

Employer

SAKO BRNO A.S.

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High-efficient combined heat and power facility utilizing renewable sources (OHB II - line K1)

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PART III, APPENDIX A6

TECHNICAL SPECIFICATIONS

FOR ELECTRICAL EQUIPMENT



**PART III, APPENDIX A6
TECHNICAL SPECIFICATIONS FOR ELECTRICAL
EQUIPMENT**

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1. INTRODUCTION

This technical specification describes the basic minimum requirements of all electrical equipment for the LineLine.

The electrical equipment consists of individual electrical components as well as complete systems and interconnections. The principal configuration of the main power supply is shown in appendix A16 *Concept Diagrams for Electrical System (Single line diagram)*.

This is not a stand-alone document. The content of this specification shall be seen in the context of the Contract and remaining part of the Part III *Employer's Requirements*. Refer to appendix A7 for technical specifications for the Control and Monitoring System (CMS). appendix A7 *Technical Specifications for Control and Monitoring System (CMS)* is subordinate to this chapter.

1.1 Strategy for electrical system

It is important to ensure an identical design and construction of the Electrical system and the CMS system, standardised and of the same product and type for the entire Line.

1.2 General Supply limits

Electrical supply limits are shown on the concept diagram for the electrical system in appendix A16 *Concept Diagrams for Electrical System (Single line diagram)*.

Electrical connections:

The termination points of the Contract Object are in general terms indicated and marked by dashed lines on the main power supply configuration in appendix A16 *Concept Diagrams for Electrical System (Single line diagram)*. Further reference is also made to appendices A1 *Overall Scope of Contract Object* and A18 *Limits of Supply*.

CMS:

The termination points of the Contract Object are in general terms indicated and marked by dashed lines on the drawing in appendix A17 *Concept Diagram for Automation (CMS Topology)*. Further reference is also made to appendix 18 *Limits of Supply*.

1.3 Main power supply configuration

The principal configurations of the main power supplies are shown in appendix A16 *Concept Diagrams for Electrical System (Single Line Diagram)*.

The configuration drawing indicates the main principles of the power distribution and shall only be regarded as a principle and guidance for tendering.

The following abbreviations are generally used:

- MDB = Main Distribution Board
- MCC = Motor Control Centre
- ACC = Auxiliary Control Centre
- UPS = Uninterruptible Power System
- SLD = Single Line Diagram

The Line (Line K1) will be connected to the existing medium voltage switchboard R2 (22 kV), where the Contractor must extend the R2 Switchboard part WA4 with two sections, each with a Circuit Breaker and protection equipment, for supplying a Power transformer T24 for normal operation and for supplying a redundant Power transformer T25 for normal operation (2x100%).

The single line diagram of the Existing facility is shown in appendix E5 *Single Line Diagram for Employer's Existing Line*, where R2 WA4 switchboard is highlighted, including the existing turbine/generator.

The SLD of R2 switchboard is shown in appendix E6 *R2 Switchboard of Employer's Existing Line*, where page 6/6 show the WA4 section and the Appendix show all the design values for the switchboards.

The exiting grid connection will be used. The existing grid connection is with two cables 2x100% from the grid substation to the switchboard R2 WA4. The two cables will be operated in parallel or as standalone depending on the consumption or export power to the main grid. In island operation the two grid circuit breakers R2 WA4-14 and R2 WA4-15 will be used for going in island operation and for synchronizing back to normal operation where the circuit breakers will be used, controlled and operated from the synchronisation equipment's on the new turbine/generator and from the existing synchronisation equipment on the existing turbine/generator. All parts of the integration between the Existing facility and the new Line including design are included the scope of Contract Object.

The power transformer for normal operation T24 (22/6.3 kV) and the redundant power transformer T25 for own normal operation (22/6.3 kV) will supply the 6.3 kV main switchboard, each with an incomer circuit breaker. During operation of the power transformer for normal operation T24 and T25 there will only be one transformer in operation supplying the 6.3 kV main switchboard. The power transformer for normal operation T24 and T25 shall be designed for parallel operation in up to 10 minutes, during switching over from one transformer to another transformer supplying the 6.3 kV main switchboard. The switch over between the transformer T24 and T25 shall be possible with maximum load.

The 6.3 kV main switchboard are the connections to the steam turbine generator and the 6.3/0.4 kV distribution transformer. The 6.3 kV main switchboard shall have two spare circuit breakers with protection equipment which must be of the same size, type and similar to the circuit breaker for distribution transformers.

The 400 V consumers will be fed via two 400 V distribution transformers (of same size) through two main distribution switchboards (MDB). The concept for the distribution transformer is with installed redundancy transformers (2x100%), designed for parallel operation of the transformers, and with switchover during operation.

The concept for the two main distribution switchboards (MDB), and the switchboard for emergency generator, is with circuit breakers in between, so that the two MDB's and the switchboard for emergency generator can be merged together to one MDB, supplied from one or two distribution transformers, and with a switchover during operation.

The MDBs will feed large individual consumers as for example combustion air fans and district heating pumps, as well as various motor control centre (MCC) switchboards.

Each of the two MDB sections shall be able to carry 100 % of the total design consumption plus spare.

The MDBs shall directly feed individual consumers larger than 90 kW.

Process related equipment must not be supplied from building related distribution switchboards.

In case of power black-out the 400V emergency diesel generator will be started. Via the two 400V MDBs, essential consumers will be feed, necessary for bringing the Line into a safe state.

A redundant uninterruptable power supply (UPS) of 400/230 V shall feed the overall CMS, all control voltage systems, all instrumentation and all critical consumers.

When the Line is in operation, the turbine driven generator is synchronized and feeds the 6.3 kV distribution switchboard and produces electricity to the public grid – this is the normal operation mode.

The Contractor shall, based on their Contract Object, work out a preliminary design as a part of the quotation with specification of the main electrical design figures including the specified spare capacity.

The preliminary electrical design values are specified in appendix A13 *Process and Design Data* and shall be considered as indicative and for information only.

The foreseeable power supply:

- 400 V system: 2 transformers each 5000 kVA
- 400 V Emergency diesel generator system: 1 Generator set of 1300 kVA
- 230/400 V UPS system: 2 UPS units for safe power supply each of 100 kVA

1.4 System operation modes

The electrical system shall be able to operate under the following main power operation modes:

1. Grid power supply. Power supply from the 22 kV grid with the steam turbine generator out of operation, for example during start-up of the Line.
2. Synchronised to the grid. The steam turbine generator is in operation and is feeding the Line consumers. The Line is exporting the net power production to the grid. This is the common operation mode.
3. Island operation disconnected from the grid. In case of a failure on the grid, the grid power supply can be interrupted. The Line shall be able to automatically continue its operation in island mode. The steam turbine generator shall continue operation and feed the Line consumers. In this case the load of the generator will decrease instantly, which will require appropriate turbine bypass systems and equipment in order to ensure the proper function.
4. Emergency operation mode. In case of general power black-out the diesel motor driven emergency power supply generator shall start-up automatically and ensure the power supply to only essential selected consumers as the capacity of the diesel emergency generator is sufficient for emergency operation mode only. The emergency operation

mode will facilitate the operation of the Line in order to ensure a proper and safe standby operation including equipment safety and essential systems.

A comprehensive number of power blackout tests shall be made during the commissioning phase and the Contractor shall participate.

2. GENERAL REQUIREMENTS

In general, all equipment shall be controlled, monitored and diagnosed by intelligent modules (circuit breakers, motor starters frequency converters, overall instrumentation etc.).

The following list (not exhaustive) highlights issues of particular importance for the concept of the electrical system:

- A fuse less concept shall be implemented in all installations, providing the ability to operate and monitor from the CMS-system.
- The concept of the energy distribution system shall reflect the concept of the process installation. This means that independent process units shall have independent power supplies.
- The concepts of the installations for building and process respectively shall be separated and function independently, which means separate boards, cables, cable ladders etc. need to be installed.
- All incoming and outgoing circuit breakers shall be suitable for remote operation. All components shall be equipped for remote monitoring.
- Remote operation and monitoring shall technically be executed by using hardwire I/O.
- For protection relays the communication between relays and to the CMS must be with optical fibres.
- The complete power distribution shall be able to be controlled manually and automatic from the CMS. The design shall be such that no dangerous situations are likely to occur during operation.
- A transparent layout enabling remote monitoring and configuring of equipment is required.
- Intelligent switchboards MDBs, MCCs, ACCs with diagnostic and protective functionality in all circuit breakers, motor starters, etc., shall be used.
- 20 % spare capacity for future extensions is to be reserved. This is applicable to all elements of the electrical power distribution, including bus-bars, cables and cable routing, UPS, MCC, cabinets etc.
- Free space for extension for at least one panel, module shall be available for switchboards, control panels, RIO panels etc.
- Redundant equipment shall have redundant power supplies from independent transformers and MDBs.
- The low voltage electrical installations shall be able to handle voltage variations within $\pm 10\%$ of nominal voltage. Voltage variations exceeding the limits may lead to switch off of parts of the installation but shall not lead to fault-states of equipment that prevent an automatic or manual restart.
- Load flow, short circuit calculations and inrush current calculations in software shall be prepared in order to design the electrical power distribution system. The editable model shall be a part of the documentation material.

2.1 Standards and legislation requirements

The electrical equipment and installations shall be in compliance with European standards and norms (EN) as well as the standards, rules and regulations in force in the Czech Republic, including more stringent Czech Republic Authorities requirements which may apply for the Line. The Contractor is asked to pay special attention to the following list of documents (not exhaustive):

Electrical supply systems:

- Regulation for grid connection. Czech national distribution grid requirements available at: https://www.eon-distribuce.cz/sites/default/files/2018-09/Priloha_c_4_Pravidla_pro_paralelni_provoz_vyroben_a_akumulacnich_zarizeni_se_siti_PDS_new.pdf
- EN 60076: Power Transformers.
- EN 60909-1-5: Short-circuit currents in three-phase a.c. systems. Calculation of currents

Medium voltage:

- EN 60044-1 Current transformers
- EN 60044-2 Voltage Transformers
- EN 60051-1 Direct Acting Indicating Analogue Electrical Measuring Instruments and their accessories
- EN 60204-11 Safety of machinery-Electrical equipment of machines – part 11: Requirement for HV equipment for voltage above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV.
- EN 60255-5 Electrical Relays
- EN 60073 Coding principles for indicators and actuators
- EN 60445 Identification of equipment terminals, conductor terminations and conductors.
- EN 60529 Degree of Protection provided by Enclosures (IP)Code
- EN 60271 Common specifications for High Voltage Switchgear and Controlgear Standards
- EN 61243-5 Capacitive voltage indicators
- EN 62053-11 Class 0.5,1 and 2 Alternating Current Watthour Meters
- EN 62271 High Voltage Switchgear and Controlgear
- EN 62271-100 High Voltage Alternating Current Circuit Breakers
- EN 62271-102 Alternating Current Disconnectors and Earthing Switches
- EN 62271-200 AC Metal Enclosed Switchgear and Controlgear for Rated Voltages above 1 kV and up to and including 52 kV

Low voltage:

- HD 60364 Low-voltage electrical installations
- 2014/35/EU: Low Voltage Directive (with later amendments).
- EN 60204-1: Safety of machinery – Electrical equipment of machines – Part 1: General requirements.
- EN 60364-x: Low-voltage electrical installations -
- EN 60439-x: Low-voltage switchgear and controlgear assemblies
- EN 60947-x: Low-voltage switchgear and controlgear.
- EN 62040-x: Uninterruptible power systems (UPS).

Cables:

- EN 50174: Information technology - Cabling installation.
- IEC 60331-x Test for electrical cables under fire condition

Rotating electrical machines:

- ISO 10816-3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ
- EN 60034: Rotating electrical machines.
- IEC 60072: Dimensions and output series for rotating electrical machines.
- ISO 8528-5: Reciprocating internal combustion engine driven alternating current generating sets – Part 5: Generating sets.

Electro Magnetic Compatibility (EMC):

- 2004/108/EC: Electromagnetic compatibility directive (with later amendments).
- EN 55011: Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement.
- EN 50561: Power line communication apparatus used in low-voltage installations – Radio disturbance characteristics – Limits and methods of measurement
- EN 61000-x: Electromagnetic compatibility (EMC)

Machine safety:

- Machinery directive, The CE Machinery Directive 2006/42/EEC: 2006 (with later amendments).
- EN 1037: Safety of machinery – Prevention of unexpected start-up.
- EN ISO 12100: Safety of machinery – General principles for design – Risk assessment and risk reduction
- EN ISO 13849-x: Safety of machinery – Safety-related parts of control systems
- EN ISO 13850: Safety of machinery – Emergency stop – Principles for design.
- EN/IEC 60204-1: Safety of machinery - Electrical equipment of machines – Part 1: General requirements.
- EN/IEC 60204-11: Safety of machinery – Electrical equipment of machines – Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV
- EN/IEC 60445: Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors.
- EN 60529+A1: Degrees of protection provided by enclosures (IP Code).

Earthing:

- EN 50310: Application of equipotential bonding and earthing in buildings with information technology equipment.
- HD/IEC 60364-5-54: Low voltage electrical installations – Part 5-54: Selection and erection of electrical equipment - Earthing arrangements, protective conductors and protective bonding conductors.

Documentation and calculations:

- The CE Identification Directive 93/68/EEC with later amendments.
- IEC 60617: Graphical symbols for diagrams
- EN 60909-x: Short-circuit currents in three-phase a.c. systems
- EN 61082-1: Preparation of documents used in electro technology – Part 1: Rules.
- EN 61346-1-2: Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 1-2.
- KKS: Identification System for Power Stations (KKS)

Miscellaneous:

- ATEX Directive 2014/34/EU

Furthermore, special standards, norms and regulations, which are valid for individual cases/areas, shall be followed.

All other items of equipment included in the Contract Object for which an applicable EN standard exists shall be subject to compliance with such standard.

2.2 Electrical magnetic compatibility (EMC)

The electrical and electronic equipment shall be designed in such a way that electromagnetic disturbances from these are limited. All electrical equipment shall have an adequate level of immunity to electromagnetic disturbances in its environment.

Special attention shall be given to EMC compliant installation and configuration of power electronic systems.

The installation of all equipment within power electronic systems shall be fit for purpose, for example via use of shielded cables and filters.

It shall be possible to use mobile telephones, portable radio communication equipment etc. close to operating equipment without causing disturbance to the equipment, even if the cubicle doors to the equipment are open.

2.3 Ambient conditions

Unless otherwise specified, the following minimum requirements shall apply as the criteria for the design, sizing and layout of the electrical equipment and installation. Please note that the figures stated below shall only be considered as guidelines. The Contractor shall become familiar with the local conditions and is responsible for design conditions influenced by the ambient conditions.

Where electrical equipment is located in an environment with ambient conditions outside the specified ranges (for example installations and locations with temperatures exceeding +40°C) the Contractor shall take the necessary precautions in the design, specification and installation of the equipment.

The Contractor shall provide all necessary heating and ventilating equipment for proper functioning of all electrical equipment, taking ambient conditions into consideration. Particular attention shall be given to the weatherproofing and corrosion protection of all electrical equipment located outdoors, with due regard to the specified industrial site conditions.

Ambient air temperature (indoor installations):

- Minimum requirement Above -5°C to + 40°C

Ambient air temperature range (outdoor installations):

- Local climate and according to CSN 33 2000-1 ED.2 (332000),
however as a minimum Above -30°C to +40 °C

Ambient air relative humidity (indoor installations):

- Minimum requirement Above 20 % to 90 %

- Short periods higher than 90 %

Altitude:

- Less than 1000 meters above sea level

2.4 Enclosure classes

All electrical equipment shall be supplied with an enclosure protection class which meets the corrosive environmental conditions at the location of the installation and shall be in accordance CSN 33 2000-1 ED.2 (332000). However, the following enclosure classes shall be considered as the minimum requirements:

Definitions:

- External housing (with closed enclosure doors)
- Internal housing (with opened enclosure doors)

Description	External housing	Internal housing
Electrical rooms for transformers (MV): <i>(Key locked rooms with restricted access)</i> <ul style="list-style-type: none"> • Distribution transformers (MV) • Bus-bars systems (LV) • RIO panels 	IP 21 IP 31 IP 55	IP00 - IP2X
Electrical rooms for Panels (LV): <i>(Key locked rooms with restricted access)</i> <ul style="list-style-type: none"> • Bus-bars systems (LV) • MDB (LV) • Sub distribution board (LV) • MCC and other boards • RIO panels 	IP 31 IP 31 IP 31 IP 31 IP 55	- IP2X IP2X IP2X IP2X
Electrical rooms for UPS (LV): <i>(Key locked rooms with restricted access)</i> <ul style="list-style-type: none"> • Battery installation • UPS units 	IP 31 IP 31	IP2X IP2X
Electrical rooms for frequency converters (LV): <i>(Key locked rooms with restricted access)</i> <ul style="list-style-type: none"> • Frequency converters (Air cooled) 	IP 54	IP2X
Electrical equipment (indoor process area): <ul style="list-style-type: none"> • Local operation panels • RIO panels • Safety disconnecting switches • Instrumentation • Electrical motors 	IP 65 IP 65 IP 65 IP 65 IP 55	IP2X IP2X - - -
Electrical equipment (outdoor process area): <ul style="list-style-type: none"> • Local operation panels • Safety disconnecting switches • Instrumentation • Electrical motors 	IP 65 IP 65 IP 65 IP 65	IP2X - - -

Description	External housing	Internal housing
Electrical equipment (chemical environment): <ul style="list-style-type: none"> Local operation panels Safety disconnecting switches Instrumentation Electrical motors 	IP 65 IP 65 IP 67 IP 65	IP2X - - -
Electrical equipment (explosive environment): <ul style="list-style-type: none"> All electrical equipment located in explosive environments must have a degree of protection according to the ATEX directive. 	See directive	

2.5 Power Supply

It is of high importance that the phase sequence is correct (in row of order: L1, L2, L3) and identical in all switchboards throughout the installation, starting at the grid transformer, and through to the final consumer.

Description	Supply
Grid connection (MV): <ul style="list-style-type: none"> 22 kV Connection to Grid company 	22.0 kV AC, 3 phase, 50 Hz
Medium voltage system (MV) <ul style="list-style-type: none"> Main supply Main supply Coupling coils Switchgear Remote operation 	22.0 kV AC, 3 phase, 50 Hz, IT 6.3 kV AC, 3 phase, 50 Hz, IT 220V DC /24V DC/ 230 V AC (UPS) 220V DC /24V DC/ 230 V AC (UPS) 24V DC (from 230 V UPS)
Turbine generator (MV): <ul style="list-style-type: none"> Connections at MV switchboard Main supply Lubrication pumps 	6.3 kV AC, 3 phase, 50 Hz, IT 400 V AC 220 V DC (safe power supply by turbine supplier)
Diesel emergency generator (MV): <ul style="list-style-type: none"> Generator supply Main supply Starting voltage 	400 V AC, 3 phase/PE, 50Hz, TN-S 400 V AC 24V DC (charge/battery)
Low voltage system (LV) <ul style="list-style-type: none"> Main supply Switchgear coil Remote operation Motors, actuators, frequency converters, etc. 	400 V AC, 3 phase/PE, 50Hz, TN-S 230 V (UPS) 24 V DC (from 230 V UPS) CMS 400 V AC, 3 phase/PE, 50Hz, TN-S

Description	Supply
<p>UPS (Building/machine installation):</p> <ul style="list-style-type: none"> • Consumers in general (LV): • Switchboard control voltage (LV): • CMS supply voltage (LV): • CMS control voltage (LV): • Instrumentation (LV): 	<p>400/230 V AC, 3 phase/N/PE, 50 Hz, TN-S 230 V AC, 1 phase N/PE, 50 Hz, TN-S 230 V AC, 1 phase N/PE, 50 Hz, TN-S 24 V DC 230 V AC, 1 phase/N/PE, 50 Hz, TN-S</p>

2.6 Location of electrical equipment

The design of the electrical energy distribution shall be in accordance with the geographical layout, layout plans for room locations and the process design.

Attention shall be made to ensure clear access around equipment, switchboards and frequency converters etc. in accordance with the standards, rules and regulations in force.

2.7 Interface to the grid

The Line shall comply all the technical and administrative requirements of the grid company, for example with respect to protection, operation and the electrical characteristics of the distribution grid.

The following shall be highlighted as part of these requirements:

- Voltage quality.
- Power factor requirements.
- Short circuit power level.
- Voltage and frequency tolerances.
- Protection philosophy

The following Technical Regulation shall be highlighted:

- Regulation for grid connection. Refer to section 2.1.

2.8 Metering for invoicing

The existing metering for invoicing on the grid connection will be used.

Billing metering, where the Contractor provides all equipment incl. the kWh counter in quality similar to the kWh counters from the grid company, is required at the following places:

- 6.3 kV level just before the generator circuit breaker.
- 6.3 kV level in the section for the two distribution transformers, before the circuit breakers.
- 400 V level in the section for Building technic/Light/outlets, before the circuit breaker.

From all installed metering points the following signals shall be transferred to the CMS system:

- Metering panel auxiliary supply failure - Digital signal
- kWh – (for both directions if appropriate)
- kVA_{rh} – (for both directions if appropriate)
- kW actual
- kVA_r actual

2.9 Spare space and capacity

The general requirement of spare space and capacity of the electrical installation is as a minimum 20% after commissioning, throughout the installation to the final consumer.

The design and installation of the electrical equipment shall ensure that spare space of 20% in all electrical rooms is available after commissioning. It shall be possible to make hardware extensions in all kinds of draw-out distribution board systems without any mechanical or electrical interruptions.

It shall be possible to perform hardwired extensions in all other distribution board systems without any electrical and mechanical interruptions by the means of DIN-rail mounting systems and the use of section circuit breakers.

2.10 Tools for electrical equipment

The Contractor shall deliver the following tools for the electrical equipment:

- Special tools, operating handles and any devices necessary for the operation and maintenance of the electrical equipment.

The Contractor shall deliver a complete set of tools for the electrical equipment located on the wall in every electrical room. A handling truck/lifting arrangement shall be provided where required to facilitate maintenance of switchgear and control panels.

2.11 Design, planning, engineering and documentation

The scope of Contract Object is of a “turn-key” nature. The Contractor shall be responsible for all aspects of the Contract Object including the performance of the whole engineering and the design of the electrical equipment and installations.

The Contractor shall execute the technical co-ordination within the Contract Object. This comprehensive task includes planning with obligation to raise co-ordination matters without undue delay.

Standardisation and co-ordination with all other parts shall cover the Contract Object, including design, installation, testing, quality control, documentation etc., in order to uniform and minimize the number of variants as well as to ease the operation and maintenance activities of the Line.

It is considered important that the entire electrical systems and installations are uniformly built with standard products known to be reliable. All components shall be installed with easy access for troubleshooting, repair and replacement. All deliveries of electrical equipment and materials, services and documentations shall be in accordance with the latest state-of-the-art for industrial installation and suitable for a modern energy-from-waste plant.

The Contractor shall in cooperation with the Employer use the Contractor's common and best practice standards in the project which shall be approved by the Employer.

The Contractor is asked to pay particular attention to the following list of documentation (not exhaustive and not prioritized) which is seen as essential for the Employer:

Installation and layout:

- User interface on the electrical equipment
- Colours of equipment e.g. enclosures, LED's and attendance buttons etc.
- Layout of equipment
- Location of equipment and access facilities
- Local control panels and local operation panels
- Installation arrangement
- Access facilities for operation and maintenance, including inspection in operation, preventative and corrective maintenance.
- Cable routing
- Bus-bar routing
- Raised floor design and type
- Transformers
- Boards
- Cable types
- EMC
- Process installations separated from the building installations
- Spare space
- Fire sealing's

Performance:

- Interface to the internal power grid
- Turbine generator power supply system
- Diesel generator power supply system
- UPS power supply system
- Voltage quality
- Redundancy
- Power supply (normal operation)
- Power supply (n-1 supply modes)
- Safe shut down to standby mode
- Large scale consumers e.g. motors and frequency converters
- Discrimination and selectivity
- Intelligent components and instrumentation etc.
- Intelligent component interface based on bus communication
- Spare capacities

Documentation and calculations (including required spare):

- Uniform and standardized Line e.g. boards, typical, layout etc.
- Single line diagram medium voltage installation
- Single line diagram low voltage installation
- Single line diagram UPS installation
- Load flow calculations
- Inrush currents
- Short circuit calculations shall be according EN/IEC 60909-3

- Discrimination and selectivity calculations
- Current heat loss in all distribution boards
- Editable model of short circuit calculations

Safety:

- Enclosure protection class (external housing)
- Enclosure protection class (internal housing)
- Over current protection
- Earthing systems, equipotential bonding and lightning
- Access facilities
- Location and number of emergency stop switches

2.12 Low voltage distribution, principle

Reference is made to appendix A16 *Concept Diagrams for Electrical System (Single line diagram)*.

The low voltage distribution system shall follow the following principle:

The 400 V MDBs (Main Distribution Boards) feeds:

- Large motor consumers ($\geq 90\text{kW}$)
- MCCs Motor Control Center
- ACCs Auxiliary Control Center
- UPSs Uninterruptable Power Supply

The MCCs feeds:

- Small ($< 90\text{kW}$) Consumers
- ACCs for related process equipment

The ACCs feeds:

- Power for small consumers

The UPS feeds:

- Uninterruptable consumers
- Control voltage for:
 - Instrumentation
 - MDBs, MCCs
 - RIO Panels, CMS equipment, Control room

All motors larger than 50 kW shall be supplied from a frequency converter.

This distribution principle shall be followed throughout the Line.

Redundant consumers must not be supplied from the same switchboard and associated cable routing shall preferably follow different cable routing ways.

2.13 System philosophy, operation and control

All provisions to comply with the following shall be provided in the Contract Object.

Reference is made to appendix A16 *Concept Diagrams for Electrical System (Single line diagram)*.

In normal operation the turbine generator is producing power, the two distribution transformers are in operation and feeding the 400 V systems for the Line consumers.

In case of blackout of the 6.3 kV switchboard:

- The incoming 400 V circuit breakers are tripped.
- The emergency generator SET shall automatically start.
- When the generator voltage is stable, the generator circuit breaker is closed and feeding the 400 V system.
- Now the consumers necessary for bringing the Line to a safe state are energized and operated via the CMS.

In case of blackout of the normal supply for one of the 400 V MDBs section:

- The corresponding incoming circuit breaker belonging to the unhealthy supply is tripped.
- The incoming grid circuit breakers are tripped.
- The two MDB sections shall now be tied together. This is facilitated by operating the appropriate circuit breakers in the MDB sections.
- The two 400 V MDB sections are tied together.
- The emergency generator SET shall automatically start. When the generator voltage is stable, the generator circuit breaker is closed.
- Now the consumers necessary for bringing the Line to a safe state are energized and operated via the CMS – the system shuts down with the emergency generator set.

When stable 22 kV or 6.3 kV supply returns - monitored on the incoming side of grid circuit breakers, or monitored on the incoming 6.3 kV circuit breakers, or when the operator has verified the reason for unhealthy supply of 400 V MDBs section, then the operator manually have to switch back to normal power on 400 V level.

Facility shall also be designed for testing purpose of the emergency generator during normal Line operation.

All systems of equipment shall be equipped with all necessary measurements, signals etc. for proper control, safety operation of the systems, including alarms for the systems – all available information in the systems shall be transferred to the CMS.

All systems of equipment shall be designed for fully remote operation from the CMS.

The maximum short circuit level on the 400 V Low Voltage shall not exceed 100 kA rms. The system shall be designed for two transformers operated in parallel, when changing from one transformer to two transformers supplying the MDB switchboards and vice versa, during operation of the Line.

The Contractor is responsible for coordination with the grid company concerning requiring necessary design figures e.g. short circuit, impedance figures – for making the design analysis.

The protection and synchronization facilities shall be duly co-ordinated with the protection system and control facilities:

- Supplied with the turbine generator
- Supplied in the 22kV switchboard by the Grid Company

The Contractor is responsible for the design discrimination analysis for feeders in the distribution system including list of settings of protection for short circuit, over current and earth fault.

The design analysis shall include main switchboards, emergency switchboards, and all sub-distribution systems including battery/UPS systems.

Minimum and maximum short circuit currents, as well as generator decrement curves shall be stated in the discrimination analysis.

The Contractor shall provide functional design specification and programming of the control and monitoring of equipment and systems.

All systems of equipment shall be equipped with all necessary measurements, signals etc. for proper control, safety operation of the systems, including alarms for the systems – all available information in the systems shall be transferred to the CMS.

All systems of equipment shall be designed for fully remote operation from the CMS.

2.14 Protection relays for medium voltage and high voltage

The relays used for the protection of equipment and systems, synchronization and voltage regulation for medium voltage and high voltage level, shall apply to the following:

- Multifunction relays, with all functions integrated.
- The relays shall be designed for protection, control, measurement, condition monitoring, data logging and bus communication.
- Intelligent relays with diagnostic and protective functionality shall be used.
- The relays shall be provided with programmable functions allowing all automation and sequence logic functions needed for the system automation to be integrated into the relays.
- The use of two setting set for the relay protection shall be anticipated due to the different operation modes.
- Provide a backup system, wherever appropriate.
- Relays shall be located in switchboards panels, control panels etc.
- The relays shall have mimics showing the status of all switchboard components and shall have sufficient number of spare digital inputs and outputs.

The relay communication interface shall comply with IEC 61850 communication standard.

The relay shall be with communication interface to the CMS for control and monitoring.

For earth fault protection –2-way and Watt metric directional relay facility shall be provided.

3. ELECTRICAL EQUIPMENT

3.1 General

For main items of equipment and associated installation included in the Contract Object reference is given to appendix A1 *Overall Scope of Contract Object*.

3.2 22/6.3 kV switchboard

The main requirements for extension of the R2 Switchboard part WA4 with two sections, each with a circuit breaker and protection equipment is that the design requirement of the existing switchboard R2 Switchboard part WA4, must be designed and installed such that entire switchboard appears as one uniform unit, designed on the same design principles and criteria, with the exception that the protection, functional and design requirement must be fulfilled.

3.2.1 22/6.3 KV SWITCHBOARDS, SYSTEM DESIGN

The protection and synchronisation facilities shall be duly co-ordinated with the protection and control facilities supplied with the turbine generator and the emergency diesel generator.

The short circuit level is normally 25.0 kA on R2 Switchboard part WA4. However, the Contractor shall be responsible for calculation of the actual short circuit level of the system and shall supply the equipment in compliance with the actual calculated figures.

The Contractor shall design and coordinate the interlock and control philosophy for all the breakers as well the external grid power supply. The compartments shall be equipped with all necessary interlocks according to local recommendations and IEC recommendations. In this way operation failures shall be avoided.

The Contractor shall work out design calculations for protection and proper fault discrimination between protection equipment.

The switchboard shall be designed for natural cooling/ventilation. All parts of the system shall be able to continuously carry the nominal currents of the individual compartments without exceeding the temperature limits according to IEC 60056 and IEC 60298. Design shall be executed with minimum 20% spare space and capacity.

3.2.2 22/6.3 KV SWITCHBOARDS, DESIGN

The switchboards shall be designed as single bus bar, metal enclosed, metal clad compartmented assembly, type tested, manufacturer standard type system for indoor installation.

The switchboards shall be of free-standing metal-clad type as defined in IEC publication 62271.

The switchboards shall comply with IEC 62271-200 and fulfil the following classifications:

- Service continuity category: LSC 2B - metal-clad design, i.e. compartmentalization into separate busbar, switching-device and cable connection compartments
- Partition class PM (metal-clad)
- Internal arc classification: IAC A FLR, Isc 1s.

Busbars shall be contained in totally enclosed, air insulated chambers and made of hard or medium hard drawn high-conductivity copper.

The horizontal busbars shall be of the same rating and cross-sectional area throughout the length of the switchboard.

Vertical busbars in incoming and outgoing feeder sections may not have reduced cross-sectional area.

All primary conductor joints shall have a rating equal to the busbars and be protected to withstand corrosion.

All major components in each panel, such as bus bars, cable terminations, circuit breakers, and low voltage (LV) control circuits shall be separated in metal enclosed compartments.

Isolating mechanisms and unit withdrawal facilities shall be suitable for operation by a single operator and designed for minimum effort and time of operation.

It shall be possible to safely carry out work on an individual or future panel including main, control and auxiliary cables, when isolated and busbar shutters padlocked closed, with the remainder of the switchboard a live - without danger from contact with live parts.

The switchgear shall be of robust construction designed to give maximum service reliability.

Panel Design in Modular Construction, Partitions

The panels shall consist of the following compartments in modular construction:

- Busbar compartment
- Switching-device compartment
- Cable connection compartment
- Low-voltage compartment

The individual sheet-steel compartment modules are bolted together to one switchgear panel. Separation walls to the adjacent panels shall always be realized in double version.

Doors and lateral switchgear end walls shall be powder-coated with resistant epoxy resin, all other walls shall be galvanised.

The complete enclosure and the partitions between the individual compartment modules and covers shall be metallic and earthed. The highest possible service continuity category LSC 2B of the switchgear (metal-clad design) and the highest possible personal safety with partition class PM according to IEC 62271-200 is required.

The service continuity category LSC 2B shall allow access to compartments while other compartments remain in operation. For example, it must be possible to maintain the cable connection compartment and the busbar compartment of the same panel as well as all compartments of the adjacent panels in operation while the switching-device compartment is open.

The modular design shall allow to replace the switching-device compartment and/or the cable connection compartment, e.g. after an earth fault in the cable connection compartment. The

individual compartments have to be pressure-resistant, so that - in case of an internal fault (arc fault) - ingress of hot gases will not pollute the adjacent compartments to an inadmissible extent. In connection with the pressure tied partitions between breaker and cable compartment a selective shut-down shall be possible.

The partition class PM has to ensure that only earthed metal plates can be touched during access to the individual compartments.

All HV sides of the switchgears must have arc flash mitigation protection installed in all switchgear compartments.

Busbar Compartment

The busbar compartment shall contain the three-phase busbars made of round profile copper, the panel bars and the bushings with the fixed contacts.

The shutter for visual inspection of the fixed contacts shall be opened and closed in the switching-device compartment. Busbars shall be bolted from panel to panel.

The upper partition and the upper metal cover have to be bolted and shall offer access to the busbar from the front during installation. In this way, access to the busbar compartment shall be "tool-based" according to IEC 62271-200.

Additional components (voltage and current transformers, earthing switches, bus riser) shall be mounted in a separately additional compartment.

Switching-Device Compartment

The switching-device compartment shall be equipped with the following devices:

- Truck mounted with draw able circuit breakers vacuum type.

Mechanical switch position indicators and control elements of the respective switching devices shall be visible in the door of the switching-device compartment. In connection with the logical mechanical interlocking system, this shall avoid any mal operation.

While racking from the service to the disconnected position or vice-versa, the module shall open or close the metal shutters covering the fixed contacts in the connection and busbar compartments.

The connection of the low-voltage wiring between the switching device and the fixed part of the panel has to be realized via a multi pole plug connection.

Generally, the low-voltage wiring has to be laid in metallic ducts with removable covers. Maintenance-free vacuum circuit-breakers shall be used. Arc quenching medium which produces highly toxic decomposition products is not accepted.

The circuit-breaker has to be type-tested in the panel according to IEC 62271-200.

Safety shutters, interlocks

Switchboard design of safety shutters, to be provided on all with draw able circuit breakers:

- Shall open and close automatically on insertion or withdrawal of the circuit breaker.
- Safety shutters shall be fitted to busbar and circuit spout orifices on the fixed portion.
- Each set of shutters shall be capable of being individually padlocked closed.
- Facilities shall also be provided to permit either or both sets of shutters to be opened for testing and maintenance purposes. Such facilities shall be automatically cancelled by the re-insertion of the moving portion.
- Manual operation for shutters shall only be accomplished after purposely defeating a mechanical interlock.
- Busbar shutters shall be fitted with labels. White lettering on red background.
- The circuit shutters on Incoming Feeders shall be clearly labelled.

Mechanical interlocks shall be provided to protect personal and equipment from dangers of mal operation, and include prevention of the following:

- Any compartment door that gives access to high voltage supplies from being opened unless the circuit breaker is in the "OFF" position
- The circuit breaker being withdrawn from or inserted into the plugged-in position with the circuit breaker in the closed position.
- The circuit breaker being closed unless correctly located in the plugged in or withdrawn for tests position unless completely removed from the fixed portion of the equipment.
- The circuit breaker being inserted or withdrawn from the fixed position unless it is in a correct state to do so.
- The circuit breaker being closed in the plugged-in position without previously having completed the protection control and auxiliary circuits between the fixed and moving points.
- The circuit breaker from being reclosed, whilst a trip condition exists.
- The circuit breaker being operated electrically whilst the breaker compartment door is open.
- Circuit breakers being engaged into any position other than that which has been selected on the selector mechanism.
- Closing of the feeder earthing switch whilst the circuit breaker is closed and vice versa.
- Switches shall be provided for tripping, closing indications, alarms and other purposes as required. All control and auxiliary switches shall be positively driven in both directions and shall be mounted so as to be readily accessible for maintenance. They shall be wired to a terminal board on the fixed portion of the switchboard.
- All spare interlock and auxiliary switches shall be wired out to a multi-core cable box.

Cable connection compartment

The cable connection compartment shall be equipped with the following components:

- Current transformers
- Make-proof earthing switch
- Voltage transformers
- Surge arresters
- Earthing busbar
- Cable current transformers

Cable connection shall be from the front. Access to the cable connection compartment has to be "interlock-based and tool-based" according to IEC 62271-200.

Cable testing equipment resp. cable testing adapters shall be easily connected without detaching the cables. For this purpose, the shutters shall be opened and locked separately. To guarantee personal safety, the shutters of the busbar compartment shall be optionally equipped with a padlock.

Due to the required design with vacuum circuit breakers applied in the system, suitable surge arrestors shall be installed in all circuits and are being part of the Contract Object.

Low-Voltage Compartment

- The low voltage compartment is located at the front. It shall be completely separated from the rest of the panel by partitions and shall be removable from the panel.
- Electrical connections between the module and the fixed part of the panel have to be performed with flexible wires and a multi pole low-voltage plug connection.
- Current transformer circuits shall be wired to terminals in the low-voltage compartment. All other panel-internal circuits shall be wired to 10-pole connectors and plugged in the low-voltage compartment.
- Bus wires shall be laid from panel to panel in the upper part of the low-voltage compartment and shall be pluggable.
- Secondary devices shall be installed in the door of the low-voltage compartment and on a mounting plate with DIN-rails. The wires shall be laid in wiring ducts with a sufficient cross-section.
- Wiring ducts shall be arranged on the left and right inside the switching-device compartment and are equipped with removable covers.
- External control cables shall be inserted from the bottom on the right side of the panel via a cut out in the panel floor.

3.2.3 22/6.3 KV SWITCHBOARDS, EXTENSION AND INTERCHANGE ABILITY

The switchgear shall have facilities for extension with panels of similar construction to the panels previously forming the ends.

The switchgear shall be designed and built to achieve maximum interchangeability. Equipment of the same current rating made by one manufacturer shall be arranged so that any moving portion may be plugged into any fixed portion of the same type and current rating without the need for modification to either main or auxiliary equipment.

Any material used for barriers, shields, covers, etc., shall be self-extinguishing, halogen free. Spouts, orifices, etc., shall be designed to avoid localized, high voltage stress concentrations irrespective of whether the moving portion is in or out. All bolted connections shall be made with high tensile strength bolts effectively secured against loosening.

Barriers shall be provided to prevent arcs occurring in incoming bus-ducts or in cable terminations from flashing to the main bus-bars.

Busbars shall be executed in a modular way, which facilitates the possibilities of future extension.

3.2.4 22/6.3 KV SWITCHBOARDS, ARC FAULTS

In case of an arc fault, pressure must generally be relieved upwards. The switchgear has to be arc-fault tested according to IEC 62271-200 and fulfil all criteria of the internal arc classification IAC A FLR according to IEC 62271-200.

The switchgear shall be designed to withstand any external fault and internal arc faults.

Arc faults pressure relief provisions shall be provided at each bus bar, cable termination and circuit breaker/contactors compartment, provisions shall be mounted at the top of the assembly. Personnel shall not be exposed to harmful flames or gasses, and circuit breaker compartment doors shall remain shut.

The Contractor shall include pressure relieving duct for the switchboards to the outside of the building.

3.2.5 22/6.3 KV SWITCHBOARDS, EARTHING

All earthing equipment including the earth bar shall be sized for the maximum fault duration and fault level, specific for the switchboard.

All non-current carrying metal parts, including the moving portion, when in service or test positions shall be connected to a copper earth bar mounted at the rear of each panel.

The bar shall be so located as to provide for the earthing of cable boxes, cable sheaths, armour clamps and the circuit-breaker earthing device.

The earth bar of each panel shall be effectively bolted to adjacent panels so as to form a continuous earth bar throughout the switchboard with facilities at each end for connection to the main earth system.

3.2.6 22/6.3 KV SWITCHBOARDS, EQUIPMENT PRIMARY

The following requirements for primary equipment shall be observed:

Vacuum circuit breakers

All vacuum circuit breakers shall be of fully with draw able truck mounted type, mechanically lockable in two positions:

- Service position (in operation)
- Test position (disconnected primary, fully testable locally and from CMS)

Note: It shall always be possible to locally switch off a circuit breaker and mechanically disconnect the circuit breaker.

All compartments shall be equipped with a multi-plug facility for the connection of a local control panel via a flexible cable.

Only breakers of identical size and type shall be mutually exchangeable.

The moving part of the plug connections shall be fixed on the circuit breaker truck in

order to facilitate maintenance of these during energized busbars.

The circuit breaker shall be provided with a motor charged spring energy operating mechanism. Manual charging of the spring shall be possible.

There shall be a separate shunt coil for trip signal from the protection system.

Incoming panels for start-up transformer, unit auxiliary transformer and all generator circuit breakers shall be provided with under voltage release.

The under voltage release shall allow the breaker to be closed, when the voltage and frequency are 85% to 110% of the nominal value. The under voltage release shall release the circuit breaker within the range 70% to 35% of the rated voltage.

All compartments with circuit breakers shall have the following mechanical indications and displays:

- Circuit breaker: Closed and open position.
- Charging spring: Charged position.
- Circuit Breaker truck: Service and test position.
- Circuit Breaker: Counter for cycles of operation.

Earthing switches

Earthing switches shall all be fixed mounted, integrated, torque operated type, make proof type, only for manually operated.

An earthing switch shall be provided for each circuit breaker to enable circuit earthing to be carried out.

For earthing facilities of busbars, the bus tie circuit breakers shall be provided with earthing switch on both sides of the circuit breaker. Reference is made to appendix A16 *Concept Diagrams for Electrical System (Single line diagram)*.

Earthing devices shall be fitted with a mechanically operated position indicator, clearly visible without removal of cubicle panels or covers.

By visual inspection it shall be possible to confirm that the earthing device is earthed properly.

The earthing switch shall contain a padlock facility.

The earthing switch shall be interlocked by key or mechanical features to prevent:

- Closing of the earthing switch if the power source can be energized.
- An equipment cubicle to be energized if its earthing switch is closed.
- The earthing switch shall be capable of being padlocked in the closed position.
- Generator circuit earth switches shall be so interlocked as to prevent the generator from being started with the circuit earth made OR the circuit earth being made while voltage is still apparent on the generator main terminals.
- Busbar earthing shall be accomplished by an earthing switch fitted on either side of the bus section circuit breaker and fitted with key interlock to prevent mal operation.

All compartments with earthing switches shall have the following mechanical indications and displays:

Earthing switch: Closed and open position.

Earthing switches, electrical interlocks

All earthing switches and circuit breakers shall be equipped with blocking coils for interlocking purpose.

The system shall be provided to ensure a failsafe operation of the equipment.

Any necessary metering from voltage transformers, position auxiliary contacts of switching equipment etc. shall be incorporated in the design – also signals from circuit breaker, earthing switch, voltage transformers for 22 kV grid company shall be incorporated.

The system shall prevent any operation fault to occur - closing of energized system on any earthed system and applying earth to energized systems.

The system shall also prevent generator systems from being excited on earthed systems as well as de-excitation of the generator systems in case of applying earth to such systems.

The safety system shall be a PLC based failsafe and comply with requirements of SIL 4 level.

All signals shall be transmitted to and monitored at the CMS. On the CMS it shall be indicated on faceplates for each individual component - whether it's safe to operate the component and provide information about any blocking condition. This is it to be given in text to guide the operators of the system.

Switchboards, Measuring transformers general

The following conditions for the transformers for metering and protection purpose shall be observed:

Quantity, rating, cores and classes of voltage and current transformers have to match the protection relays and metering equipment.

The manufacture of the transformers shall be well known and shall include calibration- and test certificate.

All secondary windings shall be solidly earthed as close as possible to the transformers.

The secondary windings shall be equipped with terminals and connections, which facilitate easy and safe maintenance and troubleshooting.

Each of the incoming and outgoing compartments shall be provided with separate VT's and CT's, for example for monitoring, protection and for metering. Measurement shall take place in all phases.

In the grid power supply compartment current measurement transformers shall be established for differential protection of grid supply transformer and -cable.

Measurements classes shall be as follows:

- Monitoring: Class 1, power rated for the connected equipment
- Metering according to Authorities, meeting their requirements
- Protection: Adequate in class and rated power for proper protection scheme - Proper settings ranges, relay sensitivity for the protection relays shall be provided.

Current transformers

For each circuit breaker a minimum of one set of 3 current transformers with separate protection and metering core shall be provided.

For each set of current transformers 3 locally mounted A-meter shall be provided.

Further cores for protection purpose e.g. differential protection and or separate current transformers for invoice metering shall be provided wherever required.

Cable current transformers for facilitating the earth fault detection shall be installed wherever appropriate.

For outgoing feeder units it shall be possible to change C.T.'s without de-energizing the busbars.

The secondary winding of each set of current transformers shall be earthed at one point only through a removable link. In addition, where the transformer core is accessible it shall be separately earthed.

Provision shall be made to automatically short circuit current transformer secondary when withdrawing protection relays.

Current transformers for protection and metering shall be 1 A rated secondary current.

Test terminals and sockets shall be provided to permit secondary injection tests to be carried out, without disconnection of any permanent wiring.

The Contractor shall be responsible for ensuring that all C.T.'s are correctly matched to their respective relays and instruments, have the correct ratio, rating and accuracy and are connected with the correct polarity.

Links shall be provided on an easily accessible terminal block to permit short-circuiting of C.T. secondary.

Voltage transformers

For each voltage metering a minimum of one set of 3 voltage transformers each with 2 separate cores shall be provided.

A locally mounted v-meter with the following shall be provided:

- A changeover switch for voltmeter with 7 positions:
- 3 Line-to-Line voltages, L1-L2, L2-L3, L3-L1
- 3 Line to earth voltages, L1-Pe, L2-Pe, L3-Pe
- Off position, Off.

The second core of the voltage transformers shall be used for protection purpose, e.g. can be used in open delta connection for facilitating the earth fault detection. Accuracy class 0.5 is required.

Further cores for protection purpose and or separate voltage transformers for invoice metering shall be provided wherever required.

The Contractor shall be responsible for ensuring that all voltage transformers are correctly matched to their respective relays and instruments, having the correct ratio, rating accuracy and being connected with the correct polarity and vector group.

Capacitive voltage indicators

The panels shall be equipped with capacitive voltage indicators for voltage indication. The units shall be in full compliance with requirements of EN 61243-5 applicable for capacitive voltage indicators.

There shall be installed indicators on both sides of all circuit breakers.

3.2.7 22/6.3 KV SWITCHBOARDS, EQUIPMENT SECONDARY

The following requirements for secondary equipment shall be observed:

Ferro resonance elimination

To protect voltage transformers against ferroresonance phenomenon in the isolated grid, due to switching or other transient phenomena, a voltage transformer guard or similar protection shall be installed. One separate VT guard shall be connected to all set of 3 voltage transformers being used in open delta connection.

Arc monitoring equipment

The following conditions for the arc monitoring equipment shall be observed:

- The system shall be equipped with arc monitoring and protection equipment (combined arc/current detection).
- The fibre optical sensors shall be located in each compartment in the individual busbar-, breaker- and cable sections.
- Arc detection in busbar- and breaker section shall trip the entire section of the busbar system.
- Arc detection in cable sections:
- Where cable can't be alive due to feedback, only the outgoing breaker shall be tripped.
- Where voltage can be alive due to feedback both the outgoing circuit breaker and the associated circuit breaker enable to feedback shall be tripped.

Protection relay functions, control and communication

Proper settings ranges, time delays, number of stages, relay sensitivity for the protection relays shall be provided.

All compartments shall have 2-way earth failure equipment. Meaning directional earth fault equipment for 1-way (forward) and directional earth fault equipment for 2-way (backward).

Energy metering for accounting

Refer to description in Section 2.8

The signals shall be transferred to the CMS and the grid company.

Measurements circuits

Terminals for measurements circuits shall be executed with disconnection facility and test jacks as well as bypass/short cut facilities for the individual circuits.

Terminals shall be of well-known make with screw connection.

Control voltage

Control voltage supply will be redundant 230 VAC, supplied from two separate safe power supply unit. A redundant switch mode power supply shall be installed, with an isolating diode bridge in between. This shall be combined with galvanic isolated safety transformers.

Control voltage is distributed throughout all compartments with branching in each compartment with individual miniature circuit breaker with auxiliary contacts. A galvanic isolated transformer shall be installed.

Aux. relays and secondary terminals

The low voltage section shall be equipped with auxiliary relays and terminal rows for connection of internal (between compartments) and external cables. All compartments shall have a dedicated terminal row for signal exchange to the CMS. All internal cores shall be equipped with insulated cable lugs, which are pressed onto the core.

Secondary terminals

Terminal blocks within the switchboard and those for the connection of control/auxiliary cable shall be mounted in readily accessible locations and be of clamp type, with self locking screws.

Conductor connections shall be limited to one per terminal side and any looping or paralleling shall be by links which are purpose designed and supplied by the terminal block manufacture.

Terminal blocks for current transformer secondary terminations shall be of the cross connecting link type, to facilitate removal of outgoing connections with current transformer energized.

Current transformer secondary terminals shall be guarded and labelled to prevent inadvertent open circuiting of the current transformers.

All terminal blocks for incoming and outgoing multi-core cables operating over 50V shall be furnished with removable plastic covers.

Terminal blocks shall be labelled for identification of item and service.

The labels shall be separate from the plastic covers. The labels shall be marked as necessary to indicate dangerous voltages, externally energized terminals, trip circuits etc.

LED lamps

LED lamps shall be used.

Secondary Wiring

The following requirements for wiring shall be observed:

- Internal secondary wiring shall be PVC insulated cable, 1.5 mm² minimum, stranded copper conductors.
- All wiring shall be flame retardant to IEC 60332-3 and be low smoke, halogen free.
- Where devices are installed which require connection via very small cross-section conductors, separate terminals shall be provided and used with 1.5 mm² wires to avoid the routing of small wires through the switchboard.
- Wiring shall be continuous between terminals. Joints will not be permitted.
- Wiring shall be in appropriate ducting.
- All wiring shall be carried out in a good class engineering manner to avoid possible damage or over tension, abrasion from sharp edges and insulation deterioration from heat sources.
- Runs of groups of wires shall be run in suitable troughs, not to exceed 75% of its capacity, or be loomed and unsupported. No wiring shall restrict the access to equipment and components.
- Connections shall be spaced to permit reasonable modifications or additions using the same fixings.
- Where connections are onto a hinged panel or door, suitable lengths of multi-stranded conductors with reinforced protection, such as flexible conduit, shall be used.
- Circuits and terminals operating at different voltages and/or performing different functions shall be adequately segregated or barriers fitted.
- Screw terminals shall be a type with a disconnect and test facility.
- Only one wire may be terminated per terminal.
- Multi-stranded wires shall be provided with terminal-tubes.
- Colour marking according to IEC 60445 and 60446 and to be agreed with the Employer.
- Logical KKS grouped terminal row blocks are to be included.
- The secondary wiring arrangements shall be such that it is readily possible to prove power operated remote or local closing, protection equipment tripping, motor interlocks, etc., with the circuit breaker moving portion in the "withdrawn for test" position.
- All wiring ducts, conduits and flexible conduits shall be adequately sized to allow an easy fit for existing specified wiring, together with an allowance for a minimum of six additions (future) secondary wiring conductors.
- Provision shall be made to allow easy pulling in of additional secondary wiring.
- Adequate spaces shall be allowed for wiring of a maximum future number of control and auxiliary switches that can be fitted to the circuit breaker. A minimum of six equipped connections shall be provided between each fixed and withdrawn portion, with each end connected onto accessible terminals.
- Terminal marking of wire at the point of termination are to be included.

3.2.8 22/6.3 KV SWITCHBOARDS, MAIN TERMINAL AND CABLES**Main Cable Terminals**

Precise details of terminals will depend on the type of cable used and the Contractor shall not proceed with their manufacture without prior discussion and written agreement from the Employer.

Main Cables

Cable glands for single core cables shall be of the non-magnetic type and provision shall be made for their mounting in removable non-magnetic gland plates. They shall also be insulated from each other and from the switchboard and be provided with facilities for cross connecting.

Where main cables in parallel are used, the positions of cable glands and terminals are to be such as to prevent the crossing, inside the termination boxes of cores of different phases.

All compartments shall be equipped with fixing facilities for cables. All compartments shall be equipped with bottom plates also in the cable section.

The switchgear shall be vermin proof.

Control and Auxiliary Cables

Removable undrilled gland plates shall be furnished for the cable terminations. Cable glands shall be provided by the Contractor and fitted at site.

3.2.9 22/6.3 KV SWITCHBOARDS, AUXILIARIES

The following auxiliaries shall be delivered as a part of the switchboard:

- Engineering support for programming and protection settings of all the electronic protection relays.
- Programming software, test and troubleshooting equipment for protection relays.

3.2.10 22/6.3 KV SWITCHBOARDS, ACCESSORIES

The following accessories shall be supplied

- Hand crank for charging the circuit-breaker spring manually.
- Operating crank for racking the movable part- truck.
- Operating crank for operating mechanism of earthing switch.
- Socket spanner for low-voltage door
- Socket spanner for high-voltage door

3.2.11 22/6.3 KV SWITCHBOARDS, OPERATION AND CONTROL

The following conditions shall apply regarding operation and control:

All circuit breakers shall be both manually operated as well as from the CMS.

Remote operation and monitoring facilities shall be available from the CMS.

The following control facilities of the circuit breakers shall be foreseen:

- Commands from the emergency diesel generator control system.
- Commands from the CMS system.
- Commands from the CMS operator screens (only limited operator access).
- Synchronization equipment shall contain automatic and manual operated facilities.

Synchronization shall take place at various circuit breakers according to the overall Line design and operation requirements.

The synchronizing functions will be executed via locally located equipment which are integrated in the generators and in the switchboards.

The synchronizing can be supervised and operated also from the CMS operator screens.

Remote control and monitoring of the switchboard shall be executed by means of a bus communication and transfer relays / potential free contacts.

All information including synchronized time stamping with the main CMS shall be available in the main CMS.

For each panel in the switchboards the following type of signals shall be transferred to the CMS.

Voltage quality monitoring.

- Circuit breaker status:
 - Closed
 - Open
 - Test
 - Ready
 - Fault
- Circuit breaker truck position:
 - In service
 - Test position
 - Withdrawn from panel.
- Earthing switch position:
 - Earthed
 - Open
- Multi-function relay monitoring:
 - All kind of fault detections.
- Component and equipment alarms.
- Control voltage monitoring
- Amperes in all phases
- Voltage between all phases
- kW monitoring
- kVAr monitoring
- Cos phi monitoring

For each panel in the switchboards there shall be installed metering in all panels comprising circuit breakers, with exception of bus tie panels.

For each panel the following type of signals shall be transferred to the CMS:

- kWh- and kVArh metering (for both directions if appropriate) - bus communication.
- Metering panel auxiliary supply failure - Digital signal

3.2.12 22/6.3 KV SWITCHBOARDS, LABELLING

The switchboards shall be provided with a durable one line synoptic diagram, clearly indicating the specific function of the different panels by means of status indications.

To be applied on each compartment – illustrating incoming-, outgoing-, busbar tie circuit breakers, earthing switches, voltage -, current transformers, generators, transformers, etc

Status indication shown on screen of protection relays will be accepted as indication.

“Main” and “Circuit breaker” designation details will be in the data sheets.

The labels shall be engraved type with BLACK letters on WHITE background.

A main rating plate shall be affixed in a prominent position on each board giving the following information:

- MANUFACTURER’s name, type and serial no.
- PURCHASER’s name and order no.
- System voltage, phases, wires
- System frequency
- Rated fault level
- Bus bar rating
- Year of manufacture
- Switchboard title and tag no.

Covers, that on removal can expose live metal, shall be provided with permanently engraved labels, warning of the presence of live metalwork. Warning labels shall be fitted to parts, which if operated incorrectly can harm personnel or damage equipment.

Each circuit breaker shall have, permanently attached to it, a rating plate engraved or stamped with, all relevant data, including the following:

- Rated voltage and frequency
- Rated current
- Rated breaking capacity – symmetrical and asymmetrical RMS current values
- Rated making capacity – asymmetrical peak current value
- Short time rating
- Serial No.
- Closing voltage
- Tripping voltage
- Year of manufacture

Circuit nameplate shall be fixed to the front of each panel.

Terminal blocks for auxiliary cable shall be suitably identified to ensure clear cross-reference with approved wiring diagrams.

All switches, relays, instruments, etc., shall be labelled and marked in durable manner, with all essential data including the designation given in the respective wiring diagram.

The height of characters on labels shall generally conform to the following sizes:

- Main switchboard label 30 mm
- Main panel label 10 mm
- Instrument/selecter switch label 5 mm
- Smallest acceptable label 3 mm

Labels shall not be fixed to removable components unless a second label is fixed internally to ensure correct replacement of covers, lids etc.

Labels shall be fixed by means of screws, rivets or nuts and bolts without compromising the integrity of enclosure. Adhesive fixing is not permitted.

The tag-numbering system of the Line shall be applied.

The language to be used for labels shall be Czech

3.2.13 22/6.3 KV SWITCHBOARDS, INSTALLATION

The following installation conditions shall be observed:

- The switchboard shall be installed in a separate 22 kV switchboard room.
- The switchboard shall be arranged in such a way that it facilitates future extension.
- There shall be a main earthing bar in the room
- The switchboard room shall be facilitated with double floor supplied by Contractor.
- The switchboards shall be mounted directly on the double floor (which shall be designed and constructed with sufficient strength).
- Cable routing shall be executed on cable ladders under the double floor.

A number of emergency stop switches for tripping of appropriate circuit breakers in respective switchboards shall be installed. The locations of these switches shall be agreed with the Employer.

3.3 Power transformer

3.3.1 POWER TRANSFORMER, INTRODUCTION

The power transformer serves to transform power from different voltage levels in and out of the Line.

The power transformers also serve to reduce the short circuit levels and for galvanic isolation of the voltage levels.

3.3.2 POWER TRANSFORMERS, DESIGN

General

Tap changer steps and range of power transformer shall match appropriate voltage variations on Grid side or on the primary side of the transformers and the short circuit voltage U_k of the transformers. Short circuit voltage U_k shall match requirements to short circuit level as well as voltage drop considerations on low voltage level. By change over between supplies from the 22 kV grid connection to 6.3 kV connection or from 6.3 kV connection to 22 kV connection the power transformers will be on load and the other part will be on off load. In this change over state the voltage drop on the low voltage side shall be below 10%.

Technical data

Name	Transformer
Type	Two winding transformer
Rated power	* MVA
Frequency	50 Hz
Nominal temperature rise oil	60 °C
Nominal temperature rise windings	65 °C
Cooling type	ONAN/
Voltage ratio	* / * V
Tap changer type	Off load
Tap changer ratio	+2x2,5%, Note 1
Vector group	*
Short circuit voltage impedances Uk	Note 2)
*) Shall be designed and informed by the Contractor Note 1) Shall be design by the Contractor Note 2) Shall be design by the Contractor respecting the required short circuit level on 6 kV level.	

Operating voltage Transformer

The transformers shall be capable of operating with the rated output at $\pm 10\%$ primary voltage without the core or other parts being damaged by overheating or abnormal vibration.

Requirements beyond this will be stated in the individual case. Similarly, they shall withstand continuous no-load operation with the primary voltage increased by 10%. The no-load current with the primary voltage increased by 10% shall be stated.

Insulation level at neutral

The transformer shall be designed for shock testing with insulation levels in accordance with the mentioned standards.

Overload capacity

For assessment of overload capacity state, the calculated winding/oil temperature differences for each individual winding at specified currents, as well as the average oil temperature at a specified load state, total loss and type of cooling.

To avoid restrictions on the overload capacity, conductive parts other than the actual winding – such as bushings, connectors, tap changers and integrated current transformers – shall be designed for a current 40% higher than the rated current.

Short-circuit strength

The transformer shall be prepared for a future short-circuit level according to the following design figures:

Short-circuit rating at 22 kV level: 25.0 kA on R2 Switchboard part WA4
 Short-circuit rating at 6 kV side: 40 kA

When designing the transformers, it may be assumed that the short-circuit and earthing currents are of the duration specified in the standards and that the asymmetrical peak value is 2.55 times the stationary effective value.

The transformers shall be guaranteed to withstand – without degradation – the short-circuit and earthing currents that may arise in the windings under these circumstances.

Noise

The transformer will be in service in a developed area and it will be demanded an upper limit for noise level at 60 dB according to IEC 60076 – 10.

The Contractor shall inform the guaranteed noise level according to IEC 60076 – 10.

Losses

The design of the transformers shall be optimized for low losses (Load loss, No-load loss).

The losses of the transformers are to be based on IEC 60076.

3.3.3 POWER TRANSFORMERS, DESIGN REQUIREMENTS**General**

The transformers shall be oil-insulated with an oil conservator and air-dryer. The materials used shall be those deemed best for the purpose for which the equipment is being used.

Oil

The transformers shall be filled with new, high quality and highly refined mineral oil, made for the use in transformers. The oil shall be certified PCB-free.

The Contractor shall provide a plan, which must be approved by the Employer, for oil sampling and analyse thereof (oil analyse and analyse of dissolved gasses). The oil-sampling period shall start before the first start up and continue to the end of the warranty period.

Core

The sheet quality and induction shall be selected such that there is no troublesome hum or excessive over temperatures that could be damaging to the sheet insulation or to neighbouring oil and insulating materials. It shall have a fixed mechanical structure, scarf joints and an adequate number of cooling channels. The structure shall not be degraded as a result of the temperature fluctuations that can occur during operation.

Press beams, core bandages and bolts shall be insulated against the core sheet for a test voltage of 2 kV and shall not be capable of forming closed current paths.

The individual sheet packages shall have a secure electrical connection without forming closed current paths, as shall the press parts. They shall be earthed so that no unearthed part can cause discharge.

The core shall be removable from the tank for inspections/service, and shall have suitable lifting lugs for this purpose.

Windings

Information on the insulation level of the individual transformers' windings shall be stated in the tender.

The conductor material shall be oxygen-free electrolytic copper and the insulation material shall be high quality paper and pressboard. The winding shall be insulated in accordance with the relevant standards.

The cooling channels of the winding shall be executed so as to allow oil to flow through freely and no pockets shall form in which oil or gas could accumulate.

The windings shall be carefully dried and pre-shrunk so that they cannot settle during operation or as a result of short circuits. Supports and winding taps shall be designed for the short-circuit forces occurring.

All the individual copper cord in the windings shall be enamel covered.

Transformer tank

The transformer tank shall be made of easily weldable steel plate. The tank and cover shall withstand 100% vacuum and all other stresses that may arise during transport and lifting, as well as pressures that can occur if there is a fault in the transformer.

It shall be completely oiltight in respect of hot transformer oil. Leaking welds shall be chiselled off and rewelded. Sealing shall not be approved.

The tank shall be equipped with the necessary grips for transport, lifting straps, towing eyelets and equipment for jacking up the complete transformer. The jacking devices shall be located 400 mm above the tank bottom.

There shall be two earthing points in the bottom of the tank, placed diagonally opposite each other. The size of the earth connections will be specified in the individual case.

The transformer tank shall be designed such that gas cannot accumulate in undesirable locations and prevent the gas from passing to the gas relay.

All gaskets used on the transformer must be of oil-resistant material.

All lifting/jacking points must be marked.

Cover

It shall be possible to unscrew the cover.

The cover shall be designed such that any gas can pass freely to the gas relay without accumulating in pockets on the underside. The cover shall have a visible fall away from the centre line of the longitudinal axis: approx. 10-15 mm per linear metre.

All bushings and stubs in the cover shall be built up above the surface of the cover to avoid water lying on the cover. All oil pipes and cable bridges on the cover and tank shall be fitted a minimum of 10 cm above the base.

Bushing devices shall be equipped with suitable air lines to the gas relay.

The cover shall have the necessary inspection and connection hatches so that the bushings can be replaced without having to lift off the cover.

Conservator

The oil conservator shall have an expansion volume at least taking into account the temperature range specified in the section on operating conditions.

The conservator shall have a hatch for inspection and cleaning as well as lifting lugs.

If the transformer has oil-filled cable boxes (bushings) the conservator shall have sufficient clearance relative to these.

The conservator shall have a rubber bellows and the lifetime of these shall be app. 25 years.

The conservator shall be removable.

To protect the oil and transformer from deterioration due to oxygen, the conservator shall be supplied with an air-tight diaphragm, made of a material which can be guaranteed to be air-tight after 25 years of service.

The diaphragm must be connected to the atmosphere through breather filled with silicagel.

Underbody

The transformer shall be equipped with an underbody with flanged wheels or bogeys for travelling longitudinally and transversely. The underbody shall be strong enough for the transformer to be transported on its own wheels.

The power transformers shall be fitted with removable wheels for local transportation. Wheels and bearings shall be constructed for a transportation distance of at least 100 m.

The wheels shall be performed with a locking facility being able to serve for parking. Wheel base for transportation is 1435 mm. Solution for permanent parking shall be described.

The transformer underbody or tank shall be fitted with 4 lifting hooks.

Surface treatment, corrosion protection

The transformer tank, cover, conservator and other iron parts shall be sandblasted internally and externally.

The inside shall be painted with a coat of oil-resistant lacquer or paint immediately after sandblasting.

The outside shall be primed with a zinc chromate-based primer and at least 2 coats of weatherproof topcoat shall be applied.

The colour shall be approved by the Employer as described in Appendix A8 *General Technical Requirements*.

The total thickness of the layers of primer and topcoat shall be at least 200 µm measured with a device such as an Elcometer. If erected outdoors 240 µm shall be required.

Sharp edges shall be rounded off with a radius of 2 mm.

Cover screws and other external screws, washers and nuts shall be in acid-proof or stainless materials. Galvanised surfaces, apart from radiators/coolers, shall be painted with topcoat.

Bushings

Oil/air bushings, to fully match cable termination being used as well as bus phases used in the system. All connections fully covered and insulated. Fully insulated solutions shall be applied and coordinated with the design of the design of cables and bus phases.

The bushings shall be executed to the same insulation class and test voltages as the associated winding taps.

Bushing types and their data shall be stated in the tender and included in all dimensioned drawings.

The bushings shall be phase-marked using raised letters which are welded or screwed permanently to the cover and which are not also removed when the bushings are dismantled. Marking shall be carried out in accordance with IEC or DIN standards.

The bushings top shall be of fine threads type.

Cable connection

In the case of cable connection with direct cable entry into the transformer: in view of the conductor temperature in the cable the temperature of the oil surrounding the cable termination must be lower than that required by the standards.

Cable and busbar terminations and connections to terminals on power transformers shall be fully insulated and provide a touch proof system.

3.3.4 POWER TRANSFORMER EQUIPMENT

Protection for Transformer

The protection relays for transformers shall trip the circuit breakers as following:

Any fault condition of short circuit nature:

- 22 kV circuit breaker in 22 kV Switchboard

Protection functions shall gain full protection of the Transformer and associated 22 kV connection and cable connection down to the 6.3 kV main switchboard.

As a minimum, but not limited to, the protection equipment shall provide the following:

- For the transformer and the 22 kV cable connection and cable connection to the 6.3 kV Main switchboard:
 - Short circuit and over current
 - Directional under impedance $Z<$ for the transformer and cable
 - Directional earth fault protection for the transformer and cable
- For the Transformer:
 - Differential protection
 - Transformer instrumentation

The use of two setting set for the relay protection shall be anticipated due to the different operation modes.

A redundant protection system shall be provided.

Transformer instrumentation

The transformers shall be supplied with the following equipment for monitoring and protection.

Gas relay

A gas relay shall be fitted in the connecting pipe between the transformer and oil conservator. It shall have contacts for a signal for slow gas generation and for responding to a rapid flow of oil or gas.

The gas relay shall have shut-off valves on both sides so that the relay can be removed for maintenance.

The gas relay shall be placed in a location where it is accessible for inspection while the transformer is being under loading.

- Gas relay with 2 digital contacts: One alarm limit and one trip limit.

Oil level indicator

The oil conservator shall be equipped with an oil level indicator for high and low oil levels. The oil level shall be able to be read from the cell floor, ideally using a separate indicator instrument placed in an easily accessible place on the transformer tank, or by angling the oil level indicator on the conservator.

- Oil level local indicator with 2 digital contacts: Low level and high level.

Dryer

The oil conservator shall be provided with an air-dryer with an oil lock. The device shall be filled with the necessary drying agent that can easily be inspected.

Rapid pressure relay

The transformers shall be supplied with two rapid pressure relays, with mechanical indicator.

- Pressure relief relay with one digital contact.

Temperature monitoring

The transformer shall have the following temperature monitoring equipment placed in pockets on the cover.

- 1 indicator thermometer with signal contacts for measuring peak oil temperature. Transformers require 4 signal contacts for thermostatically controlled cooling.
- 1 resistance thermometer for remote measurement of the peak oil temperature (Pt-100).
- Oil temperature Pt 100 sensor for analogue signal.
- To indicate the winding temperature in the hottest winding the transformers shall be equipped with one transformer and compensated thermometer pockets.
- 1 compensated pocket containing an indicator thermometer to indicate the winding temperature. A minimum of 2 contacts are required.
- 1 compensated pocket containing a resistance thermometer for remote measurement of the winding temperature.
- Winding temperature Pt 100 sensor for analogue signal.

Protection of tap changer

The protection recommended by the tap changer supplier shall be used to provide protection from gas development and pressure increases in tap changers and as oil level relays:

- Gas relay with 2 digital contacts: One alarm limit and one trip limit.
- Pressure relief relay with one digital contact.
- Oil level local indicator with 2 digital contacts: Low level and high level.

Current transformers for differential block protection

Block differential protection of transformer and TG is included in the scope of work.

Earthing

There shall be an earthing terminal on each side of the bottom of the tank for earthing purposes. These shall have at least one clamping insert and two clamping screws, with clean contact surfaces.

The size of earth grid connection, copper wire mm² shall be coordinated with grid company.

Cabinet for signal lines

Lines for the transformers monitoring devices shall lead to a separate cabinet with terminals for forwarding to the CMS.

The insulation of the signal cables and contacts must withstand a 1-minute voltage test at 2 kV eff, 50 Hz. The conductor cross-section shall not be less than 2.5 mm² Cu. For current transformers not less than 4 mm² Cu shall be used. Series terminals to be used for current measurement shall with approved joining and short-circuiting facilities.

Other equipment**Cocks**

The cocks shall be clearly marked with "Oil in" and "Oil out" and shall be placed in an easily accessible place where there will be no problems with regeneration of oil during operation.

- 1 cock with a dimension of 1½" at the bottom of the transformer tank for connection of oil filter, for oil replenishment and draining.
- 1 sampling cock suitable for the purpose located slightly above the bottom of the tank to avoid bottom sludge/water in the oil sample.
- 1 cock with a dimension of 1½" on the cover, located diagonally opposite the first cock mentioned, for connection of oil filter.
- 1 cock with a dimension of 1½" in the bottom of the oil conservator for oil replenishment and draining and for oil samples.
- 1 shut-off valve in the pipe connection between the transformer tank and oil conservator.
- shut-off valves to the transformer tank for each individual cooling circuit or for each individual radiator, and cocks at the highest and lowest point of each separate cooling circuit for filling, venting and flushing though.
- The necessary cocks on the tap changer and cable boxes for filling, emptying, venting and taking of samples.

Ladder(s)

Each transformer shall be supplied with permanently fitted ladder(s) for checking the gas relays and oil level indicators. These checks shall be able to be carried out during operation at no risk to the personnel.

The ladder(s) shall be fitted with a locking access barrier to the cover. The ladder shall be placed so as to allow the gas relays to be checked during operation without risk and without unlocking the barrier.

Tools

If operation and maintenance of the transformer or its fittings require special tools or auxiliary equipment (e.g. gas relay testing device) this shall be supplied.

3.3.5 POWER TRANSFORMERS, MARKING

All rating plates and marking of fitted equipment (cocks, instruments, sensors, etc) shall be in Czech language and the text shall be approved by the Employer. The plates shall be of the engraved or stamped type and shall be securely fixed with screws.

3.3.6 POWER TRANSFORMERS, INSTALLATION

The following installation conditions shall be observed:

- The transformer 22/6.3 kV shall be installed in a separate field
- The transformers 6/0.4kV shall be installed in separated cells.
- There shall be a main earthing bar in the room
- The arrangement shall be agreed by the Employer.

3.4 22/6.3 kV Cables**3.4.1 22/6.3 KV CABLES, DESIGN**

The design of 22/6.3 kV cables connections shall facilitate following:

If the designed bare connection may consist of parallel single-core cables in each phase, each of these single-core cables shall have this withstand capability.

The bare conductors and cable connection shall be able to withstand any possible short circuit current which may occur in the system for duration of minimum 1 second.

The bare conductors and cable-connection shall be able to transmit the full load under the worst installation method, highest ambient temperature etc.

Conductor material can be aluminium or copper, depending on economy and availability.

The cable shall be a PVC- and halogen-free type.

Termination

Not to be oil filled type.

3.4.2 22/6.3 KV CABLES, OPERATION AND CONTROL PROTECTION

The bare conductor and cable shall be protected against overload, over current and any short circuit current.

3.4.3 22/6.3 KV CABLES, INSTALLATION

Cables installed in buildings shall be installed on separate cable layer and be covered by appropriate metal plates.

3.5 6.3/0.4 kV distribution transformers

3.5.1 DISTRIBUTION TRANSFORMERS, INTRODUCTION

The distribution transformers serve to transform power from 6.3 kV to 400 V voltage levels.

The distribution transformers also serve to reduce the short circuit levels and for galvanic isolation of the voltage levels – 6.3 kV to 400 V.

3.5.2 DISTRIBUTION TRANSFORMERS, DESIGN

The following requirements apply for the transformers:

- The transformers shall be three-phase, separate winding, two-winding, dry-type for indoor installation.
- Cooling of dry-type auxiliary transformer shall be AN.
- The degree of protection shall be at least IP21.
- The bushings shall be suitable for single/multi core XLPE cables for primary connections
- Flexible connections for bus-bar for secondary connections.
- The transformer shall be fitted with lifting and pulling pins and with four jacking lugs. Each jacking lug must withstand half of the weight of the transformer.
- Each distribution transformer shall be designed for the following capacity in order to facilitate future extension possibilities while maintaining the philosophy: Transformer capacity = 1x (normal load + 20% spare capacity).
- Designed with spare capacity to temperature class F – but only allowed in service up to temperature class B.
- Two 3-wire PT100 sensors per phase winding for temperature monitoring and alarm – wired to terminals in junction box.
- Reversible rollers with lock facility.
- Vibration dampers for rollers.
- Maximum acoustic noise level 60dB(A).
- Tap changes with clear indications.
- Off-load type tap-changer, 6,3 kV± 2x2.5% / 0.4 kV.

Transformers shall be designed to withstand a primary or secondary terminal short current in the system, with the duration of minimum 1 second at rated voltage and frequency, without any damage to internal parts and enclosure.

The losses of the transformers are to be based on IEC 60076.

Load loss: at 120°C winding temperature.

3.5.3 DISTRIBUTION TRANSFORMERS, OPERATION AND CONTROL

The following requirements apply for the operation and control of the transformers:

Temperature winding monitoring shall provide facilities for:

- Temperature alarm level of the transformer
- Temperature trip level of the transformer
- The winding temperature shall be monitored from the CMS
- The transformers shall be protected via protection relays.

The electrical protection of the transformers shall as a minimum comprise:

Protection	Remarks
Over current and short circuit Overload protection Watt metric, directional, earth-fault protection	Appropriate current relay(s)
Overload protection	Winding temperature PT 100 monitoring relay
Protection against internal failures	Winding temperature monitoring PT 100 monitoring relay

3.5.4 DISTRIBUTION TRANSFORMERS, AUXILIARIES

The following conditions for auxiliary equipment shall be observed:

- Portable earth equipment, 6,3 kV voltage tester and special tools and keys mounted in the room.

3.5.5 DISTRIBUTION TRANSFORMERS, LABELLING AND IDENTIFICATION

The following labelling shall be mounted:

- Each transformer shall be equipped with name plate, specifying all the main nominal data.
- Each transformer shall have a large sign with clear text and tag. All text shall be in Czech
- All components shall be provided with an identification plate with at least manufacture, type number, ratings and standards stated on it. This plate has to be fitted to the apparatus in a clearly visible place.
- The centre of gravity of the transformer in transport condition shall be marked on the transformer cover.

3.5.6 DISTRIBUTION TRANSFORMERS, INSTALLATION

The following installation conditions shall be observed:

- The transformers shall be located in dedicated and individually divided barriers in the form of cells/rooms. It shall be possible in a safe manner to have access to one transformer with the adjacent transformer in operation.
- The transformers shall be installed indoor.

The heat dissipation will be vented via natural ventilation in the room.

3.6 400 V bus ducts

3.6.1 BUS DUCTS, INTRODUCTION

The bus-duct systems are used to transfer the power from distribution transformers to the 400 V MBDs.

3.6.2 BUS DUCTS, DESIGN

The following conditions for the 400 V bus duct, main external copper bus-bars shall be observed:

- The bus duct system shall be executed as minimum enclosed IP 31 metal enclosed with copper bus-bars.
- The bus duct system bus-bars system shall be executed as 5-conductor type for TN-S system, with 5 individual internal bus-bars, the neutral shall be rated 100% equal to the phase conductors.
- The bus duct system, busbars shall be designed with a minimum capacity according to the nominal capacity of the distribution transformer.
- The bus duct system shall be of well proven type tested modular design with various installation methods available.
- The bus duct system shall be installed with proper braided flexible copper connections to the transformer, to eliminate vibrations being transferred to the bus duct system.
- The bus duct system, busbars shall be designed to withstand a primary or secondary terminal short current in the system, with the duration of minimum 1 second at rated voltage and frequency, without any damage to internal parts and enclosure.

3.7 400 V emergency generator system

3.7.1 EMERGENCY GENERATOR SYSTEM, INTRODUCTION

The diesel generator sets shall be appropriately sized to safely shut-down the Line in the event of power blackout.

3.7.2 EMERGENCY GENERATOR SYSTEM, DESIGN

The emergency power supply system shall start-up automatically and shall together with the CMS system manage the transition to emergency standby mode. The emergency power supply shall be established within approximately 10 s, all sets being synchronized and on line.

The diesel generator emergency power supply system shall be able to supply all prioritized consumers in case of power failure.

The diesel generator systems consist of:

- Diesel generator sets.
- Erection and installation of diesel generator sets and control panels.
- Ventilation system, air intake and air outlet with acoustic silencing.
- Acoustic attenuation.
- Exhaust system and chimney.
- Fuel system and fuel tank.
- Electrical installations for diesel generator sets.
- Complete control of the diesel generator set to synchronize with the grid and to connect automatically during blackout.

Control functions shall be a part of the diesel generator set.

From the CMS it shall be possible manual to test the diesel generator emergency power supply system with a manual start and stop and with a variable setpoint of the load from 0 to 100%. In test the diesel generator emergency power supply system shall automatic synchronised with the power grid power supply.

The generator shall be able safely to switch on (including transient in-rush current) the needed distribution transformers. This might have an influence on the size /characteristics of the generator / transformer. The control functions for closing of the appropriated circuit breakers for the distribution transformers shall be part of the control system of the diesel generator system.

Upon generating emergency supply, the CMS will start the emergency consumers in delayed sequence, large consumers being started first.

Main characteristics

Power:	1.3 MVA, $\cos\varphi=\varphi=0.8-1.0$, continuous power load, and with 110% load for 1 hour in within a 12 hours period in accordance to ISO 3046/1
Voltage:	3 x 400 kV, 50 Hz
Generator temperature class:	Class H insulation, operation to rise class F
Degrees of protection:	Min. IP 23
Noise levels:	Refer to appendix A14.3 <i>Acoustic Noise and Vibrations</i>
Vibrations:	Maximum 10 mm/s in accordance with ISO 2372
EMC:	EN 61000-6-4 EN 61000-6-2

The diesel generator set shall be constructed in accordance to ISO 8528, IEC 60034-1, IEC 60034-5 and IEC 60034-22.

The diesel generator shall be designed for continuous operation.

The system shall have CE-markings and be in accordance with EN 60204-1.

The generator capacity shall be higher than the diesel engine and be designed to feed large motors with frequency converters and UPS units, which have loads containing higher harmonics currents and voltages.

The generator, with the excitation systems, shall, under steady short circuit condition be capable of maintaining, without sustaining any damage, a short circuit current, which shall be at least 3 times the rated full load current, for a duration of at least 2 s.

The generator shall be a 3-phase, brushless, self-exciting and ventilated enclosed type according to IEC 34-1 with bearings in both ends.

The engine shall be a 4-stroke engine, industry type of well-known make designed for electrical start from cold condition. Diesel engine and generator shall be mounted on a common base frame with direct and flexible coupling between engine and generator.

The engine shall have a stand-still heater/pre-heater.

There shall be installed a main earthing bar in the room.

Unit assembly

The diesel generator unit shall be assembled unit, built upon a single solid frame and shall consist of a diesel engine and generator with on a solid mounting frame.

The diesel generator and mounting frame shall be sampled in a mechanical construction to form one mechanical unit.

The mounting frame shall be fixed to the foundation/floor by vibrations dampers.

Between the diesel engine and the generator an elastic coupling shall be built in, so dangerous or disturbing torsion vibrations will be eliminated.

The diesel generator assembly shall be approved by the manufacturer of both the diesel engine and the generator.

Vibration dampers shall be placed between engine/generator and base frame or between base frame and foundation/floor.

Fuel pipe from fixes installation to the diesel engine shall be constructed by flexible Stainless Braided Fuel Hoses.

Water-cooled engine, cooling fan mounted directly on engine shaft.

3.7.3 EMERGENCY GENERATOR SYSTEM, AUXILIARY EQUIPMENT

The following requirements apply for the auxiliary equipment:

Cooling system

Cooling system for diesel engine:

- The cooling system shall be constructed, to cool the diesel engines as well as the compartment where diesel engines are placed.
- The air intake and outlet system shall be with motor-controlled dampers. The damper motor shall be equipped with a spring return to open position. The system controls shall prevent under-pressure in the compartment in proportion to adjacent areas and rooms. The dampers shall close the air intake and air outlet system as the engine is stopped.
- The cooling system consists among others of a radiator cooler mounted on the diesel engine. On the shaft of the diesel engine shaft a direct-coupled fan with air exhaust.
- The cooling system shall be designed to ensure correct mixture of water and anticorrosive liquid.
- The cooling system shall be designed so that the diesel generator can work under normal load as well as 1 hour of 110% load, while working within the supplier's specification for exhaust- and engine temperature.
- The cooling system shall be equipped with all necessary measurements, monitoring and alarms for both local and remote monitoring.
- The radiator system shall be located in the facade of the building and coordinated with the building layout and design.
- The cooling system shall contain a frost protection.
- The cooling system shall be equipped with all necessary measurements, monitoring and shut downs, alarms – all available for both local and transferred to CMS monitoring.

Combustion air inlet

Combustion air inlet takes place via an inlet filter. The air inlet shall be located away from the combustion exhaust system, and shall be equipped with a motor controlled damper. Precaution shall be made in order to avoid that ambient air pressure differences occur in adjacent areas and rooms.

Fuel system

- The fuel system includes diesel filling station including necessary piping system, pumps etc. for pumping the diesel to the day tank.
- The fuel system comprises a 5.9 m³ "day tank".
- The tank shall be double wall, and leak detector to identify leaks from inside to outside wall.
- Manual operated and electrical fuel pumps for fuel supply from storage tank to day tank.
- Manual operated and electrical fuel pumps for diesel engine fuel supply.
- Further all necessary valves, level indications etc. as well as supply and return pipes.
- Various instruments, e.g. level switches, transmitter for local and CMS monitoring, alarm, trip and controls.

Exhaust system

- The exhaust system comprises ducts, silencers, chimney, compensators and vibration damping suspensions between machinery and building parts.
- The exhaust system shall be protected against penetrating rainwater and the silencers shall be equipped with valves for draining of condensate.
- The outer part of the exhaust system shall be executed as stainless material.
- Hot parts shall be insulated.
- Thermometer exhaust temperature as well as test facilities for measurement of exhaust counter pressure shall be installed.

Start system

- The start system comprises of a 24 V start motor, a battery charger and a battery with sufficient capacity for 20 subsequent starts without re-charging.
- The battery shall be enclosed type, maintenance free with minimum lifetime of 10 years.
- The battery charger shall be able to re-charge the battery from fully discharged condition to at least 80% of its normal capacity within 4 hours and at the same time supply the load.
- The battery charger shall be equipped with monitoring of charge voltage and battery voltage. Local and CMS monitoring shall be facilitated.

Windings temperature

- Two 3-wire PT100 sensors per phase winding for temperature monitoring and alarm – wired to terminals in junction box.
- The winding temperature shall be monitored from the CMS.

Insulation level at neutral

The internal 0.4 kV networks are operated with an insulated neutral. Generator windings for this system voltages shall therefore be executed with full insulation.

Miscellaneous

The diesel engine shall be protected by proper shut down functions, as minimum but not limited to providing the following:

Over speed, over temperature, low oil pressure etc. for local and CMS monitoring, alarm, trip and controls.

The diesel engine shall be provided with thermostatic controlled preheater.

Special tools for diesel machine

A complete set of special tools shall be mounted on wall-mounted frame in the room.

3.7.4 EMERGENCY GENERATOR SYSTEM, LABELLING AND IDENTIFICATION

The equipment shall be equipped with signs, which specify all the main nominal data. All text shall be in Czech

3.7.5 EMERGENCY GENERATOR SYSTEM, OPERATION AND CONTROL

The following conditions shall apply for the operation and control:

The system shall contain dedicated and integrated control panel with local operation facilities incl. synchronization, protection and communication equipment. The local operation facilities shall contain a mimic schematic diagram. As an alternative a screen-based operator panel shall be considered. The system shall exchange signals to the CMS as well as hardwired to the switchgear. The system shall contain various measurements, for example amps, voltage, frequency, power factor, rpm, kW, hour counter, battery charge, synch meters, energy etc. Further various alarms shall be available, both locally and in the CMS.

The generator shall be equipped with automatic voltage control including automatic power factor control during parallel operation. Automatic synchronization shall be released manually by the operator in the CMS. The synchronizing functions will be executed via locally located equipment which are integrated in the generators and in the switchboards. The synchronizing can be supervised and operated also from the CMS operator screens.

The local operation facilities shall include switch for remote-local, switch for manual-auto-test and pushbuttons for manual start/stop of the system as well as generator breaker. The control panel shall contain key operated switch routine test operation. When this switch is operated a power failure is simulated and the system is started and synchronized with the main power supply. Subsequently the diesel generator will operate with a pre-set adjustable load. In case of malfunction of the control system the system shall be able to be started manually.

The generators shall be protected by proper relay protection equipment located in the 0.4 kV emergency generator switchboard, as minimum but not limited to providing the following:

- Short circuit protection.
- Earth fault protection - Watt metric directional
- Earth-fault protection – internal.
- Over current protection.
- Reverse power protection.
- Under voltage protection.
- Overvoltage protection.
- Over frequency protection.
- Under frequency protection.
- Differential protection.
- Winding temperature protection.
- The use of two setting set for the relay protection shall be anticipated due to the different operation modes.

Protection, which in the case of short circuit in the generator or in the supply cables between the generator and the generator circuit breaker – shall trip the circuit breaker and force de-excitation of the generator.

3.7.6 EMERGENCY GENERATOR SYSTEM, INSTALLATION

The diesel emergency power supply machine and its control and electrical equipment shall be installed in a separate diesel engine room.

3.8 400/230 V safe power supply

3.8.1 SAFE POWER SUPPLY, INTRODUCTION

For the essential uninterruptible consumers, safe power supply systems shall be installed.

The UPS and its distribution boards shall be designed for an n-1 configuration. The UPS main distribution system shall have enough capacity and capability to keep the Line in operation in case of a single failure or maintenance. In general, the various installations shall be separated according to the following structure:

- Building installations
- Process installations

The features of the UPS distribution are:

- High reliability.
- Easy exchange of components due to redundancy in the design.
- Easy extension of the number of outgoing feeders, mini circuit breakers etc.
- Each part of the UPS installation must be maintainable, without requiring a total stop. The UPS system including the UPS-distribution must not be a total stop key point for the Line.

The Contractor shall carry out complete design calculations of required load capacity. The Contractor shall carry out design calculations for protection and proper fault discrimination between protection equipment.

A redundant UPS supply will be distributed to all consumers by cables at the actual voltage supply level 400/230 V AC.

All local voltage converting shall take place from central redundant converters and redundant rectifiers.

Local UPSs shall only be applied if required to connect consumers over long supply distances. The number of local UPSs shall therefore be determined on the basis of load, functionality and distance to connected consumers.

The ACC switchboards supply essential auxiliary equipment and safety equipment.

3.8.2 SAFE POWER SUPPLY, DESIGN

The following design requirements apply for the equipment:

- Appendix A16 – *Concept Diagrams for Electrical System (Single line diagram)*. This concept is to be used when designing the final UPS installation.
- 3 x 400 V / 230 V safe supply for continuous operation of the CMS, components etc. with a minimum capacity of 8 hours.
- Design according to EN 50091. Battery stored energy time for one UPS: Minimum 2 hours at 50% load at the rated capacity of one UPS unit.
- Restored energy time: Maximum 2 hours.
- Rated power 100 kVA, $\cos\phi=0.8-1.0$
- Design to include minimum 20% spare space and spare capacity.

- The battery charger shall be able to re-charge the battery from fully discharged condition to at least 80% of its normal capacity within 2 hours and at the same time supply the load.
- The UPS shall be in scalable design.

The output power supply voltage of the UPS shall have the following quality:

- Symmetrical: $120^{\circ} \pm 3^{\circ}$
- Unsymmetrical up to 30%: $120^{\circ} \pm 10^{\circ}$
- Voltage tolerance: Within 5% deviation.

3.8.3 SAFE POWER SUPPLY, EQUIPMENT

The following requirements for equipment shall be observed:

- The supply shall be made through mini circuit breakers MCBs, which can be locked in the off position with a padlock.
- Batteries shall be of the enclosed type, maintenance free with a minimum lifetime of 10 years.
- The units shall be installed in standard manufacturer cabinets.
- Each UPS unit shall be identical and consists of a separate galvanic isolating transformer, rectifier, batteries and inverter. In each incomer compartment, a 4-pole hand operated circuit breaker shall be installed behind the front door.
- The service bypass circuit breaker shall be integrated in the solution depending on the actual manufacturer in question.
- The unit shall be installed in standard manufacturer cabinets.
- The UPS unit shall consist of a rectifier, batteries and inverter. In the incomer compartment a 4-pole hand operated circuit breaker shall be installed behind the front door.
- The bypass circuit breaker shall be integrated in the UPS.

3.8.4 SAFE POWER SUPPLY, OPERATION AND CONTROL

The following requirements for operation and control shall be observed:

- The units shall operate constantly in inverter mode, with automatic switchover to battery power supply in case of failures. The switchover shall take place within 10 ms.
- The battery charger shall maintain the battery capacity during normal supply of the load.
- Operator panel in panel front with display for operation, alarms and measurements for both incoming supply and outgoing supply.
- Signal exchange to CMS system to be provided, via Field bus communication, for monitoring and control of the UPS unit.
- Signal exchange to CMS system, preferably via bus communication.

3.8.5 SAFE POWER SUPPLY, 400 V / 230 V AC DISTRIBUTION SWITCHBOARD

UPS main distribution boards shall be installed. The UPS main distribution boards will have incomers for each of the UPS's and the MDB switchboard.

The design shall be in accordance with the design of the low voltage switchboards, MDB as specified in sections of this technical specification - except from the requirements for arc protection and transient protection.

The Contractor shall carry out complete design calculations for load capacity.

The Contractor shall work out design calculations for protection and proper fault discrimination between protection equipment.

3.8.6 SAFE POWER SUPPLY, INSTALLATION

The UPS unit and the switchboard shall be installed in a switchboard room. The switchboard shall be arranged in such a way that it facilitates future extension.

There shall be installed a main earthing bar in the room.

UPS equipment panels and batteries shall be installed as stand-alone panels. The batteries shall be located in separate and dedicated rooms, with panels which contain an open shelf structure where the batteries can be placed for easy access.

To ensure personnel safety, the batteries shall be secured from unauthorized access when they are energized.

3.9 Low voltage switchboards, design

The Contractor shall work out complete design calculations for load capacity. The Contractor shall work out design calculations for protection and proper fault discrimination between protection equipment.

The design of MDB, MCC, auxiliary control centre (ACC), local control panels, and local operation panels shall follow the general requirements including standardisation and uniform layout. The following items shall as a minimum be highlighted:

- Layout and structure of cubicle.
- Doors and locking facilities.
- Local indications and local operation facilities.
- Cable entries and installation of panels and cables.
- Disconnection switches and emergency stop facilities.
- Division of power and control circuits.
- Terminal rows.
- Signs and labelling.
- Marking.
- Bus communication signal exchange with CMS.
- All alarms and status signals shall be available in the CMS.
- Communication and integration with the main CMS.
- Software coding principles.
- Spare capacities.
- Wiring colours.
- Division of power supplies for power, control and maintenance.
- Form classes for separation/division components.
- Safe and emergency power supply.
- Remote operation CMS facilities (for example via screens).
- PLC manufacture.
- Earth and bonding.

- Installation of cubicles and cables.

3.9.1 LOW VOLTAGE SWITCHBOARDS, DESIGN REQUIREMENTS

The following design requirements shall be observed:

- Metal clad, type tested and factory-made industrial type switchboards shall be delivered, with frame parts of prefabricated steel.
- The switchboards shall be in compliance with EN 60204-1, EN 60439-1 and EN 60439-3.
- TN-S earthing system to be installed.
- The switchboards shall be designed, to enable the possibility of applying thermographic and ultrasound detectors. The appliance of thermographic is accepted to be limited due to draw out design requirements.
- The switchboards shall be designed for operation by an unskilled person, with no risk of getting in contact with live parts of the installation during operation of the electrical equipment.
- The short circuit level on the terminals of the outgoing feeder circuit breaker will be max. 100 kA rms.
- The Contractor shall be responsible for calculation of the actual short circuit level of all systems and shall supply the equipment in compliance with the actual calculated values.
- Cubicles must be of the freestanding type with 100 mm base frame and separate compartments for components, cable termination and bus-bars.
- Form 3b for all incoming/outgoing feeders ≤ 63 A and form 4a for all incoming/outgoing feeders > 63 A in accordance with IEC 61439-0.
- Separate sections for incoming and outgoing feeders to be installed.
- Design shall include minimum 20 % spare space and capacity.
- Spare space and appropriate terminal design for termination of a number of parallel large-scale power cables and free space per compartment/unit shall be included for this purpose.
- A minimum distance of 800 mm from the bottom of the MDB /MCC/ ACC to the cable terminals is to be observed. This is due to sufficient space for mounting of outgoing cables for large consumers. For smaller consumers 250-400 A on MCC's and were these are angled 90 gr. against the cable compartments, approximately 250-300 mm will be accepted.
- The bus-bar current rating shall be designed in order to carry the expected load + 20 %.
- The switchboard shall be designed for natural ventilation.
- All cubicles shall be of the same height. The maximum height including base frame is 2250 mm.
- Doors, cable compartments, drawers shall only be accessible by means of tools.
- All communication and exchange of signals between the switchboard and the CMS shall be based on distributed I/O-units and integrated Field bus communication in the multi-instruments and intelligent motor starters. The distributed I/O-units are located in separate panels.
- Fuse-less concept shall be implemented.
- All instruments, current transformers, voltage transformers and multifunction metering devices shall be of accuracy class 1 or better.
- Control voltage will be redundant 230 V AC fed from two separate safe power supply unit. A redundant switch mode power supply shall be installed, with an isolating diode bridge in between. This shall be combined with galvanic isolated safety transformers.
- Special attention shall be paid to heat dissipation.
- The switchboards shall be divided according to the following structure:

- Section for incoming feeder breaker
- Sections for outgoing feeders
- Sections for fix-mounted components
- Section for arc guarding equipment
- Section for control circuit power supplies
- Space and room for documentation sheets.

3.9.2 LOW VOLTAGE SWITCHBOARDS, EQUIPMENT

The following requirements for equipment shall be observed:

- All circuit breakers for incoming feeders, bus tie sections and outgoing feeders shall be 4-pole motor operated circuit breakers. The number of poles which shall be disconnected shall be adapted to the actual application and power system. Tool operated terminals isolating/disconnection facilities for the neutral conductor will not be accepted. This shall be integrated in the breaker.
- Time delayed under-voltage relays to be installed to provide continuous operation of the process in case of transient interruptions of the power supply or in case of switching-over power supply.
- LED-type lamps shall be applied. Colours shall be agreed with the Employer.
- Main earthing bar shall be distributed through all sections and compartments.
- All incoming and outgoing circuit breakers, Air circuit breakers, Moulded case circuit breakers, Miniature circuit breakers and switches for power supply shall be supplied with a padlock facility in order to ensure a de-energized machine/installation.
- All circuit breakers shall be rated for the actual short circuit level and be selected with proper service-short circuit breaking capacity Ics.
- Cascading of circuit breakers, enabling possibility to use downstream circuit breakers with less performance (Ics) is only accepted if there is coordination with the upstream breaker and full discrimination is provided.
- To ensure full discrimination between circuit breakers, only factory tested combinations of upstream and downstream circuit breakers of same manufacturer, being used though the Complete plant will be accepted.
- Energized parts of the bus-bars, which can be exposed, shall be equipped with a cover made in transparent plexiglas.
- All switchboards, incoming feeders, bus tie sections and outgoing feeders shall be equipped with a multifunction metering device. Metering voltage, current, active power, reactive power, power factor, energy, max. values etc. shall be transferred to CMS for monitoring.
- All switchboards shall be equipped with a Pt100 temperature sensor and a 4-20 mA transmitter. The sensor shall be installed in the supply compartment. The measuring signal shall be transferred to the CMS operator system for display and alarm functions.
- All circuit breakers and outgoing feeders shall be supplied with auxiliary contacts. The signals shall be transferred to the CMS operator system for display of on/off status.
- Circuit breakers of type Air Circuit Breakers or Moulded Case Circuit breakers shall be equipped with electronic trip units, with bus communication modules and metering modules.

3.9.3 LOW VOLTAGE SWITCHBOARDS, INTERNAL WIRING

The following requirements for wiring shall be observed:

- Internal wiring shall be with multi-stranded halogen-free wires.
- A minimum cross-section of 1.5 mm² for power circuits and 0.75 mm² for control circuits is required.
- Wiring shall be in appropriate ducting.
- Screw terminals shall be a type with a disconnect and test facility.
- Only one wire may be terminated per terminal.
- Multi-stranded wires shall be provided with terminal-tubes.
- Colour marking according to EN/IEC 60445 and to be agreed with the Employer.
- Logical KKS grouped terminal row blocks are to be included.
- Wire terminal markings at all termination points are included.

3.9.4 LOW VOLTAGE SWITCHBOARDS, CABLE TERMINATION

The following requirements for termination of cables shall be observed:

- Cable mounting sections shall be vertical from the extent of bottom to top.
- The width of the cable mounting sections shall be minimum 400 mm.
- The width of the cable mounting sections shall typically be 400-600 mm with sufficient space for the cables and the cable mounting work.
- The whole bottom area shall be equipped with bottom plates. Also the cable section shall be equipped with bottom plates.
- Cable fixing to cable-mounting plate, in the cable section only.
- Power cables with loads < 63 A, and control and monitoring cables, shall be terminated in terminal row blocks in the cable section.
- No terminals for cable connections must be located less than 800 mm from the bottom of the compartments.
- Only one cable conductor in one terminal.

3.9.5 LOW VOLTAGE SWITCHBOARDS, LABELLING AND IDENTIFICATION

The following requirements for signs and labels shall be observed:

- Main sign with clear text and tag.
- Manufacturer's rating label with design data and ratings of the switchboard.
- Signs on individual circuit breakers and feeders with texts and tags.
- The tag numbering system of the Line shall be applied according to KKS.
- Czech language.
- Single line mimic diagram in the full length of the switchboards fronts including all details in order to understand the configuration.

3.9.6 LOW VOLTAGE SWITCHBOARDS, INSTALLATION

A main earthing bar shall be installed in the room. An arrangement of switchboards panels in a straight line is preferred. Only as exceptions, bends and partition of switchboards and back to back lining arrangements will be accepted by the Employer.

3.10 400 V AC, MDB and MCC switchboards

Over- and under voltage protected – Relay with adjustable setting for voltage level and time delay for trip of incoming circuit breaker. Alarm / Trip are to be transmitted to the CMS via bus interface.

3.10.1 400 V AC, MDB AND MCC SWITCHBOARDS, DESIGN

The following design requirements shall be observed:

- It is important that the mechanical stability and robustness of components and components are of high quality (e.g. terminals and connectors for communication cables).
- Spare space and appropriate terminal design for termination of a number of parallel large-scale power cables and free space per compartment/unit shall be envisaged for this purpose.
- Spare empty section with cable connection compartment, complete with main bus-bar, vertical bus-bars, PE-bus-bar and front plate, back plate etc. to be included. Spare and fully equipped (plugs, sockets, wiring, terminals in cable section) spaces shall be foreseen.
- The current rating of an outgoing feeder shall correspond to the current rating of the incoming circuit breaker in the fed ACC switchboard. The power cable in-between shall as a minimum have the same current carrying capacity.
- The motor starters and the belonging mechanical drive shall be designed for DOL (direct-on-line) start. If a soft start is needed, frequency converters shall be applied.

All MDB and MCCs shall be controlled, monitored and diagnosed by the CMS. The following types of MCCs (indicative) shall be foreseen:

- Motor with constant speed.
- Motor with variable speed drives.
- Motorized valve (control valve).
- Motorized valve (on/off).
- Solenoid valve.
- Main switchboard circuit breaker.
- Bus tie circuit breaker

3.10.2 400 V AC, MDB AND MCC SWITCHBOARDS, EQUIPMENT

The following conditions for equipment shall be observed:

- All outgoing feeders shall be electrically operated circuit breakers, with motor charging, push buttons and indications in the front.
- Incoming feeders, section circuit breakers and outgoing feeders shall be equipped with auxiliary contacts for provision of interlock functions.
- Arc monitoring equipment (arc/current detection & protection) to be included in the bus-bar and the cable compartments.
- Intelligent motor starters with bus communication incl. diagnose facilities, maintain functions shall be used. Apart from the normal information's from a motor control, the intelligent motor controller shall give current, and a number of different alarms, that have to be clarified with the Employer.
- If it is not possible to use an intelligent motor control, a conventional relay control has to be installed. This can be the case for solenoid valves and similar. It is important that the

manufacturer of the intelligent motor controllers is the same as the manufacturer of the CMS-system in order to minimize coordination works. Using electrical equipment from one manufacturer should also result in better system integration.

- A motor driven actuator can be supplied from the MCC via a manual operated breaker. Where the control of the actuator itself is located on the actuator and controlled from the CMS via bus interface. This gives additional information and supervision possibilities.

3.10.3 400 V, MDB AND MCC SWITCHBOARDS, OPERATION AND CONTROL

On the switchboards panel front various controls and indication lamps shall be mounted in a height from 0.6-2.0 m. Colours of push-buttons, indicators, etc. shall be agreed with the Employer.

A number of switchboard measurements, alarms and status signals shall be transmitted to the CMS. The following type of signals shall as minimum be transferred to the main CMS:

- Control voltage power supply monitoring.
- Voltage quality monitoring from multi-instruments.
- Display of Amps in all phases, voltage between all phases, kW and power factor monitoring from multi instrument.
- Circuit breaker status: In, out, test, ready, fault.
- Fully integrated interface with all intelligent motor starters.
- Component and equipment alarms.
- Activated arc guards.
- Activated transient guards.
- Control voltage and power supply monitoring.
- Reprehensive temperature measurements inside the switchboard.

Intelligent multi metering units with interface to CMS shall be used. Further, it shall be possible to operate all circuit breakers both from the CMS, the operator station and locally.

3.10.4 400/230 V AC, ACC SWITCHBOARDS, DESIGN

The following concerns the ACCs which normally are fed by a MCC. ACCs consist of a supply circuit breaker and a number of miniature circuit breakers, CMS operated transfer relays (for example for solenoid valves – 24 V DC. The ACCs shall feed smaller consumers (up to 10 amps). The ACCs shall be made in the same design and quality as the MCCs – however with fixed mounted, DIN railed, miniature circuit breakers and contain a significantly lower load.

3.10.5 400/230 V AC, ACC SWITCHBOARDS, EQUIPMENT

The following requirements for equipment shall be observed:

- Section circuit breakers and circuit breakers for outgoing feeders shall be hand operated type circuit breakers.
- Section breakers shall be installed in every row in order to facilitate service and maintenance during operation.
- For cross wiring of the supply side of miniature circuit breakers compact busbars shall be used.

3.10.6 400/230 V AC, ACC SWITCHBOARDS, OPERATION AND CONTROL

On the switchboards panel front various controls and indication lamps shall be mounted in a height from 0.6-2.0 m. Colours of push-buttons indicators etc. shall be agreed with the Employer. A number of switchboard measurements, alarms and status signals shall be transmitted to the CMS.

The following type of signals shall be transferred to the main CMS:

- Closed, open, tripped status of all circuit breakers shall be transmitted to the CMS.
- Component and equipment alarms.
- Control voltage power supply monitoring.
- Incoming circuit breaker shall be electrically controlled from the CMS.

3.10.7 FREQUENCY CONVERTERS, DESIGN

The following design requirements shall be observed:

- The frequency converters shall be designed for momentary interruption of the power supply to motor. Furthermore, the frequency converters shall be able to remain in operation during a power cut-off of 3 - 5 seconds and shall upon the return of power be able to restart with the rotating motor. The efficiency of frequency converters shall be verified in accordance with /EN/IEC 60146-1-1.
- Frequency converters shall be designed in accordance with the applicable EMC requirements. du/dt and sine filters shall be applied in order to minimize the harmonics. < 5 % THD.
- Special precautions shall be taken to ensure that the frequency converter output has a spare capacity of 20 %.
- All frequency converters shall be equipped with a 230 V AC power supply module for the control circuit and bus communication incl. diagnose facilities, maintenance-functions by the CMS. The 230 V AC will be supplied from the UPS.

3.10.8 FREQUENCY CONVERTERS, OPERATION AND CONTROL

The frequency converters shall be provided with intelligent local control panels mounted on the front of the enclosure. The local drive operation from the control panel shall include local/remote selection, start/stop, reset, direction of motor rotation and reference settings. The front display shall be a multilingual alphanumeric display with plain text in Czech language.

In connection with changeover between front panel, CMS, and local control, the motor RPM shall remain constant.

The frequency converters shall be provided with bus adapter modules and bus connection to the CMS. It must be possible to monitor, control and diagnose the converter from the local operation panel and from CMS operator screen.

In case of an emergency, a stop push-button is required with a line contactor, and the emergency stop function shall be fully integrated in the frequency converter design.

3.10.9 FREQUENCY CONVERTERS, INSTALLATION

Frequency converters shall be installed in separate LV rooms. The frequency converters shall be mounted free-standing or on the wall enclosed in the manufacturer standard cabinet. Built-in in switchboard cabinets are not allowed.

Special attention shall be made to ensure the ambient air temperature does not exceed the temperature requirements of the installed equipment.

3.10.10 ELECTRICAL MOTORS, DESIGN

The following requirements for design and equipment shall be observed:

- All other motors shall be for 3x400 V.
- Motors shall be supplied as standard air-cooled 3-phase squirrel-cage induction motors with main dimensions in accordance with IEC Standards. The coherence between dimensions and performance shall be in accordance with CENELEC.
- Motors shall be of the energy-efficient type, having an efficiency which is better than or equal to the EU agreed efficiency classes - minimum efficiency performance requirements. The motors shall have the highest efficiency available. This means that the motors preferably shall observe efficiency class IE3, alternatively class IE2. In case a frequency converter is applied, the motor shall in all aspects be designed and adapted for this purpose.
- Motors shall be adapted to the conditions under which they are to be installed, and in general be designed for continuous operation. They shall be capable of supplying, as a minimum, the power required by the driven machinery plus 20 %.
- All motors shall be supplied with class F insulation, and only be designed for temperature rise class B.
- The motors must not exceed the maximum acoustic noise level as specified in the individual design points, and shall have a vibration level which is ≤ 1.8 mm/s. The motors shall be provided with ball or roller bearings, built into the end shields. Grease valves shall be easily accessible. Bearings on motors shall be provided with SPM-nipples for measurement of the bearing vibrations. For motors applied together with frequency converters, insulated bearing at non-drive end shall be provided.
- Motors > 25 kW shall be provided with 2 Pt100 temperature sensors in each phase for alarm and protection.
- All motors shall be provided with separate earthing bolts in addition to the earth terminal in the terminal box. Furthermore, all motors shall be given individual serial numbers and stainless rating plates as well as drain holes.
- All motors > 25 kW shall be provided with separate terminal boxes for:
 - Cable termination of power supply cable
 - Cable termination of sensors
- Motors > 180 kW shall be provided with Pt100 sensor in the bearings and shall have an efficiency > 94 %.
- All motors shall be cast iron motors.
- Motors can be constructed with permanent magnets, if these types of motors have the highest efficiency.

3.10.11 ELECTRICAL MOTORS, PROTECTION

The electric motors shall be protected as a minimum with:

- Overload protection
- Asymmetrical load
- Blocked rotor
- Electronic motor protection relay
- Frequency driven electric motors and large motors (>25 kW) shall have temperature protection (pre-alarm and trip).

3.10.12 ELECTRICAL MOTORS AND DRIVES, DESIGN

The following requirements on capacity, design and performance shall be observed:

- It shall be possible for motor drives to start at 80 % voltage when connected to the driven machinery.
- Motors shall be capable of handling three immediately succeeding starts from cold condition and two immediately succeeding starts from a warm condition.
- All motors shall, at rated voltage, be able to restart on the fly, including possible reconnection on full counter voltage (180° phase displacement) in event of transient interruptions to the power supply or switching-over to second power supply.

3.10.13 CABLE ROUTING, DESIGN

In general, the various cables shall be installed in a separate cable routing according to the following structure:

- Building installations
- Machine installations.

In general, the various cables shall also be separated according to the following level of voltage:

- 22/6.3 kV installations
- 400 V, 230 V and 110 V installation
- 24 V control and signal installation as well as data communication installation.

The following requirements apply for the cable routing:

- Cable routing shall be of a traditional heavy-duty industrial type cable ladder. Only original standard elements/fittings shall be used for fixing, suspension, assembling, and branching and bending. The width of horizontal installed main cable routing shall be 600 mm max. Cable routing material of the "Wire Cable Tray" type is not acceptable.
- Cable routing for control and signal cables shall always be located above cable routing for power cables. 22/6.3 kV cables shall be kept clear from other installation areas and routed separately. The minimum distance between cable routing for control and signal installations and for low-voltage installations shall be minimum 400 mm. The clear headroom above each ladder shall be no less than 400 mm.
- Communication cables e.g. bus, coax or fibre cables shall normally be routed in galvanized steel pipes in order to ensure mechanical protection.

- Cables for bus installations shall strictly follow the installation requirements defined by the Contractor of bus communication.
- All cable ladders shall be supported by suspension consoles or supporting consoles located at one side of the ladders only. The cable routing shall be installed with a min. distance of 50 mm from walls and other structures to allow enough space for routing of cables behind the ladder. A suspension console shall be of such a construction that it keeps its vertical position even if supporting fully loaded cable ladders.
- All material shall be hot galvanized after manufacture with a 60-100 µm zinc coating. All cutting surfaces shall be treated with zinc primer or similar, before final installation. Ladders, pendants, wall rails, etc. shall be terminated with end plugs.
- In environment where corrosive atmosphere can be expected (e.g. flue gas treatment area) another ladder material shall be considered and discussed with the Employer.
- Cable ladders and cable trays shall have 20 % spare capacity at the time of the takeover of the Line.
- In case of a 90 degree bend original standard cable ladder bends shall be used.
- Redundant installations such as motors or pumps shall be supplied from different supply cabinets, and those supply cabinets shall be supplied from different distribution transformers, this is to ensure that the power supply isn't cut off for both components at the same time.
- Process, control and safety network shall be redundant, and shall be routed as far as possible in different cable routes.
- In rooms where switchboards are located, cables for control and signal cables shall be routed under the floor, and power cables under the floor.

3.10.14 CABLE ROUTING, CABLE PENETRATIONS

The following requirements for penetrations shall be observed:

- Cable penetrations of floor partitions shall be provided with watertight stainless steel barriers or similar preventing water on the floor from seeping down to the areas below. Furthermore, there shall be a soft lining to protect the cables against sharp steel and concrete edges.
- Cable ladders shall not pass a fireproof cable penetration but shall be terminated outside the penetration. The fireproofing shall as a minimum be in accordance with the standards, rules and regulations in force in the Czech Republic as well as any more stringent Czech Authority requirements, which may apply for the Line.
- Sealing of fireproof cable penetrations shall be made with fireproof materials of an accepted make. A certified company shall issue a certificate for all fireproof cable penetrations made by the Contractor after the installation is completed. The sealing shall be 100 % smoke and gas tight.
- Cable penetrations shall be made with additional capacity and space for 20 % extra cables.

3.11 Cables, equipment

The following requirements for cables shall be observed:

- All installation cables should be fire retardant.
- The cables shall be halogen free, lead free and low smoke type. All low-voltage power cables shall be cables rated 0.6/1 kV. Cables of the type "light cables" are not allowed. All cables shall follow the same standard.

- If parallel cables are used it shall be ensured that there is sufficient space for the routing of the cables.
- All power cables shall as a minimum be designed for a high continuous ambient temperature of 40 °C. A max. voltage drop of 4 % in the low voltage supply system to the end consumer shall be observed
- Cables to be used for special safety functions or in an environment which requires fire resistant cables, must comply with the applicable standards and the requirements of the Czech authorities.
- Power cables between variable speed drives and motors shall be with screen and selected according to the instructions of the manufacturer of the frequency converters.
- All signal and control cables (< 50 V) shall be shielded cables, twisted pair, and with stranded conductor of minimum 0.50 mm².
- Control cables for control voltages (> 50 V) shall be executed as power cables and have a minimum conductor size of 1.5 mm².
- Data communication cables shall follow the requirements of the components manufacturer. The damping factors shall be tested after installation in order to ensure a proper and safe function.
- Cables shall be designed for 20 % spare capacity, compared to nominal estimated load.

3.11.1 CABLES, INSTALLATION

The following requirements apply to the installation of cables:

- All cables shall be routed in cable ladders. Individual cables shall preferably be routed in small cable ladders.
- All cables shall be installed in one continuous length without joints between the destinations.
- All signal and control cables (< 50 V) can be terminated directly in the component without any local junction box.
- Branching off from cable trays shall be executed at cable curves over the side and branching off from ladders through the bottom. Where cables pass metal edges, the cables shall be protected from the sharp edge by means of fixed covers in plastic or similar. The cables shall be routed without any crossings between cables.
- Standby power cables and cables of redundant systems shall be routed separately from each other.
- Cables shall be kept in a safe distance from machinery and pipe units.
- Cable to be imbedded in concrete constructions shall be routed in galvanized pipes or PEH ducts with smooth inside and sealed joints. Cables to be routed outside in ground shall be routed in heavy duty PEH ducts with smooth inside and sealed joints when passing under driving areas, roads etc.
- Cables shall enter equipment and components from beneath. Cables which enter equipment and components from the top are not allowed in the process area.

3.11.2 CABLES, FIXING

The following requirements apply when fixing the cables:

- Cables shall be carefully installed and firmly fixed to prevent cable twisting. Cables shall be arranged assembled and guided using flame retardant, acid resistant and sunlight resistant binders (strips) on horizontal routings and metal type clamp on non-horizontal routings.
- Single-core power cables shall be symmetrically mounted in triangle via the use of suitable triangle type cable fasteners.

3.11.3 CABLES, TERMINATION

The following requirements apply for the termination of cables:

- All cable glands shall be classified for EMC correct cable termination for instrumentation and control cabling as well as motor power cabling (frequency converter). For frequency converters the manufacturer's instruction shall be followed.
- Cables entering process equipment shall basically be relieved by means of screw glands facing downwards. Metallic screw glands on metallic equipment, non-metallic screw glands on non-metallic equipment.
- All conductors, including spare conductors, of a power cable shall be terminated in screw terminals. Terminals shall be single type and no common terminals may be used.
- Multi core signal cables may be bundled and the spare conductors shall be terminated and grounded in a terminal. Common terminals may be used for termination and grounding of spare signal conductors.
- The conductors shall be cut with additional length allowing the individual conductors to reach an arbitrary terminal in the terminal compartment or box. The conductors shall be placed properly bundled and fastened with nylon strips.
- Where the entry of the cables is located far from the terminal blocks, or where the space conditions do not allow the use of wire ducts the conductors shall be bundled together along the terminal block.
- Cores in flexible cables and multi-stranded wires shall be provided with terminal tubes before connection in screw caps.
- Pressure cable shoes shall be fixed with a rustproof bolt with a face plate and a spring washer. Pressure cable shoes shall be tightened with a torque wrench. Cable shoes without insulation shall be terminated with shrink film on the cable shoe neck and approx. 30 mm down the cable's insulation cap.
- Earth conductors shall be connected to earthing bars and components with cable shoes.
- The conductors shall be terminated according to the colour sampling sequence and shall be agreed with the Employer.

3.11.4 CABLES, LABELLING

The following requirements apply for the labelling of cables:

All cables shall be labelled in both ends according to the KKS system and shall be agreed with the Employer. The principal of labelling shall be presented to the Employer for approval. Individual cable conductors shall be identified by means of a numbering or colour code according to Appendix A14.8 *Identification and Labelling of Components*.

3.12 Earth system

The main principle of earthing is outlined in appendix A16 *Concept Diagrams for Electrical System (Single line diagram)*, including *Earthing System*. The drawings show the main principle and structure of the earth system and shall only be regarded as guidance. The Contractor shall execute the detailed design according to the valid requirements.

The power system earthing is TN-S (five conductor system: phase 1, phase 2, phase 3, neutral and protective earth), the system shall fulfil the requirements of the local electrical power distribution company.

3.12.1 EARTH SYSTEM, PRIMARY EARTHING (MEB)

A complete primary ring type main earth system shall be established. A main earth bar (MEB) shall be established in the HV room. Earthing shall be executed using the concept diagrams in appendix A16.2 *Diagram of earthing system main principle*.

3.12.2 EARTH SYSTEM, MAIN EARTHING RAIL (MER)

Main earthing bars shall be provided at various electrical equipment rooms/locations and shall be connected directly to the MEB, with 2 cables in parallel, each of 95 mm² copper conductor cable.

Earth connection plates are mounted in the building at various locations such as foundations and walls for the purpose of connection of the MERs. The equipotential bonding shall be connected to the MER, and thus to the primary earthing system.

3.12.3 EARTH SYSTEM, PROTECTIVE CONDUCTOR (PE)

The following requirements apply:

- The PE conductor shall be connected to all equipment.
- The PE-bus-bar shall be marked PE.
- All equipment shall be fed via a power supply cables with a green/yellow coloured PE protective conductor embedded in the cables.
- Where separate PE connections are made, the connection shall be made by means of a single green/yellow insulated cable.
- In all panels/switchboards, a PE-bus-bar is installed for correct termination of shielded cable installations and termination of the PE-conductor. The PE-bus-bar shall be connected directly to the MER with a 95 mm² copper cable.

3.12.4 EARTH SYSTEM, EQUIPOTENTIAL BONDING

The following requirements apply:

- The Contractor shall execute bonding between all exposed parts throughout the Line.
- To ensure a reliable EMC earthing system, a 95 mm² un-insulated, copper tinned wire shall be routed through all main cable ladders, making it possible to connect the CMS-system components to this copper cable. RIO-panels etc. shall be connected with a 95 mm² isolated copper cable. This installation has direct connection to the MER.
- The equipotential bonding connections shall be provided by means of un-insulated single core copper cables. A main 95 mm² cable shall be routed in the main cable ladders and

thus be distributed around the Line. From this cable the various bondings shall be made with a 25 mm² green/yellow insulated copper cables.

- The un-insulated PE copper conductor when routed via a cable ladder shall be bolted to each connection between sections of the cable ladder, with a minimum of one bolt per connection point.
- Cable sockets shall be used on all cable endings, except when branching off from the main 95 mm² PE conductor, which shall be made with bolted clamp connections.
- The equipotential bonding connections routed via cable ladders shall be placed in ladders assigned to the 400V power cables for machine installations. As an exception for branch PE conductors the ladders assigned to low voltage machine installations can be used.
- The equipotential bonding of machine parts shall be connected directly to the MER via a 95 mm² copper conductor cable type.

Bonding shall be made between conductive parts such as:

- Construction steel parts.
- Steel reinforced foundations of building and machinery.
- Building steel parts (platforms, stairs, etc.).
- Pipe systems (water, air, oil, etc.).
- Machine parts, machine components.
- Ventilation ducts.
- Cableways.
- Switchgears, cubicle, panels, double floors in switchgear room, CMS room and control room etc.
- Steel profile supports for control panels, junction boxes, actuators etc. mounted on concrete floors.
- Instruments (if required)
- CMS equipment.
- All connections in the earthing system shall be bolted together and not welded.

Lightning protection, metal parts, constructions etc.:

- All metal parts, constructions etc. for the process equipment, wherever they may be subject for leading current existing from lightning, shall be firmly electrical conductive connected and bolted together, being capable of leading of the lightning current occurrence to the earthing system.
- At the end of the metal parts, constructions etc. proper connections shall be made to the earthing connection points.

Only approved proper clamps, connections etc. shall be used.

3.12.5 EARTH SYSTEM, TEST OF EARTHING

The Contractor shall ensure the test of the earthing within his Scope of Contract Object. The tests shall be recorded in a report.

3.13 Local operation panel

In general, local control panels shall be avoided, since a full integration in the main CMS is envisaged. However, the Line may be equipped with some local panels in order to facilitate local operation and local maintenance routines.

The following requirements shall be observed:

- The local operation panels shall be connected to the CMS. Local control is only allowed after the panel has been enabled from the control room.
- After this a switch named "Local Control ON/OFF" can be operated.
- A LED lamp indicating enabled ("released for local operation ") and switch for "Local operation" shall be included on the local operation panel.
- All necessary operation and indication facilities shall be available, for example emergency stop, push-buttons, lamp indications, lamp test and switches.
- LED lamps shall be used.
- Labels and signs with text to be included in accordance with appendix A14.8 *Identification and Labelling of Components*.
- Drive motors for conveyors; hoppers etc. shall have a reverse switch for maintenance purposes.

3.14 Emergency stop switches

A number of emergency stops shall be placed in certain areas in accordance with the local safety regulations and as recommended by the Contractor (manufacturer of the machine). It shall be possible to identify which emergency stop has been activated by means of contact signal via a separate signal to the CMS operator system.

3.15 Local safety work switches

Local safety work switches shall be provided for all process equipment; motors, heaters, etc.

The local safety work switches shall be installed in the supply cable and placed locally at the attached component.

The local safety work switches shall be provided with aux. contacts, which interrupt the control circuit of the consumer. The CMS shall receive a signal for indication of local safety work switch positions.

The switches shall be lockable by a padlock with the switch in "0" position. The switches shall be located approximately 1.0 meter above floor next to the equipment.

3.16 Local safety work switches for plug connected equipment

Local safety work switches with $I_n < 16$ A shall be for plug connected supply cable for the supplied equipment; motors, heaters, etc. Cable plugs shall be classified for EMC installation.

Plugs to be used generally shall be heavy-duty connectors, e.g. HSB series (HARTING) or equivalent equipment. CEE plugs will not be accepted.

3.17 Plugs for instruments

Plug connections can be used wherever it facilitates easier maintenance. If plugs are a standard integrated feature in a component, plugs are allowed, e.g. in valve drives, solenoid valves etc.

4. FACTORY ACCEPTANCE TESTS (FAT)

Refer to appendix A11 *End of Assembly, Commissioning and Testing* for details on the Factory Acceptance Tests (FAT).

The actual FAT shall be carried out for all single functionalities, for group of functionalities and for the Line and may involve participation of the Employer if requested.

5. SITE ACCEPTANCE TESTS (SAT)

Refer to appendix A11 *End of Assembly, Commissioning and Testing* for details on the Site Acceptance Tests (SAT).

The SAT shall be carried out for all single functionalities, for group of functionalities and for the Line and may involve participation of the Employer if requested.