not forming part of the live circuits and all instrument transformers to be earthed.

#### Secondary Installation

All terminal blocks/ points, relays and instruments, etc., shall be located so as to be safely accessible while the equipment is in service. Suitable touch protection shall be provided to prevent access to live parts whilst a panel door is open. All secondary wiring shall be arranged and protected by ducts or trunking.

All cubicles shall be complete with all locks, lighting with door switch, socket outlet, cable end boxes/ glands, etc., internal wiring, terminal boards and accessories, as required.

Panels shall be equipped with resistance type space heaters with thermostatic control giving an alarm locally on the front door of each panel and a group alarm (for each row of panels) in the remote control room.

### LV Switchgear - MCC Feeders and Starters

#### General

Each LV circuit breaker for incoming feeders and bus-bar sectionalizers if provided with indoor switchgear shall be of the withdrawable type unless specified otherwise.

The draw-out switching units shall be mounted on trucks or slide in chassis having adequate guidance by greased, sturdy sliding rails or rollers. They shall be connected to the bus bars by means of a self-aligning plug and socket arrangement. Complete isolation of each circuit shall be attainable by drawing out the switching unit. LV panels shall have means that prevent the exposure of life bus bars upon withdrawal of the switching unit.

The contact surfaces of plugs and sockets shall be silver-plated and their design shall take into consideration the severe conditions of the site. They shall be amply sized and sufficiently strong to withstand maximum prevailing short circuits and carry continuously their normal rated current without damage or overheating of any kind.

Connections to the control circuits of the draw-out units shall be realised by plug and socket arrangements.

The draw-out units shall have clearly marked service and test positions. A mechanical interlock is to be provided to prevent withdrawal of the unit unless the power circuit has been interrupted. Each switchgear room containing draw-out switching units of more than 10 kg weight shall be furnished with a transportation carriage, adjustable to the respective installation heights.

All circuit breakers, load break switches, starters and contactors shall be suitably rated according to the electrical and mechanical performance and duties they are assigned for. They shall be of the continuously rated pattern generously de-rated to comply with the Site conditions and requirements.

All motor starters or contactors and their associated apparatus shall be capable of operating for a period of five minutes with a supply voltage of 80% of the nominal voltage at rated frequency. Means shall be provided to prevent pumping.

Tripping of any protective device (MCB, MCCB, CB, fuse, bi-metallic relay, etc.) shall be indicated by the local and remote alarm system and the event recorder. For remote alarm and event recording, group alarms may be provided.

LV motor feeders shall be equipped as follows:

Motors of up to 47 kW capacity:

* HRC fuses plus adjustable thermal overload and phase failure protection, or Circuit breaker with instantaneous over-current protection plus adjustable thermal overload and phase failure protection, or
* Motor starter units including instantaneous over-current protection, thermal overload and phase failure protection
* All above devices with auxiliary contacts for alarm and tripping
* Starter
* Ammeter (except for final control elements)

Motors above 47 kW capacity:

* HRC fuses or circuit breaker with instantaneous over-current protection, both with auxiliary contacts for alarm and tripping
* Starter
* CT operated adjustable thermal overload protection
* Phase failure protection
* Earth fault protection
* Ammeter

Moulded case circuit breakers and miniature circuit breakers may be used if they are properly selected to stand the maximum assigned short circuit current level.

#### Circuit Breakers

Circuit breakers shall be of the trip-free type, both mechanically and electrically, with a driving mechanism composed of an energy storing closing and tripping device. Means shall be provided to prevent pumping while the closing circuit remains energised should the breaker either fail to latch or be tripped during closing due to the operation of a protective device.

Spring release closing mechanism shall be effected by means of a DC solenoid coil and by means of a mechanical pull out handle. Tripping shall be effected by means of a DC solenoid shunt trip coil and by means of a mechanical push-in button.

Each LV breaker shall be provided with main and auxiliary isolating contacts, and with suitable arcing contacts, magnetic arc quenching devices, arc chutes, etc.

Moulded case circuit breakers shall have shunt trip coil and trip-free operating mechanism of the quick-break type. The moulded case circuit breakers shall have a thermal overload protection device and instantaneous magnetic trip devices.

#### Contactors

LV contactors shall be of the air break type with arc shields, class AC 3 according to IEC Standards. Butt contacts of the rolling, self-cleaning type shall preferably be utilised and all portions likely to suffer from arcing shall be easily removable.

When closed, the contactors shall withstand the system prospective fault current determined by the next co-ordinated short circuit tripping device. The associated thermal over-current releases shall either correspond to the primary current, or be fed via current transformer(s), as specified. They shall be adjustable in order to fit the motor requirements and be temperature compensated up to 70°C ambient temperature.

Suitable means shall be provided to prevent core vibration and noise. Fuses

LV fuses are only permitted in LV feeders as specified in above clauses. In any other cases MCBs or MCCBs shall be provided.

All fuses shall be of the HRC type (if 3 phase system HRC fuse should be changed to a MCB).

Fuses shall be of the current limiting type and be of such characteristic as to correspond to the upstream/ downstream circuit breaker's protection devices.

If not part of a load switch as defined below, fuses shall be inserted into lever operated fuse isolators so that no special tool is required for their replacement.

Each fuse shall be provided with supervision devices to indicate blowing locally and remote as part of the alarm system.

Load Break Switches

All load break switch (load switch) feeders shall be equipped with both, make proof load break switches and HRC fuses. Blowing of any fuse shall trip the related load switch (all poles).

The load switches shall permit manual (hand) operation from the front panel and, if required, electrical control.

The load switches shall have a padlocking device, self cleaning contacts with a high resistivity anti-arc case and quick making and quick breaking action.

Manual operated load break switches may be combined with the HRC fuses. Miniature Circuit Breakers

Miniature circuit breakers shall be provided with thermal over-current and electromagnetic short circuit release and shall have auxiliary contacts for signaling and/ or tripping. Tripping of any MCB shall be indicated locally and remote as part of the alarm system.

The operating as well as the over current mechanism shall be sealed.

The mechanism shall provide positive closing, contact roll and wiper, trip free action with follow through on opening. The contacts shall be of anti-welding silver tungsten tips fixed on high conductivity copper backings.

### LV Switchgear - MCC Control Each feeder shall have:

* One (1) mechanical "ON/OFF" position indicator or one (1) white coloured signaling lamp for the "ON" position.
* One (1) amber coloured flashing signal lamp for fault signalization of any local protection equipment (tripping of protection relay or device, blowing of power fuse, tripping of miniature circuit breaker of control circuits, control voltage failure). This lamp shall remain lit until cancelled by resetting of the device leading to fault signalization.
* Alarms shall be repeated group-wise for the different distribution boards/ MCCs via the alarm system as specified, at the local and remote control rooms, as available, and on the event recorder.

Each feeder that requires remote automatic control/ interlocking shall in addition be provided with:

* One (1) green coloured push button for "ON"
* One (1) red coloured push button for "OFF"
* One (1) key operated selector switch LOCAL - REMOTE (installed at the SWG, if not specified otherwise) for remote controlled feeders.

All remaining feeders shall receive indication as above but shall be controlled either by:

* On / off push button as above, or
* Mechanically, but without need for opening of the front door of the cubicle, respective the related compartment.

The "OFF" control shall be effective at all locations independent of the selector switch position while the "ON" control shall be restricted to the set selector switch position. Manual control of process controlled/ interlocked feeders may only be possible if the switching devices are in test position.

Process interlocking/ protection shall be in operation even in case of local SWG control as required.

Motor starters with local field control units shall have a key operated LOCAL-REMOTE selector switch at the remote location (control desk/ panel),

All interposing relays etc., as required for remote control/ supervision shall be provided.

All lamp hoods shall be made of transparent coloured heat resistant and break proof material. They shall be easily removable to replace the associated indication lamps.

All meters, indicators, switches, and the other different kinds of exposed components shall be flush mounted to the panel front.

All instruments and indication devices shall be fixed at levels not higher than 2 meters and control devices not higher than 1.8 meters.

All signal, monitoring and protection circuits as well as shunt trips of circuit breakers shall be fed by DC. All other circuits may be fed by AC, which may be derived from the relevant bus bar system via control voltage transformers. Each of the above circuits shall be individually protected by means of miniature circuit breakers with position monitoring, whereby a maximum of ten (10) consumers may be connected to one MCB.

Closing of the circuit breakers and contactors shall be possible between 85% and 115% of the rated control voltage. Holding of contactors must safely be effected by at least 75% of the rated control voltage.

AC tripping devices shall operate at 50% - 120% of the rated control voltage. DC tripping devices shall operate at 75% - 115% of the rated voltage.

Local field control by means of "ON" - "OFF" push button stations shall be provided for all motors which may need to be operated locally and cannot be supervised from their local control panel. Such push button stations shall have a shock and dust proof housing, corresponding to protection class IP 55.

The push button station shall contain:

* One (1) "ON" push button, operative only at the ‘local’ position of the selector switch
* One (1) "OFF" push button for normal stop, operative only at the ‘local’ position of the selector switch
* One (1) emergency stop push button, kept upon actuation mechanically in the "OFF" position until released by a special key. To prevent mal-operation due to inadvertent contact, the push button shall be protected by a collar or other approved means.

### Erection

Piping containing steam, water or oil shall not be permitted above electrical rooms and above electrical cubicles. Air conditioning ductwork shall not be arranged above electrical cubicles.

The minimum width of access for operation and maintenance works in front of any panel and behind panels (if not designed for arrangement direct at the wall) shall be 1000 mm.

Cable entries shall normally be from the bottom of the panels only through individual cable glands for each cable. Cable entry from top of the switchboards, panels and cubicles or through elastic rubber or plastic plates is not allowed.

### Tests

The workshop tests shall be performed as required by the applicable IEC Standards. For the individual switchgear apparatus (i.e. circuit breaker, load break switch, etc.), type and routine test certificates of the manufacturer shall be supplied.

The following site tests shall be performed:

* Visual inspection
* Megger test (to include equipment as far as possible)
* Functional tests of controls, interlocks, instrumentation
* Setting of protection relays, adjustment by the primary injection method
* HV test as far as applicable.

## Instrument Transformers

Current and voltage transformers are to be housed or accommodated to suit their particular duties. They shall meet the requirements of the latest relevant IEC Standards and shall be capable of withstanding the rated design fault current of the respective switchgear without any damage or deterioration.

If not otherwise specified in the Particular Requirements, the current transformers shall comply with the following provisions:

Current transformers shall have separate cores for metering, measuring and protection as follows:

* for measuring: 1M5
* for metering : 0.5M5
* for protection: 5P20
* Unless otherwise specified, the secondary windings shall be rated for one (1) A.

The secondaries of CTs shall be earthed by means of a heavy copper conductor. Such earth connection shall be easily accessible.

The CTs and their associated circuits shall be tested during commissioning on Site by the primary injection method.

If not otherwise specified in the Particular Requirements, the voltage transformers shall comply with the following provisions:

The voltage transformers shall have an accuracy class of 0.5%.

The secondary voltage ratings shall be:

* 110/ 1.73 V for measuring, metering, protection
* 110/ 3 V for open delta connected windings

The secondaries of VTs shall be protected by MCBs. All bus-bar VTs shall be provided with an open delta winding and loading resistor.

The Contractor shall determine the required burdens, knee point voltages and capacities taking into consideration the most unfavourable conditions and the rated design data of the relevant switchgear.

All instrument transformer calculations and data shall be submitted for approval. The calculations shall be based on the requirements as defined in the Technical Specifications for Electrical Protection Systems.

All instrument transformers shall be provided with a nameplate detailing type, ratio, class, output, serial number, and connections.

The Contractor shall supply manufacturer's test certificates on tests and measurements performed in accordance with applicable standards.

## Wiring

All wiring within cubicles, panels, racks, boards, etc. shall consist of stranded copper wires designed for insulation levels as specified below.

The insulation material shall be of polyvinylchloride (PVC), tropical grade, or of other approved type. The wiring shall be capable of withstanding, without deterioration, the conditions prevailing at the individual place of installation. The bare ends of stranded wires shall not be soldered but provided with squeezed sleeves. The minimum cross section of each copper wire shall be as given below:

* 4.0 mm2 for current transformer circuits
* 2.5 mm2 for potential transformers
* 2.5 mm2 for all power consumers, such as motors, heaters, etc.
* 1.5 mm2 for control and instrument wiring above 60 V service voltage
* 0.5 mm2 for control circuits below 60 V and telephone wiring
* About 0.2 mm2 in case the applied connection technique of standard electronic equipment does not permit the use of larger cross sections.

Wiring shall be neatly run, clear of any metal parts in rigid wire ways, filled no more than 70% after commissioning of the plant. Bundled arrangement may be performed adjacent to front panel/ door equipment.

The ends of every cable core and all panel wiring above 60 V shall be fitted with numbered ferrules of moisture and oil resisting insulation material with the identification numbers being the same as for the relevant terminals. The ferrules shall be fitted in such a way that they cannot become detached when the wire is removed from the terminal.

Wiring shall terminate in terminal boards, accommodated at the side or bottom of each panel or compartment. All wiring shall enter the terminal block at one side only. Internal wiring between instruments or other devices not using the terminal block shall be permitted within the same compartment only.

Terminal blocks shall be numbered consecutively beginning with 1 from left to right or top to bottom and shall consist of single "insertion" type terminals of non-tracking, non-inflammable synthetic plastics' lined-up in one row. All terminals shall have two (2) separate pressure-clamping plates suitable for connection of incoming or outgoing, stranded or solid conductors, respectively. Terminals with clamping screws in direct contact with the conductor are not acceptable. The following categories of terminals shall be used:

1. Terminals for power circuits
2. Terminals with short circuit facilities for current transformer circuits and earthing link terminals for CT and VT circuits
3. Terminals for measuring and control circuits, with bridging facilities to the neighbour terminal, where required.

All terminal blocks shall contain 10% spare space. Insulating barriers shall be provided between each pair of power circuits and between terminals of different categories. The height and the spacing shall be such as to give adequate protection to the terminals whilst allowing easy access to the same. All terminals shall bear the following designations besides their consecutive number:

AC Power Feeders:

* Phase 1: L1 on red ground
* Phase 2: L2 on yellow ground
* Phase 3: L3 on blue ground
* Earthed Neutral: PEN with black surrounding

Current Transformer Circuits:

* Phase 1: P1-P2 and S1-S2 respectively on red ground
* Phase 2: same as above on yellow ground
* Phase 3: same as above on blue ground

Potential Transformer Circuits:

* Phase 1: A-a on red ground
* Phase 2: B-b on yellow ground
* Phase 3: C-c on blue ground

DC Power Circuits:

* Positive: P on green ground
* Negative: N on grey ground

Any intended deviation from the above specification needs to be submitted for approval prior to commencement of any design work, failing with all wiring found non-compliant will be rejected.

Within cubicles, all LV main circuits (electrical equipment and interconnections) and control and auxiliary circuits directly connected to the power circuits shall be designed for the following minimum rated insulation voltage with respective test voltage:

Rated insulation voltage Test voltage (1 minute)

* 400 V AC switchgear 660 V 2.5 kV
* 110 V DC switchgear 300 V 2.0 kV
* 24 V DC switchgear 300 V 2.0 kV

Control and auxiliary circuits, which are not designed for connection to the main circuits, shall at least be rated as follows:

Rated insulation Test voltage

voltage (1 minute)

* Circuits below 60 V 60 V 1 kV
* Circuits above 60 V 300 V 2 kV

## Electrical Connections

All bolts/ screws/ nuts/ washers used for electrical connections shall be of corrosion protected or corrosion resistant material.

Bolted connections shall correspond to the applicable Standards and shall have two washers and one spring washer.

Bolt terminals of machines (motors, transformers, etc.) shall be equipped with secured nuts, two washers and spring washer. Fastening of such bolt connections shall be done with a torque wrench set to values to be defined by the Contractor before commencement of erection works.

Bus bar interconnections of individual units (switchgear/ bus ducts/ transformers) shall be done by flexible joints. The length shall ensure the flexibility against vibrations and for thermal or operational displacements. The joints shall also withstand the dynamic short circuit stresses.

## Auxiliary Equipment

### Auxiliary Switches

Where appropriate, each item of plant shall be equipped with all necessary auxiliary switches, contactors and mechanism for indication, protection, metering, control, interlocking, supervisory and other services. All auxiliary switches shall be wired up to a terminal board on the fixed portion of the plant, whether they are in use or not in the first instance.

Auxiliary switches associated with circuit breakers shall have additionally 1 NO and 1 NC contact for spare.

All auxiliary switches and mechanisms shall be mounted in accessible positions clear of the operating mechanism and shall be protected in an approved manner. The contacts of all auxiliary switches shall be strong and shall have a positive wiping action when closing.

### Anti-Condensation Heaters

Each individual enclosure accommodating electrical equipment and located outside air-conditioned rooms shall be fitted with heating devices suitable for electrical operation at AC single phase, of sufficient capacity to raise the internal temperature by about 5°C above the ambient temperature.

Heaters in motors shall be suitably fixed inside the windings.

Heaters in switchgear/ MCC cubicles, control cubicles, panels, desks, etc., shall be controlled automatically by adjustable hygrostats (setting range 50-100% relative humidity).

The electrical apparatus so protected shall be designed so that the maximum permitted rise in temperature is not exceeded if the heaters are energised while the apparatus is in operation. If applicable, heating elements shall be suitably screened to avoid burns due to accidental contact.

Heaters shall be connected to a suitable terminal box with main switch and indicating lamp. They shall be placed in an accessible position.

### Indication Lamps

The terms "indication lamps, lights", etc., does not necessarily require for incandescent type bulbs. The use of LED or glow type bulbs would be acceptable as long as adequate brightness is ensured.

In any case, the lifetime of bulbs operating at rated supply voltage plus maximum positive tolerance shall not be less than 2000 hrs.

All lamp hoods shall be made of transparent coloured heat resistant and break proof material. They shall be easily removable to replace the associated indication lamps.

## Protection Relays

If not specified otherwise in the Particular Requirements, all protection relays for MV and LV switchgear shall be mounted within the related panels.

The relay equipment shall consist of microprocessor based control and protection units incorporating the various protection functions specified in the particular technical specification, including synchro-check function where applicable, and shall be complete with all measuring, control, supervision, alarm and interlocking features as required.

The protective relays shall be dust proof with removable transparent covers and external resetting devices. Unless otherwise specified, the relays shall be of the hand re-settable type with start/ trip indication. The relays shall be provided with test sockets and shall be easily accessible for testing and setting purposes.

Local and the remote alarm system and event recorder shall indicate tripping of any protective relay. Remote alarms may be grouped.

Trip circuits of instantaneous current relays shall be provided with adjustable short time timers' td0 (0 - 1000 msec.), adjustable in 50 m sec. steps, if selective operation in case of short circuit cannot be achieved otherwise due to low cable/ system impedance.

The protective relays shall have sufficient contacts and/ or auxiliary relay contacts (including spare) to perform all required tripping, inter-tripping, interlocking, indication and alarm functions.

Preferably, relays shall be packed separately and shipped with the switchgear. Each relay and its place on the cubicle shall have the same identification mark as shown on the relevant wiring diagrams. All wires and terminals shall be clearly marked to facilitate easy connection during erection at site.

## Batteries and Battery Chargers (already supplied)

### Batteries

The batteries shall be of the NiCad pocket plate type and shall operate satisfactorily under all conditions. Each cell shall be enclosed in a proper transparent plastic shock-absorbing container. The container shall be provided with a removable recombination system to reduce the need for ventilation of the battery room and to extend the maintenance free period over the total service life and prevent emissions of gas and fumes.

The individual cells shall be arranged in tiers on lye resistant painted frames and wooden plans suitably impregnated against lye attack with a clear polarity mark and all fittings and connecting members shall be of corrosion resistant material.

The number of series connected cells forming a battery and the cable sections shall be such as to meet the specified voltage range requirements at the consumer terminals at all operating conditions. The battery discharge characteristic shall meet the requirements of the DC load profile.

All required accessories as well as initial alkaline filling shall be supplied.

Suitable dummy loads shall be supplied together with the batteries to allow reliable checking of all batteries installed under the contract and detection of faulty cells.

### Battery Chargers

The chargers shall be designed to supply all connectable DC consumers and simultaneously the demand for trickle charging of the batteries. The capacities shall be proved by calculations, subject to approval of the Engineer.

The battery chargers shall be as far as possible of modular design with a minimum of different components. Each charger shall be accommodated in a cubicle with all control and protection devices. It shall include incoming circuit breaker, transformers, fused thyristor rectifiers, control equipment, including voltage and current limiting devices with adjusting means, voltage regulator and outgoing feeders to the battery and to the DC distribution board. It shall be ensured that rectifier trip does not affect the battery supply of the relevant board.

The trickle charging process shall be affected by a constant voltage/ constant current (IU) characteristic.

The constant voltage value shall be adjustable according to the requirements of the proposed battery and the resulting charging current shall decrease with increasing battery capacity.

The constant current value shall be limited as required by the proposed, discharged battery until the adjusted constant voltage value of the battery is reached.

Change over between I and U characteristic and vice versa shall be fully automatic whereby the voltage set point shall be adjustable. Manual initiation shall also be possible.

For initial respectively boost charging of a battery, the DC distribution shall be disconnected and shall be fed from the second battery/ charger system only. Boost charging shall be manually initiated and automatically controlled thereafter.

The boost charging process shall be effected by an IUI - characteristic. After reaching the set maximum battery charging voltage for a set time, change over to the normal IU characteristic shall be performed. The relevant current, voltage and time data shall be adjustable according to the requirements of the proposed battery.

In any case the voltage at the DC distribution bus-bar shall not exceed 1.1 p.u. at any trickle charging condition and shall not become less than 0.9 p.u. at the design discharge end voltage of a battery. The load voltage control devices shall be designed accordingly.

Alternatively to a load voltage control system the battery capacity and charge/ discharge end voltage may be selected in such a way that additional voltage control facilities to keep within the specified voltage range may not be required.

The recharging time of the battery after having reached the design discharge end voltage up to full capacity shall not exceed 10 hours.

The feeding transformers shall be of the dry type with off-circuit tappings at the primary windings. The rectifiers shall be of the thyristor controlled type and smoothing chokes shall be provided to decrease the voltage ripple factor.

### DC / AC Inverter (UPS)

Two static DC / AC inverters are to be supplied to provide the safe AC (UPS) demand of all sensitive plant (n-1 system), e.g. measuring, monitoring, control systems, central control room emergency lighting, etc., and protect it against all power failures.

The UPS system shall operate as an on-line system with permanent conversion. The inverters shall be permanently synchronised with the normal AC system and against each other. The inverters shall be protected against operational overload through a static bypass to the main AC system.

Each unit shall be complete with necessary control and alarm systems for local and remote monitoring of the status of the UPS system

.

### Tests

#### Chargers

* Visual inspection (to be repeated on site)
* Functional tests (to be repeated on site)
* Heat run (type test)
* Output voltage stability measured for 25% load steps
* Ripple measurement with connected battery
* Insulation test (to be repeated on site)

#### Batteries

* Visual inspection (to be repeated on site)
* Insulation test (to be repeated on site)
* Discharge test

#### Fuse Box

* Visual inspection (to be repeated on site)
* Functional tests (on site)
* Insulation test (on site)

#### Inverters and Converters

* Visual inspection (to be repeated on site)
* Functional tests (to be repeated on site)
* Heat run (type test)
* Insulation test (to be repeated on site)

## Cables

### General

All cables and their accessories shall be designed in accordance with the latest issues of IEC Publications.

All cables and their accessories shall have insulation levels able to withstand any voltage surge, due to switching operations, sudden load variations, faults, etc., which is normally expected to occur in the power system in which the cable is to be included. The cables and their accessories shall be constructed to fulfil the requirements when operating with full load or at any load factor.

The conductor cross section of each cable, moreover, shall be adequate for carrying the prospective fault current determined by the next relevant short circuit protection device when operating under the specified load conditions without deterioration of the dielectric. The Contractor shall prove the correct design by means of a short circuit calculation.

Cables laid directly in the ground, the whole or part of their length, shall be of the highest thermal stability and mechanical strength type. They shall be single wire or tape armoured. The outer sheath or serving of cables shall be PVC.

Cables directly embedded in soil shall be of the armoured type.

All cables shall be of the low flammability type having low gas evolution properties.

The following tests shall have been successfully concluded on all power and control cables:

* Flammability test as per IEC (Category B)
* Acid gas emission to IEC, limited to a maximum of 20%
* Light transmission to ASTM D-2843-93 with maximum of 40%.

The cables shall be, where necessary, resistant to impression in water, solar light, chemicals used in water treatment, and fuel oil.

Cables running on or nearby hot surfaces shall be of the copper sheathed mineral insulated type (MICC), suitably supported and neatly run in position. MICC cables shall not absorb moisture, they shall be of 750 V grade in accordance with relevant IEC Standards.

Cable running on or nearby warm surfaces shall be of the silicon-rubber insulated, asbestos sheathed type, suitably run in galvanised steel conduits of approved type.

Conductors with cross section of 4 mm2 and above shall be of the stranded type.

The identity of the manufacturer and the year of manufacture shall be provided throughout the length of the cable. Letters and numerals, if applied on the outer sheath, shall be raised and shall consist of upright block character.

### Power Cables

All MV and LV power cables shall be of the cross-linked polyethylene type (XLPE) designed for a solidly grounded system. They shall be capable of continuous operation at a highest system voltage as specified with a maximum conductor temperature of 90°C, and a maximum temperature under fault conditions of not more than 250°C.

The cables shall be of the single conductor.

Cable conductors shall consist of annealed high conductivity copper wires, stranded and compacted to a circular conductor, and laid up and rendered smooth and free from defects likely to injure the insulations.

Under no circumstances will cable through joints be accepted, unless a previous written approval has been obtained from the Employer for each joint required.

Around the conductor, a semi-conducting layer shall be provided, followed by an extruded layer of dry cured cross linked polyethylene (XLPE) of such a thickness that the minimum value as required for the voltage class does not fall short at any point of the total cable length.

Over the insulation an extruded semi-conducting outer layer shall be provided. A water stopping conductive material shall be applied over the insulation screen to stop water penetration in longitudinal and axial direction followed by a lead alloy or laminated sheath of adequate thickness, and copper wires/ tapes for insulation/ shielding.

The outer jacket shall be an extruded finish layer of red coloured polyvinylchloride (PVC) or polyethylene (HDPE) with a thickness of not less than 5 mm.

All cables shall be selected to withstand without distress short circuit current in the copper and sheath related to the fault levels.

The minimum cross section of the copper conductors shall be 2.5 mm2.

The maximum allowable voltage drop shall be 3%, referred to the feeding bus bar.

All conductors shall have their insulation coloured to the phase colour or, alternatively coloured plastic sleeves may be utilised at all cable terminations.

### Control Cables

The control cables shall be of the multi-core, PVC insulated type withstanding without deterioration the conditions prevailing at the individual place of installation. Cables for analogue signals shall have a common screen of metal tape and cores shall be twisted by pairs.

The minimum cross section of each copper wire of the instrumentation and control cables shall be 1.5 mm2. For I&C cables below 60 V, the minimum cross section is dependent on the design of the electronics and subject to approval of the Employer. In all cases, the maximum voltage drop on the cable shall not be exceeded 5% at the worst temperature conditions.

The multi-core cable with more than 7 cores shall have approx. 20% spare cores for future use. Multi-core cables shall be number coded, single core cables shall be colour coded or otherwise properly identified. The colour coding or other identification marks shall be shown on the wiring diagram.

### Cable Drums

All cable drums shall be delivered on drums, which shall be clearly engraved in English as follows:

1. Name of Manufacturer
2. Purchaser's Order Number
3. Shipping Identification Marks
4. Address
5. Weights Net and Gross
6. Drum Number
7. Type of Cable
8. Sizes and Number of Conductors
9. Voltage
10. Length of Cable
11. Direction of Rotation

The ends of any cable shall be sealed against the ingress of moisture, dirt and insects and the end projecting from the drum shall be adequately protected against mechanical damage during transportation, intermediate storage and site handling.

Wooden cable drums shall be lagged with closely fittings battens and shall be thoroughly impregnated with appropriate insecticide and wood preservative.

### Cable Laying

Unless specified otherwise, cables shall generally be laid in cable ducts or on cable raceways installed in shafts, in cable trenches, in cable floors, or underneath computer floors. Cables, generally, shall not be laid directly on the floor. Cables laid outdoors, whether on cable racks or otherwise, shall be protected against direct sunlight and the effect of UV rays by covers or other suitable means.

Only in special cases such as outdoor lighting, single connections to remote consumers, etc. cables may be buried directly into the ground as described below. Necessary earthwork and material are to be provided by the Contractor.

Inside industrial rooms as machine hall or equivalent and in electrical rooms, raceways/ supports may be fitted to walls, floors and ceilings if access for equipment will not be limited thereby.

Cabling in plaster or concrete finished rooms (offices, passages, staircases, etc.) shall be executed in embedded PVC conduits. The related civil works such as placing of conduits, switch boxes, etc., as well as closing of slots and holes in walls, ceiling and floors are to be done by the Contractor.

Penetrations of cables through walls and floors shall be sealed by fire retardant material to obtain the same classification as the floor or wall itself and as defined in the civil specifications.

In any case, the Contractor is obliged to properly co-ordinate his work with the respective Civil Work.

Cables tapped or branched from general raceways and directed to the relevant equipment shall, if necessary, be protected by galvanised heavy steel conduits sealed at their ends against ingress of water.

Cable running across roads or pipe routes or inside concrete raft or foundation shall run through ducts of adequate size.

Cables vertically directed and attached to brick walls or similar civil parts shall be lined up by galvanised, multiple type cable clamps, fixed to prefabricated mounting bars. Cables shall be clamped as required by the applied forces, at least every 750 mm. Conduits embedded into concrete or buried into block works shall be of high impact PVC type.

Ducts buried into the ground shall be placed in a depth not less than 600 mm. The cross section area of such ducts shall be only 50% utilised when filled with cables. Ducts shall terminate in a concrete, de-watered manhole / pulling hole before entering a building or at acute change of direction.

Cables buried in the ground shall be laid as follows:

* The cable trench shall be excavated approximately 100 cm deep for cables up to 1 kV and 130 cm deep for cables above 1 kV, respectively.
* The cable shall be laid on to a layer of clean sand approximately 10 cm high.
* Over the cable, another layer of approximately 10 cm of clean sand shall follow protected by stones (bricks or similar).
* The excavation shall then be refilled by soft earth layers of approximately 20 cm height perfect rammed.
* A yellow plastic warning band shall be laid 20 cm above the cable stones.
* A safe distance of 30 cm to other services such as water pipes, etc., shall be observed.

Control and power cables shall be laid separately (min. distance 300 mm) under strict observation of their permissible bending radius. Special precaution shall be taken to ensure that no closed iron magnetic circuit is formed around single core cables laid in single or trefoil formation, or around any cable liable to carry unbalanced load current.

The pulling and fixing of cables and the making of all terminations shall be strictly in accordance with the manufacturer's instructions, using the recommended tools and appliances for the purpose.

The following conditions shall be observed when using cable trenches:

* Cable trench covers shall be removed in sections, according to the progress of work.
* Removed covers shall be stored in such a way that they do not create a hazard to people or traffic at site.
* Open trenches shall be properly secured by red warning tapes both sides along the trench.
* Any cover or cable/ cable tray having been damaged during handling shall be replaced by the Contractor.
* Cable trenches shall be cleaned from dirt, sand, etc., before closing.
* Trenches shall be closed as soon as possible to avoid excessive ingress of dirt and damage.

### Cable Terminations

#### General

The Contractor shall supply all material necessary for jointing and termination of cables, including cast resin cones, stress control cones, porcelain, as well as all tapes, papers, plumbing material, solder and other consumable materials, and shall carry out all work necessary for the proper jointing and sealing of all cables installed under this Contract. The Contractor shall be held responsible for checking his jointing and sealing work and for putting the completed cable installation into operation.

#### MV Cable Terminations and Joints

Every cable end of MV power cables shall be sealed and protected in an approved manner consistent with the voltage level, kind of cable and place of installation. The spacing between conductors and the earth shall be in accordance with the applicable Standards.

The Contractor is obliged to co-ordinate the layout of sealing ends with the supplier of switchgear, transformers and other consumers to which the cables are to be connected.

Suitable cable terminations for indoor respectively outdoor use are to be provided for every cable end, as applicable. The potheads shall be of the dry type and be consistent with the cross-linked conductor insulation of the cables. All cable terminations and joints must constructed to withstand the applied short circuit currents.

Joints will only be accepted if technically mandatory. If cable joints are required they shall be of the "taped" type. The conductors shall be spliced by means of welding or equivalent. The method of insulating joints, e.g. by windings of cross linkable polyethylene tape containing organic peroxides, etc. shall be proposed by the Contractor, subject to approval by the Employer. The joints should be suitable for application to single-core XLPE cables as described in the respective section.

MV terminations shall not be energised as long as the insulation reading is less than 100 Meg-ohms using a standard 500 or 1000 Volt "Megger".

Where cable terminations are likely to be disturbed for maintenance purposes, some slack cable in a loop or other suitable form is to be allowed at a convenient place in the run.

### Cable List

The Contractor shall submit all the technical data pertaining to each type and kind of power and control cable covered by the Contract, giving the following information as minimum:

* Cable item and code number
* Manufacturer
* Type of cable, insulation serving, armouring and sheathing materials
* Standard applied for manufacturing
* Cross section
* Rated ampacity (acc. to standard)
* Maximum short circuit capacity
* Cable resistance and reactance per km.

### Cable Schedule

The Contractor shall submit a cable schedule indicating:

* Cable No.
* Termination points (at both ends)
* Cable route
* Cable type
* Cross section
* Length
* Standard ampacity
* Ampacity under site conditions (temperature and grouping factor)
* Estimated load current
* Voltage drop (percentage of rated load voltage).

### Cable Route Plans and Raceway Arrangements

#### Cable Route Plans

The cable route and raceway arrangement plans shall indicate the main cable routes in the plant and inside of buildings as well as all cables buried in ground.

The main cable routes shall be numbered and divided into individual sections. Such individual sections shall be formed whenever a cable joins or leaves a main cable route. A

cable route-loading schedule shall indicate the loading of each individual section by listing the cable numbers laid on the different tray/ ladder levels.

#### Raceways

All cable raceways shall consist of cable ladders or cable trays, as applicable. Cable ladders shall have horizontal spacing between two rungs according to their size but not more than 500 mm. Cable trays shall be perforated. Cable raceways used in highly polluted or otherwise endangered surroundings shall be covered by sheet metal. The race ways shall be supported by brackets. Wherever possible, brackets shall be fixed onto supports or concrete walls at one side only to ease erection/ maintenance. Necessary anchor rails etc. shall be supplied by the Contractor.

The raceways including all supports, etc. shall be of adequate strength and size to carry in one layer the number and weight of the required number of power cables and an additional quantity of cables, not less than 15% by weight and dimensions in excess of the required ones. The design shall additionally include a factor of safety to guard against permanent distortion when supporting erection staff during cable installation.

The raceways and associated equipment shall be of galvanised steel material. In chemically polluted area additional protection as required shall be provided.

Cable raceways, arranged one above the other, shall be at least 300 mm apart in case of power cables and at least 200 mm apart for control cables. Cables shall be properly fixed either by suitable clamps of adequate size or by plastic ties.

### Tests

Cables shall be workshop tested in accordance with applicable IEC standards. The minimum scope of tests shall include:

* Partial discharge test (MV cables only)
* Dielectric loss factor test for 2.25 times rated voltage and constant ambient

temperature (MV cable sample only)

* Dielectric loss factor with increasing temperature (MV cable sample only)
* Measurement of insulation resistance
* Bending test (MV cable sample only)
* Measurement of sheathing and protecting layers thickness (samples only)
* Measurement of core resistance (MV cables only)
* High voltage test (MV cables only)
* Measurements of DC resistance and dimensions of screen (if applicable)
* Power frequency test with 30 kV for 5 min. acc. to IEC

Type tests may be waived if they have previously been performed and the Contractor produces respective certificates to the satisfaction of the Employer/ Engineer.

Test certificates of all routine rests shall be provided, proving that each cable type to be used has successfully passed all tests as required by the applicable standards.

On Site, cable systems shall be tested after installation as follows:

* Measurement of insulation resistance (Megger test)
  + Screen to earth
  + Conductor to earth
* HV test (MV cables according to IEC)
* Voltage drop of critical lengths for LV and control cables.

## Earthing

### General

Generally, each electrical device shall be provided with minimum one earthing screw of sufficient diameter suitable for connection to the earthing system. The same applies to all non-current carrying conductive equipment (metallic parts) and the Contractor is responsible that all metallic housings and other parts of complete installations such as boilers, compressors, pumps, cranes, transformer rails, structures, metallic fences, etc. are effectively connected by earth conductors to the earthing system.

If several earth connections for equipment are necessary, these connections shall be provided to different points of the earthing grid. Mounting bolts of equipment shall not be used for earthing purposes.

The earthing system of each building/ structure/ tank shall consist of a closed earthing loop laid in the soil at the circumference with at least two earthing electrodes of about 3 m length driven into the soil at diagonal points and two connections to the main earthing grid.

In transformer boxes, switchgear rooms and other areas containing electrical equipment accessible equipotential bonding/ main earthing bars, consisting of flat copper with a minimum size of 6 x 40 mm shall be provided. Each of such bars shall be connected to the main earthing system at least twice.

### Earthing Electrodes

Earthing electrodes shall consist of multi-piece, stainless steel sections not exceeding 1.5 m per section, having a diameter of not less than 20 mm.

The connection between the individual sections shall be throughout conductive and this connection shall not become loose or less effective once the electrode has been driven into the soil. For ramming the individual sections into the soil, a striking head shall be used. The top of the electrode shall terminate in an earthing pit if not otherwise approved by the Employer and all connections with other conductors of the system shall be performed in this pit.

### Specific Earthing Conditions

Exposed conductive parts which may become live under fault conditions, if operating at a voltage level exceeding the safety extra low voltage (25 V AC) shall be earthed by a connection to the plant main earth network.

#### LV System

* The LV earthing system shall be designed as a TN (TN-S-C) system acc. to IEC requirements.

#### I&C Systems

* The I&C systems shall be designed with single point earthing as required and defined in the relevant I&C specifications.

#### Switchboards, Cubicles

* Switchboards, control boards, etc., consisting of two or more individual panels shall be earthed at both ends.
* Individual panels, sections or compartments of switchboards, control boards, etc., shall be connected to earth individually, unless all panels/ parts are solidly welded together or other approved means are applied ensuring solid connections.
* All metal cases and conductive structures of circuit breakers, isolating switches, measuring transformers, bus bars, etc., shall be connected to the earthing bar inside the switchgear/ panels. This earthing bar shall be connected with the earthing grid.
* The housing of the operating mechanisms shall be earthed as near as possible to the operating handle.
* Bolt and nuts provided for earth current carrying connection of different cubicles shall be clearly marked.

#### Motors

* LV motors up to 20 kW may be earthed via a separate earthing conductor of the power cable, or as defined below for larger motors.
* LV motors above 20 kW shall be earthed via a separate earthing conductor connected to the main earthing grid via the closest earthing bar.

#### Structural Steel

* Structural steel shall be connected with the earthing grid at several points.
* A single structure shall be earthed at both legs; a square structure shall be earthed at two points diagonally across from each other.
* For a structure consisting of several bays, each leg shall be earthed.
* Steel parts for local push button stations, control cubicles, power sockets, lighting fixtures, etc., without conductive connection to other earthed steel structure shall also be connected to the earth grid by copper conductors.

#### Reinforcement Steel

* Reinforced concrete foundations for buildings housing electrical installations shall have their reinforcement steel bars connected with the earthing grid at several points.
* For structures consisting of several bays, each leg shall be earthed.
* On each concrete column a bi-metal grounding link shall be welded onto the nearest reinforcement bars.
* The link shall have a sufficiently sized stud for the connection of the copper conductor to the earthing grid.

#### Oil and Water Storage Tanks and Piping

* Oil tanks shall be connected at two diagonal points with the earthing grid.
* Piping shall be earthed at all service points. Flange connections shall be provided with links to ensure earthing continuity. The relevant rules of IEC Standards shall be observed.
* The Contractor shall prepare and provide suitable measures to protect buried pipes and other metallic parts against electro-chemical corrosion.

#### Boilers

* Boilers shall be connected to the earthing grid by several connections at diagonal points of their surface. All conductive material (inside and external) shall be interconnected to ensure effective earthing.

#### Fences

* Steel fences surrounding electrical equipment/ areas are to be protected in accordance with the regulations of VDE 0141 / 7.76 or equivalent.

#### Power Transformer

* Power transformer tanks shall be earthed at two points diagonally opposite each other.
* Transformer neutrals shall be connected directly to the subsoil earthing system via a separate earthing cable.
* Proper connection of the auxiliary equipment like instruments, control cubicles, pipes, etc., to the earthed transformer tank or to the earthing grid, respectively, must be ensured.

#### Cables

* The armour and/or shield of all cables shall be earthed by connecting a flexible braid to the shield.
* Armour / shield of power cables shall be earthed at both ends.
* The screens of I&C cables shall be earthed at one end according to the particular I&C system requirements for single point earthing.
* Other control cables shall be earthed either as power cables or as I&C cables, dependent on their particular application.
* Cable end boxes shall be earthed via copper connection on one of the mounting bolts. Wiring Conduits
* Steel conduits for wiring shall be earthed at both ends. Joints connections shall be provided with links to ensure earthing continuity

#### Lamp Posts

* Metallic lamp posts shall be earthed via the PE conductor of the feeding cable.
* Additionally, an earthing loop of about 2 meter's diameter shall be laid around each post.

## Hazardous Areas and Explosion Proof Equipment

### Classification of Hazardous Areas

Hazardous areas are locations where fire or explosion hazards may exist due to flammable gases or vapours, flammable liquids, combustible dust, or ignitable fibres.

Properties of flammable gases or vapours and volatile liquids are essential to define degree and extent of classified hazardous areas, implementing the likelihood that a flammable or combustible concentration or quantity may be present.

Classification of hazardous areas was done by considering the following internationally recognised standards, rules and regulations:

* National Electric Code, Article 500, as adopted by the National Fire Protection
* Association, issued 1982
* National Fire Protection Association, applicable Standard 85
* Recommended Practice for Classification of Areas for Electrical Installations in
* Petroleum Refineries, API RP.500 A, reaffirmed 1973
* International Electrotechnical Commission, Part 10: Classification of hazardous
* areas, publication 79.

Class I locations are those in which flammable gases or vapours are or may be present in the air in quantities sufficient to produce explosive or ignitable mixture. Class I areas are specified as follows:

* Class I, Division 1 is a location in which ignitable concentrations of flammable gases or vapours exist under normal operating conditions, or in which ignitable concentrations of such gases or vapours may exist frequently because of repair, maintenance or leakage.

In Class I, Division 1 locations, also exists the probability of ignitable concentrations of flammable gases or vapours due to break down or faulty operation of equipment or processes frequently. The criterion for these locations is that they are likely to have flammable gases or vapours present under normal conditions:

* Class I, Division 2 is a location:
  + In which volatile flammable liquids or flammable gases are handled, processed or used but normally be confined in closed containers and except when there are break downs or abnormal operation conditions hazardous concentrations do not exist;
  + In which ignitable concentrations of gases or vapours are normally prevented by positive mechanical ventilation and which become only hazardous in case of ventilation system failure;
  + Which is adjacent to a Class I, Division 1 location and to which ignitable concentrations of gases or vapours might occasionally be communicated.

### Selection of Explosion Proof Equipment

According to the kind of fuels and gases used, the danger of explosion in hazardous areas as defined in item 1 above may be caused by ordinary electrical installations.

Therefore, electrical equipment/ installations in such areas should be kept to a minimum and must be of "explosion proof design" (Ex) in accordance with German standards VDE-0165, 0170 and 0171 or any other internationally recognised standard.

The specific explosion proof design of equipment/ installations is determined by the properties of the flammable gases or vapours and volatile liquids (flash point, ignition temperature, explosion group, etc.).

All explosion proof equipment shall be of approved design and must have undergone type tests according to the appropriate standards. The selection of such equipment with reference to design features and allocation to hazardous areas shall be subject to approval by the Employer.

## Oil and Compound

### Insulating Oil and Compound

Except where otherwise specified, the first filling of insulating oil and/ or compound shall be supplied by the Contractor for any apparatus provided under this Contract requiring filling.

Oil compound shall comply with the latest approved appropriate Standard Specifications and shall be delivered in strong, hermetically sealed new drums.

Where other types of filling media are used in current transformer chambers and other parts of the equipment, they shall be of an approved type. Where drums are stored on Site in the open, they shall be kept in a horizontal position.

### Oil or Compound Filled Chambers

All joints of fabricated oil or compound filled chambers, other than those, which have to be broken, shall be welded, and care shall be taken to ensure that the chambers are oil-tight.

Defective welded joints shall not be caulked but may be re-welded subject to the written approval of the Employer.

Suitable provision shall be made for the expansion of the filling medium in all oil or compound filled chambers and the chambers shall be designed to avoid the trapping of air or gases during the filling process.

All wiring in the vicinity of oil-filled chambers shall be insulated with oil-resisting insulation of approved quality.

### Oil Level Indicators

Oil level indicators of approved design shall be fitted to all oil containers. The indicators shall show the level at all temperatures likely to be experienced in service, shall be marked with the normal level at 40°C clearly visible from normal access levels and shall be easily dismantled for cleaning. In addition, the normal filling level of all removable containers shall be marked on the inside.

## Lighting System (already installed in the power house)

### General

The design of the lighting and small power system shall strictly follow the regulations of the local authorities and be in accordance with applicable IEC Standards. The equipment shall be of such performance and quantity as to perfectly suit the purpose, subject to the approval of the Employer.

The Contractor is obliged to co-ordinate where necessary, the lighting installations with the suppliers of interfering equipment as for instance suspended ceilings, fire fighting, air-conditioning, etc.

The design of lighting fixtures for rooms with suspended ceilings shall meet the requirements of the respective ceiling suppliers.

The number of lighting fixtures in rooms provided with suspended ceiling shall not only meet the specified illumination level (minimum requirement) but also the architectonical requirements of the room (shape and symmetrical arrangement). Particular attention shall be paid to the illumination of control rooms and computer rooms to avoid any dazzling and reflection.

The illumination level of indoor lighting shall be measured horizontally at a height of 1 m above the floor, outdoor lighting of streets, access ways, outdoor working/ operation areas and of flood areas at the surface. In new condition of the equipment, the ratio of the minimum to the average illumination level shall not be higher than 1: 3; the ratio of the minimum to the maximum illumination shall not be higher than 1: 6. The whole lighting system shall be designed to produce adequate visual performance and safety and shall be free from excessive glare, stroboscopic effects and flicker from discharge lamps.

The system shall include provisions for ease of erection, maintenance, cleaning and lamp replacement. In determining the location and height of light fittings, consideration shall be given to the problem of lamp changing. Necessary mobile erection or maintenance devices (for example ladders, carriages, platforms) shall be provided.

AC lighting fixtures shall be distributed on the three phases as to ensure equal loading and be field mounted in such a manner as to obtain an uniform illumination level if half of the fixtures of a certain area were switched off (with reduction of illumination level).

Lighting calculations for all areas and rooms covered by this section shall be submitted for approval.

### Lighting Fittings

All lighting fittings complete with lamps and tubes, instant starting control gear, chokes, compensating capacitors, etc. shall be of approved manufacture, constructed of best quality materials and provided complete with all necessary installations.

Outdoor fittings shall be completely weather proof. Reflectors for fluorescent fittings, tungsten metal halogen fittings and mercury vapour fittings for use in industrial rooms and outdoors shall be constructed of vitreous enameled steel or equivalent material.

Bulkhead fittings shall be cast iron bodies with prismatic front glass and vitreous enameled reflectors. Well glass fittings shall be of galvanised cast iron with wire guards wherever necessary.

Special precaution shall be taken to protect the wiring from damage by heat generated by fitting. For compensation of the inductive current of the chokes compensating capacitors shall be provided to obtain about unity power factor.

To avoid electrical shocks when touching disconnected fittings, which include capacitors, discharge resistors of sufficient size shall be connected in parallel with all capacitors of more than 0.5 μF capacitance.

In accordance with relevant IEC regulations the equipment shall be furnished with radio interference suppressors if the maximum interference voltage stated in the regulations will be exceeded.

### Wiring

Wiring of lighting and socket circuits shall have copper conductors for the phase(s), for the neutral and for the protective earthing. It shall be of neat and clear appearance.

Wiring in plaster or concrete finished rooms shall be executed with PVC insulated conductors in embedded or buried conduits. In machine rooms, workshops, storage rooms and the like cables shall be laid in surface mounted PVC conduits, in areas endangered by or subject to mechanical damage in galvanised mild steel conduits, painted after erection. Where necessary, mineral insulated (magnesium oxide) metal-sheathed wires shall be used.

### Switches

Lighting fixtures located in self-contained rooms such as offices, switchgear rooms, battery rooms, control rooms, passages, staircases, etc. shall be switched on and off locally. Where more than two switching points are required (staircases, large rooms with several entrances, etc.) push button switches shall be provided together with pulse operated relays and contactors, arranged in the associated sub-distribution boards. All other circuits shall be directly controlled from the relevant distribution board or the control room, as appropriate.

Switches and socket outlets installed in rooms with embedded wiring shall be flush mounted in moulded plastic wall boxes and rated for 10 A. Wiring switches shall either be of the tumbler or rocker-dolly type.

### Lighting Sub-Distribution Boards

The lighting sub-distributions shall be of sheet metal, flush fronted design. Dependent on their size and location they shall either be of free standing or flush mounting type. The sub-distributions shall be designed in accordance with the relevant items of this Specification and shall be fully insulated.

The front doors shall be provided with lockable handles (one key type only for all sub-distribution boards). The protection class shall be IP 55 in case of outdoor installation and IP 42 in case of indoor installations.

They shall be individually fed (no cross or ring type connection) and shall be complete with individual bus bars for the phases, the neutral and for protective earthing. Fixed mounted incoming CBs and outgoing feeders with fixed mounted miniature circuit breakers (MCB), all with thermal and magnetic over-current release, as well as pulse relays/ contactors for remote control and voltage monitoring relays (if required) shall be provided.

Each lighting and socket outlet circuit shall be protected by said MCB, no fuses shall be permitted. The tripping characteristics of the MCB shall ensure selectivity with other switchgear connected in series.

A diagram describing the circuits that are connected to the individual fixed mounted outgoing feeders (MCBs) shall be provided on the back side of the front door. 10% (at least two) spare outgoing feeders of each type shall be provided in each distribution.

### Emergency Lighting

Emergency lighting shall be provided in all switchgear and control rooms, as well as in workshops with rotating machines.

In case of a supply failure to the normal lighting system, the lamps of the emergency lighting system shall remain on in all rooms/ areas where normal lighting was switched on prior to the failure to enable essential operation to be carried out at any time.

Safe movement of personnel shall be ensured at any time at all locations by the security lighting system. Above all doors and in floors/ staircases, etc. self-contained fixtures shall be provided for this purpose, if not specified otherwise.

## Power Socket Outlets and Plugs (already installed in the power house)

Socket outlets and plugs for small power shall be designed to comply with the local standards.

The power socket outlets and plugs shall be of the CEE 17 type, weatherproof and with housings of shockproof plastic material.

The following types of outlets shall be provided at locations to be approved by the Employer:

* Three phase AC sockets, 32 A, 63 A and higher ratings (if required), with five pins, incorporated switch and mechanical interlocking
* Single phase AC sockets, 16 A and higher rating (if required) with three pins
* Single phase safety voltage (24 V) outlets of 20 A, with three pins equipped with single phase AC/ 24 V AC transformer, 400 Watt rated continuous loading capacity, with isolated secondary windings and with earth fault protection. The transformer shall have insulation class F or higher and shall be totally enclosed in sheet steel housing providing protection against drip water. The complete unit shall be suitable for wall mounting.

Outdoor boxes subject to sun radiation shall be provided with a sunshade. At hot locations (furnace or similar) metallic housing suitably protected against corrosion shall be provided.

## Labels

### General

The proposed material of the labels, the size, the exact label inscriptions as well as proposals for the arrangement of the labels shall be submitted to the Employer for approval.

### Equipment Labels and Instruction Plates

Labels written in the contractual language shall be provided for all instruments, relays, control switches, push buttons, indication lights, breakers, etc. In case of instruments, instrument switches and control switches, where the function is indicated on the dial plate of the switch escutcheon plate, no additional label may be required. The label shall be fixed close to the device in such a way that easy identification is possible. Fixing on the dial glass of instruments will not be accepted. The wording shall conform to the wording used in engineering documents.

Instruction plates showing the sequence diagrams or cautions for maintenance shall be fitted on the inside of the front door of the electrical switchboards.

Labels shall have a size adequate for the applied purpose.

### Labels for Conduits, Cables

The material shall be non-corrodible and the inscription be done with 4 mm high letters/ ciphers.

Each cable when completely erected shall have permanently attached to it at each end and at intermediate positions as necessary, non-corrodible labels with the engraved identification number of the cable. The cable identification numbers shall comply with those of the cable schedule.

All cables in cable pits and at entry points to building blocks shall be labelled using the aforementioned type of label.

## Keys and Key Cabinets

Means shall be provided for locking all cubicle doors, live terminal shutters, etc.

Switch handles shall, where required, be lockable in the OFF-position by suitable locks or padlocks. Selector switches shall, as required, be key-lockable in all positions.

The locks or padlocks shall be co-ordinated for the different applications/ systems and shall be supplied with three keys each. A key cabinet shall be provided in each electrical/ electronic room for storing the relevant keys.

The keys for cubicles/ equipment located outside electrical rooms as well as the keys of the individual key cabinet doors shall be stored in a central key cabinet, located in the central control room.

For the key cabinet doors additional six master keys shall be provided, each suitable to open any key cabinet door. Each key shall have an identification label with the same denomination as fixed above the key hanging hook inside the cabinet.

## Technical Documents

### Electrical Diagrams

For electrical diagrams general reference is made to applicable IEC Standards. The bidder required to provide all drawings in softcopy format including AutoCAD Drawings.

#### Single-Line Diagrams

This is a diagram of the essential electrical equipment and their interconnections. It shall contain all required technical information of the equipment represented, e.g. voltage, ampacity, capacity, short-circuit level, ratios, voltage variations, positive and zero sequence impedances, measuring transformer and protection relay indices, interlocking, kind of switch drive, code designation, etc.

Single-line diagrams of individual main components and switchboards shall additionally show the control, indicating, measuring, metering, protection, automatic, and other auxiliary electric devices (also rheostats, hygrostats, cable end boxes, etc.), separated for each individual installation site and location as applicable:

* Local: switchgear room, local control room, cable termination compartment, etc.
* Remote: plant control room (operation station, control desk).

#### Circuit Diagrams

The Circuit Diagrams shall show the power circuits in all phases with the main apparatus as well as the pilot circuits (measuring and control circuits). They shall show in full the functioning of part or of all installations, equipment or circuits with all required technical information.

The control part shall be subdivided into separately drawn "current paths", each showing all its components regardless of their actual physical location. The individual circuits are to be drawn in a straight line sequence, avoiding line crossings. The current paths (to be designated by numbers) shall be drawn starting from two horizontal lines, which represent the control voltage source. All devices belonging to the equipment or forming part of the equipment or control devices shall appear between these two lines.

Contact developments of the installed switches, contactors, relays and other apparatus which appear in the diagram shall be shown below the respective contactor coil, indicating by means of numbers and, if not on the same, also the page No., the current path in which the corresponding contact has been used.

Interconnections to other circuit diagrams shall be clearly marked by means of dotted line separations and the corresponding functional designation.

The power circuit portion of the installation shall be drawn at the left side of the drawing. Circuit diagrams shall also contain all terminals and their correct designations. Terminals grouped together to terminal blocks of switchboards, distributors, etc., shall be shown on the circuit diagrams in one fictitious horizontal line surrounded by demarcation lines. If, for any reason, the current paths of circuit diagrams must be separated, the corresponding counter terminal has to be indicated by all means.

The representation of electrical equipment and control circuits shall not be terminated at the limits of the scope of supply, but has to be extended beyond this limit by all switchgear, protective, measuring and monitoring equipment required for full comprehension of the whole circuit. All terminals and functions of equipment to be supplied by others shall be taken over as well.

Standard Circuit Diagrams are patterns of circuit diagrams which have been standardised with regard to scope, arrangement, representation and allocation of equipment with the aim of simplification and easy surveillance of electrical circuitry.

#### Block Diagrams

The Block Diagrams shall be used to show in a simplified manner the main inter relationships between the elements of a system by means of symbols, block symbols and pictures without necessarily showing all the connections. The symbols used for the individual kinds of components, e.g. servo-motors, amplifiers, computing modules, etc., shall clearly be explained on the diagram or on an attached legend.

When recommendable, a Block Text Diagram may be prepared, consisting essentially of explanatory texts enclosed in outlines which are linked by lines showing the functional relationships that exist between the various parts of an installation, equipment or circuit.

#### Logic Diagrams

Logic or Functional Diagrams shall be used for representation of logic and sequence controls and for interlocking by showing only binary logic elements and their effect on the various process equipment and disregarding their electrical realisation. Logic function elements (AND, OR, NOR, STORAGE, etc.) shall be used for processing and combining binary signals.

#### Terminal Diagrams

Such diagrams shall be prepared for any type of terminal box, marshalling rack, control cubicle, switchboard, etc., and shall show the terminals (properly numbered) and the internal and/or external conductors (wires or cables) connected to them.

#### Protection Co-ordination Diagrams

These diagrams shall show in a graphical manner separately for each power supply circuit:

* A single-line diagram of the circuit with technical data of all instrument transformers and relays
* Coordinated tripping curves of related protection devices
* Setting of the protection devices.

### Lists and Schedules

The Contractor shall prepare the following lists:

#### Device Lists

The device list shall describe the contents of each cubicle / panel / switchboard / module / unit and shall contain at least the following information:

* Functional Number
* Current Path
* Quantity
* Order No.
* Designation
* Type
* Technical Data
* Make

#### Motor Lists

The motor lists shall be prepared according to the power distribution boards the motors are connected to, and shall contain at least the information/data, as requested under clause „Motors“ of this Specification.

#### Motor Starter Lists

The motor starter lists shall include all starters and contactors used for motors and contain the following technical information as a minimum:

* Plant identification number
* Electrical design data
* Maximum power cable size
* Maximum control cable size
* Current transformer ratio, class and capacity
* Type of protection relaying and catalogue number
* Setting of protection relays and maximum continuous rating of the protected circuit
* Type and current rating of the back-up fuses/MCBs for the main and control circuits.
* Note: Motor Starter Lists can be substituted by adequate equipment lists, already forming part of switchgear manuals.

#### Cable Lists and Schedules

The Cable Lists shall include for each individual cable the information as defined under clause ’Cables’ of this Specification.

#### List of Measurements

* This list shall indicate all measurements, local as well as remote, and shall contain at least: Item / code number, function code
* Description and denomination of measuring loop
* Data of tapping point
* Data of local devices (as detectors, instrument transformers, transmitters) −Data of remote devices.

#### Alarm Lists

These lists shall indicate all alarms and shall contain at least:

* Item/code number and function code
* Description and denomination of alarm
* Data of alarm detector (contact)
* Data of alarm annunciator (location and clear text labelling)
* Collection of group alarms.

#### List of Final Control Elements

* This list shall indicate all control actuators and control valves and shall contain at least:
* Item/code number
* Data of pipe and valve connections
* Data of valve layout
* Maximal required and rated power.

#### Site Test Schedules

Individual Site Test Schedules shall be prepared for equipment/installations (such as machines, switchgears, control gear, cables) and shall contain at least:

* Plant identification number
* Manufacturer
* Place of manufacture
* Place of test
* Date of test
* Kind of tests (all individual tests)
* Standards applied
* Results / Certification
* Inspection (by Employer / Independent Test Authority / Contractor/ Sub-Contractor)
* Remarks.

On the above schedule or on separate sheets the Test Procedure shall be specified giving for each test item (kind of test) a description, test method / Standards, used instruments including calibration, sample/ routine test etc.

### Framed Single Line Diagrams

Each switchgear room and the control room shall be furnished with a copy of the final as-built single line diagram detailing all electrical data and denominations. The diagram shall be made on a tear resisting material and shall be put under glass with Aluminium frame mounted on the wall at a place to be agreed upon.

Inside of every electrical switchboard, cubicle or panel, a plastic pocket shall be attached for the pertaining as-built wiring and cabling diagrams.

## Calculations

Design calculations, diagrams and operating data, etc. shall be submitted to the Employer with all formulae, standards, test results, basic assumptions, etc. used for these calculations. Submission of the calculation results only will not be accepted.

### Short-Circuit Calculations

The short-circuit calculations shall be performed in accordance with IEC Standard, as applicable. Wherever applicable, the following maximum values for equipment layout and maximum and minimum values for protection system layout shall be calculated for the individual plant components:

* Initial symmetrical short-circuit capacity S"K (3) and current J"K (3)
* Symmetrical breaking capacity SA (3) and current JA (3)
* Peak asymmetrical short-circuit current JS (3)
* Sustained short-circuit current JK (rms) (3).

Moreover, the following values shall be calculated for solidly or partially earthed network systems:

* Maximum single-pole short-circuit current J"K (1)
* Maximum earth fault current JE as determined by the earthing resistance RE
* Maximum contact voltage as determined by the values as stated above.

The impedance values of the network elements shall uniformly be calculated by taking one of the following reference values as basis:

* Reference voltage, impedance expressed in Ohm/phase
* Reference power, impedance expressed in p.u.
* No reference, impedance expressed in %/MVA.

Upon consideration of impedance values of network elements, the design figures as stipulated in the Technical Data Sheets of the Contract shall be taken as basis. If tolerances are agreed upon, then the permissible minus tolerance is to be applied. The variation of transformer impedance values caused by the position of the tap changer is to be considered in case this variation exceeds -5% of that value as stated for the middle position.

### Earthing Network Calculations

The Earthing Network Calculation shall determine, on basis of the short-circuit currents, the relevant design criteria for the layout of the plant's earthing network and the potential gradient control system, such as:

* Earthing resistance
* Earth electrodes or conductors (number and dimensions)
* Mesh network and other means for potential gradient control for different locations (mesh widths and dimensioning)
* Maximum contact and step voltages (step voltage to be considered at a distance of 1 m).

### Generator Earthing System Calculation

This calculation shall prove the correct selection of the generator earthing equipment. Load Evaluations

The load evaluations shall demonstrate for each voltage level (AC and DC), and for each individual distribution board/MCC, the following data:

* Rated capacity of all consumers
* Maximum number of identical consumers which can operate simultaneously
* Total electric demand in kVA and the power factor at nominal service of the driven machine, subdivided into
* Start-up
* Rated service
* Shut-down
* Stand-still.

The maximum load on one of the MV or LV auxiliary supply transformers shall be determined with due consideration of the most unfavourable condition when feeding, specially in case of emergency, several main and sub distribution boards.

### Selection of LV Breakers and Minimum Cable Cross Sections

This paper shall prove the correct application of LV breakers and - where required - of S.C. current limiting devices.

The minimum size of cable connections shall be calculated applying the maximum admissible temperatures and ratings (continuous and S.C. conditions). The results shall be shown in a table containing at least:

* The maximum initial symmetrical S.C. Current before and behind the switchgear (breaker/fuse)
* The breaker setting range
* The let-through current
* The resulting minimum cable cross section
* The applicable standard cross section7.1

### Protection System Calculation

All calculations as required for selection of instrument transformer and relays design parameters, as well as all studies required for selective relay setting shall be provided. Reference is made to the Technical Specifications regarding Electrical Protection System.

# Annex:

## Drawings

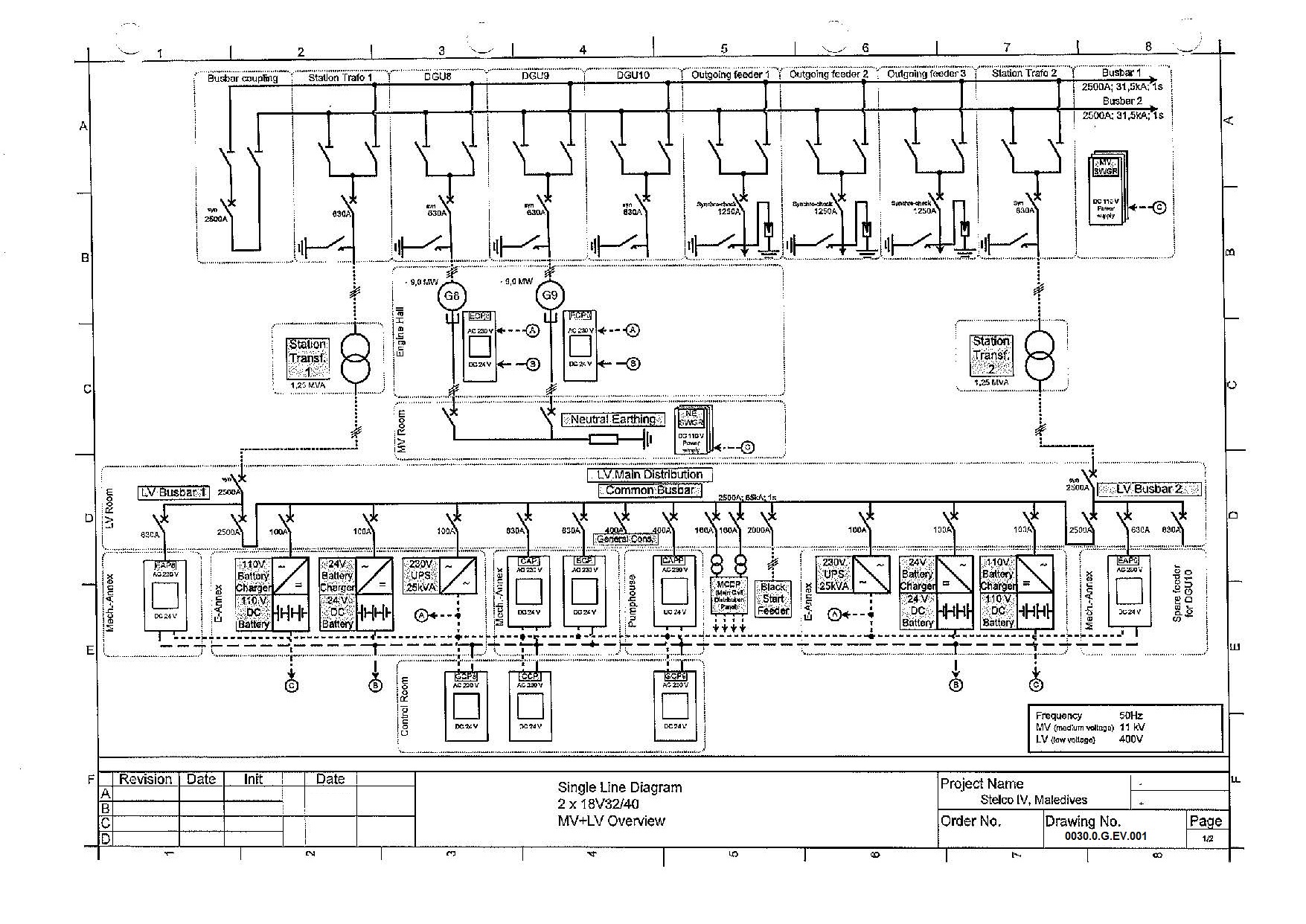
The bidder required to provide all drawings in softcopy format including AutoCAD Drawings.

**The list of drawings:**

|  |  |  |
| --- | --- | --- |
| **Item** | **Title** | **Drawing Number** |
| 1 | Single Line Diagram Exising Configuration | 0030.0.G.EV.001 |

### Single Line Diagram Of the existing configuration

Drawing No.: 0030.0.G.EV.001 page 1 of 2



Drawing No.: 0030.0.G.EV.001 page 2 of 2

