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

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PART III, APPENDIX A4
TECHNICAL SPECIFICATIONS FOR TURBINE/GENERATOR AND CONDENSERS

SAKO

RAMBOLL

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TECHNICAL SPECIFICATIONS FOR TURBINE/GENERATOR AND CONDENSERS

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1. GENERAL

The turbine shall be a backpressure turbine for district heating (DH) generation according to Appendix A15.3 *Concept Diagram for Water/Steam Cycle and DH Connection*, to supply to the existing district heating network. A solution with one or two main DH condensers is foreseen which shall also act as the turbine bypass condenser.

The turbine shall supply steam to the deaerator. Deaeration steam shall be available as bleed steam at sufficient pressure at nominal load. The Contractor may optimize the energy production by potentially employing e.g. cascaded bleeds or substituting the deaerator bleed with reduced live steam during low turbine load.

Design load points are listed in Appendix A13 *Process and Design Data*.

The turbine shall control the live steam pressure within the specified interval during the short-term variations in live steam flow and parameters from a steam boiler operated with an inhomogeneous fuel as waste. The live steam pressure variations must not exceed ±0.2 bara during stable operation.

The turbine shall be designed for continuous operation at 70–110 % thermal boiler load. The bypass station shall also have a swallow capacity of 110 % of nominal steam flow rate. Combined bypass and turbine operation shall also be possible, for instance with 100 % steam to the steam turbine and 10 % steam to the bypass station.

Further it shall be possible to operate the Turbine Generator set (TG-set) in island mode, where the TG-set shall provide the complete parasitic load for the Line. Islanding shall be possible for at least two hours, in safe and stable operation. It shall be possible to return to normal operation without intermediate outages in power production.

The Line shall be designed for fully automatic operation. Start up (within all allowed conditions) and shutdown procedures shall also be fully automatic, allowing these procedures to be fully controlled from the control room. All valves to be operated in continuous operation and during start up and shut down shall be delivered with pneumatic actuators and connected to the turbine control system, enabling operation from the control room under full control of the safety interlocking system. Valves without the possibility of control from the control room may only be valves to be operated in connection with stops of more than 48 hours duration.

The turbine bypass valve (fast acting i.e. pneumatic or hydraulic operated) shall automatically take control of the live steam pressure in the following operating situations:

- Start-up and shut-down of the boiler.
- After trip of the turbine.
- When live steam parameters are unacceptable to the turbine.
- When operating the turbine at a specified electric power output (e.g. island mode, combined turbine/bypass mode).

It shall be possible to control the bypass valve by manual override when the turbine control system is not in operation.

2. STEAM TURBINE

The swallow capacity of the steam turbine shall be 110% of the nominal steam flow measured in kg/s at nominal steam parameters.

The TG-set shall be designed mechanically and electrically for the forces, shaft output etc., arising from the maximum permissible steam flow. The turbine protection system shall trip the TG-set if the steam turbine is operated outside its design specifications.

The turbine rotor, shafts, couplings, bearings and mechanical design shall be able to withstand the dynamic forces during trip from maximum load.

A permanent steam strainer shall be built into the emergency shutdown valve preventing foreign matter carried by the steam from entering the turbine. To additionally safeguard the turbine from particles after superheater replacements, the Contractor shall also supply an additional fine mesh (0.2 mm mesh size) steam strainer intended for temporary short-term operation.

In the low-pressure part with risk of condensation the turbine blades shall be in erosion proof design.

Necessary nozzles for connection of dry air conservation equipment for the turbine and condensers in connection with long-term standstill of the Line shall be available. A hot-air drier shall be included in the Contract Object. The Contractor shall provide documentation of proper design and operation of the hot air drier.

Generally, the design of the turbine shall be in accordance with IEC publication 60045-1.

3. TURBINE BLEEDS AND GLAND SEAL SYSTEM

The number and location of bleeds shall be selected based on the Contractor's experience. The Contractor can also choose to supply a steam-fed condensate preheater, if the Contractor deems that condensate preheating will be cost-effective in terms of optimizing electrical output. The Contractor is also encouraged to consider water-side (condensate) process optimisations.

The Contractor shall confirm that the opening of the turbine is possible during turbine bypass operation in the combined bypass condenser. The Contractor shall implement the necessary shut-off valves on the water and steam side of condensers, if required, for instance double shut off valves in the exhaust lines. It shall be possible to do repair works on an open turbine during bypass operation without interrupting the operation of the boiler.

One bleed shall be foreseen for supply of steam to the de-aerator/feedwater tank and air preheaters. Check valves, double shut-off valves and other relevant safety valves in the bleed line shall be included in the Contract Object. If the temperature at the bleed steam exceeds the temperature limit given in Appendix A13 *Process and Design Data*, a water injection unit must be included in the Contract Object upstream the interface point to ensure that the bleed temperature limit is not exceeded at the interface. Shut-off valves shall be 100% tight with a block-and-bleed configuration, to avoid steam leakage to the turbine during turbine outage/maintenance.

The turbine protection system shall protect the turbine against entrainment of water/steam back through the various bleeds into the turbine. The protection system shall close the isolation valves against the DH system, if unallowed high water level is detected in any of the condensers.

The gland seal system shall be of a design which secures that a minimum amount of vapour escapes to the turbine hall. This implies that a gland steam condenser system or equivalent connections to recover gland steam at the rotor ends back into the steam cycle are included in the Contract Object.

3.1 Turbine/generator Base Plate

3.1.1 EXECUTION

The turbine and the generator shall be mounted on a common spring supported concrete or steel base plate/slab which secures that transfer of vibrations and noise to other building constructions are minimised, cf. Appendix A14.3 *Acoustic Noise and Vibrations*.

The upper surface of the turbine base plate shall be flush with the floor level in the turbine hall.

The turbine/generator base plate design and dimensions shall follow the turbine supplier's (Sub-contractor) requirements and recommendations.

The detailed design and dimension control before start of erection of machinery shall be included in the Contract Object.

Springs and dampers as well as related equipment shall be selected, supplied and installed by the Contractor. The installation shall be conducted under the turbine supplier's supervision and control.

The steam turbine supplier shall measure, inspect and approve the turbine base plate before and after casting of the concrete. The inspection report shall be submitted to the Employer.

3.1.2 DESIGN CALCULATIONS

The design calculations to be made by the Contractor shall include conventional static calculations as well as analysis of the dynamic behaviour of the turbine base plate.

The analysis shall include the determination of own frequencies and amplitude oscillations at bearing supports. The calculation shall be carried out as a finite element calculation with 3-dimensional elements.

The calculation shall be based on DIN 4024 "Machine foundation" as well as the Contractor's own information on unbalance and transient loads. In the calculations, static and dynamic elasticity modules as well as damping, realistic for the prescribed concrete and steel quality, shall be used. Especially the amplitude oscillations shall be examined in connection with passage of the own frequencies of the construction.

4. TURBINE INSULATION

The heat insulation shall be demountable and easily remounted after completed assembly of the turbine.

Service and maintenance access to all instrumentation at the TG-set shall be secured in the design of the turbine heat insulation

The surface of the turbine insulation shall be sturdy, as smooth as possible, easy to clean, and oil repellent.

The turbine insulation shall be installed so that the concrete foundation is never exposed to excessive temperatures.

The turbine hall shall comply with the sound emission to the required level stated in Appendix A14.3 *Acoustic Noise and Vibrations* by means of sound dampening of the walls and ceiling of the turbine hall. A solution without a noise hood is preferred.

5. TURBINE TURNING GEAR

The turbine or its reduction gear shall be equipped with an automatically functioning rotor turning (barring) gear. The motor of the turning gear shall be supplied from an UPS based emergency power source, allowing automatic turning of the turbine during a power failure.

Furthermore, manual turning of the turbine shall be possible.

6. POWER TRANSMISSION

The power transmission includes the shafts and couplings between turbine and generator.

The power transmission shall be designed for continuous operation at the maximum possible steam turbine load.

The power transmission shall be designed to absorb the forces from a generator short circuit.

The critical speed in relation to vibrations shall be in good distance from the synchronous speed.

The reduction gear shall be designed in accordance with ISO 6336-1 with a service factor of 1.3 and be a double helical type gear. Further the gear shall be designed to adequate standards preventing formation of micro pittings. The design shall allow operation with ordinary turbine lubrication oil without load-carrying ability enhancing additives.

The system shall be designed for preventing any unacceptable vibration phenomena’s without use of hydraulic dampening equipment.

7. LUBRICATION OIL SYSTEM

The Contract Object shall include a complete system for supplying any necessary lubrication oil for the Line.

A design with a directly driven main lubrication oil pump is preferred. If no directly driven lubrication oil pump is offered, a detailed description of the redundancy and measures to ensure availability of lubrication oil at all times must be provided in the Tender. In case of low oil pressure (e.g. at start up and stop) an electric motor driven (AC) oil pump shall automatically take over. The operation manual shall describe a safe procedure to test this pump without interrupting the operation of the Line. In case of turning (barring) of the turbine after a power failure it shall be possible to supply the AC pump from the emergency power supply.

An emergency oil pump shall be supplied from the UPS based emergency power source and shall take over in case of a lower oil pressure. The emergency oil pump shall be capable of supplying adequate oil for safe shutdown of the turbine.

The oil system shall be equipped with two parallel oil filters and two parallel oil coolers each designed for 100% oil flow. Oil coolers shall be designed in accordance with cooling water temperatures specified in Appendix A13 *Process and Design Data*.

A lubrication oil cleaning unit (oil separator) for continuous off-line fine filtration of the oil shall be included in the Contract Object.

Oil filters and coolers shall have a shut off arrangement (3 way valve) ensuring safe operation when the Line is in operation. Visible oil drains, local thermometers and double Pt100 elements shall be installed in all bearings on turbine, and generator.

The oil system shall be designed in accordance with recognised standards.

The entire oil system shall be pickled after the last welding is carried out and before the system is oil-flushed and later oil-filled.

Necessary cleanliness of the oil systems shall be in accordance to relevant norm and proved by particle counting of the flushing oil before commissioning of the system.

It shall be possible during normal operation of the equipment to take out representative oil samples.

8. CONTROL OIL SYSTEM

The Contract Object shall include a complete system for supplying any necessary control oil.

A design with 2 x 100 % electric motor driven (AC) control oil pumps is preferred.

The control oil system shall be equipped with two parallel oil filters and two parallel oil coolers each designed for 100% oil flow. Oil coolers shall be designed in accordance with cooling water temperatures specified in Appendix A13 *Process and Design Data*.

A control oil cleaning unit for continuous off-line fine filtration of the oil shall be included in the Contract Object.

Control oil filters and coolers shall have a shut off arrangement (3 way valve) ensuring safe operation when the Line is in operation.

The control oil system shall be designed in accordance with recognised standards.

The entire oil system shall be pickled after the last welding is carried out and before the system is oil-flushed and oil-filled.

Necessary cleanliness of the oil systems shall be in accordance to relevant norm and proved by particle counting of the flushing oil before commissioning of the system.

It shall be possible during normal operation of the equipment to take out representative oil samples.

A solution with separate control oil and lubrication oil is required. That is, it is not allowed to use the same oil sump for both control and lube (in the case that the oil is physically the same).

9. TURBINE CONTROL SYSTEM

The turbine control system shall maintain full control of the turbine under all load and operation conditions, normal as well as abnormal.

In case of de-excitation the generator or opening the generator circuit breaker, with the system being at full load, the turbine speed must be controlled accurately enough to prevent release of the safety regulator. The maximum speed after full load disengagement must not exceed 98.5 % of the lowest over-speed trip limit.

The offered control system shall be in compliance with VGB-R 117 C: "Maschinentechnischer Blokschutz für Wärmekraftwerke", the latest issue.

The control system offered shall be suited for the operation described in the Contract and shall be integrated (including exchange of signals) with the overall control and monitoring system (CMS). Sum/Common alarms and signals are not accepted.

A turbine bypass control system shall be supplied, and incorporated in the overall CMS system. Generally, start-up, shutdown and operation in general, shall be possible from the control room without the need of manual/local intervention.

The control system shall allow for fully automated operation in all load points defined in Appendix A13 *Process and Design Data*.

The Turbine Control System shall be in compliance with the Requirements with regard to safety, risk assessment and functional safety" as set out in Appendix A8 *General Technical Requirements for Process*. The control philosophy shall be according to the fail-safe principle.

10. WATER-STEAM CYCLE

The foreseen concept diagram for the water-steam cycle is shown in Appendix A15.3 *Concept Diagram for Water/Steam Cycle and DH Connection*.

11. TURBINE BYPASS SYSTEM

The main purpose of the Turbine Bypass Station is to reduce the steam pressure and temperature during start-up and shut down of the turbine as well as during all periods, when the turbine is out of operation or in operation on partial load.

The Turbine Bypass Station must be able to operate continuously under full load, part load or in stand-by mode and to do so for at least 50.000 accumulated hours before any major internal inspection/maintenance are foreseen. The spare parts must include parts for one complete bypass station.

It must be ensured that idle bypass valves are kept sufficiently warm according to their specifications to avoid thermal shock issues when activated.

To reduce turbulence induced wear at the bypass valve, it must be installed with a straight pipe with a length of at least 5 pipe diameters upstream and at least 10 pipe diameters downstream the bypass valve. The steam outlet must be designed with smooth transitions.

The complete turbine bypass system shall be designed for 10-110% of nominal live steam flow.

It shall be possible to operate the turbine bypass system with the steam turbine systems totally stopped and isolated.

The Contract Object includes a fast reacting shut-off valve upstream the bypass station which must ensure that the pressure downstream the bypass station does not exceed the design pressure in case of a malfunction in the bypass station.

The boiler start-up valve shall be included in the turbine trip sequence to relieve a controlled amount of steam in order to avoid that the boiler safety valve is trigged.

The bypass station shall produce steam of such conditions, that the condenser Contract Object properly in the whole load range. Measures shall be taken against erosion caused by droplets in the outgoing steam. Special consideration shall be given to start-up conditions, where production of "cold" DH water shall be avoided.

After replacement of boiler super heaters or other boiler parts, foreseen regularly, it shall be possible to undertake steam blasting directly through the bypass station and to the bypass condenser.

At start-up of the boiler wet steam will be led to the bypass valve, and after further firing the bypass station will be an active part of the start-up procedure for the boiler (pressure being ramped up to nominal pressure).

The bypass system shall be able to perform control of the inlet steam pressure under all operating conditions within the specified limits. The chosen design shall be able to withstand inlet steam at conditions near saturation (+10 °C) during normal operation and at saturation during boiler start-up.

Injection water for the bypass station shall be drawn from an intermediate pressure outlet of the feed water pumps to the inlet of the shut-off valve of the bypass station water side connection line.

It shall be possible to limit the turbine electricity production to an operator defined level by controlling the flow through the bypass valve. The Line shall fully comply with the regional/national power grid company requirements, which may entail frequency control by offering short term on-demand power export or other grid support services. The boiler steam production will not be affected. Instead, the power export is foreseen to be regulated by the combined turbine/bypass mode.

The CMS for the bypass station shall be separated from the CMS for the turbine enabling operation of the bypass station during update of software and revisions of the turbine. The bypass CMS shall be implemented in the main CMS. Logic diagrams, functional descriptions and other relevant material for proper execution of implementation in the main CMS are included in the Contract Object.

If hydraulic operated, the turbine bypass station shall have its own hydraulic power pack independent of the turbine control oil systems.

It shall be possible to safely do maintenance on the bypass station during turbine operation. Further, it shall be possible to safely open the turbine during full turbine bypass operation without interrupting boiler operation.

Full service of the bypass station shall be possible while operating the steam turbine, and necessary shut-off valves shall be included.

12. SAFETY-VALVE BLOW OFF PIPING

Outlets from all safety valves included in the Contract Object shall be led to a common blow-out pipe, which shall be routed to a position over the roof, approved by the Employer. The blow-off valve upstream the bypass valve shall have a separate blow-out pipe.

The blow-off pipes shall include all necessary supports and hangers, suitable drainage as well as a muffler. The blow-off pipes shall comply with Appendix A14.4 *Insulation and Cladding* to avoid touching hot surfaces (if accessible). Guard rails may be accepted by the Employer. The blow-off pipes shall comply with Appendix A14.3 *Acoustic Noise and Vibrations*.

13. DISTRICT HEATING CONDENSERS

The Contract Object shall include one or two DH condensers including condensate pumps, as indicated in Appendix A15.3 *Concept Diagram for Water/Steam Cycle and DH Connection* along with the district heating connection.

At least one turbine condenser shall act as combined turbine condenser and turbine bypass condenser. Simultaneous operation of the turbine and turbine bypass must be possible.

The DH water quality is listed in Appendix E2 *Quality of Water Flows* and the design figures for DH are listed in the tables in Appendix A13 *Process and Design Data*.

The design of the condensers with respect to steam side pressure loss and pinch point temperature difference is to be optimised by the Contractor.

The condensers shall be able to withstand the forces and vibrations generated under all operating conditions, including conditions, where the condenser receives the steam from the bypass station.

It shall be possible to install a hot air supply for drying out the condensers during stand still.

The pressure vessels shall be designed, manufactured and tested according to requirements in the PED directive and delivered with a declaration of conformity.

The heaters shall be heat exchangers of shell and U-tube type. Integral drain coolers (condensate coolers) are not foreseen in the design.

All aspects of design, manufacture and testing shall be in accordance with EN-codes including EN 13345 for unfired pressure vessels in general and the following EN 287, EN 12952-5, EN 13480, EN 15613 and EN 15614 as applicable for their specific areas. The list shall be completed by the Contractor for specific areas not covered by the mentioned codes.

The condenser tubes shall be in a stainless steel material well suited for the district heating water quality. The tubes shall be welded to the tube sheets – solid from stainless steel or stainless steel plated.

One piece of condenser tube of minimum 0.5 meters length shall be delivered as test sample and handed over to the Employer.

The shells and water boxes are expected being of mild steel.

Pipe connections shall be flanged on the water side; all other pipe connections shall be welded.

The water boxes must be provided with flanged covers to allow full access to the tube plate.

The nozzle for bypass steam shall be of sufficient diameter to admit the steam flow and with a proper inlet design without risk of pipe erosion damage to the outer tubes in the heat exchanger bundle.

Tube bundles shall be designed to avoid vibrations and to enable efficient air extraction without formation pockets inside the condensers.

The condenser shall be equipped with safety relief valves on both the steam and the water side (the latter located on the waterbox chamber). Rupture discs will not be accepted. The steam side safety valve shall be of a capacity preliminary assumed at 10% as a minimum, if this can be accepted by PED. The final capacity and possibly larger capacity to take into account the specific steam leakage rates in shut-off inlet valves and tube bursts shall be determined by the Contractor.

The hotwells shall be ample sized for load variations in steam flows to take into account that the steam turbine can be taken fast into operation or tripped. The district heat condensers shall cope with such events without entering into over-flooding or other risks for continued operation.

Adequate provision must be made to protect the turbine against the back flow of water from the district heat condensers in any case.

14. CONDENSER AIR EVACUATION EQUIPMENT

The system offered shall have sufficient capacity to remove all non-condensable gasses and maintain the saturation pressure in the condensers under all operating conditions at the level specified necessary for the guaranteed performance.

A design based on 2x100 % water ring pumps will be preferred.

15. CONDENSATE SYSTEM

15.1 General

The condensate system shall handle all the condensate generated.

The Contractor is free to optimize the condensate connections within the Contract Object, although full redundancy of all components shall be adhered to.

The condensate level in the condensers shall always be in control and monitored closely, including the unexpected shifting to 110 % steam flow bypass operation from turbine operation.

The condensate will be conditioned (in the feed water tank) with NH_3 in order to control the pH value at the specified level.

Necessary nozzles shall be placed in the condensate system to facilitate sampling. A layout showing the positions of the nozzles shall be submitted to the Employer for commenting as part of project data, cf. appendix C1 *Reviewable Project and Design Data*.

15.2 Condensate Pumps

Condensate pumps on all the condensers shall be in redundant configuration with 2 x 100 % capacity, each designed and optimised for the condensate flow within the specified operation interval. Condensate pumps shall be equipped with frequency controllers.

Condensate pumps shall be designed for the NPSH and the pressure in the feed water tank, including pressure loss in piping, filters and other components upstream the pumps to the feed water tanks.

16. DRAIN SYSTEM

The drain system shall include all necessary drains from sources generating condensate in connection with the warming up of components. All drained condensate from these sources shall be led to a drain and/or flash tank (included in the Contract Object). If an atmospheric drain tank is installed, it shall be connected to blow-off piping.

Condensate generated continuously under operation shall be reused in the condensate system.

All drain valves and restrictions shall be arranged in one common rack so that they are easily accessible for inspection and maintenance.

17. CONTROL, MONITORING AND SURVEILLANCE (CMS)

Wherever possible "black boxes" shall be avoided, although the turbine governor is an exception. "Black boxes" shall be approved by the Employer.

It shall be possible to carry out testing of the turbine safety systems during turbine operation.

All measurements shall be made available for the overall CMS for the Line. The offered turbine safety and protection system shall — to the extent possible — comply with VGB-R 117 C: "Maschinentechnischer Blokschutz für Wärmekraftwerke", the latest issue. Deviations from this shall, if any, be stated elsewhere in the Contract.

Further reference is made to Appendix A7 *Technical Specifications for Control and Monitoring System (CMS)*.

18. SYNCHRONOUS GENERATOR

18.1 General

Nominal Ratings:

- Frequency: 50 Hz
- Nominal voltage: 3x6.3 kV
- Operation Voltage (typical): 3x6.3 kV
- Rated power of the generator shall match or exceed the maximum turbine shaft power.
- Rated power factor shall be in accordance with requirements of the Technical Regulation mentioned in the following section.

Efficiency: To be high efficient type.

All other data, any requirements, are all to be in full compliance with Czech Transmission System Operator, Grid company, Technical Regulation for Thermal Power Station Units and Regulation for grid connection. All deviations to this regulation must be approved by the Employer.

18.2 Norms and Standards

The generator shall comply with the following standards:

- EN 10106: Cold rolled non-oriented electrical steel sheet and strip delivered in the fully processed state.
- ISO 10816-1: Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating part – Part 1: General guidelines.
- EN 50209: Test of insulation of bars and coils of high-voltage machines
- EN 60034-1: Rotating electrical machines – Part 1: Rating and performance.
- EN 60034-2: Rotating electrical machines – Part 2: Standard methods for determining losses and efficiency from tests.
- EN 60034-3: Rotating electrical machines – Part 3: Specific requirements for synchronous generators driven by steam turbines or combustion gas turbines.
- EN 60034-4: Rotating electrical machines – Part 4: Methods for determining synchronous machine quantities from tests.
- EN 60034-5: Rotating electrical machines – Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification.

- EN 60034-6: Rotating electrical machines – Part 6: Methods of cooling (IC code).
- EN 60034-7: Rotating electrical machines – Part 7: Classification of types of construction, mounting arrangements and terminal box position (IM code).
- EN 60034-8: Rotating electrical machines – Part 8: Terminal markings and direction of rotation.
- EN 60034-9: Rotating electrical machines – Part 9: Noise limits.
- EN 60034-11: Rotating electrical machines – Part 11: Thermal protection.
- EN 60034-14: Rotating electrical machines – Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of vibration severity.
- EN 60034-15: Rotating electrical machines – Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines.
- EN 60034-16: Rotating electrical machines – Part 16: Excitation systems for synchronous machines
- EN 60034-18: Rotating electrical machines – Part 18: Functional evaluation of insulation systems.
- IEC/TS 60034-23: Rotating electrical machines – Part 23: Specification for the refurbishing of rotating electrical machines.
- IEC/TS 60034-24: Rotating electrical machines – Part 24: Online detection and diagnosis of potential failures at the active parts of rotating electrical machines and of bearing currents - Application guide.
- EN 60034-29: Rotating electrical machines – Part 29: Equivalent loading and superposition techniques - Indirect testing to determine temperature rise.
- IEC 60072: Dimensions and output ratings for electrical machines.
- IEC 60085 Electrical insulation - Thermal evaluation and designation
- IEC 61850: design of electrical substation automation.
- ISO 8528-5: Reciprocating internal combustion engine driven alternating current generating sets – Part 5: Generating sets.

Further Norms and Standards stated are stated in Appendix A6 *Technical Specifications for Electrical Equipment*.

18.3 Generator system

Reference Appendix A16 *Concept Diagrams for Electrical System (Single line diagram)*.

On the line side of the generator shall be installed cables connected to the 6 kV Generator Circuit Breaker Switchboard.

From the 6 kV Generator Circuit Breaker Switchboard signals for de-excitation of the generator etc, e.g. earthing switch being closed – will be given to the generator control system.

The generator control system also controls the generator circuit breaker for protection and synchronizing purpose.

18.4 Connection to the Grid

The generator is connected to the grid through at 6 kV level as shown on Appendix A16 *Concept Diagrams for Electrical System (Single line diagram)*.

The Contract Object shall include all necessary excitation and control equipment, synchronising equipment, relay protection, generator switchboard and all other necessary equipment and installations for a complete generator set.

Further details concerning the installation of the generator, associated switchboards etc. are stated in Appendix A6 *Technical Specifications for Electrical Equipment*.

18.5 System Operation Modes

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

1. Synchronised to the grid.
   1.1. The steam turbine generator is in operation.
   The power production is exported to the grid.

2. Not synchronised to the grid.
   2.1. The steam turbine generator is in operation.
   The generator will on command be synchronized to the grid.

   2.2. The steam turbine is out of operation.
   The system is taking out for revision. At this mode it shall be possible to test the components (e.g. starting a pump etc.) without entering the software code – the system shall facilitate this.

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 consumers of the Line. 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 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 will be made during the commissioning phase and the Contractor shall participate.

18.6 Design Requirements for Generator Including Electrical Equipment

The Contract Object shall include all necessary excitation and control equipment, synchronising equipment, relay protection and all other necessary equipment and installations for a complete generator set.

The generator shall be a brushless synchronous generator designed for continuous operation at rated conditions.

The generator shall be designed to avoid mechanical and thermal unbalance, irrespective of the size and variation of the excitation current.

The stator winding shall be able to accept the conditions, electrically, mechanically and thermally, at a current of minimum 300 % of nominal current for 10 seconds with a 3-phase short-circuit at the generator terminals.

The generator, including auxiliary equipment, shall be capable of resisting a 2-phase short-circuit at full load and maximum voltage and a subsequent relief to no-load.

It shall be possible for the generator to achieve stable operation under all operating conditions in the range of minimum load in isolated operation (not connected to the grid), to full load connected to the grid.

In island mode the generator must stabilize the frequency at 50 Hz.

The complete generator/gear/ turbine transmission train shall, when operated connected to the grid, be able to accept full counter voltage (180° phase displacement) caused by non-synchronised couplings in the network.

The Contractor shall state the short circuit output of the generator.

The generator stator and rotor shall be executed with insulation in class F (IEC 60085), but shall under all operation modes only be operated, not exceeding the maximum temperature rise corresponding class B level.

The generator and its panels etc. shall have the degree of enclosure suitable for the location of installation considering the minimum requirements stated in Appendix A6 *Technical Specifications for Electrical Equipment*.

Other requirements in Appendix A6 *Technical Specifications for Electrical Equipment* shall also be applied. The CMS shall follow the requirements of Appendix A7 *Technical Specifications for Control and Monitoring System (CMS)*.

18.7 Terminal Boxes

All six winding ends of the generator shall be brought to a main terminal box for high voltage, with sufficient spaces for measuring transformers for protection and metering propose, both on line and neutral sides.

A separate terminal box for measurements with clear separation from the main terminal box shall be provided for connection of:

- Pt100 sensors
- Other monitoring
- Anti-condensation heating

18.8 PD (Partial Discharge) Monitoring

The generator shall be equipped with online measuring sensors for partial discharge monitoring in order to facilitate condition based monitoring via the connection of a PD logging analyser (analyser not included).

18.9 Bearings

Measures shall be taken to ensure that the magnetic circuit between the rotor and the stator has no detrimental effect on the bearings.

18.10 Component Cooling System

Heat from the generator cooling, oil cooling and water ring pumps cooling shall be cooled by component cooling circuit.

There shall be made provisions for water leakage detection for the cooling water system. The system shall shut the cooling system in case of detected leakage and prevent water from accessing the generator during operation. The system shall consist of redundant instrumentation. Local flow indicator shall be visible and easily accessible during operation. The Contractor shall document that the cooling system can keep the stator and rotor within the guaranteed range of temperatures under all operation modes and shall include documentation for the cooling circuit (process diagram), cooling medium, mass flow and a listing of the temperatures before and after cooling.

18.11 Temperature Monitoring

Resistance detectors type Pt100 (3 wire mode) shall be used for monitoring of temperatures at:

- Two sensors in each stator winding
- Each bearing and
- the cooling system (inlet/outlet)

Minimum two Pt100 detectors shall be provided at each measuring point (one operational sensor and one spare sensor).

The Pt100 shall be provided with necessary surge arrestor and compensation and be hard wired to a tripping relay in the control panel with adjustable tripping level.

All analogues signals shall be transmitted to CMS according to Appendix A7 *Technical Specifications for Control and Monitoring System (CMS)*.

18.12 Anti-condensation Heating

The generator shall be provided with anti-condensation heaters in the main machine, exciter and terminal boxes, which shall be automatically activated in case of operation stop of the generator.

The heating elements shall be located to ensure that the heat will be distributed evenly into the subject to be heated. The heating elements shall be connected to a 400 V supply system.

18.13 Voltage and Current Transformers

All necessary voltage- and current transformers shall be provided for the measurements for metering and protection purpose on the line side and neutral side.

Separate transformer cores shall be used for different circuits; protection and metering.

18.14 Excitation System and Voltage Regulator

The excitation system shall be of the brushless type with pilot exciter.

The excitation system for the synchronous generator shall be a transistorized excitation system consisting of exciters and rotating-rectifier diodes.

To reduce stator damage due to fault, accelerating decay of field flux by field forcing to zero functions shall be applied by using de-excitation circuits.

Various interlocks signals from earthing switch etc. in the generator switchboard shall be applied in the system.

The excitation system shall be fully tested and installation in a standard cubicle.

The voltage regulator shall be of electronic type with automatic voltage control and field control for manual excitation. The AVR system shall consist of dual independent channels as a double AVR system.

The following modes of AVR control shall be possible:

- voltage control
- power factor control

The generator shall be capable of switching over from voltage control to power factor control after been connected to the grid.

It shall be possible to select between manual and automatic without any gaps in the voltage and frequency of the generator.

The excitation equipment shall include the possibility of remote indication and remote control.

Alarms (remote indication) for semi-conductor equipment and from the rotating field magnet circuit shall be included.

18.15 Generator Protection Equipment

The Contractor shall include, specify and describe the protection equipment based on IEC61850 proposed for the generator.

The protection equipment shall be adapted to the system concept, including required coordination between the generator and the 6 kV grid.

The protection system shall as be in full compliance with requirements from the Grid Company – however these requirements does not gain any limitation from other requirements.

The protection shall multifunction device based, be microprocessor based type, with watch dog functions to facilitate identification of component failure.

The protection equipment shall be divided into two independent redundant systems (including control voltage supply) functioning as mutual backup.

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

- Over voltage $U_{>>}$ and $U_{>}$
- Under voltage $U_{<}$
- Positive-sequence under voltage $U_{1<}$
- Zero-sequence voltage $U_{0>}$
- Over frequency $f_{>}$
- Under frequency $f_{<}$ and $f_{<<}$
- Frequency gradient $df/dt_{1<}$ and $df/dt_{2>}$

- Short circuit and over current $I_{>}$ + $I_{>>}$,
- Inverse current protection relay $I_{2>}$
- Excitation current $I_{e<}$
- Stator differential $I_{d>}$
- Overspeed $n_{>}$
- Inverse voltage $U_{2>}$
- Reverse power $P_{2>}$
- Earth fault protection $I_{o<}$ (stator)
- Earth fault protection $I_{o<}$ (rotor)
- Internal and external earth fault
- Temperature monitoring in the windings.
- Diode fault protection
- Shaft vibration measurement (based on 2 instruments out of 3 instruments system)
- Differential protection with metering for four-restraint differential applications with standard three-phase voltage and independent ground inputs.

Over current protection function shall have measuring-inputs from the current transformers placed on the neutral sides of the generator.

Earth fault protection $I_{o<}$ (stator) shall have measuring-input from the current transformers placed between the neutral point and the earthing point of the generator.

Third-Harmonic comparator based earth fault protection technology shall be applied.

The protection shall be able to discriminate external earth faults.

Protection functions shall gain full protection of the system and full discrimination in any operation mode – up through the grid connection

The Contractor has to provide full relay study to guaranty this issue.

Quantity, rating, cores and classes of voltage and current transformers have to match the protection relays. Proper settings ranges, time delays, relay sensitivity for the protection relays shall be provided in the protection system.

18.16 Protection functions

The protection system shall:

- Trip the generator circuit breaker by any external fault detections.
- Trip the generator breaker and de-excitate the generator by any internal fault detections.
- Trip the switch disconnector in the neutral in case of internal earth fault detections in the generator stator windings.

18.17 Overvoltage protection

Further the following shall be provided on the outgoing side of the generator switchboard:

- Surge capacitors
- Lightning arrestors

Design coordination between the Contractor and the Grid Company, concerning these components shall be expected.

18.18 Synchronisation Equipment etc.

Equipment for both automatic and manual synchronising, with the 6 kV connection, by means of operation the generator circuit breaker, which can be controlled and operated both locally and from the CMS, in the Central Control Room, shall be included.

It shall be possible to synchronise the generator into the network in full compliance with the requirements for voltage variation at 6 kV level.

During manual synchronisation it shall only be possible to close the circuit breakers if enabled via synchronising check devices.

The synchronising system shall include Dead bus closing functions where appropriate.

An alarm shall be engaged, if the automatic synchronisation does not take place within 3 minutes after the command is given. The control system shall leave from 'automatic synchronisation'.

Selector switches shall be provided for selection of circuit breaker for synchronising.

The complete voltage control for the system from the generator terminals to the 6.3 kV grid connection point shall be included.

18.19 Neutral Earthing Arrangement

High-impedance earthing of the neutral point of the stator winding shall be provided, including neutral resistance and all measuring transformers, electrical operated switch disconnector etc. The earth fault current has to be eliminated to approximate 5-10 A. The system shall be able to carry at least 10 A for 10 sec.

The Contractor shall clarify and coordinate the neutral earthing system with the Grid Company.

The Generator system is not supposed to operate with isolated neutral and during operation the switch disconnector shall be closed and enable the generator circuit breaker to be closed – appropriate interlocks between the components shall be applied.

The Contractor shall confirm that his proposal considers all conditions and operating situations, including any third harmonic currents, unsymmetrical load and transient voltages.

18.20 Generator Tests

The Contract Object shall include factory and site testing of the generator and equipment with participation of the Employer.

The Contractor shall state which tests are included and which standards are forming the basis for tests.

A vibration test in accordance with ISO 10816-3 (Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts - Part 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) on an operation warm generator shall be included.

The Employer shall be notified of time of the tests at least 14 Days before the tests. Test procedures and operation and maintenance manuals shall be submitted to the Employer not later than one Week prior to the test.